# Exploring low back pain in adolescent athletes

Julia Wall

BSc. (Honours) Physiotherapy, P. Grad. Cert. (Statistics)

Supervisor: Dr. Fiona Wilson

Submitted for the Degree of Doctor of Philosophy

University of Dublin, Trinity College

School of Medicine

Discipline of Physiotherapy

2023

# Declaration

I declare that this thesis has not been submitted as an exercise for a degree at this or any other university and it is entirely my own work. I agree to deposit this thesis in the University's open access institutional repository or allow the Library to do so on my behalf, subject to Irish Copyright Legislation and Trinity College Library conditions of use and acknowledgement. I consent to the examiner retaining a copy of the thesis beyond the examining period, should they so wish (EU GDPR May 2018).

Author: Date: December 20, 2022

# Summary

Low back pain (LBP) is a ‘pain, ache or discomfort in the low back with or without referral to the buttocks or legs.’ It is known that LBP affects people of all ages. Adolescents (aged 10 to 19 years old) experience LBP regularly, although less is known about LBP in this age group. For adolescents participating in sport, LBP can disrupt the development of lifelong healthy physical activity habits in adolescence. Additionally, since a previous episode of LBP is a risk factor for future LBP, the development of LBP in adolescence can increase LBP risk later in life. The aim of this thesis was to explore and characterise LBP in adolescent athletes to inform future development of evidence-based management strategies for LBP in this population. The work in this thesis explored the epidemiology, lived experiences, and current clinician management and beliefs about LBP in adolescent athletes.

Study I investigated the prevalence, incidence, risk factors, and common morphologies of LBP in adolescent athletes. It found that LBP was common in adolescent athletes, with a 12-month incidence estimate of 36.0% (95% CI 4-68, $I^2$=99.3%), and a 12-month prevalence estimate of 42% (95% CI 29-55, $I^2$=96.6%). Risk factors for LBP included sport participation, sport volume/intensity, concurrent lower extremity pain, overweight/high BMI, older adolescent age, female sex, and family history of LBP. Spondylolysis was the most commonly reported morphology in this population. Incidence and prevalence varied widely due to differences in methodological quality and LBP definition.

Study II explored current management of LBP diagnoses in adolescent athletes. Findings showed that non-specific LBP was the largest diagnostic group in adolescent athletes, followed by spondylolysis or spondylolisthesis. There were some associations between female sex and facet-based or SI-joint pain compared to spondylolysis or spondylolisthesis.

Commonly used management techniques in this cohort were diagnostic MRI, physical therapy, relative rest, and bracing. There was a high rate of imaging use although there is no consensus on imaging for spondylolysis in adolescent athletes.

Study III summarised the lived experiences of adolescent athletes with LBP. The main themes were: 1) The culture of normalising LBP in sport negates safeguarding efforts aimed at protecting adolescent athletes against injury and pain, 2) LBP changes how athletes are perceived and perceive themselves, and 3) Low back pain has broad effects on the well-being of adolescent athletes. Overall, the lived experience of LBP for adolescent athletes showed that the normalisation of LBP in adolescent sport can create safeguarding risks for adolescent athletes, particularly in terms of competing with pain.

Study IV examined clinician management techniques and LBP beliefs. While clinician management largely followed existing guidance on LBP management, it is important to note that there are no management guidelines or clinical pathways specific to adolescent athletes. Although LBP beliefs were largely helpful in this cohort, there were still some beliefs that were not supported by evidence  held by clinicians in this participant group.

Collectively, these studies aimed to explore and characterise LBP in adolescent athletes. The results of this thesis will contribute to the evidence based about LBP in adolescent athletes and may be a starting point for future research in this area to ensure optimal management of this condition. Future research in this area should focus on the development of a LBP definition and management guidelines specific to adolescent athletes, investigation into optimal methods of spondylolysis diagnosis and management, educational programmes about pain for coaches and athletes, and ongoing clinician education about LBP beliefs.

## Acknowledgements

I would like to express my deepest gratitude to Dr. Fiona Wilson, my PhD supervisor, for her guidance and support throughout the PhD journey.

I would also like to extend my sincere thanks to all co-authors on my publication in the British Journal of Sports Medicine: Dr. William Meehan, Dr. Conor Gissane, Mr. David Mockler, Dr. Katharina Trompeter, Dr. Nicol van Dyk, and Dr. Fiona Wilson. Thank you for your time, effort, and attention to detail in guiding me with this review.

Many thanks to Dr. Emer McGowan, for sharing her expertise about the qualitative aspects of my thesis.

Thank you to the team involved in survey development: Dr. Kellie Wilkie, Dr. Maire Brid Casey, Dr. Seán McAuliffe, Dr. William Meehan, and Dr. Fiona Wilson.

I am grateful to Dr. William Meehan and the team at the Micheli Center for Sports Injury Prevention, especially Danielle Hunt, Scott Passalugo, and Danielle Cook.

I would like to acknowledge all my colleagues in the postgraduate physiotherapy office for their help and support. I have had the pleasure of working with the best group of people over the past three years. Special thanks to Caitríona Quinn, Dr. Clíodhna McHugh, Dr. Megan Kennedy, Ragy Tadrous, and Emily Smyth for their help with proofreading.

I would also like to recognize the contribution of the participants in my research. Without their willingness to contribute time and effort to participating in my studies, none of this would have been possible.

Last but certainly not least, thank you to all my family and friends for your unwavering support throughout my PhD. Each and every one of you have helped me immensely along the way. Special thanks to Mom, Dad, and James.

# Impact of the Covid-19 Pandemic

The Covid-19 pandemic began to heavily affect Ireland six months after the start of this PhD research. Because in-person research was not possible in the setting of the pandemic, all research in this thesis was significantly delayed. Several adaptations were made to ensure that this project could continue during the pandemic.

Overall, there was limited access to both the postgraduate physiotherapy research office and to the research sites involved in this thesis. The chart review study (Study II) was planned to be conducted in person in Boston Children's Hospital over the summer of 2020. Since the hospital site could not be accessed for research, Julia Wall had to be virtually onboarded as an associated researcher and accessed charts online only. This virtual onboarding process delayed the start of Study II by approximately five months.

The qualitative interview study (Study III) was set to begin in March 2020. Ethical and data protection approval for this study had already been obtained, however in-person interviews suddenly could not take place. The interviews were adapted to take place via Microsoft Teams, using Microsoft Forms for questionnaires. This raised additional ethical and data protection considerations that the study previously did not have. Because of this, the ethical and data protection process had to be completed twice for the same research project, and the planned research in Ireland could not start until late August 2020. The part of this study based in Boston was delayed even further because of the necessary prioritisation of Covid-19 research in hospitals. The application for ethical review at the Boston site was delayed by approximately ten months. The portion of the study planned to take place in Boston had to be adapted to take place via Zoom, using REDCap for questionnaires.

# List of Tables

# List of Figures

# List of Appendices

# Publications during this Thesis

*Peer-reviewed publications*

**Wall J**, Meehan WP, Trompeter K, *et al* Incidence, prevalence and risk factors for low back pain in adolescent athletes: a systematic review and meta-analysis. *British Journal of Sports Medicine* 2022; **56:1299-**1306. http://dx.doi.org/10.1136/bjsports-2021-104749.

*Conference presentations*

*Systematic review and meta-analysis of prevalence and risk factors for low back pain among adolescent athletes.* **Oral presentation by Julia Wall**, British Association of Sports & Exercise Medicine Annual Conference 2022. Brighton, UK.

*Other publications*

**Wall, Julia.** "Incidence, prevalence, and risk factors for low back pain in adolescent athletes: a systematic review and meta-analysis." Web blog post. BJSM Knowledge Translation Blog. British Journal of Sports Medicine, 24th October 2022.

*Submitted for review*

**Wall J,** McGowan, E, Meehan WP, Wilson F. *"Back pain is part of sport … I'm just gonna have to live with it": Exploring the lived experience of sport-related low back pain in adolescent athletes.* Submitted to Physical Therapy in Sport for review January 2023.

## List of Abbreviations *(listed alphabetically)*

**AIS:** Adolescent idiopathic scoliosis

**ANOVA:** Analysis of variance

**APTA:** American Physical Therapy Association

**ASIA chart/impairment scale:** American Spinal Injury Association Impairment Scale

**BackPAQ:** Back Pain Attitudes Questionnaire

**BCH:** Boston Children's Hospital

**BMI:** Body mass index

**CDC:** Centres for Disease Control

**CINAHL**: Cumulated Index to Nursing and Allied Health Literature

**COREQ:** Consolidation Criteria for the Reporting of Qualitative research

**Covid-19 pandemic:** Coronavirus Disease 2019 (SARS- CoV-2)

**CT:** Computed tomography

**DOB:** Date of birth

**HCP:** Healthcare professional

**HIPAA:** Health Insurance Portability and Accountability Act

**IASP:** International Association for the Study of Pain

**IOC:** International Olympic Committee

**IPAQ:** International Physical Activity Questionnaire

**IRB:** Institutional Review Board

**LBP:** Low Back Pain

**MET:** Metabolic equivalent minutes

**MFS:** Micheli Functional Scale

**Modified ODI:** Modified Oswestry Disability Index

**MRI:** Magnetic resonance imaging

**NMQ:** Nordic Musculoskeletal Questionnaire

**NSAIDs:** Non-steroidal anti-inflammatories

**NS-LBP:** Non-specific low back pain

**OR:** Odds ratio

**PhD:** Doctor of Philosophy

**PPI:** Patient and public involvement

**PRISMA:** Preferred Reporting Items for Systematic Reviews and Meta- Analyses

**PROSPERO:** International Prospective Register of Systematic Reviews

**QOL:** Quality of life

**RCTs:** Randomised controlled trials

**REDCap:** Research Electronic Data Capture

**RMDQ:** Roland Morris Disability Questionnaire

**SI joint:** Sacroiliac joint

**VAS:** Visual Analogue Scale

**WHO:** World Health Organization

**YLD:** Years lost to disability

# Table of Contents

# Chapter 1: Introduction

## 1.1 Overview

Adolescence is defined by the World Health Organization (WHO) as 'the phase of life between childhood and adulthood, from ages 10 to 19'[1]. It is a time when many changes are occurring, including physical (increased rate of growth and maturation, musculoskeletal considerations such as epiphyseal growth plates, and differences in coordination/skills), cognitive (a developing sense of risk and emotional regulation), and social changes (increased influence of peer interactions).

Because of these features unique to adolescence, adolescents must be considered separately from adults for a variety of musculoskeletal conditions, including low back pain (LBP). For adolescents participating in sport, sport presents a unique duality in which sport participation can both decrease risk in some areas (ex: cardiovascular disease) and increase risk in others (ex: sports injury)[2]. This thesis focuses on LBP in adolescent athletes specifically. This chapter will provide background on the importance of investigating LBP in adolescent athletes and demonstrate the value of this thesis characterising LBP in adolescent athletes. It will discuss the benefits and risks of physical activity, considerations specific to adolescents in sport injury, types of injury and pain in adolescents, LBP and injury in adolescents, LBP in adult athletes, and LBP in adolescent athletes.

## 1.2 Physical activity and sport in adolescents

1.2.1 Benefits of physical activity for adolescents

Physical activity in adolescence is important for developing improved health outcomes, such as cardiorespiratory and muscular fitness, bone health, weight status, and cognitive development[3]. In addition to physical health outcomes, physical activity during adolescence can aid cognitive development[3] and mental health[4 5]. It is important to maintain physical activity throughout the lifespan, but habits developed in adolescence can affect physical activity and related health outcomes later in life[6]. Physical activity in adolescence has been found to contribute to levels of physical activity in adulthood[7]. Improved health outcomes due to physical activity in adolescence also transfer into adulthood, both physical[3] and mental[8].

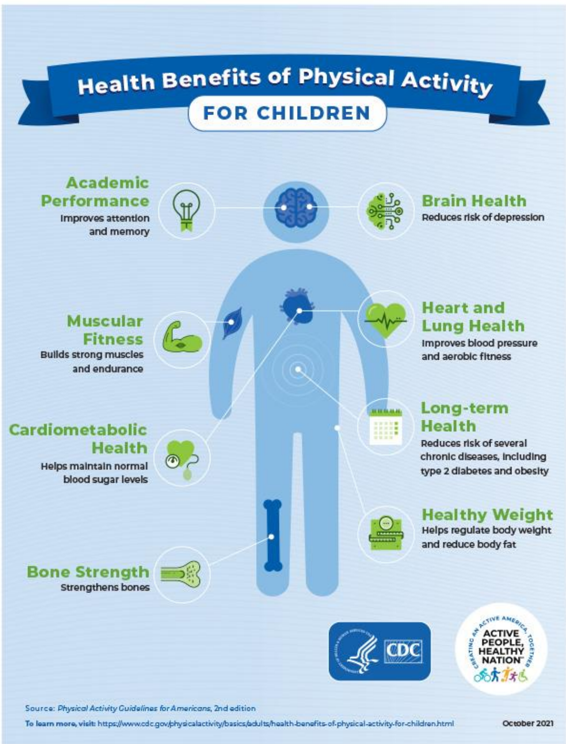


**Figure 1-1:** Benefits of physical activity.
Source: https://www.cdc.gov/physicalactivity/basics/adults/health-benefits-of-physical-activity-for-children.html

1.2.2 Sport in adolescence

One type of physical activity which adolescents can engage in is organised sport. The number of children and adolescents participating in sport appears to be increasing, propelled in part by public health initiatives that encourage youth sport participation[9-12]. It is estimated that, in the United States alone, 60 million children (ages 6-18) play an organised sport[13]. Adolescents participating in sport can benefit from improved bone health, increased aerobic capacity[14], and muscular fitness. There is also evidence that participation in sport, especially team sport, provides psychosocial[15] and mental health[4 5] benefits beyond those conferred by participation in physical activity. In a cross-sectional study of Irish adolescents, those who participated in sport had higher levels of well-being, and lower levels of reported anxiety and depression, with additional benefit in those participating in team sport[5]. Similarly, a cross-sectional survey in Norway found that adolescents who participated in team sport had higher reported self-esteem and life satisfaction[4]. Participation in sport during childhood and adolescence has also been linked to greater fitness in adulthood[16 17].

1.2.3 Barriers to physical activity and sport in adolescence

The physical activity recommendation for adolescents is 60 minutes of moderate to vigorous physical activity per day[18 19]. Research shows, however, that many adolescents do not meet this guideline[3]. Further, girls were overall less active than boys[3].

Despite its many benefits and the higher rate of children and adolescents now engaging in sport, there is still a high rate of drop out in adolescent sports-35% of children and adolescents annually drop out of sport in the United States[20]. Participation in sport appears to peak around age 11-13 years and then decline[15]. In an Irish cross-sectional study of adolescents, the frequency of activity declined with age[5]. In a Norwegian cross-sectional study, fewer senior high school students participated in sport than junior high school students[4]. Research has shown that girls drop out of sport twice as often as boys by the age of 14[21]. There are many factors contributing to this, including physical[20] and psychosocial barriers[20 22] to sport participation. Examples of psychosocial factors associated with sport dropout are lack of enjoyment or decreased perceptions of competence[20 22]. Another physical factor which can contribute to adolescent sport dropout is injury[20] or fear of reinjury.

### 1.3 Sport injury-specific differences between adults and adolescents

There are several factors specific to adolescents which may impact the rate of pain and injury experienced by adolescents. Young athletes may have increased susceptibility to injury for a variety of reasons, including high physical stress during growth, cognitive considerations, and the possibility of poor coaching[23].

In the United States alone, there are an estimated 60 million young athletes between the ages of 6 and 18 years old who participate in organised sport[23]. It appears that the rate of sport participation is highest in childhood/adolescence compared to other life stages[20]. Although this is generally thought to be positive due to the beneficial effects of physical activity for young people, participation in sport also carries considerable risk of injury. In the European Union, the annual incidence of hospital-treated sports injuries in those under age 15 is 1.3 million[24]. Young people are the group with the highest rate of sports injury burden[25]. Further, there may be a higher prevalence of injuries in organized sport compared to other forms of physical activity[26].

#### 1.3.1 Biological considerations in adolescents

##### *1.3.1.1 Immature skeleton*

The adolescent skeleton has several features that are unique compared to adults. During the adolescent stage of life, the skeleton is immature. Because of musculoskeletal considerations specific to adolescents such as epiphyseal growth zones on growing bones, the same mechanical force can result in different injuries for adults and adolescents. For example, adolescents are at a higher risk of overuse injuries than adults[27]. Other common injuries in those that are actively growing include physeal plate injuries, apophyseal injuries (including Sever's disease and Osgood Schlatter disease), and stress fractures. During adolescent growth, structures such as physes, apophyses, and articular surfaces are less able to withstand stress because there is less collagen and calcified tissue than in mature bone[28-30]. This susceptibility to injury appears to increase during growth[30]. Further, bone and muscle growth occur at different rates, which can cause a difference between rates of growth or flexibility and strength[31].

*1.3.1.2 The adolescent growth spurt*

In adolescents, growth refers to 'changes in body size, shape, and/or composition'[29]. Many adolescents undergo a growth spurt, which is a 'fast and intense increase in the rate of growth in height and weight'[32]. The onset and length of the adolescent growth spurt varies person by person. Generally, the adolescent growth spurt begins earlier for girls than for boys. The average age of onset is 11-12 years for boys and 9-10 years for girls[32]. For boys, the adolescent growth spurt is generally longer than for girls, and there is a higher peak growth rate[32].

The growth spurt can be a period during which an adolescent is at increased risk of injury[28 33]. The timing of an adolescent's growth spurt is important for those participating in sport. It may coincide with a significant increase in workload or significant sporting events[29].

*1.3.1.3 Maturation*

Maturation can be defined as 'the act of progression from conception towards the adult/mature state'[29 34]. There are several ways that maturation state can be identified, including skeletal age, secondary sex characteristics, and peak height velocity. There is some evidence that maturation can be estimated by youth sports coaches[35].

Generally, girls mature at an earlier age than boys. Maturation status does not correlate directly with chronological age, meaning that some adolescent athletes competing in the same age category may be at different rates of maturation[36]. Differences in maturation status in adolescents of the same age can potentially lead to unbalanced competition. Those that have matured earlier are more likely to have size, strength, and power advantages[27 36]. Later maturing adolescents can also have deficits in muscle strength and coordination[36].

The interaction between maturation status and training load could also lead to increased or decreased injury risk in adolescents[37], although evidence in this area is conflicting. For instance, a late-maturing athlete may experience temporary decreases in skill at a more important time in their athletic career than an earlier-maturing athlete of the same chronological age. This may involve an increase in workload accompanied by a reduction in skill, leading to increased injury risk[29]. In a study of male track and field athletes, late-maturing athletes experienced more lower limb injuries than those that matured earlier[38]. Conversely, a recent study of adolescent male football players demonstrated that earlier-maturing athletes were at greater risk of injury[39]. In another study of adolescent male footballers, early maturing athletes experienced more injuries, but when confounding variables such as playing time were controlled, there was no longer a significant difference in injury rate[40]. The relationship between maturation status and injury requires further research.

Another feature of adolescent maturation is the onset of menarche for biologically female adolescents. Menarche typically occurs between 10 to 16 years of age, at an average age of 12.4 years old[41]. The onset of menarche and the effect of the menstrual cycle on sport performance and injury is an emerging area of research and should be considered as a factor which can impact the sport performance of adolescents who menstruate[42].

#### *1.3.1.4 Differences in coordination/skills*

Another consideration specific to adolescent sport is potentially underdeveloped coordination or motor skills. Complex motor skill acquisition is not completed until ages 10-12, which is at the beginning of the adolescent age range[43].

During growth, there can also be temporary reductions in coordination abilities[36]. This has been documented in several sports and is sometimes referred to as ‘adolescent awkwardness’[44]. In gymnastics, there can be changes in postural control during growth, affecting gymnastic performance[45]. Similarly, in adolescent soccer, postural control is affected by maturation state[46]. There were decreases in balance as athletes underwent maturation[46].

### 1.3.2 Psychosocial considerations in adolescents

There are also important psychosocial considerations that may contribute to sports injury risk in adolescence. Adolescents may have an under-developed sense of their own ability, and tend to overestimate their own ability in sport skills[29]. This overestimation of one's own ability is associated with sports injury[29]. During adolescence, athletes may also have a still-developing sense of risk. There may be less consideration for the future impact of sport participation and sport injury during adolescence, as they may not yet be able to estimate the long term impact[29]. Emotional regulation and identity are also developed during adolescence. For adolescents participating in sport often, an 'athletic identity' can be developed[29]. This refers to the degree that an athlete identifies with the athlete role[47]. This can also increase risk of injury, as an individual with a strong sense of athletic identity may be more likely to overtrain, as well as to compete with pain or injury[48 49].

Athletes who have been injured can report feelings of social isolation, fear of re-injury and loss of motivation if they are not able to participate in sport[50]. Further, lower self-esteem has been demonstrated in some injured athletes in research in runners and football players, although this has not been consistent across all sports investigated[50].

### 1.3.3 Sports injury in adolescence

#### *1.3.3.1 Common sports injuries in adolescents*

Table 1-1 provides an overview of several injuries that adolescent athletes may be particularly susceptible to, along with factors specific to adolescents that may contribute to this susceptibility. Injuries common to those actively growing include physeal plate injuries, apophyseal injuries and stress fractures[10].

| Type of injury | Example | Brief explanation |
|---|---|---|
| Apophyseal injury | Sever’s disease, Osgood-Schlatter disease | Inflammation at a tendon insertion site. Sever’s disease occurs at the calcaneus, Osgood-Schlatter at the tibial tuberosity.[51] |
| Stress fracture | Spondylolysis | Stress fracture at the pars interarticularis. Could be due to repetitive forces through an immature spine[29]. |
| Physeal plate injury | Salter Harris type II fracture | Fracture through a growth plate. |

**Table 1-1:** Common sports injuries in adolescence.

Common to all these injuries is the presence of pain. The next section outlines unique factors in addressing pain in adolescents specifically.

## 1.4 Understanding pain in adolescents

The International Association for the Study of Pain (IASP) defines pain as: 'An unpleasant sensory and emotional experience associated with, or resembling that associated with, actual or potential tissue damage,'[52], noting that pain is a 'personal experience…influenced to varying degrees by biological, psychological, and social factors'[52]. Pain is a common symptom experienced by adolescents, although it can be under-recognised and under-treated in this population[53]. It is estimated that up to 20-30% of children and adolescents experience chronic pain worldwide[53]. The most common types of pain experienced by children and adolescents include abdominal pain, migraine, and musculoskeletal pain[54].

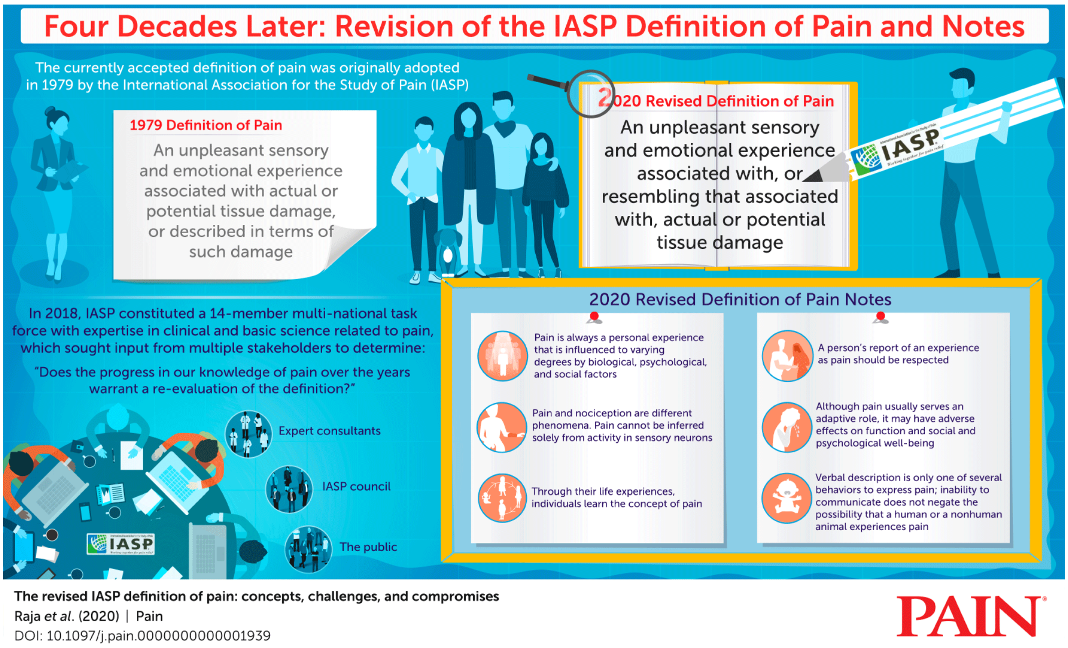


**Figure 1-2:** IASP definition.
Source: https://painmanagementcollaboratory.org/the-iasp-revised-definition-of-pain/

### 1.4.1 Differences between adult and adolescent pain

There are several unique factors which influence adolescent pain compared to adult pain. The presence of parent/guardians or relatives at a medical appointment can contribute to the paediatric experience by increasing the child's pain or distress[55]. Self-report is the gold standard for pain evaluation in children[56], however, adults are often consulted about their child's pain[57]. Research has shown that parents' perception of their child's pain differs from the child's, with the adult often underestimating the pain of their child [58 59]. This approach can disregard the individualised nature of a child's pain, and it is best to consider a child-centred approach to pain management[60].

Pain is often under-treated in children due to misconceptions around paediatric pain[55]. One such example is the misconception that children do not feel pain as much as adults. Although there is slower transmission of pain in children, the length of the pain pathway is shorter, meaning that pain is felt the same in adults and children[55]. In fact, children can have a higher sensitivity to pain due to a higher amount of neuromediators[55].

1.4.2 Biopsychosocial factors unique to children and adolescents

The biopsychosocial model of pain was first introduced in 1977, and considers biological, psychological, and social factors which may impact an individual's health[61].

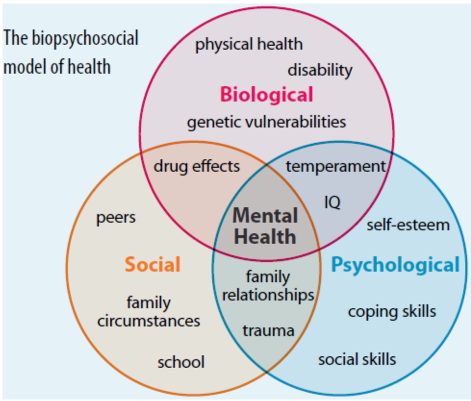


**Figure 1-3:** Biopsychosocial model of health.
Source: https://www.physio-pedia.com/File:Biopsychosocial-model-of-health.PNG

The biopsychosocial nature of pain is included in the IASP definition[52]. This considers all factors which may influence an individual's experience of pain. For children and adolescents specifically, there are some unique biopsychosocial factors to consider. During adolescence, children undergo changes in all parts of their life, including hormonal changes, emotional maturation, and new social environments[62]. Other people, such as parents/guardians or friends, may have a larger influence on adolescents. A parent or guardian's response to the child's pain can affect the pain response of the child[63]. In addition, the presence of a parent or guardian experiencing pain themselves can affect a child's reports of pain[63]. Adolescents are also more easily influenced by relationships with their peers and social acceptance than younger children[64].

### 1.4.3 Risks of pain in adolescence

Pain in adolescence can have broad effects on the adolescent and their family. Adolescents with chronic pain have self-reported reduced social functioning[65], higher rates of absenteeism from school, and decreased academic success[66]. There is also a high financial cost[67], and increased parental leave from work[68].

Beyond immediate effects of the experience of pain during adolescence, it has been shown to predict the occurrence of pain later in life[68]. Adolescents with pain at multiple sites, for instance LBP and headaches[69], have been found to be at even higher risk of developing pain in the future. One-third of adolescents have chronic pain[63], and up to 70% of adolescents with under-managed pain in adolescence go on to develop chronic pain in adulthood[70].

It is important to mitigate initial episodes of pain in adolescence to prevent negative effects on social life, school, family, and future pain. One type of pain that affects this age group is LBP.

## 1.5 Low Back Pain and Injury in Adolescence

### 1.5.1 Overview

LBP is defined as a 'pain, ache or discomfort in the low back with or without referral to the buttocks or legs' [71], with the low back area defined as 'the posterior aspect of the body from the lower margin of the twelfth ribs to the lower gluteal folds' [72]. There are many pathologies associated with LBP, including congenital conditions, injuries, and degeneration; however, up to 90% of all LBP is non-specific, meaning there is no known specific associated pathology [73]. Back pain can affect people all of ages, and it is estimated that as many as 50 to 80% of adults will experience LBP at least once in their lifetime [74].

Over recent years, there has been a noted increase in reported LBP in adolescents (aged 10-19 years) [1 75]. Some studies estimate lifetime prevalence of LBP to be as high as 70-80% by the age of 20 [76]. Other estimates have indicated that the twelve-month prevalence of LBP in adolescents is between 33-57% [77-79] and point prevalence falls between 3.2%-35% [77]. Since a previous episode of LBP is a risk factor for the development of future LBP, the onset of LBP early in life puts adolescents at higher risk for continuing LBP later in life [80 81]. Thus, an episode LBP in adolescence can have a notable impact on an individual throughout life. This section will explore the outcome measures, risk factors, associated pathologies, treatment methods, and impacts associated with LBP in adolescents.

### 1.5.2 Outcome measures

There are up to 36 LBP-specific outcome measures, but a scarcity of those specific to adolescents [82 83]. Some of the most common outcome measures used to assess LBP include the Roland Morris Disability Questionnaire (RMDQ) and the Oswestry LBP Disability Questionnaire (ODI) [82]. According to the British Pain Society, the ODI is the "gold standard" for LBP assessment [84]. Although the RMDQ has good construct validity, internal consistency, responsiveness, and reliability in assessing disability related to LBP, it is inadequate to assess psychological or social problems [83]. The ODI is more suited to explore social problems, but is recommended in patients with more severe persistent LBP [83]. Neither questionnaire was developed specifically for adolescents. A modified version of the ODI has been used to assess LBP in adolescent athletes previously [85].

The Nordic Musculoskeletal Questionnaire (NMQ) is another questionnaire that has been used to assess LBP in adolescents. It assesses prevalence of pain at nine body regions, including the low back region. The NMQ has acceptable validity and is repeatable and sensitive [86]. Although not specifically designed for use in the adolescent age group, some versions of the NMQ have been adapted for use in adolescents, such as the French version [87]. The NMQ has also been used to assess LBP in adolescent research [88].

The Micheli Functional Scale (MFS) was designed to measure LBP in adolescent athletes specifically. This is a five-item questionnaire which includes one question about symptoms, three questions about activities of daily living (extension, flexion, and jumping), and a Visual Analogue Scale (VAS). In a study of 93 adolescents, the MFS had acceptable reliability and concurrent validity [89].

### 1.5.3 Risk and associated factors

Factors associated with LBP in adolescents that have been identified include female sex, overweight and obesity, psychosocial factors, age, family history, and lifestyle factors. The factors associated with LBP in adolescents are presented here.

#### *1.5.3.1 Sex*

Female sex is associated with an increased risk of LBP. This may evolve throughout the adolescent age range. At age 14, chronic LBP is present in 11% of both sexes [90], but by the age of 17 there are significant differences, with 26% of female adolescents and 13% of male adolescents reporting chronic LBP [91]. However, other research has found a higher LBP prevalence in girls aged 11-14 compared to boys of the same age, demonstrating that this association is present across the younger adolescent age range [92]. Although it is unclear whether this relationship changes as adolescents age, there is consistent cross-sectional evidence demonstrating associations between LBP and female sex. Internationally, data from 28 countries indicates that LBP is more prevalent in girls [68]. When further examined in school environments, there are significant associations between female sex and LBP in adolescents [93 94]. Although some research has found no difference in the rate of LBP by sex [95 96], it is generally thought that there is an association between female sex and LBP in the adolescent age group.

*1.5.3.2 BMI*

A high body mass index (BMI) or weight has also been identified as a risk factor for adolescent LBP. In a study of medical records of 829,791 adolescents over 12 years, there was a dose-response relationship between higher BMI and LBP in both boys and girls, with underweight adolescents at lowest risk of LBP [97]. Other research has found associations between BMI and LBP only over a certain BMI. In 13 to 16 year old adolescents, a BMI over 25 $kg/m^2$ has been associated with moderate to severe recurrent or continuous LBP [98]. There have also been associations between BMI and LBP across a range of adolescent ages, although there was a stronger association between BMI and LBP in younger adolescents (9 to 11 years old) than older adolescents (12 to 14 years old) [99]. These findings demonstrate that there may be a relationship between high BMI and LBP in adolescents.

*1.5.3.3 Psychosocial factors*

There is evidence that psychosocial factors play a role in the experience of LBP for adolescents. In a population-based cohort study of adolescents aged 11-14 years old, those that reported higher exposure to adverse psychosocial factors were more likely to develop LBP at one-year follow up [100]. In an interdisciplinary pain clinic setting, there were associations between catastrophising and reported disability related to chronic LBP in patients aged 8-18 [101]. There has been cross-sectional evidence that in in schoolchildren aged 12-16, self-reported depression, stress, and poorer mental health factors are associated with increased risk of LBP [102] [103]. An adolescent's perception of LBP may also affect their experience of LBP. In a cross-sectional study of back pain beliefs in 17-year-olds, negative LBP beliefs affected behaviour associated with LBP, including increased care seeking and activity modification [104]. The research in this area demonstrates that there is a strong association between adverse psychosocial factors and LBP in adolescents.

*1.5.3.4 Age*

Research has shown that the prevalence of LBP in adolescents increases with age. International data from 28 countries indicates that six-month prevalence of LBP increases from 27.4% at age 11 to 46.7% at age 15 [68]. Similarly, in a five-year longitudinal study, lifetime prevalence between ages 11-15 rose from 11.6% to 50.4% [105], and a Danish cross-sectional study demonstrated an age-related increased in LBP of 13.2% from under 14 years to over 15 years old [98]. In a six-year follow up study, point prevalence increased significantly each year until the age of 13 [99], and in a cross-sectional study, LBP point and lifetime prevalence increased as year in school increased [106]. LBP risk increases with age, starting as young as in adolescence.

*1.5.3.5 Family history of LBP*

Adolescents with a family history of LBP appear to be at greater risk of developing LBP. In a study of 7542 adolescents in school, those that reported a positive family history of LBP had an associated increased risk of LBP [93]. Similarly, in a study of 1608 14-year-olds examining the relationship between carer and adolescent LBP, adolescent experience of LBP was associated with the carer's experience of LBP [90]. The risk of LBP increased in adolescents when their carer had LBP and increased further if two carers experienced LBP (odds ratio(OR)= 1.6)[90]. As opposed to an association with parental LBP history, in a cross-sectional study of 615 schoolchildren aged 12-17, there were associations between adolescents whose siblings reported LBP and increased risk of LBP [107]. Family history and experiences of LBP impacts an adolescent's risk of developing LBP.

*1.5.3.6 Lifestyle factors*

*Mechanical load*

Mechanical load as a possible risk factor for LBP in adolescents is often discussed in relation to backpack use. Overall, it is not clear whether there is an association between backpack use or backpack weight and LBP. There is some cross-sectional evidence that heavier backpack use [108] or heavier backpack weight is associated with LBP [94 109]. However, a recent systematic review of 69 studies found that there is insufficient evidence to support an association between factors related to carrying a schoolbag and LBP [110]. There is evidence that perceived schoolbag weight may play a role rather than actual schoolbag weight, further indicating the significance of psychosocial factors in adolescent LBP [111].

There has not been as much focus on spinal mechanical loading during activities in adolescent LBP research as there has in adult LBP research, but there is some evidence that adolescent male rowers with LBP adopt different movement patterns than those without LBP during a 15-minute ergometer trial [112].

*Sleep*

Insufficient sleep may also be a risk factor for LBP in adolescents, although there is little research in this area specifically. A Finnish study of 6911 adolescents showed that insufficient sleep at age 16 predicted LBP at age 18 in both sexes [113].

*Diet*

Diet may have an impact on LBP in adolescents, although there is little evidence in this area. A cross-sectional study of 1424 adolescents found weak and inconsistent associations between some elements of diet and LBP in 14-year-olds [114].

*Physical activity*

Very low and very high levels of physical activity may increase risk of LBP. In a recent systematic review of physical activity and LBP in children and adolescents, there was an association between physical activity and LBP in 6 of 9 included studies, with moderate evidence [115]. Similar to the 'U-shaped relationship' between physical activity and LBP previously observed in adults [116], the findings of this review supported associations between very high and very low levels of physical activity [115]. Other research has also supported an association between low levels of physical activity and LBP. Increased sedentary behaviour, such as time spent sitting to do homework or use electronic devices, is associated with increased risk of LBP [117 118].

### 1.5.4 Conditions associated with low back pain in adolescents

#### *1.5.4.1 Overview*

There are many conditions which are associated with LBP in adolescents, including spondylolysis, spondylolisthesis, adolescent idiopathic scoliosis (AIS), Scheuermann's kyphosis, and disc disease. Non-specific LBP must also be considered in adolescents, although adolescents appear to have a higher likelihood of being assigned a specific diagnosis[119].

#### *1.5.4.2 Spondylolysis and spondylolisthesis*

Spondylolysis is a fracture of the pars interarticularis of the vertebrae, often associated with repeated mechanical stress [120]. In the general population, most cases of spondylolysis are asymptomatic [120-122]. In adolescents, spondylolysis is often asymptomatic, with a prevalence of 6% [103 123]. Symptomatic spondylolysis occurs most often in adolescent athletes [120]. There is a higher incidence of symptomatic spondylolysis in young athletes than in the general adult population, with one study finding spondylolysis in 47% of young athletes presenting to a sports medicine clinic, compared to 5% of adults [124]. Spondylolisthesis is a condition related to spondylolysis, in which one vertebra slips on the other, either anteriorly or posteriorly. Anterior slippage (anterolisthesis) is more common than posterior (retrolisthesis), and the most common site of spondylolisthesis is L5 [125].

Slippage increases during growth in adolescents [125]. Pain is the most common symptom at the initial stages of spondylolisthesis[125].

*1.5.4.3 Adolescent idiopathic scoliosis*

Adolescent idiopathic scoliosis (AIS) is the most common form of scoliosis in children and adolescents, and is often diagnosed between the ages of 10 and 18[126]. There is a moderately high rate of LBP associated with AIS, with nearly 20% of adolescents reporting pain in the lumbar region in a retrospective chart review[127]. In a cross-sectional study of 43,630 students in Japan, the risk of LBP in those with AIS was twice as high as it was in individuals without AIS (OR 2.3, $P = 0.01$ for point and OR 2.1, $P = 0.01$ for lifetime prevalence)[128]. However, a recent systematic review concluded that while many adolescents with AIS experience LBP, AIS may not be an aetiological contributor to LBP [129]. Cobb angle and LBP were not correlated in adolescents, and the rate of LBP experience by adolescents with AIS was similar to that of those without AIS [129]. Overall, current evidence does not support a linear relationship between LBP and AIS.

*1.5.4.4 Scheuermann's kyphosis*

Scheuermann's kyphosis is a condition that has a hallmark of excessive kyphosis of the spine[130]. There are two types of Scheuermann's kyphosis: Type 1 typically affects the thoracic spine, and Type 2 affects both the thoracic and lumbar spine[130]. It is commonly identified in adolescents aged 12 to 17, with males more commonly affected than females[130]. Research has shown that Scheuermann's kyphosis can be associated with LBP, although it may develop later in life. A 37-year follow up study of those with untreated Scheuermann's kyphosis found that Scheuermann's kyphosis was significantly associated with higher risk of constant back pain (37.5%, OR 2.5 (1.4-4.5)), disability due to back pain in the past five years (53.3%, OR 2.6 (1.4-4.7)), and back pain in the past 30 days (71.1%, OR 3.7 (1.4-4.3)) when compared to a control group from the general population[131].

*1.5.4.5 Disc disease*

Disc disease can also be associated with LBP in adolescence, although when compared to the rate of LBP-related disc disease in adults, it is relatively infrequent[124]. A retrospective case comparison study comparing adolescent and adult LBP found that discogenic LBP was diagnosed in 11% of adolescents compared to 38% of adults[124]. One type of disc disease, disc herniation, often presents with LBP in the adolescent age group but is not common, representing only 3.5% of disc disease in adolescents[132]. Magnetic resonance imaging (MRI) findings of disc degeneration appear to be prevalent in adolescents, with signs of disc degeneration present in up to 30% of 13-year-olds[133].

*1.5.4.6 Non-specific low back pain*

In adults, up to 90% of LBP is non-specific[134], meaning that there is no identifiable pathology associated with the pain. LBP in adolescence also appears to be mostly non-specific[135 136], although adolescents are more likely to receive a specific diagnosis related to LBP, when compared to adults[119]. The rate of non-specific LBP in adolescents may be lower than that of adults, although still representing the majority, with a retrospective chart review of 648 patients indicating that there was no organic cause in 57% of LBP cases [135].

1.5.5 Treatment of low back pain in adolescents

There has been little investigation into the optimal treatment for non-specific LBP in adolescents. A systematic review of physical therapy treatments for LBP included eight studies of low methodological quality[77 79]. In this review, a combination of physical conditioning and manual therapy was most effective in treating LBP when compared to control interventions, although the generalisability of this review was limited by low methodological quality[79]. Another systematic review of LBP interventions in children and adolescents indicated that there is a paucity of evidence regarding treatment of LBP in children and adolescents, although exercise may be effective[137]. This review included four randomised controlled trials investigating treatment of LBP[137]. Further research into the optimal treatment of LBP in adolescents in required.

Interventions examining pain generally have found that management following a biopsychosocial model has positive effects on adolescent pain. Of these interventions, the common aspects have been pain education, psychological interventions, and involvement of physical and occupational therapy[54]. A large focus of theses interventions is the self-management of pain.

### 1.5.6 The impact of low back pain on adolescents

#### *1.5.6.1 Activity limitation*

LBP influences adolescents' ability to participate in social activities and activities of daily living. In a survey of 500 adolescents, 7.8% of participants reported absence from school related to LBP[138]. In the same study, nearly 10% of participants were unable to participate in sport or physical activity due to LBP[138]. In those that reported recurrent LBP, there was a higher rate of absence from school[138]. Activity limitation is strongly linked to LBP in adolescents, with difficulties reported in activities such as sitting in school, sports participation, carrying a school bag, and standing for over ten minutes[138-140]. In a cross-sectional study of 17-year-olds, LBP was associated with medication taking, reduced recreational activity, absence from school, and lower health-related quality of life[91]. The difference in the physical functioning and mental health areas of health-related quality of life (QOL) was both statistically significant and clinically meaningful[91]. This indicates that LBP has a substantial effect on QOL in adolescents. As this research has shown, LBP can have a significant effect on the lives of adolescents through limiting participation in school, social, and sports activities.

*1.5.6.2 Recurrence of adolescent low back pain*

A first episode of LBP, or initial onset, can have significant impacts on an adolescent's life. There are also strong links between LBP in early life and recurrent episodes throughout life. A previous episode of LBP is a risk factor for the development of future LBP[80 81]. Longitudinal studies have found that LBP during adolescence is a risk factor for LBP in adulthood [80 141]. Those who experienced a longer episode of LBP in adolescence had a higher risk of future LBP, demonstrating the importance of effective management of LBP in adolescents[80]. A review on the long-term course of LBP also found that those with previous LBP were twice as likely to report LBP in future[81].

LBP in early adolescence has also been linked to recurrent LBP in late adolescence. The rate of recurrent LBP appears to increase with age at least until the age of 16[105 138]. Those with recurrent LBP also reported a higher rate of disability than those without recurrent LBP[138]. Another study of adolescents aged 11-14 found that 25% of participants reported persistent LBP after four years[142].

An episode of LBP in adolescence can have a notable impact on an individual throughout their life. Since optimal management of LBP in adolescents is not currently supported by high quality evidence, there needs to be more research in this area to prevent lifelong LBP-related disability.

## 1.6 Low back pain in athletes

### 1.6.1 Overview

LBP is a prevalent issue for athletes across different sport disciplines[143 144]. Lifetime prevalence of LBP in athletes has been reported to range from 1-94%[145], with a cumulative weighted mean prevalence of 63% in adults[146]. Point prevalence has been reported to range from 18-80%[145 146], with an estimated mean of 42% in adults[146].

Two recent systematic reviews of athlete LBP found that LBP in sport was common[145 146]. Both reviews found that there was a large amount of variation in the reported prevalence of LBP in athletes[145 146]. Disruptions to competition and training are unique to LBP in sport, which were not captured in many LBP definitions[146].

### 1.6.2 Risk and associated factors

In a recent systematic review of adult athletes, there were associations between LBP and load increases and years of participation in sport[146]. Other reported risk factors for LBP in sport include previous history of LBP[146-148], high training volume[146 149], repetitive motion[149], and high physical load[149].

### 1.6.3 Treatment

The optimal treatment for LBP in athletes is unclear. Several systematic reviews of the treatment and management of LBP have concluded that there were no treatments that were clearly more effective than others[150 151]. Most existing research on management of sport-related LBP did not report of the effect of interventions on return to sport, which is an important measure for athletes[150]. There is a need for more high-quality research in this area[150].

### 1.6.4 The impact of low back pain in adult athletes

LBP can affect adult athletes throughout their lives, both in relation to sport and in their daily lives. A previous episode of LBP is a risk factor for future LBP, meaning that some athletes experience continuing LBP-related disability[146 152]. For some professional athletes, LBP can be career-ending[146]. In a qualitative study on LBP in adult rowers, some participants discussed LBP impacting their non-sport related jobs, as well as their ability to take college exams[153]. Some athletes felt that the disclosure of LBP to coaches and teammates might make them seem weak or a liability[153]. The impacts of LBP on adult athletes are variable, from affecting an athlete's sport participation or career to affecting their mental health.

### 1.6.5 Psychosocial injury models within sport

#### *1.6.5.1 Stress-injury model*

The Stress-Injury model was proposed by Andersen and Williams in 1988[154], with an updated critique in 1998[155]. This model proposes that several factors can affect how an athlete copes with a potentially stressful situation, which in turn affects the likelihood of this athlete being injured. The way an athlete handles a stressful situation modulate the level of injury risk. This model is widely accepted within sports psychology. There are clear associations between high life stress and injury.

#### *1.6.5.2 Integrated model of response to sport injury*

This model, posited by Diane Wiese-Bjornstal and colleagues[50], builds on the Stress-Injury model to suggest that the same factors which impact susceptibility to injury can also influence response to injury after the fact. Personal and situational factors can impact how an athlete cognitively appraises the threat of an injury to themselves. This in turn affects emotions, which can impact athlete behaviour. This could also go the other way, in that athlete behaviour affects their emotions, impacting their cognitive appraisal of an injury situation. This model better accounts for the individuality of injury responses.

#### *1.6.5.3 Biopsychosocial model of sport injury*

The biopsychosocial model includes the effect of biological, psychological, and social factors on injury and rehabilitation outcomes. There are a variety of ways that this could manifest. For example, psychological factors can directly impact self-reported injury outcomes like pain, quality of life, and symptom reporting[156]. Psychological factors could also impact adherence to treatment regimens, in turn affecting rehabilitation outcomes[23]. Furthermore, psychological or social factors such as life stress could directly affect biological factors. For example, stress and other psychological factors can impact immune function[157] and wound healing[158]. This model has limited evidence in this domain.

*1.6.5. 4 Multilevel model of sport injury*

The multilevel model of sport injury includes the impact the environment has on an athlete in their injury risk and recovery. This includes the athlete as well as their relationships and social circle, the institution/organisation sport is practiced in, cultural influences, and local and national policy[23]. This model is newer and has limited research but includes important recognition that the athlete operates within a specific context, and sport injuries can be affected by this context.

1.6.6 Differences between adult and adolescent athletes

There are important differences to consider when assessing adult and adolescent athlete LBP. For instance, the reasons for participation in sport may be different between adults and adolescents. Although not all athletes are motivated by the same factors, in child and adolescent sport, fun is the main reported reason for participation[159]. For adults, the main motivators for sport participation may lean more towards physical and mental health benefits[160], community[160], or mastery[161] and competition[160].

Adolescence is also a habit-forming time of life. For instance, adolescents who play sport are eight times more likely to play sport as young adults (at age 24)[162]. Adolescent sport participation is a significant predictor of adult sport participation[162]. Injury or pain during this time may affect the formation of beneficial physical activity habits.

In adolescents, the impact of teammate and parent/guardian relationships may be greater. This can influence an adolescent's risk of pain and injury in different ways to adult athletes. There is also the formation of identity in adolescence[163], which can include an athletic identity formation. This is the extent to which an athlete identifies with an athlete role[47], and can form in those that participate in a large amount of sport in adolescence. Those with a stronger sense of athletic identity can be at higher risk of pain and injury[48 49].

Because of the unique considerations in adolescent sport outlined here, low back pain in adolescent athletes must be considered separately to adults.

## 1.7 Low back pain in adolescent athletes

### 1.7.1 Overview

LBP is a common problem among athletes, even as early as adolescence. There has been a lack of emphasis in research focusing on the epidemiology, presentation, lived experience, and beliefs associated with this condition. The incidence, prevalence, risk factors, and impacts that LBP has on adolescent athletes may be like those seen in the general adolescent population and the adult athlete population, but there has been a lack of evidence synthesis of available studies to date.

Presentation of LBP in the adolescent athlete appears to vary by sport, although there has been no published overview of aetiologies related to specific sports. Contact sports are more likely to result in acute low back injuries, whereas sports like gymnastics or dance are more likely to result in overuse injuries due to repetitive extension[164]. In adolescent athletes, spondylolysis appears to be most associated with LBP. In a randomised case comparison study, compared to the adult prevalence of 5%, 47% of adolescent athletes presenting with LBP were diagnosed with spondylolysis[124].

In some cases, LBP resulting from sport may result in ongoing disability for adolescent athletes. Studies have reported that up to one fifth of all injuries during youth sport are classified as ‘severe’, meaning they result in four weeks or more away from sport[165]. Additionally, LBP in adolescence can lead to adult LBP[80]. More importance must be placed on understanding presentation and management of adolescent LBP. This could prevent recurrent problems later in life, as well as loss of training and competition time.

The research from this thesis will contribute to the evidence base about LBP in adolescent athletes. It will provide more insight into the rate of LBP in adolescent athletes, the clinical presentation and management of these athletes, and their lived experience of LBP. It will also explore adolescent and clinician understandings of LBP, which may affect the rate of specific diagnoses in this age group.

## 1.8 Rationale for thesis

Although under-represented in research, adolescent athletes appear to report LBP regularly[164]. LBP can lead to an adolescent athlete taking time off from playing sports or quitting sports entirely[59]. For some, LBP can become more pervasive, affecting not only participation in sport, but home and school life as well[103]. There is currently a paucity of high-quality evidence on the impact of LBP on adolescent athletes specifically. The primary aim of this PhD research was to fill the gaps in existing research by documenting the following:

- Prevalence, incidence, risk factors, and associated morphologies with LBP in adolescent athletes.
- Common pathologies and treatment methods for adolescent athletes experiencing LBP and presenting to a sports medicine clinic.
- Qualitative accounts of the effects LBP can have on the lives of adolescent athletes.
- Clinician LBP beliefs about LBP.
- Current assessment and management techniques for adolescent LBP

This research included both qualitative and quantitative methodologies and took place in both Ireland and in the United States.

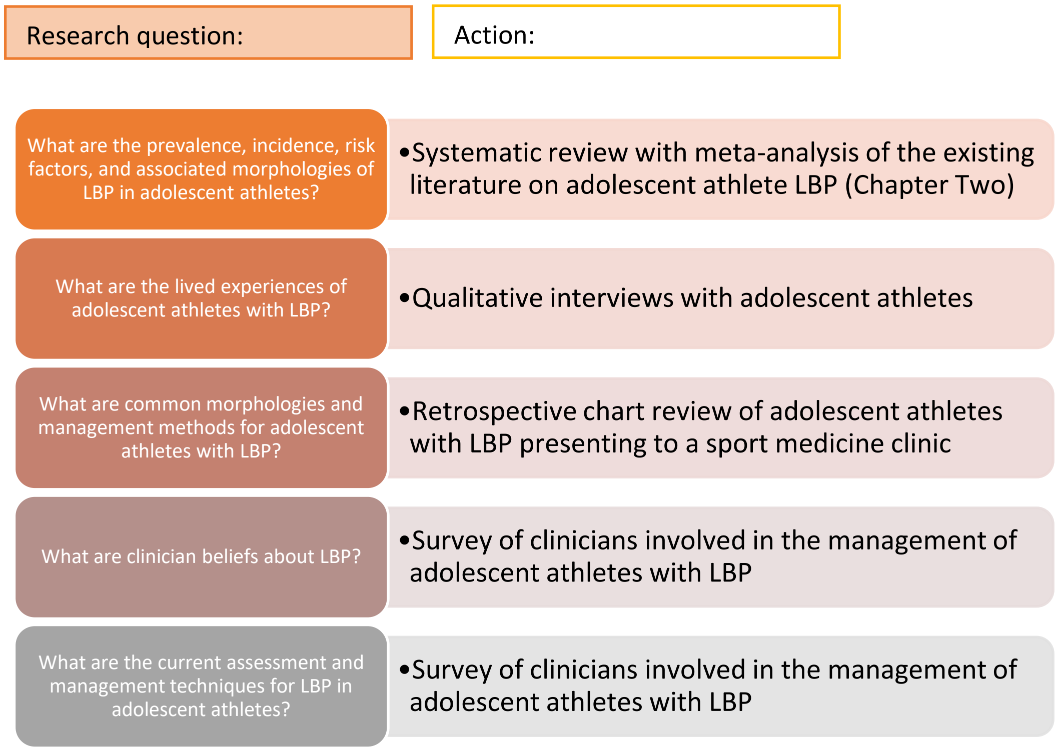


**Figure 1-4:** Research questions and actions within this thesis to investigate each research question.

## 1.9 Value of research

This research contributes to an under-researched area in the field of Sports Medicine. The international nature of this research between Ireland and the United States increases the scope and impact of the results. It quantifies the rate of LBP in this population and highlight associated risks and pathologies. It provides insight into the lived experiences of adolescent athletes with LBP and highlight issues which are important to the athletes themselves. It provides an overview of the current clinical management pathways of adolescent athletes with LBP. Finally, it provides a snapshot of the beliefs about LBP held by clinicians. Current management of LBP in adolescent athletes is explored, which may inform appropriate management strategies. The results of this body of work contribute to increased understanding of how LBP affects adolescents participating in sport.

## 1.10 Overall Thesis Aim and Hypotheses

The overall aim of this thesis is to *characterise* LBP in adolescent athletes and *explore* current management practices. This includes cumulative incidence and prevalence, lived experience, common conditions, clinician pain beliefs, and management. To give structure to this thesis, the Sackett model of evidence-based medicine is used throughout (Figure 1-6)[166].


**Figure 1-5:** Sackett model of evidence-based medicine exploring LBP in adolescent athletes.

### 1.10.1 Thesis hypothesis

LBP in adolescent athletes is common. Awareness of the prevalence and risk factors, the lived experience of athletes, common morphologies, and the current management practices and beliefs of clinicians will improve understanding of this condition. This may modify risk and improve athlete experience and clinician management.

1.10.2 Aims and objectives of Study I

*Title:* Incidence, prevalence, and risk factors for low back pain among adolescent athletes: a systematic review and meta-analysis.

*Aim:* To systematically examine and synthesise research about LBP in adolescent athletes.

*Objectives:*

- Estimate the cumulative incidence and prevalence of sport-related LBP in adolescent athletes across a variety of sports
- Report risk factors for sport-related LBP in adolescent athletes
- Outline the common conditions associated with sport-related LBP in adolescent athletes
- Investigate the quality of studies in adolescent athlete LBP

1.10.3 Aims and objectives of Study II

*Title:* Diagnoses associated with low back pain in adolescent athletes: a retrospective chart review of 400 patients

*Aim:* To characterise presentation of adolescent athletes presenting to a Sports Medicine clinic with LBP.

*Objectives:*

- Categorise the differences in LBP aetiology and presentation by sport, by sex, and by age.
- Identify conditions associated with LBP in adolescent athletes.
- Examine current treatment and management methods of LBP in adolescent athletes.

#### 1.10.4 Aims and objectives of Study III

*Title:* "Back pain is part of sport … I'm just gonna have to live with it": Exploring the lived experience of sport-related low back pain in adolescent athletes

*Aim:* To examine the lived experiences of adolescent athletes reporting an episode of sport-related LBP.

*Objectives:*

- To examine the effects of LBP on daily life.
- To examine adolescent athlete relationships with parents/guardians, teammates, and coaches with relation to LBP.
- To examine adolescent athlete experiences of treatment/management for LBP.
- To document adolescent athletes' understanding of LBP.

#### 1.10.5 Aims and objectives of Study IV

*Title:* Healthcare professionals' assessment, management, and beliefs about low back pain in adolescent athletes

*Aim:* To investigate current management of LBP in adolescent athletes, including the LBP beliefs of clinicians.

*Objectives:*

- To establish current assessment and management practices of HCPs managing LBP in adolescent athletes.
- To establish the back pain beliefs of HCPs managing LBP in adolescent athletes.
- To establish whether assessment, management, or beliefs varied based on geographical region or healthcare profession.
- To explore the components of adolescent LBP care that HCPs identify as differing from adult LBP care.

# Chapter 2: Incidence, prevalence, and risk factors for low back pain in adolescent athletes: a systematic review and meta-analysis

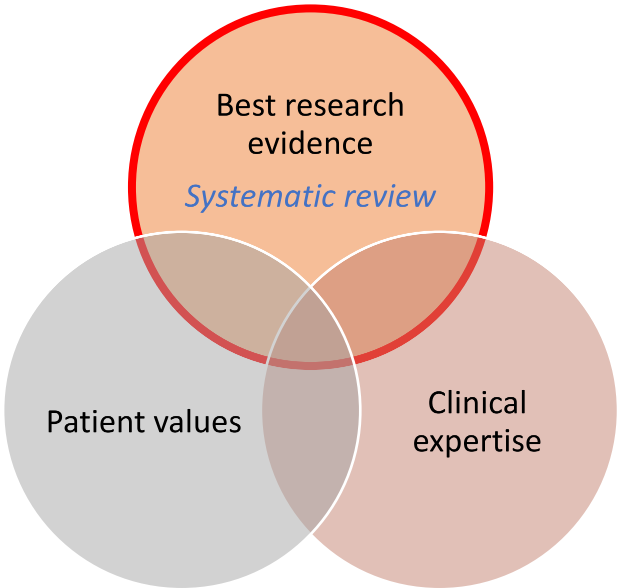


**Figure 2-1:** Sackett model of evidence-based medicine exploring LBP in adolescent athletes.

## 2.1 Introduction

A leading cause of disability worldwide,[73] low back pain (LBP) is prevalent in adolescents, with some studies estimating a twelve month prevalence to be 33-57%[77 78] and lifetime prevalence to be 70-80% by the age of 20[76].

LBP can pose unique risks to adolescents participating in sport. Estimates suggest that 10-15% of young athletes experience LBP, with some variation based on sport played[164 167]. Although LBP resolves quickly for some athletes, it can result in consequences, including time off from playing sports or quitting sports entirely[59]. Since a previous history of LBP is a risk factor for the development of future episodes, the onset of LBP during adolescence also carries other risks, such as the potential for continued LBP later in life[80 81]. There has not been a published synthesis exploring prevalence of LBP in adolescent sport even though adolescent athletes report LBP regularly[164].

In this review we aim to create a comprehensive synthesis across multiple sports about the incidence, prevalence, morphologies, and risk factors associated with LBP in adolescent athletes. Our objectives were to establish the 1) incidence and prevalence, 2) risk factors, and 3) morphologies associated with LBP in adolescent athletes.

### 2.1.1 Aims and objectives

*Aim:* To systematically examine and synthesise research about LBP in adolescent athletes.

*Objectives:*

- Estimate the cumulative incidence and prevalence of sport-related LBP in adolescent athletes across a variety of sports
- Report risk factors for sport-related LBP in adolescent athletes
- Outline the common conditions associated with sport-related LBP in adolescent athletes
- Investigate the quality of studies in adolescent athlete LBP

## 2.2 Methods

2.2.1 Protocol and registration

We used the Preferred Reporting Items for Systematic Reviews and Meta- Analyses (PRISMA)[168] recommendations in the reporting of this systematic review. Prior to beginning the review, criteria were established and published in a protocol on the International Prospective Register of Systematic Reviews (PROSPERO) (https://www.crd.york.ac.uk/prospero/), registration number: CRD42020157206. Differences between protocol and review can be found in Appendix 2-1.

2.2.2 Study eligibility criteria

We included prospective and retrospective studies that evaluated the prevalence and/or incidence of LBP in athletes aged 10-19 years old. An athlete was defined as an individual participating in extracurricular sport. Population studies and studies that compared athletes to a non-sport population were included if they reported sport-related LBP. This review was limited to observational studies, including case control, cross-sectional, and cohort studies. We excluded studies that were published in a language other than English without an easily accessible translation, and conference papers with insufficient data (Figure 2-2).

2.2.3 Sources and study selection

We searched five sources (Medline, Embase, Cumulated Index to Nursing and Allied Health Literature (CINAHL), Web of Science, Scopus) from inception to September 30$^{th}$, 2021, using a search strategy designed by a medical librarian experienced in the process (DM) (Appendix 2-2). The final search was conducted on September 30$^{th}$, 2021. Search results were exported to EndNote (Clarivate Analytics, Philadelphia, USA) citation management software where duplicates were removed. Studies were uploaded to Covidence Systematic Review Software (Veritas Health Innovation, Melbourne, Australia). Two researchers (FW and JW) screened the titles and abstracts of these studies using Covidence. Titles, keywords, and abstracts were screened to determine whether they met inclusion criteria. Disagreements identified by Covidence were discussed until consensus was reached. There was no blinding to study author, institution, or journal. The same two researchers conducted full text screening of studies using Covidence software. Gray literature was included by searching the reference lists of included studies as well as American College of Sports Medicine conference abstracts 2016-2020, American Physical Therapy Association conference abstracts 2015-2020, and World Physiotherapy conference abstracts 2019 and archive.

#### 2.2.4 Data extraction and management

One review author (JW) independently extracted data from included studies using a customised data extraction form, based on a recent systematic review of LBP in adult athletes[146]. Extracted data contained the following study details: design, aims, objectives, country, sport, sample size, and setting. Characteristics of participants were extracted including age and type of participants. We also extracted main observations, outcome measures, definition of LBP (if included), reported incidence and/or prevalence, time period used, and risk factors.

#### 2.2.5 Data analysis

We synthesized data to calculate an overall weighted mean prevalence and incidence of LBP in adolescent athletes for each different time period used. Data from studies on six-month, 12-month, and two-year time periods for incidence were synthesized. For prevalence, data from high-quality studies 12-month period prevalence, three-month period prevalence, and point prevalence were synthesized. Weighted means were calculated for high-quality studies in each time period to consider the effect of sample size using a random effects model in Metafor in R Core Team (2020). Forest and funnel plots were generated for all time periods. It was assumed that random effects followed a normal distribution. For the meta-analyses an expit link function was used with a random effects model [$y_i = (\mu + \mu_i)\ \varepsilon_{ij}$] that allowed for random errors and true variation between studies. Where $y_i$ is the dependent variable (prevalence), $\mu$ is the mean prevalence effect, $\mu_i$ is the study specific deviation with between study variation, $\varepsilon_{ij}$ is the difference between observed and predicted

Meta-regression analyses using a mixed-effects model were conducted using Metafor in R[169]. Factors which could potentially contribute to heterogeneity in prevalence and incidence estimates were investigated, including methodological quality (high or low), number of participants (N), outcome expression (percentage of people with LBP or percentage of injuries to the low back out of all injuries), LBP definition (yes or no, included written and drawn definitions), sex (male or female), mean age, sport (specific sport or multiple), prospective or retrospective study design, and method of data collection (questionnaire or other). The linearity assumptions were tested using Q-Q plots and residual plots.

2.2.6 Assessment of methodological quality

Two reviewers (KT and JW) assessed included studies using a quality appraisal tool developed by Lebeouf-Yde and Lauritsen (1995)[170] to assess quality in studies of LBP cohorts (Table 2-3). This tool was modified by Walker (2000)[171] to include an additional criterion. It was further modified by Trompeter et al. (2017)[145] to consider studies scoring 65% and above as high quality. This tool (Appendix 2-3) assesses three main areas (twelve items in total): whether the final sample was representative of the target population (three items), quality of the data (six items), and definition of back pain (three items). Each item is scored as criteria fulfilled (+), criteria not fulfilled (-), or not applicable (NA). The percentage of items with criteria fulfilled out of the total applicable items represents the methodological quality score.

## 2.3 Results

2.3.1 Search strategy

After removing duplicates, the search yielded 1,907 papers for screening. After screening and exclusions (Figure 2-2), 80 studies were eligible for data extraction.

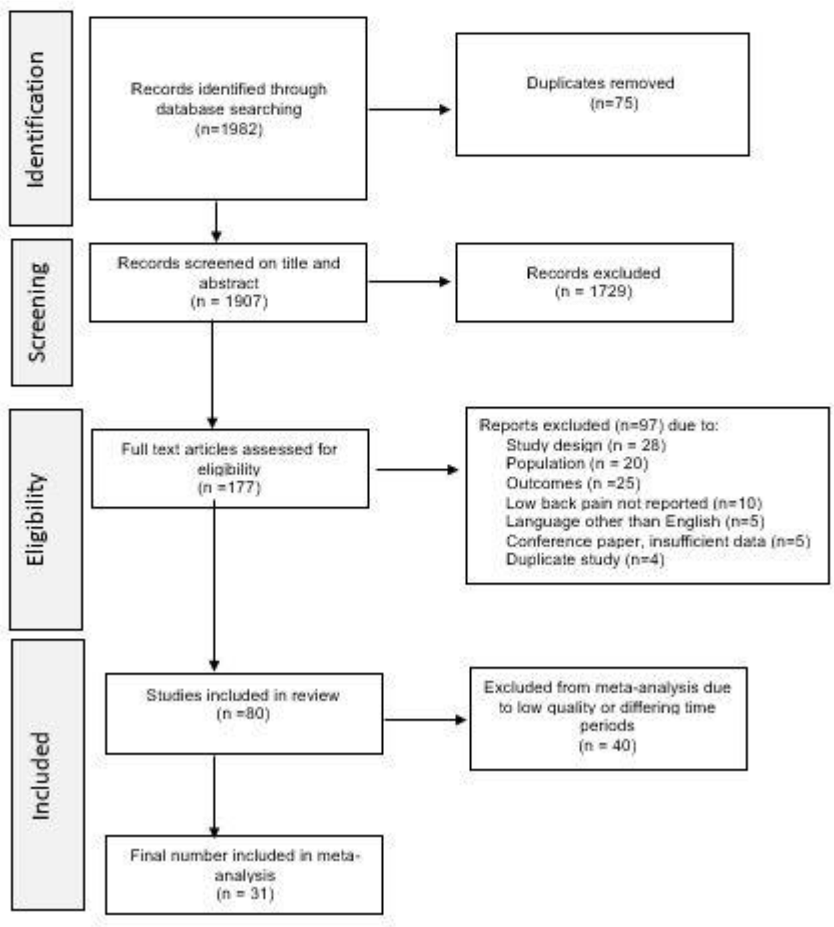


**Figure 2-2:** Flow chart of study selection for the analysis of incidence, prevalence, and risk factors for low back pain in adolescent athletes.

2.3.2 Characteristics of included studies

A total of 80 studies included 31 cohort studies and 49 cross-sectional studies (Table 2-1). Athlete-specific participant numbers ranged from 7[172] to 21,280[173]. There were 60 sports across 23 countries. Data were most often collected by use of a questionnaire. Common questionnaires included Nordic Musculoskeletal Questionnaire[174] or adaptations thereof, and the Oslo Sports Research Trauma Centre Questionnaire[175].

Among the 49 cross-sectional studies, 30 were included in meta-analysis of high-quality studies reporting lifetime prevalence (n=18), 12-month prevalence (n=8), three-month prevalence (n=4), and point prevalence (n=15). Among the 31 cohort studies, 10 were included in meta-analysis of studies reporting two-year incidence (n=2), 12-month incidence (n=4), and six-month incidence (n=4). Since there were so few high-quality cohort studies reporting the same time period, data from high- and low-quality cohort studies was included in meta-analysis for incidence. Further details of reported incidence, prevalence, and risk factors can be found in Table 2-4.

Data from 74 studies (study reporting explanation in Appendix 2-4) was included in the analyses. For this review, “soccer” refers to football, while other football codes are explicitly stated (i.e., “American football”, “Australian Rules football”, and “Gaelic football”).

**Table 2-1: Characteristics of participants of all the included studies.**

| Author, year | Country | Sport(s) | Study design | Setting | No. of participants (F%/M%) | Mean/ median participant age (SD/IQR) | Type of participants | Variables | Data collection mode |
|---|---|---|---|---|---|---|---|---|---|
| *Abe et al. 2017* | Japan | Team sports (Baseball, softball, basketball, soccer, volleyball, other) | Cross-sectional | Junior high schools and high schools in Unnan City, Shimane, Japan | N= 632<br>41%F/59%M | 13.8 (1.5) | Students participating in team sports | - Pain sites<br>- Relationship of number of teammates to MSK pain<br>- Team quantity index (TQI) | Questionnaire |
| *Alricsson and Werner 2006* | Sweden | Cross country skiing | Longitudinal cohort | Northern part of Sweden | N=15<br>53.3%F/46.7%M | *Start of study* 13.6 (0.9)<br><br>*Five year follow up* 18.5 (0.9) | Young elite cross-country skiers | - Kyphosis<br>- Lordosis<br>- Presence of LBP<br>- Training hours per week<br>- Weekly participation in sport other than cross country skiing | - Questionnaire<br>- Debrunner's kyphometer |
| *Alricsson and Werner 2005* | Sweden | Cross country skiing | Cross-sectional with age matched controls | High schools in Northern Sweden | N=120 cross country skiers<br><br>N=993 controls<br><br>Sex N/R | *Study group* 18. 1 (1.1)<br><br>*Control group* 18 (1) | Cross-country ski students from all 5 ski high schools in Sweden. Control group was from 3 school districts in the North part of Sweden. | - Physical activity<br>- Physical health<br>- Location of symptoms/injuries<br>- Back pain in skiers | Questionnaire |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Auvinen et al. 2008* | Finland | *Multiple (population-based study)*<br>Included: walking, jogging, cycling, cross-country skiing, swimming, soccer, ice hockey, floorball, rinkball or bandy, Finnish baseball, basketball, volleyball, ice-skating, figure skating, track and field, horseback riding, aerobics, gymnastics, dancing, gym training, downhill skiing or snowboarding, roller-skating or skateboarding, badminton, tennis, orienteering running, judo or karate or wrestling, and golf. | Cross-sectional | Questionnaire based on the Finnish Physical Activity Survey as part of the Northern Finland Birth Cohort (1986) | N=6947<br><br>Sex N/R | N/R | Children born in the two northernmost provinces of Finland between July 1, 1985, and June 30, 1986 | - MSK pain<br>- Health habits such as physical activity, sedentary behaviour, smoking | Questionnaire |
| *Balague et al. 1988* | Switzerland | *Multiple (population-based study)*<br>Included: soccer, skiing, gymnastics, swimming, bodybuilding, volleyball, aerobics | Cross-sectional | Schools in Switzerland | 1715<br>51%F/49%M | 12 | Schoolchildren in the fourth school district of the Sarine area near Fribourg, Switzerland | - Frequency and location of back pain<br>- Hours per day spent watching TV<br>- Number of cigarettes smoked<br>- Sports | Questionnaire |
| *Balague et al. 1994* | Switzerland | *Multiple*<br>Included tennis, volleyball, cycling, and swimming | Cross-sectional | Primary and secondary schools in Switzerland | N=1716<br>50.6%F/49.4%M | *Mean* 11.7<br>*Median* 12 | Primary and secondary school children in One school district of | - Lifetime and 7-day hx of LBP<br>- Localization of LBP<br>- Medical tx of LBP<br>- Parents hx of LBP | Questionnaire |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Fribourg, Switzerland | - TV watching<br>- Sports activity<br>- GPA | |
| *Bayne et al. 2016* | Australia | Cricket | Cohort | District and/or state junior cricket squads, data collection took place at the University of Western Australia | N=25<br>100%M | *Injured* 15.5 (1.4)<br><br>*Non-injured* 16 (1.2) | Fast bowlers from district and/or state junior cricket squads | - MRI<br>- MSK screening<br>- 3D biomechanical bowling analyses | Clinical examination |
| *Brown and Kimball 1983* | USA | Powerlifting | Cross-sectional | The 1981 Michigan Teenage Powerlifting Competition | N=71<br>100%M | N/R | Teenage powerlifters | - Training, experience<br>- Medical history<br>- Injury types<br>- Injury sites | Questionnaire |
| *Burnett et al. 1996* | Australia | Cricket | Cohort | Male fast bowlers at the beginning of the 1991-1992 cricket season and at the completion of the 1993-1994 cricket season | N=19<br>100%M | *Study start* 13.6<br><br>*Study end* 16.3 | 19 male cricket fast bowlers | Filming of maximum velocity bowling and MRI | Film and radiographic procedures |
| *Cejudo et al. 2020* | Spain | Equestrian sports | Cross-sectional | Equestrian Technical Centre of the Region of Murcia (Murcia, Spain) | N=19<br>58%F/42%M | 14.7 (1.9)<br><br>*Male* 13.9 (1.8)<br><br>*Female* 15.3 (1.9) | Child equestrian athletes of the Murcia Regional Team | - Demographic data<br>- Sport related background info<br>- Training workload<br>- LBP<br>- Risk factors | Interview questionnaire<br><br>Clinical examination |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Cezarino et al. 2020* | Brazil | Soccer | Cohort | Brazilian first division male youth soccer academy | N=228<br>100%M | 16.51 (2.59) | Male youth soccer players | - Anthropometric measurements<br>- Injury and exposure data | - Measurements taken by club physiologist<br>- Injury report form completed by physiotherapist<br>- Training and match exposure forms completed by assistant coaches |
| *Cupisti et al. 2004* | Italy | Gymnastic/s | Cross-sectional | 19 gymnastics clubs affiliated with the Italy Federation of Gymnastics | *Study group* N=67<br><br>*Control group* N=104<br><br>100%F | Both groups 14.7 | Competitive club level gymnasts and age matched controls | - Presence, location, intensity of back pain<br>- Smoking habits<br>- Age of menarche<br>- Mental stress questionnaire<br>- Skinfold thickness measurements | Questionnaire and clinical examination |
| *Dennis et al. 2005* | Australia | Cricket fast bowling | Cohort | Club and district cricket leagues in Australia | N=44<br>100%M | 14.7 | Australian fast bowlers playing at the club and district level | - Match and training deliveries bowled each day<br>- Conditions/injuries<br>- MRI at baseline and post-injury | - Logbook<br>- MRI |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Farahbakhsh et al. 2018* | Iran | *Multiple*<br>Included: football, volleyball, basketball, wrestling, gymnastics, fitness, shooting, track and field, and swimming | Cross-sectional | Tehran Province, Iran between July and August 2017. Sports Medicine Research Centre of Tehran University of Medical Sciences | N=377<br>100%M | 15.95 | Male athletes participating in the sport Olympiad | - Questionnaire about prevalence of neck and LBP | Questionnaire |
| *Fouasson-Chailloux et al. 2020* | France | Soccer | Cohort | French regional academy | N=161<br>100%M | N/R | Youth male soccer players | - Injury diagnosis<br>- Date<br>- Nature<br>- Location<br>- Severity | Injury data recorded by sports physician |
| *Gamboa et al. 2008* | USA | Ballet | Retrospective descriptive cohort | Elite preprofessional ballet boarding school in Washington DC | N=359<br>80%F/20%M | 14.7 (1.9) | Elite adolescent pre-professional ballet dancers | - Demographics<br>- Past medical history<br>- Posture<br>- Strength<br>- Flexibility<br>- Orthopaedic testing<br>- Function | Clinical examination |
| *Gregory et al. 2002* | England | Cricket | Prospective cohort | Centres of Excellence of 3 "First Class" Counties in England in January 1998 | N=113 | 14.9 | Young cricketers | - Injuries caused by/interfering with bowling | Telephone questionnaire |
| *Grimmer and Williams 2000* | Australia | Multiple | Cross-sectional | 12 High schools in Adelaide, Australia in 1998 | N=1193<br>49%F/51%M | N/R | High school students in Australia | - Backpack and student weights<br>- Height<br>- questionnaire answers-information on LBP in the past two weeks | Questionnaire and clinical examination |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Ha et al. 2017* | South Korea | Baseball | Cross-sectional | Elementary schools, junior high schools, senior high schools in South Korea | N=293<br>100%M | 12.8 (2.1) | South Korean male baseball players | - Prevalence (Point and Lifetime)<br>- Recurrence<br>- Age of onset for LBP<br>- Peak height velocity calculated | Questionnaire and health records |
| *Harreby et al. 1999* | Denmark | Multiple | Cross-sectional | 46 municipal schools in 3 counites of Sealand, Denmark | N=1389,<br>52%F/48%M | 92.4% were either 15 or 16 years of age | 8th and 9th grade Danish schoolchildren | - LBP frequency and severity<br>- Sports participation frequency and intensity | Questionnaire |
| *Hickey et al. 1997* | Australia | Basketball | Retrospective review of records | Sports Medicine Department at the Australian Institute of Sport in Canberra, Australia | N=49<br>100%F | 17.6<br>*at time of injury presentation* | Elite female basketball players with scholarships at AIS | - Injury<br>- Anatomical location<br>- Nature<br>- Acute or chronic | Retrospective review of clinical examination |
| *Hjelm et al. 2010* | Sweden | Tennis | Cohort | Swedish local tennis club | N=55<br>65%F/45%M | 15.4 | Junior tennis players in Sweden, playing at least twice per week | - Gender<br>- Anatomic location<br>- Month<br>- Injury type<br>- Injury severity | Clinical examination |
| *Hoskins et al. 2010* | Australia | Australian Rules football | Cross-sectional | Junior Australian rules football leagues | N=102<br>*Elite junior*<br><br>60 *Non-elite juniors*<br><br>100 *Control* | *Elite junior* 17.2 | Junior Australian rules football players, both elite and non-elite, and Australian high school | - Prevalence<br>- Intensity<br>- Quality<br>- Frequency of LBP | Questionnaire |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | students as the control group | | |
| *Hutchinson 1999 a* | USA | Gymnastics | Cohort | U.S. Rhythmic Gymnastics National Team | N=7 100%F | 16 | 7 members of the U.S. national team for rhythmic gymnastics | - Injuries<br>- Treatments<br>- Injury severity | Clinical examination |
| *Hutchinson 1999 b* | USA | Gymnastics | Retrospective review of injuries | U.S. Rhythmic Gymnastics National Team | N=12 100%F | 16 | Elite rhythmic gymnasts | - Complaints severe enough to be seen by a physician | Retrospective review of records |
| *Iwamoto et al. 2005* | Japan | Rugby | Cohort | High schools in Japan | N=327 100%M | N/R | High school rugby players in Japan | - Radiographs<br>- Presence of LBP | Radiological examination and clinical examination |
| *Iwamoto et al. 2004* | Japan | Football | Cohort | High schools and college in Japan between 1986 and 1994 | N=171 *Freshman high school players*<br><br>N=742 *Freshman college players* | N/R | Incoming freshman high school and college football players in Japan | - Abnormal radiographic findings<br>- Presence of LBP | Radiological examination and clinical examination |
| *Kaldau et al. 2021* | Canada | Badminton | Cross-sectional | BWF World Junior Championships 2018 | N=166 44%F/56%M | 17.1 (0.8) | Junior badminton players | - Player demographics<br>- Significant injuries<br>- Symptoms | Questionnaire |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Kamada et al. 2016* | Japan | *Multiple*<br>track and field, soft tennis, table tennis, badminton, Kendo, Judo, Karate, swimming, baseball, softball, basketball, soccer, volleyball, other | Cross-sectional | 7 Junior high schools and 3 high schools in Unnan, Shimane, Japan in 2008 and 2009 | N=2267 *students in 2008*<br>2212 *students in 2009*<br><br>52%F/48%M | 14.5 | All students in 7 junior high schools and 3 high schools in Unnan, Shimane, Japan | - Descriptive statistics<br>- Participation in organized sports<br>- MSK pain using a questionnaire | Questionnaire |
| *Kikuchi et al. 2019* | Japan | Multiple (population-based study) | Cross-sectional | Single birth cohort of students, followed up in elementary and junior high school from 2005 to 2010 | N=32596<br>21280 athletes | N/R | Elementary and junior high schoolers in Japan who are part of a single birth cohort study | - Descriptive statistics<br>- Participation in organized sports<br>- Presence or absence of LBP | Questionnaire |
| *Kountouris et al. 2012* | Australia | Cricket | Prospective cohort | Australia in 2002-2003 | N=38<br><br>100%M | 14.9 | Adolescent male cricket fast bowlers in Australia in 2002-2003 | - MR imaging to get Cross-sectional area of quadratus lumborum<br>- Low back pain followed by clinician investigation | MRI and self-report |
| *Kujala et al. 1997 a* | Finland | Soccer, ice hockey, gymnastics, ballet | Cross-sectional | Sports clubs and public-school controls | N=138<br><br>58%F/42%M | N/R | Athletes from different specific sports clubs and public-school controls | - Physical activity<br>- Lifetime cumulative LBP<br>- Pain symptoms<br>- Various physical measurements | Questionnaire and measurements |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Kujala et al. 1997 b* | Finland | Soccer, ice hockey, gymnastics, figure skating, ballet | Cohort | Elementary schools and sports clubs | N=119 56%F/44%M | N/R | Elementary school aged athletes and nonathletic controls | - History of physical activity<br>- Lifetime cumulative incidence of LBP<br>- LBP interfering with school or leisure activities during past 12-months<br>- Continuous/recurrent LBP<br>- Sciatica<br>- Acute back trauma<br>- Height<br>- Weight<br>- Body fat percentage<br>- Hypermobility<br>- Other anthropometric measures | Questionnaire and clinical examination |
| *Kujala et al. 1997 c* | Finland | Ice hockey, soccer, ice skating, gymnastics | Cohort | Elementary school and sports clubs | N=98 49%F/51%M | *Male nonathletes* 11.9 (0.3) *Male athletes* 11.9 (0.3) *Female nonathletes* 11.9 (0.4) *Female athletes* 11.7 (0.8) | Young athletes and nonathletes. Male athletes were involved in ice hockey and soccer, female athletes in gymnastics and figure skating | - Past and present PA<br>- Acute injuries causing LBP<br>- Occurrence of LBP<br>- Duration<br>- Location<br>- Stages of maturity<br>- MRI | Questionnaire and MRI |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Kujala et al. 1997 d* | Finland | Ice hockey, soccer, ice skating, gymnastics | Cohort | Elementary school and sports clubs in Finland | N=98 49%F/51%M | *Male nonathletes* 11.9 (0.3) *Male athletes* 11.9 (0.3) *Female nonathletes* 11.9(0.4) *Female athletes* 11.7 (0.8) | Young athletes and nonathletes. Male athletes were involved in ice hockey and soccer, female athletes in gymnastics and figure skating | - Past and present PA<br>- Acute injuries causing LBP<br>- Occurrence of LBP<br>- Duration<br>- Location<br>- Stages of maturity<br>- MRI | Questionnaire and clinical examination |
| *Lee et al. 2020* | Korea | Soccer | Cross-sectional | U15 soccer teams in Korean Football Association during the 2019 season | N=681 100%M | 13.6 (1.01) | Youth male soccer players | - Demographic information<br>- Training information<br>- Injury information (location occurrence, severity, type, cause, recurrent, surgery, days to return, treatment expenses) | Injury report questionnaire |
| *Legault et al. 2015* | Canada | Multiple | Cross-sectional | 2012 Quebec Summer Games | N=1771 *Athletes* 48%F/52%M<br><br>N=700 *Control group* 54%F/46%M | *Athletes* 14.12(1.22)<br><br>*Controls* 14.69(138) | Adolescent athletes in the 2012 Quebec Summer Games and an age-matched control group | - Socio-demographic and anthropometric information<br>- Physical activity participation level<br>- Prevalence and impact of | - IPAQ<br>- Teen Nordic MSK Questionnaire<br>- Clinical examination |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | MSK symptoms | |
| *Linek et al. 2018* | Poland | Soccer | Prospective longitudinal cohort | Sports and recreation centre in in the Silesian region of Poland | N=97 100%M | *No LBP* 12.8 (2.2) *LBP* 13.7 (3.0) | Adolescent male soccer players | - USI data about LAMs<br>- Occurrence of LBP | - Ultrasound imaging<br>- Oslo Sports Trauma Research Centre questionnaire with visual analogue scale |
| *McMeeken et al. 2001* | Australia | Dance and gymnastics | Cross-sectional | Community, secondary schools, University of Melbourne, Australian Ballet School, Victorian College of the Arts and other ballet and gymnastics schools. | N=614 63%F/37%M | *Females* 16.9(2.1), *Males* 17.3 (1.9) | Dancers, gymnasts, and a control group | - Physical activity<br>- Back pain<br>- Severity | Questionnaire |
| *Mizoguchi et al. 2019* | Japan | Volleyball | Cross-sectional | High school volleyball teams in Saitama, Japan | N=123 49%F/51%M | 15.8 (0.7) | High school volleyball players | - Demographic details<br>- Environmental factors<br>- Injury history<br>- Presence/absence of LBP in the past year | Questionnaire |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Mogenson et al. 2007* | Denmark | *Multiple*<br>Included: Jump gymnastics, rhythmic gymnastics, soccer, other ball games, swimming, badminton/tennis, horseback riding, running, cycling, roller skating/skateboarding, martial arts, other | Cross-sectional | Schools in Odense, Denmark in 2001 | N=439<br>52%F/48%M | N/R | Adolescents living in Odense, Denmark | - Sports<br>- Number of hours per week<br>- Puberty stage | Questionnaire and clinical examination |
| *Mueller et al. 2016* | Germany | 19 different sports in 4 sport categories | Cohort | Elite sports schools | N=321<br>43%F/57%M | 13.1(1.4) | Elite adolescent athletes | - Anthropometrics<br>- Occurrence of back pain<br>- Sport type | Questionnaire (5-step face scale) |
| *Müller et al. 2017* | Germany | 17 different sports in 4 sports categories | Cross-sectional | Elite sports schools | N=2116<br>39%F/61%M | 13.3 (1.7) | Elite adolescent athletes | - Back pain Point prevalence at time and last 7 days<br>- Restrictions to sport<br>- Type of sport<br>- Training details<br>- Anthropometric data | Questionnaire (5-step face scale) |
| *Muntaner-Mas et al. 2018* | Spain | *Multiple*<br>Included: football, basketball, swimming, cycling, tennis, rhythmic gymnastics, futsal, athletics, volleyball, martial arts, handball, and others | Cross-sectional | 26 primary schools in Majorca, Spain | N=2032,<br>46%F/54%M | 11.1 | 5th and 6th grade primary school students | - LBP occurrence<br>- Treatment<br>- LBP in bed or upon waking<br>- LBP at the end of PE<br>- Scoliosis<br>- Leg length discrepancy<br>- Anthropometric data<br>- Sport participation | Questionnaire |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Ng et al. 2014* | Australia | Rowing | Retrospective cross-sectional | Independent boys' and girls' schools in Western Australia | N=365, 64%F/36%M | *Males* 15.1 (0.8), *Females* 15 (0.8) | Rowers who competed for different schools in Western Australia | - Anthropometrics<br>- Questions about LBP such as intensity and aggravating factors | Questionnaire with VAS and One question adapted from Nordic MSK questionnaire |
| *Noll et al. 2016* | Brazil | Multiple | Cross-sectional | Brazil 2015 | N=251 31%F/79%M | 16.4 (1.4) | High school athletes participating in the Jogos dos Institutos Federais (Federal Institutes Games) | - Occurrence of back pain<br>- Demographics<br>- Behavioural factors<br>- Postural factors<br>- Heredity<br>- Level of physical activity | - Questionnaire "Back Pain and Body Posture Evaluation Instrument" (BackPEI)<br>- Anthropometry<br>- Manual and lumbar force<br>- Weight asymmetry |
| *O'Connor et al. 2016* | Ireland | Gaelic football and hurling | Prospective cohort | 6 secondary schools in Ireland | N= 292 100%M | 15.7(0.8) | Under 16 male adolescent Gaelic footballers and hurlers | - Sport<br>- Onset of injury<br>- Side<br>- Location<br>- Type<br>- Nature<br>- Time occurred<br>- Severity<br>- Mechanism<br>- Month<br>- Protective equipment worn | Injury report form based on the National College Athlete Association Injury Surveillance System and influenced by other epidemiological research |
| *Ogon et al. 2001* | | Alpine skiing | Prospective cohort | Elite alpine skiing high school in 1994 and 1995 | N= 120 35%F/65%M | 17 | Elite adolescent skiers | - Radiographic abnormalities<br>- Development of low back pain<br>- Duration<br>- Treatment | - Radiographic evaluation<br>- Diaries collected every Three-months |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | - Physical therapy records |
| *Palmer-Green et al. 2015* | England | Rugby | Cohort | 2 seasons (2006/7 and 2007/8) in a male rugby union in England | N=250 100%M | N/R | Male youth rugby union players | - Date of injury<br>- Injury classification<br>- Injury event<br>- Date of return | Questionnaire |
| *Rossi et al. 2016* | Finland | *Multiple*<br>Included: Basketball, cross-country skiing, floorball, football, gymnastics, ice hockey, orienteering, skating, swimming, track and field | Cross-sectional | Part of the Finnish Health Promoting Sports Club study, 154 youth sports clubs in Finland in 2013 | N=962 | Broken down in Table 1 | Adolescents who are members of youth sports clubs in Finland and secondary school non-members | - Health behaviours<br>- Physical activity<br>- Injuries<br>- Musculoskeletal health | Two questionnaires |
| *Rossi et al. 2018 a* | Finland | Basketball, floorball, ice hockey, and volleyball | Retrospective cross-sectional | Finnish female and male basketball, floorball, ice hockey and volleyball teams | N=464 | Mean age 16 (1.9) | Players from 22 basketball, floorball, ice hockey, and volleyball teams | - Prevalence of LBP<br>- Gender<br>- Age<br>- Sport<br>- Family LBP history | Questionnaire |
| *Rossi et al. 2018 b* | Finland | Basketball and floorball | Cross-sectional | Nine basketball teams and nine floorball teams from Tampere city district, Finland | N=401<br><br>47%F/53%M | Mean age 15.8(1.9) | Young floorball and basketball players | - Background information<br>- LBP in the previous 12-months | Questionnaire |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Rossi et al. 2018 c* | Finland | Basketball and floorball | Cohort | 9 basketball and 9 floorball teams in Finland | N=396 | Mean age 15.8(1.9) | Young floorball and basketball players | - Location<br>- Cause<br>- Type<br>- Time of onset<br>- Mechanism | Questionnaire and anthropometry |
| *Peterhans et al. 2020* | Switzerland | Alpine skiing | Cross-sectional | Swiss- Ski and related regional ski federations | N=108<br>39%F/61%M<br>42F/66M | 14.83 (0.58)<br><br>*Females*<br>14.74 (0.66)<br><br>*Males*<br>14.88 (0.52) | Youth competitive alpine skiers | - MRI from T10 to S1<br>- Anthropometric assessments<br>- OSTRC questionnaire responses | - MRI<br>- OSTRC questionnaire<br>- Personal retrospective interviews and physical examinations performed by sports physician |
| *Sato et al. 2011* | Japan | *Multiple*<br>Included: swimming, basketball, soccer, baseball, tennis, wind-instrument music, table tennis, volleyball, athletics, kendo, karate, badminton, ballet, dance, judo, gymnastics, golf, dodgeball, rugby, sumo wrestling and wrestling, archery | Cross-sectional | All students in fourth to sixth grade elementary school (21,893) and all students in first to third year junior high (21,737) in Niigata City | N= 26766 | N/R | Elementary school and junior high school students in Niigata City, Japan | - Presence of LBP<br>- Sports activities | Questionnaire |
| *Schmidt et al. 2014* | Germany | *Multiple*<br>Included 31 sports. The following had more than ten athletes: volleyball, biathlon, swimming, canoe racing, tobagganing, alpine skiing, short track, canoe | Cross-sectional | Centre for Orthopaedics and Traumatology | N=272<br>42%F/58%M | 15.4(2.0) | Young competitive athletes coming to the centre for an annual medical check-up | - Point, 1-year, and Lifetime prevalence rates of LBP<br>- Severity<br>- Intensity<br>- Duration<br>- Number of episodes of LBP | Questionnaire with VAS and clinical examination |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | slalom, ice skating, figure skating, rowing | | | | | | - Hours of weekly practice<br>- Years of training | |
| *Schoeb et al. 2020* | Switzerland | Alpine Skiing | Cohort | Certified regional performance centres of Swiss-Ski | N=167 | 13.89 (0.60)<br><br>*Females* 13.80 (0.68)<br><br>*Males* 13.94 (0.54) | U15 and U14 competitive alpine skiers | - Anthropometric measurements<br>- OSTRC questionnaire responses | OSTRC questionnaire and supplemental interview with a sports physician |
| *Sekiguchi et al. 2018 a* | Japan | Baseball | Cross-sectional | The Miyagi Amateur Sports Association in north-east Japan | N=1582, 4%F/96%M | *Median* 11 | Youth baseball players who belonged to the Miyagi Amateur Sports Association | - Demographic information<br>- Number of years in sport<br>- Level<br>- Number of hours<br>- intensity<br>- Presence of pain in knee, shoulder, low back elbow | Questionnaire |
| *Sekiguchi et al. 2018 b* | Japan | Baseball | Cross-sectional | Amateur sports association | N=1609 | *Median* 11 (IQR 10-12) | Young baseball players | - Presence of LBP and knee pain<br>- Demographic information<br>- Team level<br>- Amount of training<br>- Intensity of training | Questionnaire |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Shah et al. 2015* | UK | Soccer | Cohort | English Premiership soccer academy squads between 1998 and 2006 | N=12306<br>100%M | N/R | Youth soccer players in England | - Mechanism of injury<br>- Timing<br>- Nature<br>- Time to return to participation<br>- Any further clinical examinations | Prospective injury data collection and event analysis |
| *Shimozaki et al. 2018* | Japan | Weightlifting | Prospective three-year cohort study | Weightlifting team in Japan | N=12<br>50%F/50%M | *Start of study*<br>11.4(2) | Child/adolescent weightlifters who had been competing in weightlifting events for at least 2 years | - Practice frequency<br>- Presence of LBP<br>- MRI findings | Questionnaire and lumbar MRI findings |
| *Skoffer and Foldspang 2008* | Denmark | *Multiple*<br>Included: Soccer, jogging, biking, dance, handball, badminton, swimming, fighting, basketball, gymnastics, riding, scouting, golf, tennis, table tennis, shooting, other | Cross-sectional | 14 public schools in Aarhus, Denmark | N=555<br>47%F /53%M | 97.8% were 15 or 16 | Schoolchildren in 9th grade in Denmark | - Occurrence of LBP<br>- Intensity<br>- Duration<br>- Pain coping<br>- Physical activity<br>- Sports<br>- TV<br>- Computer<br>- Method of transporting school bag<br>- Smoking<br>- Furniture | Questionnaire |
| *Smoljanovic et al. 2009* | Multiple (world champs) | Rowing | Cross-sectional | Junior World Rowing Championships in Beijing in 2007 | N=596<br>39%F/61%M | N/R | Junior rowers competing in the Junior World Rowing | - General information<br>- Rowing specific information | Rowing-specific questionnaire and interviews |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Championships (coxswains not included) | - Amount of training<br>- Injuries (traumatic and overuse) | |
| *Smyth et al. 2020* | Australia | Netball | Prospective cohort | 2018 17/U&19/U Australian National Netball Championships | N=192 | N/R | Athletes participating in the Australian National Netball Championships 2018 | - Incidence of injuries occurring in the 2018 17/U & 19/U ANNC<br>- Athlete exposure | N/R |
| *Sogi et al. 2018* | Japan | Soccer | Cross-sectional | Miyagi Amateur Sports Association in Japan | N=1139<br>6%F/94%M | *Median* 11 (IQR 9-12) | Adolescent soccer players | - Lower extremity pain<br>- Trunk pain<br>- Covariates: sex, age, BMI, height increase, days training, competition level, frequency of participation in games, previous injuries | Self-reported questionnaire |
| *Sommerfield et al. 2020* | New Zealand | *Multiple*<br>Including: netball, soccer, field hockey, lacrosse, swimming, athletics, badminton, rowing | Prospective cohort | Girls' secondary school in New Zealand | N=103<br>100%F | 14.0 (0.6) | Girls from PE classes at a secondary school | - Sports and PE injury rates<br>- Association between injury and phase of menstrual cycle | - OSTRC questionnaire with modification to include information about menstrual cycle<br>- Apps used for menstrual cycle: |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | FITrWoman or My Calendar |
| *Son et al. 2020* | Korea | Taekwondo | Cohort | Korea Taekwondo Association | N=183<br>37%F/63%M | 15.4 (1.72)<br>*Male*<br>15.2 (1.74)<br>*Female*<br>15.75 (1.62) | Youth athletes registered at the Korea Taekwondo Association | - Mechanism<br>- Location<br>- Type of injury<br>- Sports specific items<br>- Time loss<br>- Personal information: age, sex, height, weight, history, years of experience | ISS questionnaire (comprised of info form IOC and US NCAA ISS questionnaires) |
| *Steffen et al. 2020* | Norway | *Multiple*<br>Including: Rugby, boxing, badminton, gymnastics artistic, cycling, wrestling, futsal, judo, beach volleyball, weightlifting, hickey 5s, basketball 3x3, diving, athletics, tennis, triathlon, taekwondo, fencing, beach handball, karate, trampoline, sailing, gymnastics rhythmic, modern pentathlon, gymnastics acrobatic, break dancing, canoeing, golf, shooting, table tennis, swimming, archery, roller | Cohort | Buenos Aires 2018 Youth Olympic Summer Games | N=3984<br>50%F/50%M | *Female*<br>16.9 (0.9)<br>*Male*<br>17.2 (0.8) | Athletes competing in the Youth Olympic Summer Games | - Injuries<br>- Illnesses | IOC injury and illness report form |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | speedskating, equestrian, climbing, rowing, kitesurfing, BMX freestyle | | | | | | | |
| *Sugimoto et al. 2020* | USA | Figure skating | Cross-sectional | Four figure skating clubs in the Northeast region of the U.S. | N=132<br>100%F | 16.8 (3.0) | Adolescent female figure skaters in the Northeast U.S. | - Sport specialization<br>- Presence of back injury diagnosed by a health professional<br>- Demographic questions<br>- Figure skating training questions | Questionnaire |
| *Sundell et al. 2019* | Sweden | *Multiple*<br>Including: soccer, floorball, strength training, ice hockey, aerobics, judo sports, swimming, equestrian, athletics, gymnastics | Cross-sectional | High schools in a municipality in the north of Sweden | N=2550 | N/R | Student attending high school in a municipality in the north of Sweden | - Individual characteristics<br>- Questions about physical activity level<br>- Sport | 23 of the 73 items from the Standardized Nordic Questionnaire, modified for students |
| *Swain et al. 2018 a* | Australia | Ballet | Cross-sectional | One pre-professional ballet school, two pre-professional university dance programs, and a professional nationally touring ballet company | N=110<br>83%F/17%M | *Males*<br>17.1 (3.7),<br><br>*Females*<br>17.9 (2.7). | Male and female classical ballet and contemporary dancers | - Presence of LBP<br>- Demographic information<br>- Menstruation<br>- Dance participation | Questionnaire |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Swain et al. 2018 b* | Australia | Ballet | Prospective cohort | One pre-professional ballet school, two pre-professional university dance programs, and a professional ballet company | N=119 83%F/17%M | *Males* 17.1 (3.7) *Females* 17.9 (2.7) | Pre-professional and professional ballet dancers | - Demographic data<br>- Dance participation information<br>- LBP history data | Questionnaire |
| *Sweeney et al. 2019* | USA | Gymnastics | Cross-sectional | Gymnastics facilities in Colorado | N=67 100%F | *those with LBP* 13.7 (2.8), *those without LBP* 11.7 (2.8) | Gymnasts who participate in the USA Gymnastics Women's Artistic Junior Olympic Programs levels 3 to 10 | - Demographic and medical history<br>- History of LBP<br>- Flexibility | Questionnaire and clinical examination (measurements of flexibility) |
| *Thoreson et al. 2017* | Sweden | Mogul skiing | Cross-sectional | Are Ski Academy in Jarpen, Sweden and age-matched students at the Ostesund and Are/Jarpen High Schools | *Study group* n=16 13%F/87%M *Control group* n=28 in 68%F/32%M | *Study group* 17.6 *Control group* 16.4 | 16 elite Mogul skiers and age matched controls | - MRI<br>- Back pain<br>- Average weekly exercise | - MRI from T5 to sacrum<br>- Three-part questionnaire regarding present or previous back pain, Visual Analog Scale (VAS), the Oswestry questionnaire (ODI), and the EuroQoL questionnaire |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Van Hilst et al. 2015* | The Netherlands | Field hockey, football, speed skating | Cross-sectional | Field hockey, football, and speed skating clubs in the Netherlands | N= 181<br><br>43%F/57%M | *Male field hockey* 17 (15-24)<br><br>*Female field hockey* 16 (14-19)<br><br>*Male football* 18 (16-19)<br><br>*Male speed skating* 18(15-23)<br><br>*Female speed skating* 18(14-25) | Young elite athletes participating in field hockey, football, and speed skating | - Participant characteristics<br>- Sport participation<br>- Work<br>- Prevalence and severity of LBP<br>- Preventive measures against LBP | Nordic MSK questionnaire<br><br>Acute LBP screening questionnaire |
| *Vanti et al. 2010* | Italy | Gymnastics | Cohort | School of Physiotherapy, University of Bologna Italy | *Study group* N=91 93%F/7%M<br><br>*Age-matched control group* N=375 46%F/54%M | *Gymnasts* 12(3.63)<br><br>*Control group* 13.07(0.95) | Young gymnasts | - Back pain<br>- Physical activity<br>- Social-behavioural factors<br>- Anthropometric factors<br>- Lumbar range of motion | Questionnaire and LBP ROM using electronic motion evaluation system |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Yabe et al. 2020 a* | Japan | Basketball | Cross-sectional | Amateur sports association | N=592<br>44%F/56%M | *Median*<br>13 (12,14) | Youth basketball players | - Low back pain<br>- Lower extremity pain<br>- Covariates: sex, age, team level, BMI, number of days training, frequency of participation in games, practice intensity | Self-report questionnaire (no title) |
| *Yabe et al. 2020 1a* | Japan | Basketball | Cross-sectional | Miyagi Amateur Sports Association in Japan | N=590<br>44%F/56%M | *Median* 13 (IQR 12-14) | Elementary and middle school aged basketball players | - Pain assessment (upper extremity pain and LBP)<br>- Covariates including sex, age, BMI, training volume, practice intensity, frequency of participation in games | Self-report questionnaire |
| *Yabe et al. 2020 b* | Japan | Volleyball | Cross-sectional | Amateur sports association | N=566<br>74%F/26%M | *Median*<br>11 (10,12) | Youth volleyball players | - Low back pain<br>- Lower extremity pain<br>- Covariates: sex, age, team level, BMI, number of days training, frequency of participation in games, practice intensity | Self-report questionnaire (no title) |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Yabe et al. 2020 c* | Japan | Martial arts (judo, kendo, karate) | Cross-sectional | Amateur sports association | N=896<br>32%F/68%M | *Median*<br>11 (9,13) | Youth martial artists | - Point prevalence of LBP<br>- Covariates: sex, age, team level, BMI, number of days training, frequency of participation in games, practice intensity | Self-report questionnaire (no title) |
| *Zaina et al. 2016* | Italy | Tennis | Cross-sectional | A public school and private competitive tennis societies in Italy | N= 305 total<br><br>*Tennis players*<br>N= 102<br>(51%F/49%M)<br><br>*School students*<br>N= 203<br>(50% F/50%M) | *Female tennis players*<br>12.0(0.8)<br><br>*Male tennis players*<br>12.0(1)<br><br>*Female students*<br>12.3(0.9)<br><br>*Male students*<br>12.4(1.0) | Competitive tennis players and age-matched students | - Clinical evaluation for spinal deformities<br>- presence of LBP past and present | - Measure of angle of trunk rotation using Bunnell scoliometer<br>- Questionnaire |

### 2.3.3 Pain definitions

There were 23 studies with definitions of LBP that included a reference to an anatomical location, either written or with a reference image (reported in 30 papers) (Table 2-2). There was no agreement between studies on LBP definition used, but the definitions of pain and injury could be grouped into five main areas. A total of eighteen studies used time loss from training/competition or impaired ability to participate as part of the definition[176-194]. There was a specific duration of pain in three studies[178 195 196]. Treatment from a doctor or physiotherapist was used to define an injury in five studies[172 186 197-199]. A specific pain frequency per week was used in two studies[200 201]. A threshold of pain severity was used in two studies[202 203].

**Table 2-2: Pain or injury definitions.**

| Study name | Study type (LBP-specific or general musculoskeletal/injury surveillance) | Injury or pain definition used | LBP-specific definition (Y/N) | Low back anatomical site defined (Y/N) |
|---|---|---|---|---|
| *Abe et al. 2017* | General MSK | "Pain was defined by frequency and part of the body area that was painful. Pain should be present at least once a week in at least one part of the body". | N | Y |
| *Alricsson and Werner 2005* | LBP-specific | N/R | N | N |
| *Alricsson and Werner 2006* | LBP-specific | N/R | N | N |
| *Auvinen et al. 2008* | General MSK | N/R | N | Y |
| *Balague et al. 1988* | LBP-specific | "LBP concerns only lumbar pain, and back pain is a global statement of all spinal pain". | Y | N |
| *Balague et al. 1994* | LBP-specific | N/R | N | N |
| *Bayne et al. 2016* | LBP-specific | Injury was defined as pain that affected a bowler's ability to perform in a match. The definition of injury was expanded to include radiological evidence of lumbar bone stress. | N | N |
| *Brown and Kimball 1983* | General MSK | N/R | N | N |
| *Burnett et al. 1996* | LBP-specific | N/R | N | N |
| *Cejudo et al. 2020* | LBP-specific | LBP for longer than 1 week or whether they did not attend at least three days of training due to LBP within the last 12 months. | Y | N |
| *Cezarino et al. 2020* | General MSK | Any physical complaint sustained by a player during a soccer match or soccer training that results in a player being unable to take full part in future soccer training or match play (i.e., time-loss injury). | N | N |
| *Cupisti et al. 2004* | LBP-specific | A yes response to the question "do you often have back pain?". | Y | N |

| | | | | |
|---|---|---|---|---|
| *Dennis et al. 2005* | General MSK | "Injury was defined as a condition that affected availability for team selection, limited performance during a match, or required surgery. Minor injuries which only affected participation in training sessions were not examined in this study." | N | N |
| *Farahbakhsh et al. 2018* | LBP-specific (in addition to neck pain) | Pain between the lowest rib bone and the lower gluteal fold which would limit the athlete's daily or sports activities more than one day. | Y | Y |
| *Fouasson-Chailloux et al. 2020* | General MSK | A physical complaint reported by a player about an injury occurring during competition or training and requiring medical attention. | N | N |
| *Gamboa et al. 2008* | General MSK | "An injury was considered to have occurred when a dancer sought at least One treatment session from a physical therapist". | N | N |
| *Gregory et al. 2002* | General MSK | Only injuries occurring during bowling were recorded in incidence data. Injuries not severe enough to impair bowling performance were not included. | N | N |
| *Grimmer and Williams 2000* | LBP-specific | N/R | N | N |
| *Ha et al. 2017* | LBP-specific | N/R | N | N |
| *Harreby et al. 1999* | LBP-specific | "LBP was defined as pain in the lower back and was illustrated by a text and drawing at the front of the questionnaire". | Y | Y |
| *Hickey et al. 1997* | General MSK | An injury was defined as any injury examined by the medical practitioners of the AIS Sports Medicine Department. | N | N |
| *Hjelm et al. 2010* | General MSK | Injury defined as when it was impossible for the player to participate fully in regular tennis training or matches during at least One occasion. Injury to the lumbar spine was defined as low back pain. | Y | N |
| *Hoskins et al. 2010* | LBP-specific | To assist with answering the questions a diagram of a mannequin that defined the anatomical boundaries of the low back as a shaded area between the last ribs and the gluteal folds was provided. For the purposes of this survey the shaded area represented the low back and subjects were told to focus only on LBP and not other sources of pain. | Y | Y |
| *Hutchinson 1999* | General MSK | Injury defined as those that required an evaluation from a physician. | N | N |
| *Iwamoto et al. 2005* | LBP-specific | LBP defined as "non-traumatic back pain that resulted in stopping playing rugby completely for at least one day". | Y | N |
| *Iwamoto et al. 2004* | LBP-specific | LBP defined as nontraumatic low back pain if it resulted in the subject not playing football for at least one day. | Y | N |

| | | | | |
|---|---|---|---|---|
| *Kaldau et al. 2021* | General MSK | Current musculoskeletal symptoms defined as experiencing pain or stiffness in most of the last 30 days prior to competing at the World Junior Badminton Championships. | N | N |
| *Kamada et al. 2016* | General MSK | Students were considered to suffer from musculoskeletal pain if pain was present recently at least several times a week in at least one part of the body. | N | Y |
| *Kikuchi et al. 2019* | LBP-specific | Answering yes to the question "Do you have any pain in your lower back now?". | Y | N |
| *Kountouris et al. 2012* | LBP-specific | N/R | N | N |
| *Kujala et al. 1997 a* | LBP-specific | LBP interfering with schoolwork or leisure activities during the last 12 months. | Y | N |
| *Kujala et al. 1997 b* | LBP-specific | LBP limiting schoolwork or leisure time activities been limited during the past 12 months. | Y | Y |
| *Kujala et al. 1997 c* | LBP-specific | LBP interfering with schoolwork or leisure activities for at least a one-week period. | Y | Y |
| *Kujala et al. 1997 d* | LBP-specific | LBP interfering with schoolwork or leisure activities for at least a one-week period. | Y | Y |
| *Lee et al. 2020* | General MSK | An injury was defined as a physical complaint reported by a player experienced during a soccer match or training and included the following two factors: (1) a "medical attention" injury was defined as an injury that required a player to receive medical attention and (2) a "time loss" injury was considered an injury that rendered a player unable to participate in full training or a match. | N | N |
| *Legault et al. 2015* | General MSK | N/R | N | Y |
| *Linek et al. 2018* | LBP-specific | LBP was defined as a pain between the last rib and lower gluteal fold, which is bad enough to limit or change athletes' daily routine or sports activities for more than 1 day. | Y | Y |
| *McMeeken et al. 2001* | LBP-specific | Back pain defined as "back pain or pain, you think comes from your back" lasting more than two days in the last year. | Y | N |
| *Mizoguchi et al. 2019* | LBP-specific | Pain or discomfort in the low-back region, within the region between the lowest rib and the buttocks, however no definition provided in questionnaire | Y | Y |
| *Mogenson et al. 2007* | LBP-specific | "Back problems were defined as the 1-month prevalence (pain reported on the day of the study, in the week, or in the month preceding the interview) specifically for any area of the spine (low back, mid back or neck)". | Y | N |

| | | | | |
|---|---|---|---|---|
| *Mueller et al. 2016* | LBP-specific | "Acute pain present at the time of answering the questionnaire and/or during the 7 days prior to the examination". Faces 3-5 on face pain scale considered pain. | Y | N |
| *Müller et al. 2017* | LBP-specific | "Acute pain present at the time of answering the questionnaire and/or during the 7 days prior to examination". Faces 3 to 5 on the face pain scale considered pain | Y | N |
| *Muntaner-Mas et al. 2018* | LBP-specific | LBP defined as "pain or discomfort in the low back region, from the lower rib curvature to the lower part of the seat region". | Y | Y |
| *Ng et al. 2014* | LBP-specific | LBP defined as pain located between L1 and gluteal folds. | Y | Y |
| *Noll et al. 2016* | LBP-specific | N/R | N | N |
| *O'Connor et al. 2016* | General MSK/injury surveillance | Injury was defined as any injury sustained during competition or training resulting in restricted performance or time lost from play. | N | N |
| *Ogon et al. 2001* | LBP-specific | N/R | N | N |
| *Palmer-Green et al. 2015* | General MSK/injury surveillance | Consistent with the 2007 International Rugby Board consensus statement. Any injury that prevents a player from taking a full part in all training and match play activities typically planned for that day for a period of greater than 24 hours from midnight at the end of the day the injury was sustained. | N | N |
| *Rossi et al. 2018 a* | LBP-specific | LBP defined as "ache, pain, or discomfort of lumbar region with or without radiation to one or both legs". | Y | Y |
| *Rossi et al. 2018 b* | LBP-specific | LBP was defined as "ache, pain or discomfort of lumbar region with or without radiation to one or both legs (sciatica)". | Y | Y |
| *Peterhans et al. 2020* | LBP-specific | N/R | N | N |
| *Rossi et al. 2018 c* | LBP-specific | Pain in the upper and/or lower back area that prevented the player from fully participating in the team training and playing during the following 24 hours. | Y | Y |
| *Rossi et al. 2016* | LBP-specific | LBP was defined as "an ache, pain, or discomfort of the lumbar region with or without radiation to one or both legs (sciatica)". | Y | Y |
| *Sato et al. 2011* | LBP-specific | Definition depended on participant judgement. | N | N |
| *Schmidt et al. 2014* | LBP-specific | N/R | N | Y |

| | | | | |
|---|---|---|---|---|
| *Schoeb et al. 2020* | General MSK | N/R | N | N |
| *Sekiguchi et al. 2018 a* | LBP-specific and knee pain and upper extremity pain | A yes response to the question, “Do you have low back pain?”. | Y | N |
| *Sekiguchi et al. 2018 b* | LBP and knee pain | A positive answer to "Do you have lower back pain?" was considered LBP. | Y | N |
| *Shah et al. 2015* | LBP-specific | An injury was defined as an absence from participating in full training and matches for 48 hours or longer. | N | N |
| *Shimozaki et al. 2018* | LBP-specific | “Participant was unable to practice weightlifting for more than a week due to the pain. Practice was stopped if the slightest pain was present and restarted when the pain runs out". | Y | N |
| *Skoffer and Foldspang 2008* | LBP-specific | LBP defined as "pain or discomfort in the low back region, from the lower rib curvature to the lower part of the seat region" Shown in a drawing in the questionnaire. Menstrual pain excluded | Y | Y |
| *Smoljanovic et al. 2009* | General MSK | All injuries classified by loss of training time if present. | N | N |
| *Smyth et al. 2020* | General MSK | Concurrent Injury Definitions Concept Framework (ID+)23 definitions were utilised. | N | N |
| *Sogi et al. 2018* | General MSK | “Do you have pain in any parts of your body now? If yes, please check the following parts” (multiple choices were allowed). Anatomical areas indicated by a drawing. | N | Y |
| *Sommerfield et al. 2020* | General MSK | Injuries were defined as any physical problem affecting training or competition in the previous week. | N | N |
| *Son et al. 2020* | General MSK | N/R | N | N |
| *Steffen et al. 2020* | General MSK | Injuries included musculoskeletal complaints, concussions and other non-musculoskeletal trauma, such as dental injuries. | N | N |
| *Sugimoto et al. 2020* | LBP-specific | ‘Have you had any of the following diagnoses by a healthcare professional?’ Muscular spine pain, stress fracture, spondylolysis, spondylolisthesis, disc protrusion/herniated disc, sciatica, and spinal cord injury. | Y | N |
| *Sundell et al. 2019* | LBP-specific | LBP- ache or pain in the lowest part of the back. | Y | Y |
| *Swain et al. 2018 b* | LBP-specific | "In the past month, have you had pain in your lower back?" accompanied by a diagram of the posterior aspect of the body, highlighting the region between the lower margin of the 12th ribs and the gluteal folds. | Y | Y |

| | | | | |
|---|---|---|---|---|
| *Swain et al. 2018 a* | LBP-specific | "Have you ever experienced pain in your lower back?" accompanied by a diagram of the posterior aspect of the body, highlighting the region between the lower margin of the 12th ribs and the gluteal folds. | Y | Y |
| *Sweeney et al. 2019* | LBP-specific | N/R | | N |
| *Thoreson et al. 2017* | LBP-specific | Back pain defined as present or previous pain in the thoraco-lumbar back. | Y | Y |
| *Van Hilst et al. 2015* | LBP-specific | LBP defined as ache, pain or discomfort in the region of the lower back whether or not it extends from there to One or both legs (sciatica). Indicated with a shaded picture. | Y | Y |
| *Vanti et al. 2010* | LBP-specific | "In order to define back pain, the following questions were used: 'Have you ever had a backache and with what frequency?' and 'how would you rate your usual pain in a scale from 0 to 10?'". | Y | N |
| *Yabe et al. 2020 a* | LBP and lower extremity pain | Do you have pain in any parts of your body now? If yes, please mark the parts where you have pain with a circle (multiple answers were allowed). | N | Y |
| *Yabe et al. 2020 1a* | LBP and upper extremity pain | The participants who checked lower back, shoulder, or elbow were considered to have LBP, shoulder pain, or elbow pain, respectively. | Y | Y |
| *Yabe et al. 2020 b* | LBP and lower extremity pain | “Do you have pain in any parts of your body? If yes, please check the parts you have pain”. Body parts, including the head, lower back, and each joint, were illustrated by a drawing. | N | Y |
| *Yabe et al. 2020 c* | LBP and general MSK | “Do you have pain in any parts of your body now? The body parts and names were illustrated using a drawing, and participants who checked lower back were considered to have LBP. | Y | Y |
| *Zaina et al. 2016* | LBP-specific | N/R | N | N |

2.3.4 Methodological assessment

Of the included studies, 33 studies (reported in 42 papers) [98 106 118 177 181 186 189 195 196 199-201 204-236] scored above 65% on the quality appraisal tool, indicating high quality (Table 2-3). Only 16 studies (reported in 20 papers) described reasons for non-response or compared the sample and target population[173 182 188 195 196 204 205 209 211-217 224 230 232 237 238], although this criterion was only applicable to 63 studies. Of the five studies that included interviews, one used a validated, reproducible, or adequately described interview format[217]. Of the 13 studies that included a clinical examination, four used a validated, reproducible, or adequately described examination method[178 188 191 223], such as the use of a standardised pro forma for injury reporting. Only 38 studies had a precise anatomic location of back pain or reference to an easily attainable article that contained a precise location[98 118 181 183 187 189 200 201 205-211 213-219 221 222 224 225 227-232 234-236 239-241].

**Table 2-3: Methodological quality assessment.**

| Author | Date | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | SCORE (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Abe et al.* | 2017 | + | - | + | - | + | + | + | NA | NA | + | + | - | 70.0 |
| *Alricsson and Werner* | 2006 | - | - | + | + | + | + | + | NA | NA | + | + | + | 80.0 |
| *Alricsson and Werner* | 2005 | + | + | + | + | + | + | + | NA | NA | + | + | + | 100.0 |
| *Auvinen et al.* | 2008 | + | - | + | - | + | + | - | NA | NA | + | - | + | 60.0 |
| *Balague et al.* | 1988 | - | - | + | + | - | - | + | NA | NA | + | + | + | 60.0 |
| *Balague et al.* | 1994 | + | - | + | + | - | - | + | NA | NA | + | + | + | 70.0 |
| *Bayne et al.* | 2016 | - | NA | + | + | + | + | NA | - | NA | - | + | + | 66.7 |
| *Brown and Kimball* | 1983 | + | - | + | - | + | + | + | NA | NA | + | + | - | 70.0 |
| *Burnett et al.* | 1996 | - | NA | NA | + | + | + | NA | - | NA | - | - | - | 37.5 |
| *Cejudo et al.* | 2020 | - | - | - | + | + | + | - | NA | + | - | + | + | 54.5 |
| *Cezarino et al.* | 2020 | + | NA | NA | - | - | - | - | NA | NA | - | - | + | 25.0 |
| *Cupisti et al.* | 2004 | - | + | NA | + | + | + | - | NA | NA | + | + | - | 66.7 |
| *Dennis et al.* | 2005 | - | NA | NA | - | + | + | NA | NA | NA | - | - | - | 28.6 |
| *Farahbakhsh et al.* | 2018 | + | - | + | + | + | + | + | NA | NA | + | + | + | 90.0 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Fouasson-Chailloux et al.* | 2020 | + | NA | NA | - | - | + | NA | NA | - | - | - | + | 37.5 |
| *Gamboa et al.* | 2008 | + | NA | NA | - | - | + | NA | NA | NA | - | - | + | 42.9 |
| *Gregory et al.* | 2002 | - | + | + | - | + | + | - | NA | NA | - | - | - | 40.0 |
| *Grimmer and Williams* | 2000 | - | - | + | - | + | + | - | NA | NA | - | - | + | 40.0 |
| *Ha et al.* | 2017 | - | NA | NA | + | - | + | - | NA | NA | - | - | + | 37.5 |
| *Harreby et al.* | 1999 | + | - | - | + | + | + | + | NA | NA | + | + | + | 80.0 |
| *Hickey et al.* | 1997 | + | NA | NA | - | - | + | NA | NA | - | - | - | + | 37.5 |
| *Hjelm et al.* | 2010 | - | - | + | - | + | + | NA | NA | - | + | + | + | 60.0 |
| *Hoskins et al.* | 2010 | - | + | - | + | + | - | + | NA | NA | + | + | + | 70.0 |
| *Hutchinson* | 1999 | - | NA | NA | - | + | + | NA | NA | - | - | + | + | 50.0 |
| *Iwamoto et al.* | 2005 | + | NA | NA | + | - | + | NA | NA | - | - | - | + | 50.0 |
| *Iwamoto et al.* | 2004 | + | NA | NA | + | - | + | NA | NA | - | - | - | + | 50.0 |
| *Kaldau et al.* | 2021 | + | + | + | - | + | + | - | NA | NA | - | + | + | 70.0 |
| *Kamada et al.* | 2016 | + | - | + | - | + | + | + | NA | NA | + | + | - | 70.0 |
| *Kikuchi et al.* | 2019 | - | - | + | + | - | - | - | NA | NA | - | - | + | 30.0 |
| *Kountouris et al.* | 2012 | - | - | - | + | + | + | NA | NA | - | - | - | + | 40.0 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Kujala et al. 1997 a* | 1992 | - | + | + | + | + | + | - | NA | NA | - | + | + | 70.0 |
| *Kujala et al. 1997 b* | 1994 | - | + | + | + | + | + | - | NA | NA | + | + | + | 80.0 |
| *Kujala et al. 1997 c* | 1996 | - | + | + | + | + | + | - | NA | NA | + | + | + | 80.0 |
| *Kujala et al. 1997 d* | 1997 | - | + | + | + | + | + | - | NA | NA | + | + | + | 80.0 |
| *Lee et al.* | 2020 | + | - | + | - | + | + | + | NA | NA | - | + | + | 70.0 |
| *Legault et al.* | 2015 | + | + | + | - | + | + | + | NA | NA | + | + | + | 90.0 |
| *Linek et al.* | 2018 | - | - | - | + | - | - | NA | - | NA | + | + | - | 30.0 |
| *McMeekan et al.* | 2001 | - | + | - | + | + | + | + | NA | NA | - | + | + | 70.0 |
| *Mizoguchi et al.* | 2019 | - | - | - | + | + | + | - | NA | NA | + | - | + | 50.0 |
| *Mogenson et al.* | 2007 | - | + | + | + | + | + | NA | + | NA | + | - | + | 80.0 |
| *Mueller et al.* | 2016 | - | NA | - | + | + | + | + | NA | NA | - | + | + | 66.7 |
| *Müller et al.* | 2017 | - | - | - | + | + | + | + | NA | NA | - | + | + | 60.0 |
| *Muntaner-Mas et al.* | 2018 | + | - | - | + | + | + | + | NA | NA | + | + | + | 80.0 |
| *Ng et al.* | 2014 | - | NA | + | + | + | + | + | NA | NA | + | + | + | 88.9 |
| *Noll et al.* | 2016 | - | - | + | + | + | + | + | NA | NA | - | + | + | 70.0 |
| *O'Connor et al.* | 2016 | - | - | NA | - | + | + | + | NA | - | - | + | + | 50.0 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Ogon et al.* | 2001 | + | - | + | + | + | + | - | NA | - | - | + | + | 63.6 |
| *Palmer-Green et al.* | 2015 | - | + | NA | - | - | - | NA | NA | + | - | + | + | 44.4 |
| *Peterhans et al.* | 2020 | - | - | + | + | + | + | + | NA | + | - | + | + | 72.7 |
| *Rossi et al. 2018 a* | 2014 | - | - | - | + | + | + | + | NA | NA | + | + | + | 70.0 |
| *Rossi et al. 2018 b* | 2016 | - | - | + | + | + | + | + | NA | NA | + | + | + | 80.0 |
| *Rossi et al. 2018 c* | 2018 | - | - | + | + | + | + | + | NA | NA | + | + | + | 80.0 |
| *Rossi et al.* | 2016 | + | + | + | + | + | + | + | NA | NA | + | + | + | 100.0 |
| *Sato et al.* | 2011 | + | + | + | + | + | - | - | NA | NA | - | + | + | 70.0 |
| *Schmidt et al.* | 2014 | + | - | NA | + | + | + | - | NA | NA | + | + | + | 77.8 |
| *Schoeb et al.* | 2020 | + | - | + | - | + | + | + | NA | NA | - | - | + | 60.0 |
| *Sekiguchi et al. a* | 2018 | + | - | + | + | + | + | - | NA | NA | - | - | - | 50.0 |
| *Sekiguchi et al. b* | 2019 | + | - | + | + | + | + | - | NA | NA | - | - | + | 60.0 |
| *Shah et al.* | 2014 | + | NA | NA | - | - | + | NA | NA | + | - | - | + | 50.0 |
| *Shimozaki et al.* | 2018 | - | - | NA | + | + | + | - | NA | NA | - | - | - | 33.3 |
| *Skoffer and Foldspang* | 2008 | - | - | + | + | + | + | - | NA | NA | + | + | + | 70.0 |
| *Smoljanovic et al.* | 2009 | + | - | + | - | + | + | - | - | NA | - | + | + | 54.5 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Smyth et al.* | 2020 | + | NA | NA | - | + | - | + | NA | NA | - | - | + | 50.0 |
| *Sogi et al.* | 2018 | + | - | + | - | + | + | - | NA | NA | + | - | + | 66.7 |
| *Sommerfield et al.* | 2020 | - | - | + | - | + | + | + | NA | NA | - | + | + | 60.0 |
| *Son et al.* | 2020 | + | NA | NA | - | + | + | - | NA | NA | - | + | + | 62.5 |
| *Steffen et al.* | 2020 | + | NA | NA | - | - | + | + | NA | NA | - | + | + | 62.5 |
| *Sugimoto et al.* | 2020 | - | - | + | + | - | - | - | NA | NA | - | - | - | 20.0 |
| *Sundell et al.* | 2019 | + | - | + | + | + | + | + | NA | NA | + | + | + | 90.0 |
| *Swain et al. 2018 a* | 2018 | - | - | + | + | + | + | - | NA | NA | + | + | + | 70.0 |
| *Swain et al. 2018 b* | 2017 | - | - | + | + | + | + | - | NA | NA | + | + | + | 70.0 |
| *Sweeney et al.* | 2019 | - | - | - | + | + | + | - | NA | NA | - | - | + | 40.0 |
| *Thoreson et al.* | 2017 | - | + | + | + | + | + | + | NA | NA | + | + | + | 90.0 |
| *van Hilst et al. 2015* | 2015 | - | - | + | + | + | + | + | NA | NA | + | + | + | 80.0 |
| *Vanti et al.* | 2010 | - | + | - | + | + | - | - | NA | NA | - | + | + | 50.0 |
| *Yabe et al. 2020 a* | 2020 | + | - | + | + | + | + | - | NA | NA | + | - | + | 70.0 |
| *Yabe et al. 2020 1a* | 2020 | + | + | + | + | - | - | + | NA | NA | + | - | + | 70.0 |
| *Yabe et al. 2020 b* | 2020 | + | - | + | + | + | + | - | NA | NA | + | - | + | 70.0 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Yabe et al. 2020 c* | 2020 | + | - | + | + | + | + | - | NA | NA | + | - | + | 70.0 |
| *Zaina et al.* | 2016 | + | + | + | + | + | + | + | NA | NA | - | + | + | 90.0 |

2.3.5 Included sports

Soccer was included in 13 studies[173 179 181 186 187 191 197 202 212-215 217 227 231 234], while 10 studies included prevalence estimates for gymnastics[118 122 172 173 195 202 209 217 227 238]. Skiing[205 206 223 230 242 243], volleyball[173 181 202 207 235 241], swimming[118 173 202 207 217 227], basketball[173 181 189 199 210 232], and martial arts[173 202 217 227 236 244] were investigated in six studies each. This review does not include a meta-analysis of incidence or prevalence rates categorised by sport. Sports cannot be compared closely in this review due to methodological heterogeneity, including differing recall periods, definitions, and quality, however some general patterns were noted in studies reporting on specific sports. Soccer[186 187 191 197 234] and martial arts[236 244] reported generally lower levels of LBP, whereas ballet[228 229], gymnastics[122 172 238], and rowing[193 219] reported generally higher levels of LBP.

2.3.6 Cohort study design

Of 31 studies with a cohort study design, only nine were high quality (30%). Twenty-nine studies reported incidence of LBP. More than one study reported on three incidence time periods: six-month (n=4), 12-month (n=4), and two-year (n=2). Only three of these 10 studies were high quality. Since there were so few, both high- and low-quality studies were synthesized for meta-analyses.

*2.3.6.1 Incidence estimates of low back pain in adolescent athletes*

The pooled incidence estimate of four studies reporting six-month incidence was 14% (95% CI 7 to 22, $I^2$ 76%) (Figure 2-3)[177 180 182 187]. In the meta-regression analysis, methodological quality had a significant effect on the heterogeneity between studies (p=0.003) and accounted for 100% of observed heterogeneity (Appendix 2-5). Of note, there was only one high quality study of cohort design reporting six-month incidence (36%)[177].

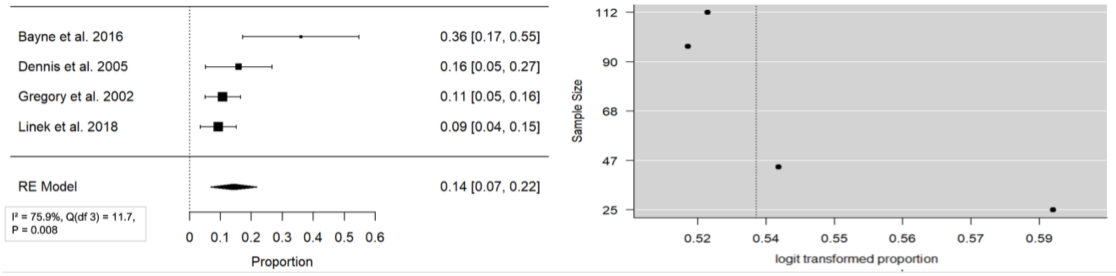


**Figure 2-3:** Forest (left) and funnel (right) plot of weighted pooled means of studies reporting six-month incidence of LBP.

The pooled incidence estimate of four studies reporting 12-month incidence was 36% (95% CI 4-68%, $I^2$ 99.3%) (Figure 2-4)[184 185 215 244]. In the meta-regression analysis, LBP definition and methodological quality had a significant effect on heterogeneity ($p<0.0001$ for both) and accounted for 99.98% of the high heterogeneity between studies (Appendix 2-5). Of note, there was only one high quality study of cohort design reporting 12-month incidence (10.4%)[215].

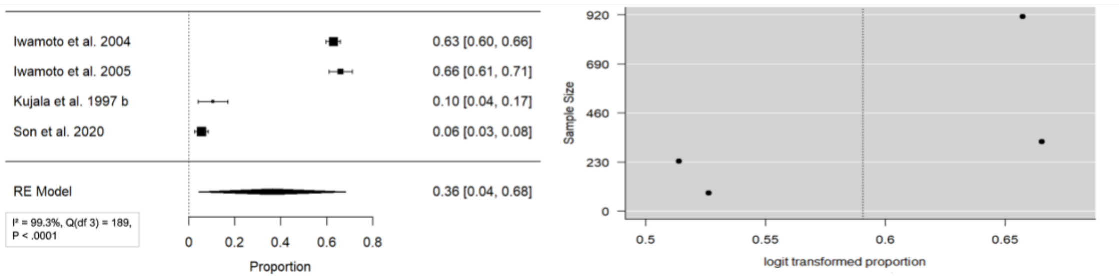


**Figure 2-4:** Forest (left) and funnel (right) plot of weighted pooled means of studies reporting 12-month incidence of LBP.

The pooled incidence estimate of two studies reporting two-year incidence was 11% (95% CI 8.0-13, $I^2$ 0%) (Figure 2-5)[202 242]. Because of the low heterogeneity and low number of studies, meta-regression could not be conducted. Of note, there was only one high quality study of cohort design reporting two-year incidence (10%)[202].

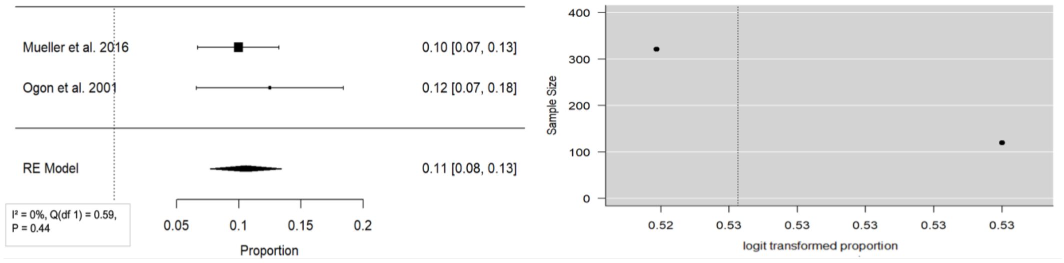


**Figure 2-5:** Forest (left) and funnel (right) plot of weighted pooled means of studies reporting two-year incidence of LBP.

*2.3.6.2 Risk factors for low back pain in cohort studies*

One study of cohort design reported sport volume or intensity as a risk factor for pain or injury. In this study, injured cricket bowlers participated in sport more frequently than non-injured, although this did not separate by type of injury[180].

2.3.7 Cross-sectional study design

Of 49 studies with a cross-sectional design, 36 were high quality (73%). Of these, 30 were included in meta-analyses of high-quality studies reporting lifetime prevalence (n=18), 12-month prevalence (n=8), three-month prevalence (n=4), and point prevalence (n=15).

*2.3.7.1 Lifetime prevalence*

Lifetime prevalence in adolescent athletes was reported in 19 studies[98 173 181 195 196 204 207-209 211 218 219 222 224 225 227 228 230]. Cumulative lifetime prevalence in these studies ranged from 9.6%[196] to 91.9%[211]. The pooled lifetime prevalence estimate of 18 high quality studies was 50%, (95% CI 39-60, $i^2$ 99.5%)[98 173 195 196 204 207-209 211 218 219 222 224 225 227 228 230 237]. The $I^2$ value for these studies was 99.5%, indicating considerable heterogeneity in the results. Meta-regression was conducted including the factors LBP definition, number of participants, sport, sex, and data collection method. None of these factors had a statistically significant effect on heterogeneity. The factors included in the meta-regression analysis did not account for any heterogeneity, and the test for residual heterogeneity was significant (p<.0001) (Appendix 2-5).

*2.3.7.2 12-month prevalence*

12-month prevalence was reported by 12 studies (reported in 13 papers) and ranged from 14.6%[181] to 64%[122 172 178 181 195 222 225 227 228 231 241]. The pooled 12-month prevalence estimate of eight high quality studies was 42%, 95% CI 29-55, $I^2$ 96.6% (Figure 2-6)[181 195 212 222 223 225 228 231].

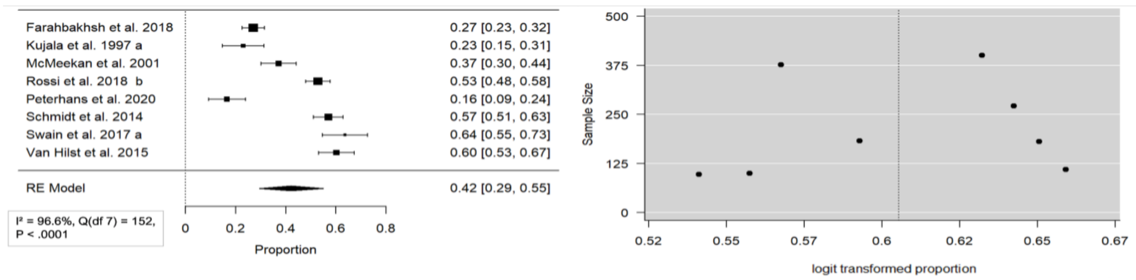


**Figure 2-6:** Forest (left) and funnel (right) plot of weighted pooled means of studies reporting 12-month prevalence of LBP.

Meta-regression was conducting using the factors LBP definition, number of participants, sport, sex, and data collection method. None of these factors were statistically significant. The factors included in the meta-regression analysis did not account for any heterogeneity, and the test for residual heterogeneity was significant (p<.0001) (Appendix 2-5).

*2.3.7.3 Three-month prevalence*

Overall three-month prevalence was reported in 4 studies and ranged from 43.7%[220] to 51.3%[118]. The pooled three-month prevalence estimate of four high-quality studies was 46%, 95% CI 41.0-52, $I^2$= 56%, (Figure 2-7)[118 205 220 228]. Meta- regression was conducted using LBP definition. Variation in LBP definition had a statistically significant effect on heterogeneity (p=0.01) and accounted for 100% of the moderate heterogeneity among these studies.

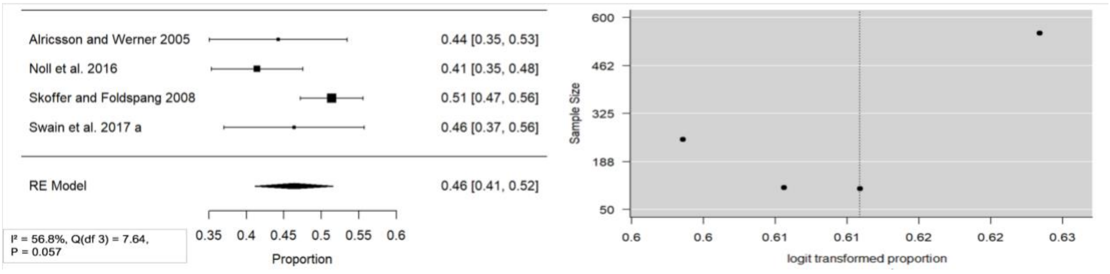


**Figure 2-7:** Forest (left) and funnel (right) plot of weighted pooled means of studies reporting three-month prevalence of LBP.

### *2.3.7.4 Point prevalence*

Point prevalence was reported by 18 studies (reported in 22 papers)[181 196 200 201 203 210 218 219 222 224-228 230 232-236 245 246]. Overall point prevalence ranged from 3.2% [234] to 86%[172]. The pooled point prevalence estimate of 15 high quality studies (reported in 13 papers) was 16%, 95% CI 9-23, $I^2$= 98.3% (Figure 2-8).

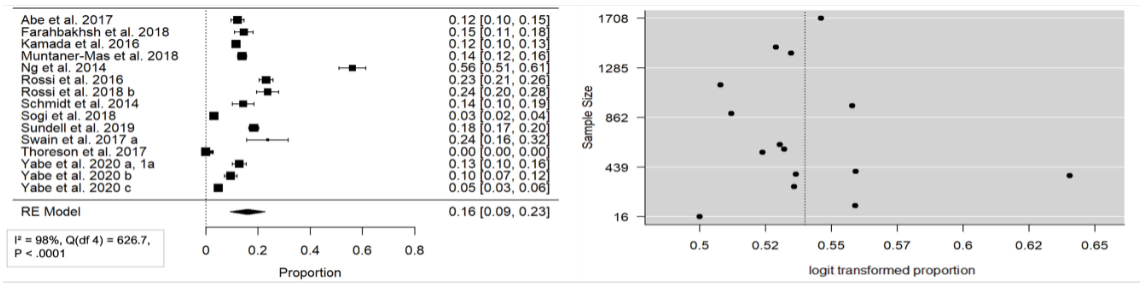


**Figure 2-8:** Forest (left) and funnel (right) plot of weighted pooled means of studies reporting three-month prevalence of LBP.

Meta-regression was performed using the factors LBP definition, number of participants, sport, sex, and outcome. Sport ($p<.0001$) and number of participants ($p=0.02$) had a statistically significant effect on heterogeneity. The amount of heterogeneity accounted for was 45.9%, leaving an unaccounted-for heterogeneity level of 27.0%.

*2.3.7.5 Other recall periods*

Other recall periods were used to report prevalence in five studies, including two week[247], one month[217 229], six month prevalence[216 239], and eleven month prevalence[186]. Further details of reported incidence, prevalence, and risk factors can be found in Table 2-4.

**Table 2-4: Prevalence or incidence and risk factors.**

| Author, year of publication | Sport | Percentage of athletes with LBP | Prevalence or incidence and time period | Percentage of control group with LBP | Associated factors |
|---|---|---|---|---|---|
| *Ogon et al. 2001* | Alpine skiing | 12.5% | Two-year incidence | N/A | Severe anterior lesions |
| *Peterhans et al. 2020* | Alpine skiing | 16.5% | 12-month prevalence | N/A | N/R |
| *Schoeb et al. 2020* | Alpine skiing | 8.5% | Other prevalence (two week) | N/A | - Female gender<br>- Older age (U15) |
| *Hoskins et al. 2010* | Australian Rules football | 91.9% | Lifetime prevalence | 7-34% | Elite participation in Australian Rules football |
| *Kaldau et al. 2021* | Badminton | 19.4% | Other prevalence (one month) | N/A | N/R |
| *Gamboa et al. 2008* | Ballet | 9.4% | Other prevalence | N/A | - Higher current disability scores<br>- History of LBP<br>- Foot pronation on the right<br>- Insufficient ankle plantarflexion<br>- Less lower extremity strength |
| *Swain et al. 2018 (a)* | Ballet | 1. 73.6%<br>2. 63.6%<br>3. 46.4%<br>4. 23.6% | 1. Lifetime prevalence<br>2. 12-month prevalence<br>3. Three-month prevalence<br>4. Point prevalence | N/A | Dance participation |
| *Swain et al. 2018 (b)* | Ballet | 78% | Nine-month incidence | N/A | Dance participation |
| *Ha et al. 2017* | Baseball | 1. 58.9%<br>2. 37.5% | 1. Lifetime prevalence<br>2. Point prevalence | N/A | - Baseball<br>- Peak height velocity<br>- Age |
| *Sekiguchi et al. 2018 (a)* | Baseball | 8.4% | Point prevalence | N/A | Elbow and/or shoulder pain |

| | | | | | |
|---|---|---|---|---|---|
| *Sekiguchi et al. 2018 (b)* | Baseball | 8.4% | Point prevalence | N/A | Knee pain |
| *Yabe et al. 2020 1a* | Basketball | 12.9% | Point prevalence | N/A | Upper extremity pain including shoulder |
| *Hickey et al. 1997* | Basketball | 37.5% | 6-year period prevalence | N/A | - Weight/strength training<br>- Elite level |
| *Yabe et al. 2020 a* | Basketball | 12.8% | Point prevalence | N/A | - Knee pain<br>- Ankle pain |
| *Rossi et al. 2018 (b)* | Basketball and floorball | 1. 54.9%<br>2. 52.9%<br>3. 23.7% | 1. Lifetime prevalence<br>2. 12-month prevalence<br>3. Point prevalence | N/A | - Older age<br>- Family history of musculoskeletal symptoms |
| *Rossi et al. 2018 (c)* | Basketball and floorball | 13% | 1-3 year follow up, incidence | N/A | N/R |
| *Rossi et al. 2018 (a)* | Basketball, floorball, ice hockey, and volleyball | 54.9% | 12-month prevalence | N/A | - Family hx of LBP<br>- Higher age |
| *Bayne et al. 2016* | Cricket | 36% | Six-month incidence | N/A | - Incorrect technique<br>- Trunk and hip muscle weakness<br>- Inadequate workload management |
| *Burnett et al. 1996* | Cricket | 58% | 2.7-year incidence | N/A | - Mixed bowling technique over an extended period. (Versus front-on or side-on) |
| *Dennis et al. 2005* | Cricket | 52% | Six-month incidence | N/A | High bowling workload |
| *Gregory et al. 2002* | Cricket | 10.7% | Six-month incidence | N/A | Fast bowling |
| *Kountouris et al. 2012* | Cricket | 44.7% | One season incidence | N/A | Higher BMI |
| *Alricsson and Werner 2005* | Cross country skiing | 44.2% | Three-month prevalence | N/R | - Prolonged back flexion<br>- Weakness in back muscles |
| *Alricsson and Werner 2006* | Cross country skiing | 46.6% | Three-month prevalence | N/A | - No regular participation in sports or other physical activities other than cross country skiing |
| *McMeekan et al. 2001* | Dance and gymnastics | 1. 54.1%<br>2. 37% | 1. Lifetime prevalence<br>2. 12-month prevalence | 1. 47.6%<br>2. 32.3% | Total activity hours (over 30 per week) |

| | | | | | |
|---|---|---|---|---|---|
| *Cejudo et al. 2020* | Equestrian sports | 42.1% | 12-month prevalence | N/A | - High body fat percentage<br>- Trunk lateral flexor endurance lower than 65 seconds |
| *Van Hilst et al. 2015* | Field hockey, football (soccer), speed skating | 60% | 12-month prevalence | N/A | - Pilates<br>- Training hours<br>- More time spent warming up |
| *Sugimoto et al. 2020* | Figure skating | 25% | Lifetime prevalence | N/A | -Independent association between chronological age and low back injury |
| *Iwamoto et al. 2004* | American football | 62.9% | 12-month incidence | N/A | - Spondylolysis (radiological risk factor)<br>- Disk space narrowing<br>- Spinal instability |
| *O'Connor et al. 2015* | Gaelic football<br>Hurling | 5% Gaelic injuries<br>22% hurling injuries | Incidence | N/A | Adolescent Gaelic games |
| *Cupisti et al. 2004* | Gymnastics | 10.4% | Lifetime prevalence | 26% | - Being overweight<br>- Older (adolescent) age<br>- Smoking |
| *Hutchinson 1999a* | Gymnastics | 86% | Point prevalence | N/A | Rhythmic gymnastics |
| *Hutchinson 1999b* | Gymnastics | 23.9% | 12-month prevalence | N/A | N/R |
| *Sweeney et al. 2019* | Gymnastics | 45% | 12-month prevalence | N/A | Menarche |
| *Vanti et al. 2010* | Gymnastics | 1. 46%<br>2. 26% | 1. Lifetime prevalence low level LBP<br>2. Lifetime prevalence medium/high level LBP | 1. 60%<br>2. 36% | - Female gender<br>- Sedentary lifestyle<br>- Psychosocial risk factors<br>- Parents/siblings with LBP |
| *Yabe et al. 2020 c* | Martial arts | 4.8% | Point prevalence | N/A | - Older age<br>- Lower extremity pain |
| *Thoreson et al. 2017* | Mogul skiing | 50% | Lifetime prevalence | 42% | Mogul skiing (exposed to different high loads) |
| *Kikuchi et al. 2019* | Multiple | 6.6% | Point prevalence | 6.5% | - Female gender<br>- Extracurricular sports |
| *Legault et al. 2015* | Multiple | 35.8% | Six-month prevalence | 45.4% | Female gender |

| | | | | | |
|---|---|---|---|---|---|
| *Schmidt et al. 2014* | *Multiple*<br>31 sports. The following had more than ten athletes: volleyball, biathlon, swimming, canoe racing, tobagganing, alpine skiing, short track, canoe slalom, ice skating, figure skating, rowing | 1. 65.8%<br>2. 57%<br>3. 14.3% | 1. Lifetime prevalence<br>2. 12-month prevalence<br>3. Point prevalence | N/A | Competitive sport participation |
| *Rossi et al. 2016* | *Multiple*<br>Included: basketball, cross-country skiing, floorball, football, gymnastics, ice hockey, orienteering, skating, swimming, track and field | 1. 56.4%<br>2. 23.2% | 1. Lifetime prevalence<br>2. Point prevalence | 1. 54.5% non-sports club members | Higher screen time during leisure time |
| *Müller et al. 2017* | *Multiple*<br>Included: Boxing, soccer, artistic gymnastics, weightlifting, handball, judo, canoeing, track&field, modern pentathlon, cycling, horse riding, wrestling, rowing, swimming, shooting, triathlon, volleyball | 8% | Point prevalence | N/A | - Older adolescent age<br>- Sports with repetitive translation, reclination and rotation (like judo, wrestling, rowing and canoeing) |
| *Mogenson et al. 2007* | *Multiple*<br>Included: Jump gymnastics, rhythmic gymnastics, soccer, other ball games, swimming, badminton/tennis, horseback riding, running, cycling, roller skating/skateboarding, martial arts, other | 58.4% | One-month prevalence | 39% | - Martial arts<br>- Roller skating/skateboarding<br>- Horseback riding |
| *Sommerfield et al. 2020* | *Multiple*<br>Included: Netball, soccer, field hockey, lacrosse, swimming, athletics, badminton, rowing | 7.5% | 30-week incidence | N/A | N/R |
| *Steffen et al. 2020* | *Multiple*<br>Included: rugby, boxing, badminton, gymnastics artistic, cycling, wrestling, futsal, judo, beach volleyball, weightlifting, hickey 5s, basketball 3x3, diving, athletics, tennis, triathlon, taekwondo, fencing, beach handball, karate, trampoline, sailing, gymnastics rhythmic, modern pentathlon, gymnastics acrobatic, break | 6.9% | 12-day incidence | N/A | N/R |

| | | | | | |
|---|---|---|---|---|---|
| | dancing, canoeing, golf, shooting, table tennis, swimming, archery, roller speedskating, equestrian, climbing, rowing, kitesurfing, BMX freestyle | | | | |
| *Sundell et al. 2019* | *Multiple*<br>Included: soccer, floorball, strength training, ice hockey, aerobics, judo sports, swimming, equestrian, athletics, gymnastics | 44.2% | 12-month prevalence | 1. 46.2 overall (athletes and non-athletes)<br>2. 42.4 overall (athletes and non-athletes) | - Female gender<br>- Sport activity (especially lasting more than 6 hours pe week) |
| *Skoffer and Foldspang 2008* | *Multiple*<br>Included: soccer, jogging, biking, dance, handball, badminton, swimming, fighting, basketball, gymnastics, riding, scouting, golf, tennis, table tennis, shooting, other | 51.3% | Three-month prevalence | N/ | - Jogging<br>- Handball<br>- Gymnastics<br>- Riding |
| *Noll et al. 2016* | *Multiple*<br>Included: volleyball, basketball, handball, soccer | 43.7% | Three-month prevalence | N/A | - Overweight/obesity<br>- Psychosocial variables<br>- Posture<br>- Smoking<br>- Lumbar force |
| *Abe et al. 2017* | *Multiple*<br>Teams sports (Baseball, softball, basketball, soccer, volleyball, other) | 12.4% | Point prevalence | N/A | - Regular player<br>- Fewer teammates |
| *Grimmer and Williams 2000* | Multiple (not specified) | 11% | Two-week prevalence | N/R | - Time spent sitting<br>- Carrying heavy loads<br>- Increased participation in sport for the youngest students |
| *Harreby et al. 1999* | Multiple (not specified) | 53% | One-month prevalence males in high level sport | 30.6% overall | - Female gender<br>- Daily smoking<br>- Heavy job in leisure time |

| | | | | | |
|---|---|---|---|---|---|
| Balague et al. 1988 | *Multiple (population- based)*<br>Included: soccer, skiing, gymnastics, swimming, bodybuilding, volleyball, aerobics | 35.6% | Lifetime prevalence | 33% | - Time spent watching TV<br>- Smoking<br>- Competitive sports |
| *Balague et. al 1994* | *Multiple (population-based)*<br>Included: tennis, volleyball, cycling, skiing, gymnastics, soccer and swimming | 18% | Lifetime prevalence | 20% | - Age<br>- Gender (female)<br>- Parent LBP<br>- Sports activities<br>- Time spent watching TV |
| *Auvinen et al. 2008* | *Multiple (population-based)*<br>Included: walking, jogging, cycling, cross-country skiing, swimming, soccer, ice hockey, floorball, rinkball or bandy, Finnish baseball, basketball, volleyball, ice-skating, figure skating, track and field, horseback riding, aerobics, gymnastics, dancing, gym training, downhill skiing or snowboarding, roller-skating or skateboarding, badminton, tennis, orienteering running, judo or karate or wrestling, and golf. | 4.7% | Six-month prevalence | 44% female<br>33% male | - Participation in One single risk sport vs multiple sports |
| *Mueller et al. 2016* | *Multiple*<br><br>Combat sports<br>(boxing, karate, judo, wrestling)<br><br>Game sports<br>(soccer, handball, volleyball)<br><br>Explosive strength sports (Bob, artistic gymnastics, weightlifting, athletics track&field, modern pentathlon<br><br>Endurance sports with strength component | 10% | Two-year incidence | N/A | Game sports |

| | | | | | |
|---|---|---|---|---|---|
| | (canoeing, cycling, horse riding, rowing, swimming, shooting, triathlon) | | | | |
| *Kujala et al. 1992 (c)* | *Multiple*<br>Ice hockey, soccer, ice skating, gymnastics | 45% | 3-year follow up | 18% | Sports which have low back injury risk |
| *Kujala et al. 1992 (d)* | *Multiple*<br>Ice hockey, soccer, ice skating, gymnastics | 45% | 3-year follow up | 18% | - Low maximal lumbar extension<br>- repetitive lumbar extension |
| *Muntaner-Mas et al. 2018* | *Multiple*<br>Included: football, basketball, swimming, cycling, tennis, rhythmic gymnastics, futsal, athletics, volleyball, martial arts, handball, and others | 1. 66.8%<br>2. 13.9% | 1. Lifetime prevalence<br>2. Point prevalence | 1. 66.2% | - Female gender<br>- overweight/obesity |
| *Farahbakhsh et al. 2018* | *Multiple*<br>Included: football, volleyball, basketball, wrestling and other (which meant gymnastics, fitness, shooting, track and field, and swimming | 1. 42%<br>2. 27%<br>3. 14.6% | 1. Lifetime prevalence<br>2. 12-month prevalence<br>3. Point prevalence | N/A | Playing basketball |
| *Sato et al. 2011* | *Multiple*<br>Included: swimming, basketball, soccer, baseball, tennis, wind-instrument music, table tennis, volleyball, athletics, kendo, karate, badminton, ballet, dance, judo, gymnastics, golf, dodgeball, rugby, sumo wrestling and wrestling, archery | 34.9% | Lifetime prevalence | 32.1% | Sports participation |
| *Kamada et al. 2016* | *Multiple*<br>Included: track and field, soft tennis, table tennis, badminton, Kendo, Judo, Karate, swimming, baseball, softball, basketball, soccer, volleyball, other | 11.6% | Point prevalence | 27.4% | Participation in organized sport |
| *Kujala et al. 1992 (a)* | *Multiple*<br>Soccer, ice hockey, gymnastics, ballet | 23% | 12-month prevalence | 21% | Tightness of hip flexor muscles |
| *Kujala et al. 1992 (b)* | *Multiple*<br>Soccer, ice hockey, gymnastics, figure skating, ballet | 10.4% | 12-month incidence | 24% | Individual sports (figure skating and gymnastics) |

| | | | | | |
|---|---|---|---|---|---|
| *Smyth et al. 2020* | Netball | 9.7% | Six-day incidence | N/A | N/R |
| *Brown and Kimball 1983* | Powerlifting | 50% | Point prevalence | N/A | Powerlifting |
| *Ng et al. 2014* | Rowing | 1. 83.5%<br>2. 57% | 1. Lifetime prevalence<br>2. Point prevalence | N/A | - Ergometer rowing<br>- Long rowing sessions<br>- Sweep rowing |
| *Smoljanovic et al. 2009* | Rowing | 32.3% | One-season incidence | N/A | Cross training |
| *Iwamoto et al. 2005* | Rugby | 66% | 12-month incidence | N/A | Spondylolysis (radiological risk factor) |
| *Palmer-Green et al. 2015* | Rugby | 19.4% (trunk)<br>0.07-0.57 per 1000 player-hours | 2-season incidence | N/A | Lower level of play in rugby |
| *Cezarino et al. 2020* | Soccer | 3.2% | One-season incidence | N/A | - Older age group<br>- Match vs training |
| *Fouasson-Chailloux et al. 2020* | Soccer | 6.5% | 5-year incidence | N/A | N/R |
| *Lee et al. 2020* | Soccer | 4.1% | One season prevalence | N/A | N/R |
| *Linek et al. 2018* | Soccer | 9.3% | Six-month incidence | N/A | Asymmetry in OI (obliquus internus) measurement |
| *Shah et al. 2014* | Soccer | 1.5% | Eight-season incidence | N/A | - Second half of first half of match<br>- Contact with other players<br>- After breaks |
| *Sogi et al. 2018* | Soccer | 3.2% | Point prevalence | N/A | Knee pain |
| *Son et al. 2020* | Taekwondo | 5.05% | Point prevalence | N/A | N/R |
| *Hjelm et al. 2010* | Tennis | 21% | Two-year incidence | N/A | Female sex |
| *Zaina et al. 2016* | Tennis | 53% | Lifetime prevalence | N/R | N/R |

| | | | | | |
|---|---|---|---|---|---|
| *Mizoguchi et al. 2019* | Volleyball | 48% | 12-month prevalence | N/A | - Ankle injury within the past year<br>- Years of participation in volleyball |
| *Yabe et al. 2020 b* | Volleyball | 9.5% | Point prevalence | N/A | - Knee pain<br>- Ankle pain |
| *Shimozaki et al. 2018* | Weightlifting | 25% | Three-year incidence | N/A | N/R |

2.3.8 Interpretation of funnel plots

There were outlying studies throughout the funnel plots. There was no clear explanation for many of these outliers. Variation in report incidence and prevalence is likely to reflect inconsistencies in methodological design, in particular, variance in definitions, sample size, and method of recruitment.

- **Figure 2-3**: There is one outlier in this funnel plot which reported a higher incidence proportion. The remaining three studies are clustered around the midline. The outlier had 50% lower study numbers than the other three. All studies had similar definitions of injury. It is not possible to comment if there was recruitment bias in the outlying study.
- **Figure 2-4:** In this funnel plot, there are two extremes. Two studies reported high incidence proportions, and two reported low incidence proportions. One study also had a higher sample size than the other three studies. There was a large range in sample sizes in these studies. There were varying definitions in the included studies (see Table 2-2).
- **Figure 2-5:** There were also two extremes in this study, with one study reporting a higher incidence proportion. The study reporting a lower incidence proportion had a higher sample size. There were varying definitions in these two studies which could result in different reported incidences (see Table 2-2).
- **Figure 2-6:** This funnel plot is well distributed, with four studies below the midline and four above. There was a large range in reported prevalence in these studies. Varying definitions of LBP were used in included studies (see Table 2-2).

- **Figure 2-7:** There is one outlier in this funnel plot. This study reported a higher sample size and a higher prevalence than the remaining three studies.
- **Figure 2-8:** This funnel plot is well distributed. Most points are clustered around the midline. There is one study which reported a higher prevalence, which is an outlier on this funnel plot. This study was LBP-specific, which could possibly result in recruitment bias.

2.3.9 Risk factors for low back pain in cross-sectional studies

In eight studies that compared athletes to a non-sport group, sport participation was identified as a risk factor for developing LBP[118 172 173 225 227 230 240 246]. Some studies identified risk associated with certain sports, such as basketball[181], jogging[118], handball[118], and gymnastics[118 172].

A further nine studies (reported in ten papers) reported sport volume or intensity as a risk factor for developing LBP[195 201 207 213 219 225 227 231 247]. In one study, the level of sports exposure, measured by hours of sport participation per week, was only associated with LBP in younger athletes[247]. In the youngest girls (mean age 12.9 ± 0.5 years), 6-10 hours per week of sport participation increased risk of LBP (unadjusted OR 5.3, 95% CI 1.2-24.3). In the second youngest group of boys (mean age 13.8 ± 0.4 years), 10+ hours of sport participation increased risk of LBP (unadjusted OR 6.6, 95% CI 1.2-35). Finally, another study reported that both female and male athletes participating in sport more than six hours per week experienced higher rates of LBP than female and male athletes participating in less than six hours of sport per week[227].

There were three high-quality cross-sectional studies that reported that concurrent lower extremity pain was associated with LBP[232 235 236]. These studies adjusted for sex, age, body mass index, team levels, number of days for training per week, number of hours in practice per day on weekdays and weekends, frequency of participation in games, and practice intensity. The adjusted ORs were 6.56 (95% CI 1.57-27.3) for judo, 21.66 (95% CI 6.96-67.41) for kendo, 11.07 (95% CI 5.64-21.71) for volleyball, and 4.25 (95%CI 2.55-7.07) and 3.79 (95% CI 2.26 -6.36) for knee and ankle pain respectively in basketball.

Three studies reported being overweight/having a higher BMI as an associated factor[209 218 248]. In one study, the odds of developing LBP when classified as overweight was 1.4 times higher (OR 1.4, 95% CI 1.1-1.7 [analyses adjusted by sex])[218]. In another study, those who did not report LBP had lower BMI and body weight compared to those that did report LBP[209]. In the third study, overweight participants were more likely to have higher risk of lifetime or severe LBP compared to those with normal weight (OR 1.4, 95% CI 1.1–1.7 and 1.7, 95% CI 1.2–2.5 [analyses adjusted by sex])[218].

Older adolescent age was reported by three studies (reported in four papers) as an associated factor[203 207 221 222]. In one study, the prevalence of LBP in children > 13 years old more than doubled when compared to those aged 8-12 years[207]. Similarly, another study found that the prevalence of LBP increased from 2-4% in those aged 11-13 years, to 12-20% in those aged 14-17 years[203].

A group of seven studies reported female sex as a potential associated factor[98 207 216 218 227 238 246]. In three studies which reported on athletic girls specifically, there was a significantly higher prevalence of LBP in female athletes than in male athletes[216 238] with one study noting this especially in older grades[246]. Another study found that female sex was associated with only severe LBP[98], and female sex was associated with double the risk of lifetime LBP in a 5$^{th}$ and 6$^{th}$ grade primary students (OR 2.5, 95% CI 1.7-2.5 [analyses adjusted by sex])[218] , although these did not separate athletes from non-athletes.

Three studies (reported in four papers) reported a family history of LBP or musculoskeletal pain as an associated factor of LBP in adolescent athletes[207 221 222 238]. Those with parents who were treated for LBP had twice as much chance of LBP in one study (adjusted OR

1.73, adjusted for age, sex, and 'other independent variables', as reported by the study)[207]. Similarly, a second study reported a doubled risk of LBP when there was a family history of musculoskeletal disorders (OR 2.0, 95%CI 1.2 to 3.3 (adjusted by team level))[222].

2.3.10 Diagnoses and morphologies associated with low back pain in adolescent athletes

Thirteen studies reported specific diagnoses relating to LBP. Spondylolysis and spondylolisthesis were most often reported and were included in nine of the thirteen studies[172 180 184 185 191 192 199 230 248]. This was followed by Schmorl's nodes[184 185 223 230 242], disc degeneration[192 213 223 249], strains[172 180 191], spina bifida occulta[184 185 242], end plate changes[213 242], and scoliosis[230 242].

The most common method of imaging used to confirm diagnoses among the thirteen studies was MRI[180 192 213 223 230 248 249]. Lumbar radiographs/films were also used in four studies[242 249 184 185].

## 2.4 Discussion

The prevalence of LBP in adolescent athletes is comparable to the general adolescent population. Although, in some studies, sports participation is associated with LBP among adolescents in studies where an age-matched non-sporting group was available for comparison, it is unclear from this review whether it exacerbates LBP prevalence above a rate that is normally seen in adolescence.

2.4.1 Comparison to general adolescent population

The reported incidence and prevalence estimates of LBP in adolescent athletes range widely. The LBP incidence and prevalence estimates for adolescent athletes are consistent with LBP estimates in the general adolescent population. Research indicates that annual incidence can range from 12-33%[250]. Similarly, studies show that point prevalence of LBP in adolescents can range from 3.2%-39%[77 250], and that lifetime prevalence can range from 7-80%[76 77 250 251]. The combined weighted mean for 12-month risk as well as point and lifetime prevalence all fall within these range. There was a wide reported range of lifetime prevalence in this review, which may be due to limitations that occur with the use of long recall periods. Errors in recall resulting in reporting bias may occur with longer recall periods[252-254]. Similarly, the range of lifetime prevalence in the general adolescent population is wide.

Physical activity can be both a risk factor and preventive factor for LBP, depending on the level of physical activity[116]. It is unclear from this review whether the "U-shaped" [116] relationship between physical activity and LBP found in adults is also present in adolescents. The decrease in risk of LBP that accompanies physical activity participation in adults was not observed in adolescent athletes, contradicting the protective findings of physical activity on LBP in adults. While this does not consider a more nuanced view of the level of physical activity adolescent athletes participate in, several studies in this review did explore level of sport workload or exposure as a risk factor for LBP[118 172 173 181 208 225 227 230 240 246]. Those with a higher level of sport exposure were at higher risk of LBP.

It is also possible that the rate of LBP reported in adolescent athletes is too heavily attributed to sport. The general adolescent population does not engage in sufficient physical activity[3] and still reports a high prevalence of LBP[76 77 251]. Since it is unclear at this point whether the prevalence of LBP increases based solely on sport engagement, the benefits of sports likely outweigh the risk of LBP for adolescent athletes. It may be more important to examine the causes and duration of LBP in adolescent athletes, as these may differ from the overall adolescent population.

2.4.2 Common morphologies associated with low back pain in adolescent athletes

Like previous research in this area, spondylolysis is the morphology that appears in the highest number of studies in this review. It is well supported that spondylolysis is most common in adolescent athletes[120 121 124]. It appears that the rate of spondylolysis that is reported in adolescent athletes is greater than that of the general adolescent population. The rate of spondylolysis reported in radiographs of those aged 12-18 has been documented as between 5.2-6%[255]. Some studies suggest that the majority of spondylolysis is asymptomatic[120 121 256], and in adults, imaging reveals incidental asymptomatic findings of spinal changes that are not necessarily associated with pain[257-260]. It is possible that some of the spondylolysis findings in adolescents are also not associated with the LBP that the athlete is experiencing and are a normal response to high levels of loading and stress on a developing spine in this population. MRI was the most commonly used method of confirming diagnosis in this review, although it is not the most sensitive tool to assess spondylolysis[261]. MRI was chosen over CT scan in several included studies due to the risk of increased radiation exposure in adolescents[180 192]. From a clinical standpoint, it may be important to assess the methods used to confirm diagnoses in adolescents and consider that a focus on imaging may lead to over-diagnosis. Currently, a diagnosis of spondylolysis can lead to specific treatment methods that impact significantly on an adolescent's life, such as lumbar bracing[120], rest from sport[28], pharmacologic pain management[256], and surgery[120 256]. Optimal diagnosis (including a better understanding between the relationship of imaging findings and clinical presentation), treatment and management methods for spondylolysis in this population should be better refined.

### 2.4.3 Comparison to adult athletes

A recent systematic review of LBP in adult athletes found a high prevalence of LBP, with a history of LBP associated with risk of new onset[146]. The onset of LBP early in life puts adolescent athletes at higher risk for continuing LBP later in life[80 81]. Thus, the use of appropriate load monitoring and education to reduce risk of a primary episode of LBP in adolescence might mitigate future risk of LBP-related disability in adulthood. In addition, LBP was more common in adults with high training volumes[146]. This review has a similar finding, suggesting that an emphasis on adequate load management beginning as early as adolescence may decrease the risk of LBP in athletes of all ages.

As with adult literature[146], there is little agreement on the definition of LBP in studies among adolescent athletes. In the meta-regression analyses, methodological quality and LBP definition accounted for most of the heterogeneity in studies of cohort design. Similarly, LBP definition accounted for all heterogeneity in cross-sectional studies reporting 3-month prevalence. The results of the meta-regression suggest that the lack of standardised method of assessing LBP in adolescent athletes may affect the overall prevalence reported. A definition of LBP more specific to adolescent athletes may improve assessment of LBP in this group.

### 2.4.4 Adolescent-specific factors in comparison to adult athletes

Several factors that may increase risk of LBP are unique to adolescent athletes when compared to adult athletes, including the effect of lower extremity pain and female sex on risk of developing LBP. Several studies identified female sex as a potential risk factor for LBP in adolescent athletes. Female adolescent athletes drop out of sport twice as often as their male counterparts by the age of 14[21]. There are many factors contributing to this, including physical and psychological barriers[22] to sport participation. It is possible that increased rate of pain or injury may be a contributing factor, but this requires further exploration. Further research into causes of a higher the prevalence of LBP among female adolescent athletes may be essential to mitigating risk and retaining female athlete participation in adolescence.

There are three high quality studies that suggest that concurrent lower extremity pain may be associated with LBP (OR 8.3, 95% CI 4.8, 14.4, $I^2$ 45%)[232 235 236]. Pain reporting can be influenced by factors such as female sex[262], social factors[262 263], and past experiences with pain[264]. It is possible that the adolescents reporting concomitant lower extremity pain and LBP are more likely to report pain in general, although further exploration of factors influencing pain reporting in adolescent athletes is required. The role of parent/guardian involvement is a unique challenge of LBP prevalence assessment in adolescent sport. Several studies in this review allowed parents to answer the questionnaire on behalf of their children. Research has shown that parents' perception of their child's pain differs from the child's, with the adult often underestimating the pain of their child[58 59]. This could lead to an inaccurate representation of the prevalence of LBP in adolescent athletes and should also be reflected in considerations of injury prevention and load monitoring education. Adolescent athletes are best able to report their own pain, with appropriate adult consultation and consent.

In the meta-regression analyses of cross-sectional studies reporting lifetime and 12-month prevalence, none of the factors explored contributed to heterogeneity between the studies. This suggests that there may be other factors impacting heterogeneity among studies on adolescent athlete LBP that may not have been explicitly explored in the reported studies

2.4.5 Confidence in estimated values

There was considerable variability across studies in terms of methodology, definitions, and data collection mode. This suggests a lack of standardisation in studies evaluating incidence and prevalence of LBP in adolescent athletes. A standardised definition of LBP for adolescent athlete research may enhance accuracy of the reported findings. Caution in interpreting results is warranted due to the overall low quality of available evidence and high heterogeneity among included studies. The search strategy was designed to capture studies exploring LBP incidence or prevalence in adolescent athletes, and did not specifically address risk factors, so some relevant studies may have been left out of this section.

2.4.6 Clinical implications

The results of this review suggest that clinicians should be aware of LBP as a common condition in adolescent athletes. Spondylolysis is the most reported morphology, suggesting that further research into methods of diagnosis and treatment in this population is warranted.

2.4.7 Limitations

Less than half of included studies were deemed as high quality. The majority of studies in this review were of cross-sectional design (49 studies), which does not represent the highest level of the aetiology hierarchy[265]. Only nine of the 31 cohort studies were considered high-quality. There was not sufficient information to describe how the study population reflects the broader population size.

The pooled estimates of incidence are limited by the lack of high-quality cohort studies reporting on incidence in the same time period- there was a low number of studies in these meta-analyses. This also limited the use of meta-regression in some meta-analyses.

Confounding in OR estimates was unmeasured, as some studies used crude ORs or did not specify covariates included in OR adjustment. There are important limitations to consider in reporting ORs from cross-sectional studies, including reverse causality.

This review only included studies published in English or with an English translation available. The term “back pain” was considered LBP unless otherwise specified, since back pain and LBP are often used interchangeably. Low back injury was also considered LBP until otherwise specified. The determination was made at the stage of full text screening that the study included an investigation of LBP. The quality appraisal tool used is specific to LBP but not specific to athletes or adolescents. The term “point prevalence” in this review included current pain or pain in the past 7 days.

## 2.5 Conclusion

LBP is as common among adolescent athletes as in the general adolescent population. Some factors associated with LBP reported by included studies were sport participation, sport volume or intensity, concurrent lower limb pain, being overweight/having a higher BMI, older adolescent age, female sex, and family history of LBP or musculoskeletal pain. Spondylolysis was the most reported morphology associated with LBP in adolescent athletes.

**What was already known?**

- LBP is prevalent in the general adolescent population and in adult athletes.
- LBP is a notable cause of disability and can stop athletes from participating in sport.

**What this study adds:**

- LBP is common among adolescent athletes.
- Incidence and prevalence of LBP varied considerably due to differences in methodology, LBP definition, and data collection.
- Spondylolysis was the most common reported morphological presentation.
- Potential risk factors for LBP in adolescent athletes presented in included studies were sport participation, sport volume/intensity, concurrent lower extremity pain, overweight/high BMI, older adolescent age, female sex, and family history of LBP.

**How this study might affect research, practice, or policy:**

- In clinical practice, clinicians should be aware of LBP as a common condition in adolescent athletes
- Further research into methods of diagnosis and treatment of spondylolysis in adolescent athletes may be warranted
- A clear, specific definition of LBP for adolescent athletes would benefit future research in this population.

**Figure 2-9:** Summary of Study I.

# Chapter 3: Diagnoses associated with low back pain in adolescent athletes: a retrospective chart review of 400 patients

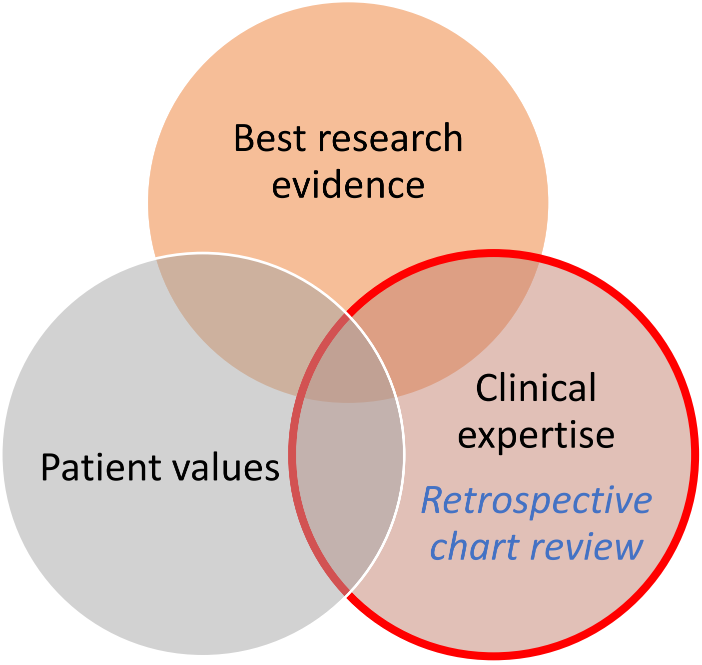


**Figure 3-1:** Sackett model of Evidence Based Medicine exploring LBP in adolescent athletes.

## 3.1 Introduction

Low back pain (LBP) is a common condition in young athletes. In the previous chapter, we established a 12-month incidence estimate of 36.0% (95% CI 4-68, $I^2$=99.3%), and a 12 month prevalence estimate of 42% (95% CI 29-55, $I^2$=96.6%)[266]. LBP is a symptom with a wide variety of associated causes in some cases, including congenital causes, injuries, degeneration, nerve and spinal cord issues, and non-spine related causes[267]. The most common causes for LBP in adolescents appear to differ from those of adults, with pars interarticularis injuries more common, and disc-related back pain less common[124 164]. Up to 90% of all LBP in general is non-specific, meaning there is no known associated pathoanatomical cause[134]. Although most LBP in the general population is non-specific[120 121 256], it appears that adolescents may be more likely than adults to receive a distinct diagnosis[268]. Fitting with this, in the previous chapter, the most commonly reported morphology was spondylolysis or spondylolisthesis[266]. Also commonly reported were

Schmorl's nodes, disc degeneration, strains, spina bifida occulta, end plate changes, and scoliosis[266].

The overall prevalence of LBP in young athletes is known to vary by sport, but it is unclear whether the type of sport impacts the etiological presentation of LBP in adolescent athletes[28]. Broadly, contact sports may be more likely to result in acute injuries, whereas repetitive sports such as gymnastics more often result in overuse injuries[164]. It is thought that LBP prevalence in adolescents varies by the type of sport in which an adolescent participates[164]. In our systematic review, sports could not be compared closely due to methodological heterogeneity, including differing recall periods, definitions, and quality, but there were some general trends noted[266]. Soccer and martial arts had generally lower levels of LBP, while ballet, gymnastics, and rowing reported higher general levels of LBP. There is currently no published overview of specific aetiologies diagnosed in adolescent athletes categorised by sport.

It is important to explore LBP diagnoses in this population to advance evidence-based management techniques. A retrospective chart review design was chosen for this study. In a retrospective chart review, the data was originally collected for reasons other than research, such as for continuity of treatment[269 270]. This research design has some limitations such as the potential for incomplete medical notes or differing levels of quality[269]. However, the benefits of a retrospective review include: it is an inexpensive research methodology[11], it is useful in exploring a condition over time[13], and it provides a uniquely detailed document of a patient's clinical journey[271]. Retrospective chart review designs have previously been used to characterise poorly understood patient populations, such as those with complex regional pain syndrome[272] and bipolar disorder[273]. The retrospective chart review design was chosen for this study because of the level of detail provided in medical notes, as well as the ability to follow temporal trajectories of LBP. A longitudinal design would be ideal to follow LBP trajectories over time, however, due to the time and funding constraints of PhD research, the retrospective chart review design was chosen as a richly populated and unique data set was available in the population of interest.

The aim of this study is to characterise the presentation of adolescent athlete LBP as diagnosed in a clinical setting. The objectives were to 1) identify conditions associated with LBP in adolescent athletes, 2) categorise the differences in LBP aetiology and presentation by sport, sex, BMI, and age, and 3) examine treatment and management methods of LBP in adolescent athletes.

### 3.2 Methods

This retrospective medical chart review was conducted in the Sports Medicine Division of Boston Children's Hospital (BCH), a tertiary paediatric academic hospital. Boston Children's Hospital is the world's largest paediatric research centre[274]. It is one of the largest paediatric medical centres in the United States, housing 40 clinical departments[274]. The Sports Medicine Division is the largest paediatric and young adult sports medicine practice in the United States, with over 45,000 patient visits per year[275]. There are over 45 clinicians (orthopaedic surgeons, sports medicine physicians, podiatrists, psychologists, dietitians, physician assistants, nurse practitioners, registered nurses, physical therapists, and athletic trainers) involved in this department[275]. Institutional Review Board exemption was obtained from the BCH IRB (IRB protocol number IRB-P00035872) (Appendix 3-1).

In March 2020, a search of records in the BCH Sports Medicine Division was conducted to identify all athletes aged between 10 and 19 years who presented between January 2015 and March 2020 for LBP. Criteria for inclusion were: 1) Athletes aged 10-19 years old, 2) LBP was the primary reason for presentation to the Sports Medicine clinic. LBP was defined as a 'pain, ache or discomfort in the low back with or without referral to the buttocks or legs'[71], with the low back area defined as 'the posterior aspect of the body from the lower margin of the twelfth ribs to the lower gluteal folds'[72]. In the absence of detail, best judgement was used if organised sports participation was evident in the medical chart.

The variables of interest in this study are detailed in Table 3-1.

| Variable | Description of what was collected | Rationale |
|---|---|---|
| **Demographic and anthropometric data** | | |
| Age | Date of birth (DOB) for age calculation | Inclusion criteria for the study and for comparison within participants across age groups |
| Sex | Sex assigned at birth as documented in medical chart | For comparison within participants across groups. |
| Height and weight | Height and weight as documented in medical chart for BMI calculation | For comparison within participants across BMI groups |
| **Sport-specific information** | | |
| Sport(s) | Name(s) of sport(s) participated in at the time of appointment | For comparison within participants across sport groups. |

| | | |
|---|---|---|
| Training and competition information | • Level of competition (varsity, junior varsity, club/travel, college club, college varsity, high school (unspecified), college (unspecified), middle school, not specified in chart<br>• Months/years participating<br>• Organised training (hrs/week) | Inclusion criteria for the study. |
| Sport position | Primary position played in each sport (if applicable) | To meet the objectives of the study |
| **Diagnosis/LBP** | | |
| Etiological presentation | Examination and diagnosis provided by clinician in medical chart, including investigations and findings and treatment prescribed. | To meet the objectives of the study (Identify conditions associated with LBP in adolescent athletes) |
| Date of initial visit | Visit date (MM/DD/YYYY) | To calculate age at initial visit |

| | | |
|---|---|---|
| Age at initial visit | Age on the day of the initial visit | For inclusion criteria for the study |
| LBP specific information | • Type of onset (acute or insidious)<br>• Mechanism of injury<br>• Time of season during onset (in-season, pre-season, off-season, not specified)<br>• Sporting activity at onset (practice, competition, strength training, not sport-related, not specified in chart)<br>• Does the pain radiate?<br>• Aggravating and easing activities<br>• Does the pain affect the patient's sleep? | To meet the objective of the study. |

**Table 3-1:** Variables of interest.

Study data were collected and managed using a customised form on REDCap (Vanderbilt University) electronic data capture tools hosted at Boston Children's Hospital[276 277]. The form was designed by JW in consultation with FW, and contains questions related to the variables of interest presented in Table 3-1. REDcap software is a cloud-supported, Health Insurance Portability and Accountability Act (HIPAA) compliant platform.

3.2.1 Statistical methods

Statistical analysis was conducted using SAS software version 9.4 (SAS Institute, Cary NC). To decide how many charts would be needed to assess for between-group differences in variables, two researchers used a Chi-Squared test with degrees of freedom ranging from 5 to 20, power 0.80, alpha 0.05, and an effect size of 0.2 or 0.3 (JW and DC). The number of charts that allowed for a small effect size to be seen was 400 charts.

A Chi-Squared test for association was used to assess potential associations between aetiological presentation and sport groups, age groups, sex, and BMI groups (JW and DC). Multiple comparisons were done using the Holm-Bonferroni p-value correction[278] if the initial chi-square test had a p-value less than 0.05. This was done to reduce the likelihood of Type I error with multiple comparisons.

Aetiologies related to LBP were categorised by sport group, age at onset, sex, and BMI. The sports classification system used in this study was based on a three-group approach used in several recent studies[279-281] (Table 1), as there is currently no published consensus on the classification of sport categories. The International Olympic Committee (IOC) consensus statement on methods for recording and reporting of epidemiological data on injury and illness and sport 2020[282] recommends a clear description of the sports classification system used in the methods section of any report. For this study, the categories “technical sports”, “team sports”, and “endurance sports” were used (Table 3-2).

| **Technical sports** | **Team sports** | **Endurance sports** |
|---|---|---|
| Dance | Soccer | Rowing |
| Gymnastics | Basketball | Cross-country skiing |
| Cheerleading | Lacrosse | Cross-country running |
| Track and Field (athletics)<br><br>Short-distance and field events | Football | Track and Field (athletics)<br><br>Middle- and long-distance events |
| Figure skating | Ice Hockey | Swimming |
| Synchronized skating | Baseball | |
| Equestrian sports | Volleyball | |
| Wrestling | Field Hockey | |
| Golf | Softball | |

| | | |
|---|---|---|
| Tennis | Gaelic Football | |
| Diving | | |
| Rock climbing | | |
| Boxing | | |
| Kickboxing | | |
| Powerlifting | | |
| Martial arts | | |
| Alpine skiing | | |
| Ski jump | | |

**Table 3-2:** Sport categorisation system.

Where the type of skiing or type of Track and Field event was not specified, it was classified as a technical sport.

There is no standardised method for classifying age groups within adolescence. Age was classified into three groups: early (10-14 years), middle (15-17 years), and late (18-19 years) adolescence, based on source material published by the WHO Department of Child and Adolescent Health[283].

Sex assigned at birth was classified as either female or male. BMI was classified according to the Centers for Disease Control (CDC) classification of BMI-for-age (Table 2)[284].

| | |
|---|---|
| **Underweight** | Less than 5th percentile |
| **Healthy weight** | 5th percentile to 85th percentile |
| **Overweight** | 85th to >95th percentile |
| **Obese** | 95th percentile or greater |

**Table 3-3:** BMI-for-age.

Due to low participant numbers in the underweight and obese groups, for statistical analyses, participants below the 85th percentile were deemed healthy and greater than or equal to the 85th percentile were categorized as overweight.

Diagnoses related to LBP were categorized into six groups based on the most common diagnoses recurring in the dataset:

- Spondylolysis group
    - ‘Spondylolysis’ included these diagnostic labels: Spondylolysis or spondylolisthesis
- Facet joint group
    - ‘Facet joint’ included these diagnostic labels: facet joint irritation, facet joint pain, facet joint dysfunction

- Sacroiliac joint (SI joint) group
    - ‘SI joint’ included these diagnostic labels: SI joint irritation, SI joint pain, SI joint dysfunction, sacroiliitis
- Disc, group
    - ‘Disc’ included these diagnostic labels: disc herniation, disc protrusion, discogenic pain
- Non-specific LBP group
    - “Non-specific LBP” included these diagnostic labels: non-specific LBP, mechanical pain, mechanical LBP with increased lordosis, musculoskeletal based LBP, LBP, back pain, atraumatic axial LBP, extension-based back pain, complex spine pain, lumbar pain, left- or right-sided LBP, flexion based lumbosacral pain with a reassuring exam, low lumbar pain, chronic LBP with minor spinal asymmetry, lordotic LBP, functional LBP, biomechanical LBP, benign LBP.
- Other group
    - “Other” included these diagnostic labels: flat back syndrome, Berlotti syndrome, lower back contusion, scoliosis, LBP hemipelvic in nature, Scheurmann’s kyphosis, compression fracture, transitional vertebrae, bursitis, piriformis syndrome, psoas tendinitis, spinous process apophysitis, fusion anomaly, traction apophysitis, strain, sacralized S1, foraminal narrowing, osteitis pubis, paraspinal muscle tightness, nerve irritation, displacement of L5 nerve, diffuse stress injury, paraspinous muscle contusion, coccyx fracture.

## 3.3 Results

There were 474 charts reviewed for inclusion. Of these, 400 charts met the inclusion criteria, and data were extracted from 400 charts into a customised data extraction form (Appendix 3-2). One researcher (JW) extracted information from 400 records, working from most recent to least recent. There were 37 patients who did not receive a formal diagnosis clearly documented in the sports medicine chart, as they may not have followed up after radiological investigations. Since the characteristics of this group were not different, these participants were removed from statistical analysis, resulting in a total of 363 participants.

### 3.3.1 Participant characteristics

The number of visits per participant ranged from 1 to 15 visits within the study dates. Participant characteristics are summarized in Table 3-4. The mean age at initial visit was 15.4 years old, and mean BMI at initial visit was 22.2. Fifty percent of the cohort were in middle adolescence and 66% were female. Forty-nine percent of the cohort participated in a team sport as their primary sport.

**Table 3-4. Participant characteristics (N=363).**

| **Characteristic** | **Freq.** | **(%)** |
|---|---|---|
| Age | | |
| Early adolescents | 142 | (39%) |
| Middle adolescents | 183 | (50%) |
| Late adolescents | 38 | (11%) |
| Sex | | |
| Male | 124 | (34%) |
| Female | 239 | (66%) |
| BMI (n=337) * | | |
| Underweight | 1 | (0%) |
| Healthy weight | 251 | (75%) |
| Overweight | 64 | (19%) |
| Obese | 21 | (6%) |
| Primary sport | | |
| Technical sport | 162 | (45%) |
| Team sport | 177 | (49%) |
| Endurance sport | 24 | (7%) |
| Secondary sport (n=130) * | | |
| Technical sport | 36 | (28%) |
| Team sport | 83 | (64%) |
| Endurance sport | 11 | (9%) |

| | | |
|---|---|---|
| Tertiary sport (n=46) * | | |
| Technical sport | 10 | (22%) |
| Team sport | 35 | (76%) |
| Endurance sport | 1 | (2%) |
| Primary diagnosis | | |
| Spondylolysis or spondylolistheses | 102 | (28%) |
| Facet joint irritation/pain/dysfunction | 20 | (6%) |
| SI joint irritation/pain/dysfunction/sacroiliitis | 26 | (7%) |
| Disc herniation/protrusion/discogenic pain | 29 | (8%) |
| Non-specific LBP | 123 | (34%) |
| Other | 63 | (17%) |

BMI, body mass index; LBP, lower back pain.
*The number in parentheses represents the number of cases with available data for the given characteristic.

**Table 3-4:** Participant characteristics.

The 400 included participants took part in 30 different sports (Figure 3-2). There were 260 single-sport athletes and 140 multi-sport athletes. Of the multi-sport athletes, 91 participated in two sports, 39 participated in three sports, and ten participated in more than three sports. The most common sports were soccer (68 participants), basketball (66 participants), gymnastics (61 participants), and dance (61 participants). The least common sports had one participant each: boxing, Gaelic football, kickboxing, and powerlifting.

Of 46 charts with information on sport level available, there were 9 participants in club/travel teams, 3 participating in sport at a middle school level, 20 participating in high school sport at an unspecified level, 12 participating in college sport at an unspecified level, 2 participating in college varsity teams.

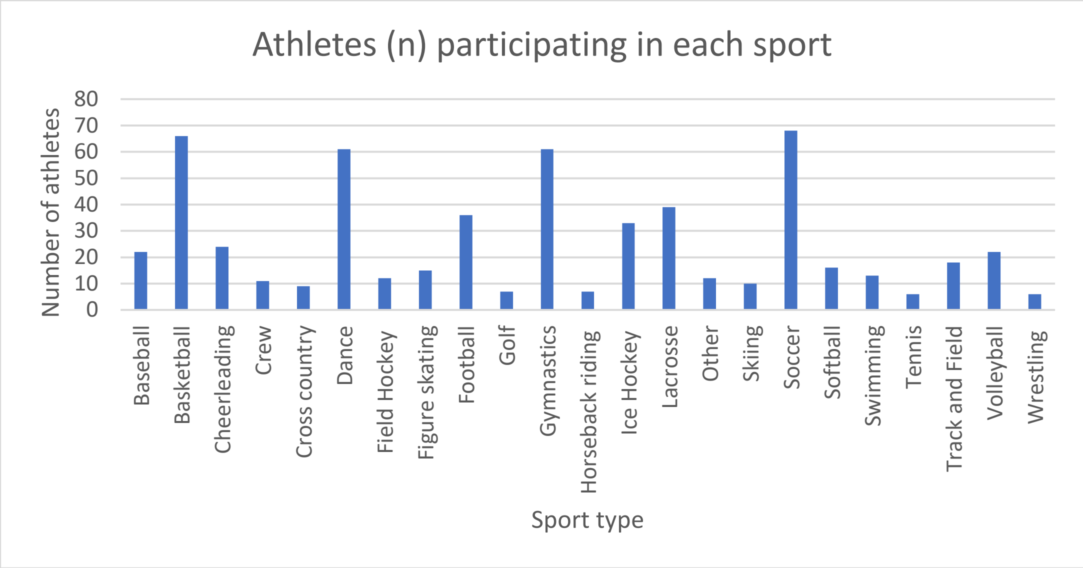


**Figure 3-2:** Athletes (n) participating in each sport.

### 3.3.2 Characteristics of pain

Of 392 charts with information available, there were 86 participants with an acute onset of LBP and 306 participants with an insidious onset of LBP. Out of 84 charts that reported pain descriptors at the initial visit (Figure 3-3), the most common pain descriptors were “sharp” (19 participants reported), “achy” (15 participants reported) and “sore” (13 participants reported).

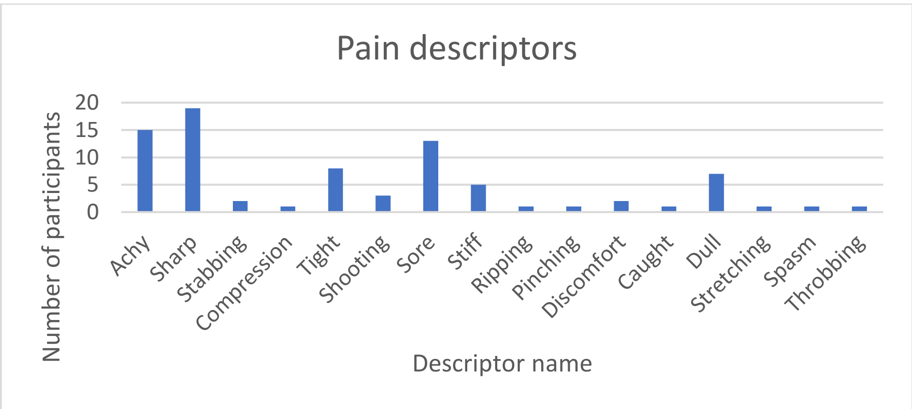


**Figure 3-3:** Pain descriptors

Out of 351 total aggravating factors reported (Figure 3-4), the most common self-reported aggravating factors at the initial visit were extension movement of the spine (110 participants reported), sports/activities/sport-specific movements (71 participants reported), and prolonged sitting (66 participants reported).

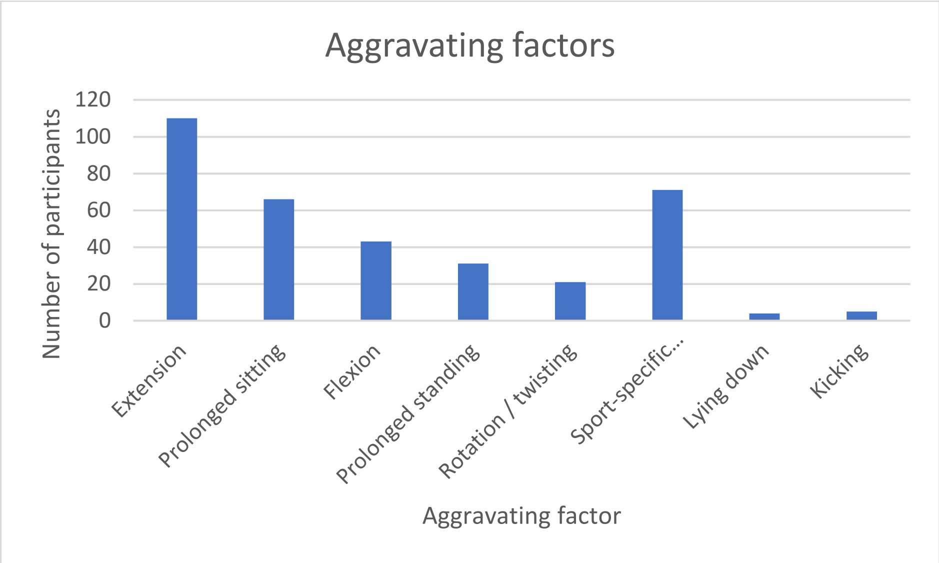


**Figure 3-4:** Aggravating factors.

Out of 52 easing factors reported (Figure 3-5), the most common self-reported easing factors at the initial visit were rest (16 participants reported), medication (various types) (15 participants reported), and heat (10 participants reported). Out of 31 charts with information available, 16 athletes reported that the pain affected their sleep (10 initial visit, 6 follow-up visits). The mean pain severity reported at the initial visit was 3.5/10 (data available from 134 participants). The median pain severity was 4/10 (data available from 134 participants) (Figure 3-6).

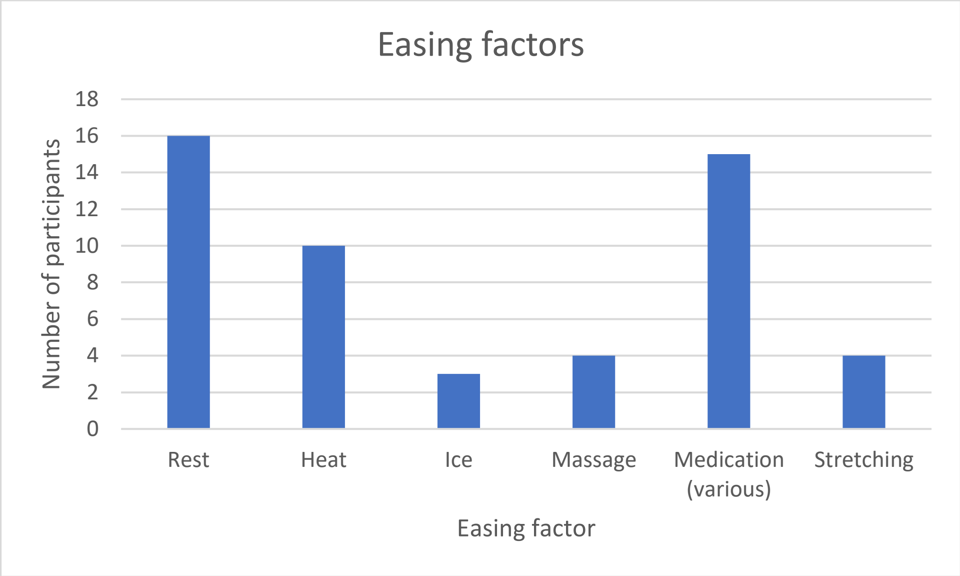


**Figure 3-5:** Easing factors.

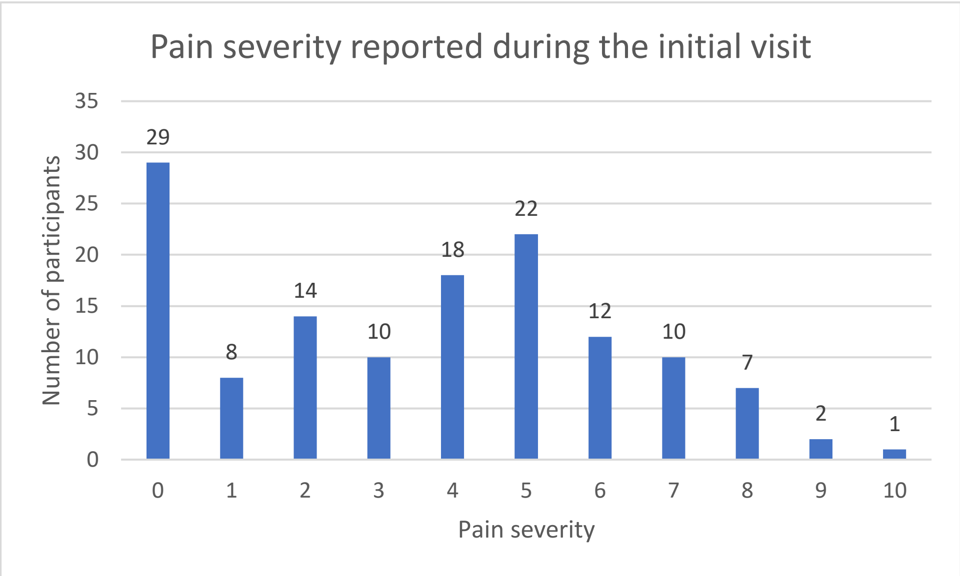


**Figure 3-6:** Pain severity reported during the initial visit.

### 3.3.3 Statistical results

There was a significant difference in presentation according to sex among LBP diagnoses ($p<0.001$). There was a higher proportion of females in the facet joint irritation/pain/dysfunction diagnosis group (90%) compared to the spondylolysis or spondylolisthesis group (50%, $p=0.001$). Similarly, there was a higher proportion of females in the SI joint irritation/pain/dysfunction/sacroiliitis diagnosis group (89%) and the non-specific LBP diagnosis group (74%) compared to the spondylolysis or spondylolisthesis group (both $p<0.001$) (Table 3-5).

| Table 3-5: Participant demographics compared between diagnosis type (N=363). | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Spondylolysis or spondylolisthesis (n=102) | | Facet joint irritation/pain/ dysfunction (n=20) | | SI joint irritation/pain/ dysfunction/ sacroiliitis (n=26) | | Disc herniation/protrusion/di scogenic pain (n=29) | | Non-specific LBP (n=123) | | Other (n=63) | | |
| **Characteristic** | **Freq.** | **(%)** | **Freq.** | **(%)** | **Freq.** | **(%)** | **Freq.** | **(%)** | **Freq.** | **(%)** | **Freq.** | **(%)** | **P-value** |
| Age | | | | | | | | | | | | | 0.15 |
| Early adolescent | 43 | (42%) | 7 | (35%) | 9 | (35%) | 7 | (24%) | 56 | (46%) | 20 | (32%) | |
| Middle adolescent | 52 | (51%) | 8 | (40%) | 15 | (58%) | 19 | (66%) | 56 | (46%) | 33 | (52%) | |
| Late adolescent | 7 | (7%) | 5 | (25%) | 2 | (8%) | 3 | (10%) | 11 | (9%) | 10 | (16%) | |
| Sex | | | | | | | | | | | | | <0.001 |
| Male | 51 | (50%) | 2 | (10%) | 3 | (12%) | 11 | (38%) | 32 | (26%) | 25 | (40%) | |
| Female | 51 | (50%) | 18 | (90%) | 23 | (89%) | 18 | (62%) | 91 | (74%) | 38 | (60%) | |
| BMI (n=337) * | | | | | | | | | | | | | 0.07 |
| Healthy | 71 | (73%) | 17 | (90%) | 18 | (75%) | 16 | (57%) | 80 | (73%) | 50 | (85%) | |
| Overweight | 26 | (27%) | 2 | (11%) | 6 | (25%) | 12 | (43%) | 30 | (27%) | 9 | (15%) | |

LBP, lower back pain; BMI, body mass index.

*The number in parentheses represents the number of cases with available data for the given characteristic.

**Table 3-5:** Participant demographics.

While there was a significant difference in diagnosis between team sports and non-team sports (p=0.045), there were no significant differences found when conducting the multiple comparisons between each diagnosis (Table 3-6).

**Table 3-6: Comparison of diagnoses by primary sport type (N=363).**

| | **Technical sport (n=162)** | | **Non-technical sport (n=201)** | | |
|---|---|---|---|---|---|
| **Diagnosis** | **Freq.** | **(%)** | **Freq.** | **(%)** | **P-value** |
| Spondylolysis or spondylolisthesis | 35 | (22%) | 67 | (33%) | 0.08 |
| Facet joint irritation/pain/dysfunction | 13 | (8%) | 7 | (4%) | |
| SI joint irritation/pain/dysfunction/sacroiliitis | 11 | (7%) | 15 | (8%) | |
| Disc herniation/protrusion/discogenic pain | 14 | (9%) | 15 | (8%) | |
| Non-specific LBP | 62 | (38%) | 61 | (30%) | |
| Other | 27 | (17%) | 36 | (18%) | |

| | **Team sport (n=177)** | | **Non-team sport (n=186)** | | |
|---|---|---|---|---|---|
| **Diagnosis** | **Freq.** | **(%)** | **Freq.** | **(%)** | **P-value** |
| Spondylolysis or spondylolisthesis | 63 | (36%) | 39 | (21%) | 0.05 |
| Facet joint irritation/pain/dysfunction | 6 | (3%) | 14 | (8%) | |
| SI joint irritation/pain/dysfunction/sacroiliitis | 12 | (7%) | 14 | (8%) | |
| Disc herniation/protrusion/discogenic pain | 13 | (7%) | 16 | (9%) | |
| Non-specific LBP | 54 | (31%) | 69 | (37%) | |
| Other | 29 | (16%) | 34 | (18%) | |

| | **Endurance sport (n=24)** | | **Non-endurance sport (n=339)** | | |
|---|---|---|---|---|---|
| **Diagnosis** | **Freq.** | **(%)** | **Freq.** | **(%)** | **P-value** |
| Spondylolysis or spondylolisthesis | 4 | (17%) | 98 | (29%) | 0.40 |
| Facet joint irritation/pain/dysfunction | 1 | (4%) | 19 | (6%) | |
| SI joint irritation/pain/dysfunction/sacroiliitis | 3 | (13%) | 23 | (7%) | |
| Disc herniation/protrusion/discogenic pain | 2 | (8%) | 27 | (8%) | |
| Non-specific LBP | 7 | (29%) | 116 | (34%) | |
| Other | 7 | (29%) | 56 | (17%) | |

LBP, lower back pain.

**Table 3-6:** Comparison of diagnoses by primary sport type.

3.3.4 Management techniques

At the initial visit, the most reported management technique was a referral for MRI (diagnostic), followed by referral to physical therapy, relative rest/avoidance of certain activities, and the use of bracing (Figure 3-7).

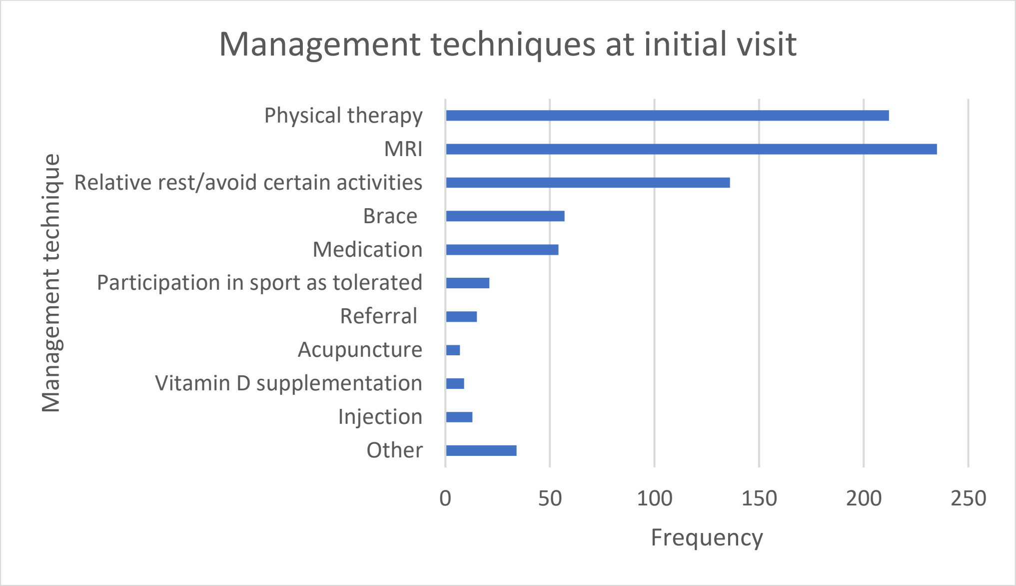


**Figure 3-7**: Management techniques at initial visit.

At the first follow-up visit, the most reported management technique was a referral to physical therapy, followed by bracing, then relative rest/avoidance of certain activities, and participation in sport as tolerated (Figure 3-8).

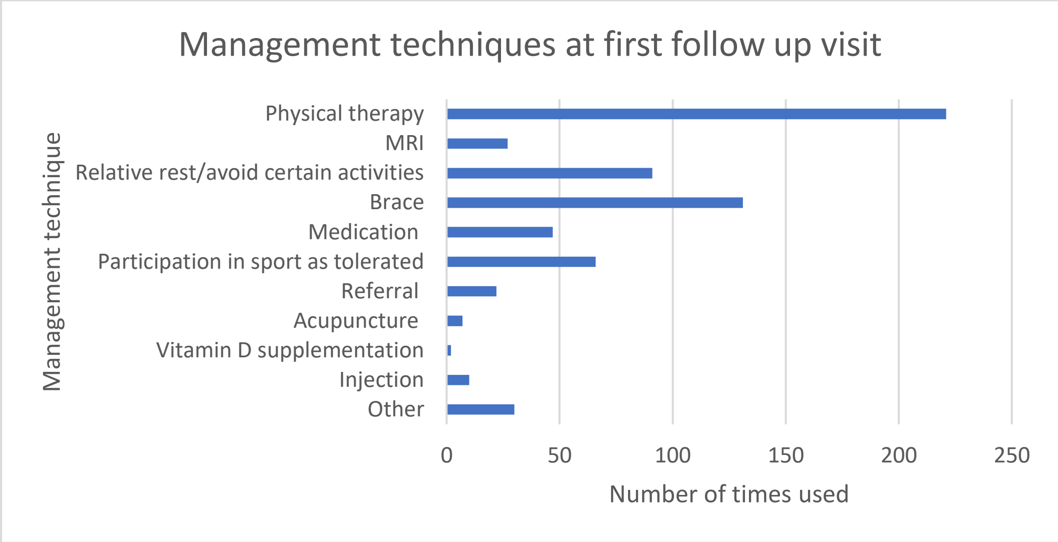


**Figure 3-8:** Management techniques at first follow up visit.

The types of medications prescribed at the initial visit included non-steroidal anti-inflammatories (NSAIDs), muscle relaxants, anaesthetics, analgesics, and anticonvulsant/nerve pain medications. Referrals to other clinics or departments included referrals to sports dietetics (3 participants), rheumatology (1 participant), neurology, orthopaedics (1 participant), dance screening (2 participants), and pain clinic (2 participants). There were seven participants referred for injections, including epidural injection (4 participants), facet joint injection (1 participant), and sacroiliac joint injection (2 participants).

### 3.3.5 Management of spondylolysis

Because spondylolysis was the most common diagnosis, a specific analysis of spondylolysis management is presented here. At the initial visit (Figure 3-9), the most common management techniques reported for spondylolysis were MRI (diagnostic), referral to physical therapy, and advice to remain out of sport activity.

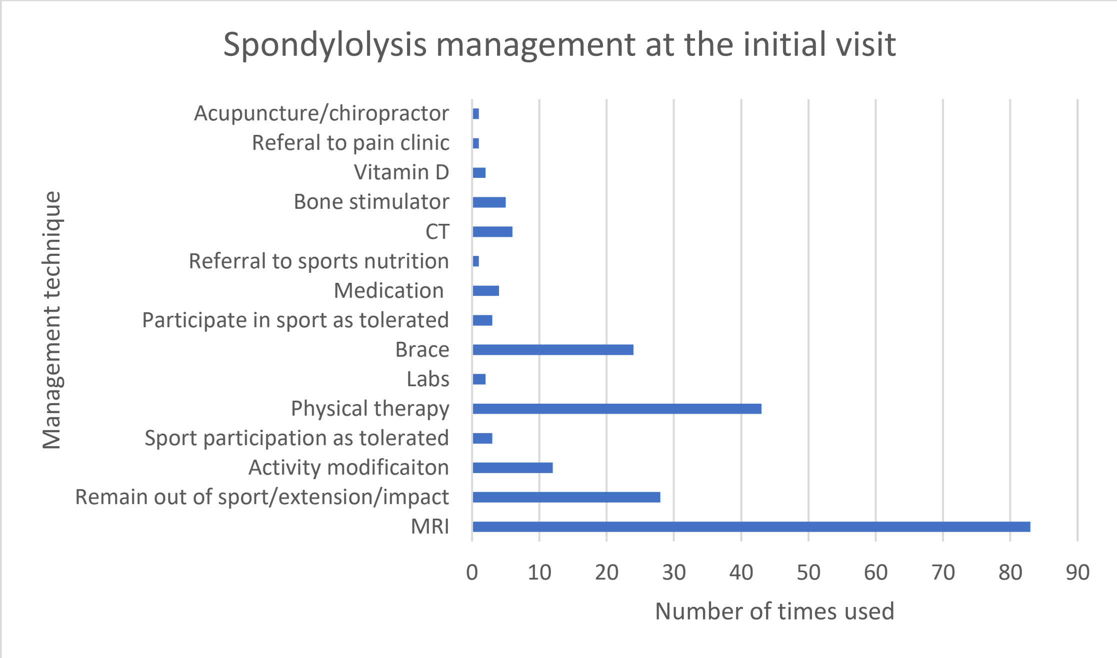


**Figure 3-9**: Spondylolysis management at the initial visit.

At the first follow-up visit (Figure 3-10), the most common management techniques were physical therapy, the use of bracing, and advice to remain out of sports activity.

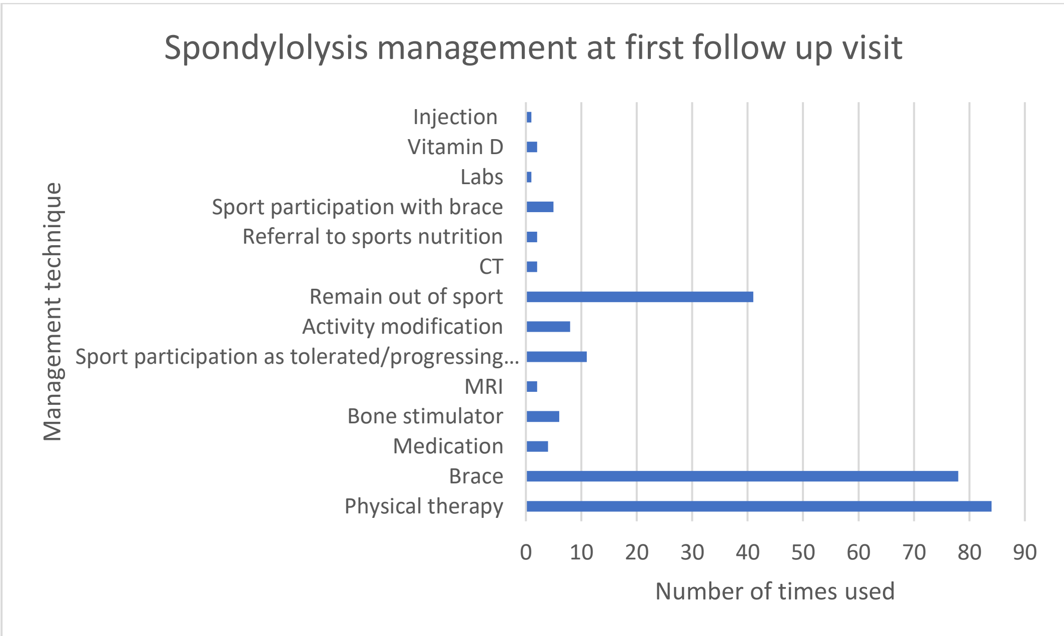


**Figure 3-10:** Spondylolysis management at the first follow-up visit.

3.3.6 Reasons for MRI referral

There were 265 lumbar MRI referrals evaluating LBP in 400 adolescent athletes over all visits. Of these, 233 were conducted and had follow up. The most reported reason for MRI referral was clinical suspicion of spondylolysis (n-151), followed by concern for stress fracture/injury (n=40), and disc pathology (n=33).

3.3.7 Clinical concern vs. diagnosis

Of the 233 MRIs conducted during the study dates, 8 were not for diagnostic purposes (i.e., to better visualise a lesion visible on previous imaging) or did not have clearly documented original clinical suspicion easily obtainable from the medical chart. With the 225 remaining, we sought information on whether the reason for MRI referral was the same as the ultimate diagnosis, or whether an alternative diagnosis was given after MRI. Of 225 MRIs, 91 (39%) confirmed the clinical suspicion. 134 MRIs (58%) had an alternative diagnosis.

3.3.8 Recurrence rate

Of 363 participants with follow up, 46 (13%) experienced a clearly documented recurrence of LBP (new onset) within the study timeframe. There were 38 recurrences of LBP in participants with spondylolysis as their first diagnosis. There were 20 recurrences of spondylolysis, and 18 were other types of LBP. There were 6 participants with spondylolysis as their initial diagnosis who had two recurrences of LBP during the five-year time frame. The average time to recurrence of spondylolysis was two years, ranging from one month to three years.

## 3.4 Discussion

Non-specific LBP and the specific diagnosis of spondylolysis were commonly reported diagnoses in this adolescent athlete cohort. There were significant differences in diagnoses for females compared to males. There was a significant difference when comparing team sports to non-team sports, but no other associations were noted between the type of diagnosis and sports group, BMI group, or age group. Imaging use, specifically MRI, was high in this population.

### 3.4.1 Characteristics of participants

Many of the characteristics of this adolescent athlete cohort were consistent with known risk factors for LBP in adolescents.

Half the participants in this cohort were in the middle adolescent age range (age 15-17). In the general adolescent population, the prevalence of LBP in adolescence appears to increase with age, and there is some evidence that the prevalence of LBP increases further as adolescents enter middle adolescence[98 285]. Research drawing on data from 28 counties has shown that the six-month prevalence of LBP increases from 27.4% at age 11 to 46.7% at age 15[285]. Other research in Denmark demonstrated an age-related increase in LBP of 13.2% from under 14 years to over 15 years old[98].

Two-thirds of this retrospective cohort were female. Evidence in the general adolescent population indicates that female sex is linked to an increased prevalence of LBP[93 94 140 285], although some research has found no difference in the rate of LBP by sex[95 96]. In this cohort, there was a significant difference in sex among LBP diagnoses. There was a higher proportion of females in the facet joint irritation/pain/dysfunction diagnostic group and SI joint irritation/pain/dysfunction/sacroiliitis diagnostic group compared to the spondylolysis or spondylolisthesis group. Research suggests that there may be a higher incidence of spondylolysis in males[121 286], which is consistent with this finding. Spondylolysis, however, was still the second most reported diagnostic group in this majority-female cohort.

In this cohort, 75% of adolescent athletes were in the healthy weight category. This contradicts evidence in the general adolescent population which suggests that there may be a relationship between higher BMI and LBP[97]. It is possible that the apparent relationship between BMI and LBP may differ when comparing athletic adolescents to the general adolescent population.

There were almost twice as many single-sport athletes compared to multi-sport athletes in this study. There is increasing emphasis on sport specialisation in young athletes, which involves an athlete focusing exclusively on one sport, often year-round[287 288]. Sport specialisation can result in a higher rate of injury in young athletes, which may suggest that more emphasis should be placed on diversifying an adolescent athlete's training[289]. Since many of the adolescent athletes in this cohort are already focusing on one sport, however, it may be more beneficial to implement injury prevention and reduction programmes tailored to the risks of specialization in each sport.

### 3.4.2 Diagnoses among adolescent athletes

Non-specific LBP (NSLBP) was the largest diagnostic group among adolescent athletes (34%). In the adult population, up to 90% of LBP is non-specific[290], and it is unclear if this is the same in adolescents. LBP also appears to be mostly non-specific in the adolescent age group[135 136], although some research indicates that, compared to adults, adolescents are more likely to have a specific pathoanatomical cause of LBP[268]. The most commonly reported specific diagnosis in this cohort was spondylolysis. This is in line with previous research indicating that there is a high rate of spondylolysis in the adolescent age group, specifically in adolescent athletes[120 121 124].

It appears that imaging is used differently for adult and adolescent LBP, which could influence this difference in rate of NS-LBP. Guidelines for adult LBP recommend imaging only in cases with severe neurological deficits or when serious underlying conditions are suspected, and should only evaluate those with persistent LBP with MRI or CT if the person with LBP would be a candidate for surgery or a steroid injection[291]. In contrast, there is no accepted consensus for the imaging of spondylolysis in adolescent athletes[28]. In addition to the lack of imaging guidelines for adolescent athletes, LBP may not correlate with imaging findings, even in adults. Spinal changes on imaging may be asymptomatic findings in adults and are not necessarily associated with pain[257-260].

3.4.3 Magnetic Resonance Imaging utility in adolescent athletes

In this study, less than half of the MRIs had findings that matched the documented clinical suspicion. As previously mentioned, this fits with existing findings that suggest that LBP may not correlate with imaging findings, and that spinal changes on imaging may be asymptomatic findings[257-260]. It is possible that the higher use of imaging in adolescent athletes may give way to a higher apparent rate of spondylolysis. The use of diagnostic imaging in adolescent athlete LBP must be carefully examined for utility, to potentially reduce negative outcomes in this population. Potential negative outcomes of increased imaging in adolescent athletes could include the overmedicalisation of conditions such as spondylolysis, as well as the potential for unnecessary differences in treatment approaches. Although LBP management guidelines are largely based on recommendations for adults, they do not recommend routine imaging unless in the case of suspected serious pathology[292].

3.4.4 Management of adolescent athletes with low back pain

There are currently no management guidelines or recommendations that are specific for adolescent athletes. The absence of treatment guidelines specific to adolescent athletes overlooks the differences between adult and adolescent athletes which may warrant alternative management strategies. For instance, while routine imaging is not recommended in the general adult population[291], an athletic adolescent population differs significantly from the general adult population, with physiological changes such as the maturing adolescent spine[293]. Even between the general adolescent population and athletic adolescent populations, there are greater stresses placed on this spine in athletes which may warrant different rehabilitation requirements than less active peers.

*3.4.4.1 Physical therapy*

Athletes in this study were often referred to physical therapy. It was one of the most common management methods for spondylolysis. Physical therapy management of LBP can vary widely, and there was little information provided in the reviewed charts on specific physical therapy management plans. There is a standardised physical therapy plan for spondylolysis within the Sports Medicine Division at BCH, but not all patients attended there for physical therapy. There is a paucity of evidence in this area, but exercise, physical conditioning, and manual therapy may be effective in adolescent athlete LBP[79 137]. Physical therapy is also recommended in the IOC consensus statement on pain management in elite athletes[294].

*3.4.4.2 Relative rest*

Some athletes in this study were recommended relative rest (or rest from sport) for periods of time. This was often recommended in the management of spondylolysis in conjunction with the use of a brace. Activity is recommended for adult athletes with LBP[150]. It is unclear from many of the charts reviewed for this study the level of inactivity sustained during relative rest, as many athletes cross-trained or attended physical therapy during this period.

Very low and very high levels of physical activity may increase the risk of LBP in adults. In a recent systematic review of physical activity and LBP in children and adolescents, there was an association between physical activity and LBP in 6 of 9 included studies, with moderate evidence[115]. Similar to the "U-shaped" relationship between physical activity and LBP previously observed in adults[116], the findings of this review supported associations between very high and very low levels of physical activity[115].

*3.4.4.3 Bracing*

The use of external support or bracing was another common method of management in this study, especially for those with spondylolysis. Research has shown that bracing may be effective in combination with other treatments[184 295], however other research has demonstrated effective outcomes achieved without the use of bracing[3]. An initial study on the use of bracing from the 1970s showed that bracing achieved favourable outcomes, although it required the use of a brace for 23 hours per day for 6 months[296]. There was also no control group included in this study which did not use bracing[297]. There have since been studies showing that pain relief and increased function can be achieved without the use of a brace, but with activity modification and physical therapy[298]. A systematic review by Klein et al. also found that there were no long-term benefits to the use of bracing in the management of spondylolysis[123]. This was supported by further work by Selhorst et al. which showed that bracing did not have an effect on long-term outcomes, including recurrence, pain, functional ability, and perceived outcome[299].

There is some evidence that athletes that use a brace can return to pain-free sport faster than those that do not (4-6 weeks)[297]. Although the use of bracing may achieve a slight advantage in time to return to sport, the quality of life of the athlete must also be considered.  For many athletes, the required 23 hours per day may be difficult to comply with[297]. There are also rising costs associated with the use of bracing[298]. In adolescents with adolescent idiopathic scoliosis, the use of bracing has been linked to a decrease in quality of life, with self-image being most affected[45]. The use of bracing to treat adolescent LBP must be carefully considered to allow for the best quality of care while also taking into consideration practical factors and the athlete's quality of life.

3.4.5 Clinical implications

An awareness of the sex-based differences in diagnoses may be useful for clinicians treating LBP in adolescent athletes. There were significantly higher proportions of female adolescent athletes diagnosed with facet joint irritation/pain/dysfunction and SI joint irritation/pain/dysfunction/sacroiliitis than spondylolysis or spondylolisthesis. There were no significant differences in diagnosis when comparing by type of sport, but there were fewer participants in the endurance sport group than in the technical and team sport groups. It may be important to refine methods of diagnosis of LBP in this group, as there was a high rate of diagnostic MRI use. The development of management guidelines specific to LBP in adolescent athletes may assist in the optimal management of this condition.

3.4.6 Limitations

The conclusions drawn from this study are limited by the information recorded in medical charts. The number of sports recorded are based on available information documented in the medical chart, and the primary sport was chosen based on the information in the chart. It is possible that some of the primary sports documented may not have been the primary sport at the time of presentation to the sports medicine clinic. Data was collected retrospectively and not for the purpose of this study; therefore, it could not be standardized. Originally, the inclusion criteria specified a set number of times participating in sport per week, however, this information was not available in most charts, so the level of athletic participation may vary between participants. The setting of this study was a sports medicine clinic- other populations of adolescent athletes may have different characteristics.

It is possible that those presenting to a clinic may have been experiencing pain for a longer time/higher level than other populations. There was also no sport-by-sport comparison possible due to the high number of sports. Conclusions drawn are limited by the sport groupings created for this study. There were differing numbers of participants in each sport grouping, with far fewer in the endurance group (n=24) compared to the technical (n=162) or team sport (n=177) groups.

### 3.4.7 Recommendations for future research

- Development of imaging and management guidelines for the adolescent age group.
- Brace efficacy in spondylolysis management.
- Longitudinal assessments of LBP diagnoses categorised by sex, age, BMI, and sport type.

### 3.8 Conclusion

Non-specific LBP was the largest diagnostic group in adolescent athletes, followed by spondylolysis or spondylolisthesis. There were some associations between female sex and facet-based pain or SI-joint pain compared to spondylolysis or spondylolisthesis. Commonly used management techniques in this cohort were diagnostic MRI, physical therapy, relative rest, and bracing.  Future research should be directed towards the development of management guidelines specific to LBP in adolescent athletes to assist in the optimal management of this condition.

**What was already known?**

- LBP is common in adolescent athletes.
- Spondylolysis appears to be more common in this population than in adults or the general adolescent population.

**What this study adds:**

- Non-specific LBP and spondylolysis/spondylolisthesis were the most common diagnoses in the adolescent athlete cohort.
- There was a significant difference in diagnoses between female and male athletes. There was also a significant difference in diagnoses in team vs. non-team sports.
- Imaging use in this cohort was high, particularly regarding the use of MRI.

**How this study might affect research, practice, or policy:**

- In clinical practice, clinicians should be aware of potential sex-based differences in common LBP diagnoses.
- Further research into the efficacy of diagnostic MRI and brace usage in the management of spondylolysis may be warranted.
- Longitudinal assessments of LBP diagnoses categorised by sex, age, BMI, and sport type may benefit future research in this population.

**Figure 3-11:** Summary of Study II.

# Chapter 4: "Back pain is part of sport … I'm just gonna have to live with it": Exploring the lived experience of sport-related low back pain in adolescent athletes

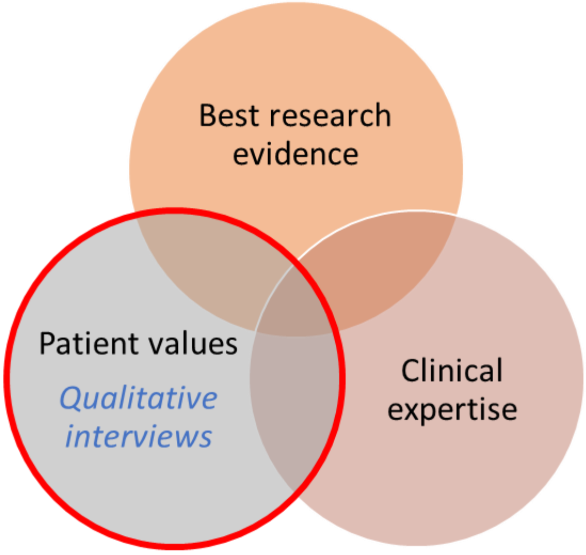


**Figure 4-1:** Sacket model of evidence-based medicine exploring LBP in adolescent athletes.

## 4.1 Introduction

As established in the previous chapters, low back pain (LBP) commonly occurs in adolescent athletes across different sports[266], with the prevalence of LBP in adolescence appearing to increase with age[68 98 99 105 106]. Pain, defined by the International Association for the Study of Pain (IASP) as 'an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage'[52], is a personalised experience, and may be different for each individual because of varying biological, psychological, and social factors[52]. Pain in adolescence can have long-lasting effects, including the occurrence of pain later in life[285].

The large economic and social costs of pain have been explored in adulthood[300], but there has been little research on the lived experience of adolescents (aged 10-19 years old[1]) with LBP. LBP is the leading cause of disability globally. One method of gauging the impact of disability is through years lost to disability (YLD)[301]. 70% of YLD for LBP happen in the working age range (20-65 years)[300]. This can result in direct economic losses such as medical costs, or indirect costs, such as time off work[302]. LBP resulting in disability can also cause social disruption due to work absenteeism and loss of ability to meet social expectations[302].

Previous research into the experiences of adolescents with LBP has focused on physiotherapy management specifically[303]. There has been even less research focus on adolescent athletes, mainly focusing on experiences of adolescents returning to sport following injury[304]. The implications of LBP in adolescent sport are important to investigate, as LBP during adolescence is a risk factor for future LBP[69 80 81].

There are factors specific to adolescence that may affect the experiences of LBP reported by adolescent athletes. The involvement of parents/guardians in medical care is an experience unique to childhood and adolescence and can potentially contribute to an adolescent's pain experience[55]. Parent behaviour and parent anxiety have direct effects on a child's pain and anxiety in medical settings[305]. The influence of peer relationships may also have a greater impact in adolescence, including effects on risk taking behaviour[306-308] and decision making[306 308], as well as positive effects[308], such as increased socialisation, shared experiences, and conflict resolution[309]. Because of this, experiences with teammates may have a greater effect on adolescent athletes. There are also known psychosocial factors which may impact the experience of LBP for adolescents; for instance, an adolescent's beliefs about LBP may affect their experience of LBP. In 17-year-olds, negative LBP beliefs affected their behaviour associated with LBP, including increased care seeking (including seeking medical care and medication usage) and activity modification (including absenteeism and reduced participation in extracurricular activities)[104]. In athletes specifically, there are sport-specific factors which may impact an athlete's experience of pain or injury, such as their status within the team or sport[310]. Pain experienced during sport may be different to pain experienced by the general population, due to a dual meaning of pain in sport (i.e. ‘good pain’ versus ‘bad pain’)[311].

Qualitative research in this area may be able to help ‘bridge the gap’[312] between research and clinical practice in the understanding of LBP in adolescent athletes by considering complex factors that may not be included in quantitative research[312]. It is now recognized that sports injuries and pain in sport are complex, multifactorial issues which require management strategies that may be outside the scope of the traditional biomedical model[313-315]. An injury experienced by an athlete cannot be separated from the context in which the injury occurred[316 317]. A qualitative research approach was therefore chosen to allow for the consideration of contextual factors such as the physical and social environment in sport, and interactions between these factors[314]. The inclusion of the adolescent athlete voice in research may improve clinical outcomes in this population[312].

Furthermore, patient-based evidence is an essential part of healthcare research, forming one of the three main areas of evidence-based medicine, along with clinical expertise and best research evidence[318]. This includes information that patients provide, such as patient narratives and experiences[319]. Although patient-based evidence forms an important part of the evidence-base, there has been little research on the lived experiences of adolescents with LBP. Document the adolescent athlete perspective to allows for the best quality care to be delivered.

### 4.1.1 Aims and objectives

*Aim:* To examine the lived experiences of adolescent athletes reporting an episode of sport-related LBP.

*Objectives:*

- To examine the effects of LBP on the daily lives of adolescent athletes.

- To examine adolescent athlete relationships with parents/guardians, teammates, and coaches with relation to LBP.
- To examine adolescent athlete experiences of treatment/management for LBP.
- To document adolescent athletes' understanding of LBP.

## 4.2 Methods

### 4.2.1 Design and recruitment

A qualitative approach was chosen for this study, which allowed for adolescent athletes' individual experiences of having LBP to be documented. A relativist ontological standpoint was used, as the aim was to detail the various meanings in the dataset[320]. The epistemological standpoint for this study was constructionist, using an experiential qualitative framework, as the study sought to capture and describe lived experiences of LBP[320]. In keeping with this methodological paradigm, the six-phase process of reflexive thematic analysis outlined by Braun and Clarke was chosen for data analysis[320-323]. This study is reported according to the Consolidation Criteria for the Reporting of Qualitative research (COREQ) guidelines[324].

Study recruitment took place in both Dublin, Co. Dublin, Ireland, and Boston, Massachusetts, United States. Ethical approval for this study was obtained from both the Trinity College Dublin Faculty of Health Sciences Research Ethics Committee (Appendix 4-1) and Boston Children's Hospital Institutional Review Board (Appendix 4-2). Participants were recruited via convenience sampling and snowball recruitment through a study poster placed on Twitter (Appendix 4-3). Interested potential participants were given detailed study information (Appendix 4-4). An interview was scheduled after a period of seven days if participants were still interested and willing to participate. A parent/guardian signed the consent form (Appendix 4-5), and the participant signed an assent to participate form (Appendices 4-6 and 4-7). The researcher reviewed this information with the parent/guardian(s) and study participant prior to the interview, and they were given several opportunities to ask questions. Study recruitment took place from August 2020 to February 2022.

Participants were otherwise healthy athletes aged between 10 and 19, who experienced LBP within the year prior to their interview. For this study, the authors defined an athlete by participation and competing in organised sport at least three times per week. LBP was defined as a 'pain, ache or discomfort in the low back with or without referral to the buttocks or legs'[71], with the low back area defined as 'the posterior aspect of the body from the lower margin of the twelfth ribs to the lower gluteal folds'[72].

4.2.2 Procedure

Each participant was scheduled for an individual semi-structured interview via Zoom (Zoom Video Communications, Inc., San Jose, USA) or Microsoft Teams (Microsoft Corporation, Redmond, USA). The interview content was based on a qualitative study of adult rowers' experiences of LBP (Table 4-1)[153].

**Interview questions**

| | |
|---|---|
| 1. | **Tell me about your back pain/injury? (Track from your first episode and history of any following episodes, describe the pain, severity, activity limitations, night pain, did it affect school?)** |
| 2. | **Who did you tell first when you had back pain? (How did they react?)** |
| 3. | **Tell me about the treatment you have had? (Was the treatment helpful? Is there any treatment ongoing? What kind of stretches or exercises?)** |
| 4. | **What is causing your back pain (in your words and in what you have been told)?** |
| 5. | **Why do you think [specific group of athletes ex. Rowers, basketball players] get back pain?** |
| 6. | **How do you think [specific group of athletes ex. Rowers, basketball players] can prevent back pain?** |
| 7. | **Do you think your relationship with your coach influenced your experience of back pain? (Did you tell your coach, how did they react, what did they say or do to make you feel that?)** |
| 8. | **Do you think your position in the team influenced your experience of back pain (if you were selected or pending selection or a 'valuable' member due to performance history, do you think this is good or bad, do you think there are risks)?** |
| 9. | **Did/do you feel comfortable disclosing the details of your back pain to teammates, coaches and selectors? (Did other teammates have back pain?)** |
| 10. | **What do you think about your sport and back pain? (Is it considered "normal" in the sport?)** |
| 11. | **What do you think your future in the sport is with back pain?** |
| 12. | **Can you summarize your experience of back pain? Is there any advice you would give?** |
| 13. | **Is there anything else you feel you want to add?** |

**Table 4-1:** Interview questions for semi-structured interviews.

Four young athlete partners were consulted for readability of the interview questions and to ensure patient and public involvement (PPI) in the study design. All four athletes had previously experienced LBP during adolescence but were no longer in the adolescent age range. These young athlete partners were not participants in this study. Interviews were audio and video recorded. The interviews averaged 29-minutes in length and were conducted by one (seven interviews) or two (two interviews) interviewers (JW and FW). A parent/guardian was present for each interview.

Participant recruitment continued for three rounds. Pragmatic considerations for sample size were used rather than the concept of data saturation, as it is not recommended for reflexive thematic analysis[325]. The authors invite the reader to consider the transferability of this dataset to their own context[320].

To collect demographic information and confirm that each participant met eligibility criteria, each participant was sent two questionnaires: The Modified Oswestry Disability Index (Modified ODI) (Appendix 4-8) and the International Physical Activity Questionnaire (IPAQ) (Appendix 4-9).

The IPAQ was used to assess participants' self-reported level of physical activity. The Modified ODI was chosen because it has previously been used to assess LBP in adolescent athletes specifically[85]. It is a valid, reliable, and responsive tool[326] to assess self-reported disability[327]. The IPAQ has demonstrated excellent test-retest reliability[328] and acceptable validity for those aged 18-65[329]. Further questions to elicit detail on training volume were presented as an open text box on Microsoft Forms. Participants were asked to describe a typical week of sports activity at the time of LBP onset (Appendix 4-10). This was added in addition to the IPAQ to gather more granular detail of the level of physical activity at the time of LBP onset.

Field notes were made during and after the interviews (JW). The interviews were transcribed verbatim by one author (JW). Member-checking occurred prior to data analysis, meaning that each participant had an opportunity to make modifications to their interview transcript. No participant chose to modify their interview transcript. Each participant was assigned a study identification number which was used to ensure confidentiality during data analysis. There were no repeat interviews.

4.2.3 Researcher characteristics

Two authors (JW and FW) conducted the interviews. JW was a PhD student at the time of the study, and FW was a PhD supervisor and head of the Physiotherapy department. All researchers involved in interviewing, data analysis, and theme development are female. All researchers have previous experience with qualitative research. All researchers are trained physiotherapists. There was no prior relationship established between researchers and interviewees. The participants were aware of the reasons for research and the interviewers' interests in the research topic. The researcher involved in coding and developing themes (JW) is a trained physiotherapist, and may bring to this research preconceived LBP belief, and knowledge of factors that can influence LBP.

4.2.4 Data analysis

In keeping with the stated ontological and epistemological standpoints, we chose the six-phase process of reflexive thematic analysis outlined by Braun and Clarke for data analysis (Table 4-2)[320-323]. The theoretical flexibility of this method allowed for athlete experiences of LBP to be explored fully, both capturing experiences as described and interrogating them further for underlying meaning. Because of this, there was both a deductive and inductive orientation to the data[320]. We had a deductive orientation to the data since interviews were semi-structured, and the data was analysed within this framework. An inductive approach was also used, as themes beyond the interview questions were coded and developed. The focus of meaning was mainly semantic to allow the adolescent athletes' experiences to be described in their own words, but some latent ideas were explored. This meant that analysis mainly explored the adolescent athletes' meaning as it was explicitly expressed. Fitting with this, our theoretical framework was more essentialist/realist than relativist/constructionist, since the researchers aimed to capture the adolescent athletes' experiences as they were expressed[320].

| Step of the analytic process[320] | Method in this data analysis |
|---|---|
| **1. Dataset familiarisation** | • Reflections on how I as the researcher am situated in relation to the data.<br>• Read of each transcript three times.<br>    o First reading: no notes, immersing self in data.<br>    o Second reading: brief notes on possible analytic ideas. Reflections.<br>    o Third reading: notes on analytic ideas and how transcripts may relate to each other.<br>• Listened to each interview recording twice.<br>    o First listening: no notes, immersing self in data.<br>    o Second listening: brief notes on analytic ideas. |
| **2. Data coding** | • Initial coding by hand – highlighting or writing out quotations and applying a code label.<br>• Coding was then done using NVIVO- 11 initial code labels were used. This expanded to 16 code labels. |
| **3. Initial theme generation** | • Word map developed to show patterns of meaning across the dataset.<br>• Consulted with FW and EM.<br>• Coded data with candidate themes. |
| **4. Theme development and review** | • Assessment and revision of candidate themes.<br>• Discussed new candidate themes with FW and EM.<br>    o Excel spreadsheet of candidate themes and quotations. |
| **5. Theme refining, defining, and naming** | • Wrote a brief description of each theme.<br>• Refined theme names several times to capture the meaning of the data being presented. |
| **6. Writing up** | • Writing up research report.<br>• Several drafts. |

**Table 4-2:** Six-step process for reflexive thematic analysis and how it was applied in this study.

After familiarisation with the data through repeated listening and multiple readings of transcripts, one author (JW) coded all of the interviews, following best practice advice from Braun and Clarke[320], with input from the second and third authors. Data was coded manually in initial rounds (example: Figure 4-4), and NVIVO software was used in later rounds of coding (QSR International, available from qsrinternational.com/nvivo).

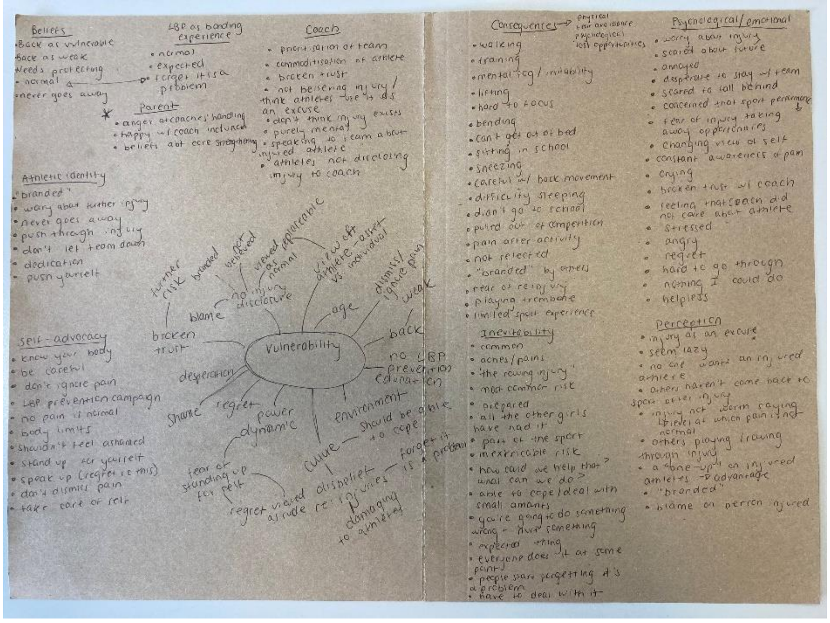


**Figure 4-2**: Word map developed during initial rounds of code generation.

For this study, a theme was defined as 'a shared, multi-faceted meaning, patterned across at least some of a qualitative dataset;' which, 'encapsulates several related analytic insights, unified by a central organising concept or idea; developed initially in thematic analysis by clustering together codes'[320]. From initial coding, 16 codes were developed. Themes and subthemes were developed by JW in consultation with EM and FW. There were several rounds of re-coding as subthemes were developed, considering that thinking evolved several times during the analytic process. An example of a code that evolved throughout the process is available in Appendix 4-11.

The questionnaires were analysed using the scoring system for each measure. Regarding the Modified ODI, 0% to 20% represents minimal disability, 21% to 40% represents moderate disability, and 41% to 60% represents severe disability. For the IPAQ, the number of Metabolic Equivalent (MET)-minutes/week and active days/week are used to categorise participants' physical activity levels as high, moderate, or low.

## 4.3 Results

### 4.3.1 Participant characteristics

We interviewed nine participants for this study (no enrolled participants dropped out). Participant ages ranged from 14 to 19 years (mean age: 16, median age: 16). Three participants self-identified as male, five participants self-identified as female, and one participant preferred not to disclose. The sports that participants were involved in were rowing (n= 6), cycling (n= 1), hurling (n= 1), Gaelic football (n= 1), rugby (n= 1), American football (n= 1), basketball (n= 1), lacrosse (n= 1), and competitive cheer (n= 1). Four participants were multi-sport athletes, and five were single sport athletes.

### 4.3.2 Questionnaire results

Scores on the Modified ODI ranged from 4% to 24%. Eight participants (89%) scored in the minimal self-reported disability category. One participant scored in the moderate self-reported disability category. The pain intensity category was reported to affect participants the most. No participants reported difficulty with sleeping.

On the IPAQ, six participants scored in the high physical activity category, and three participants scored in the moderate physical activity category.

### 4.3.3 Themes identified

Through the thematic analysis process, three themes were developed from the dataset of participant transcripts. These themes (Figure 4-5) demonstrate the ways in which LBP can affect the lives of adolescent athletes. Quotations are verbatim and have been modified with ellipses to remove potentially identifiable information.

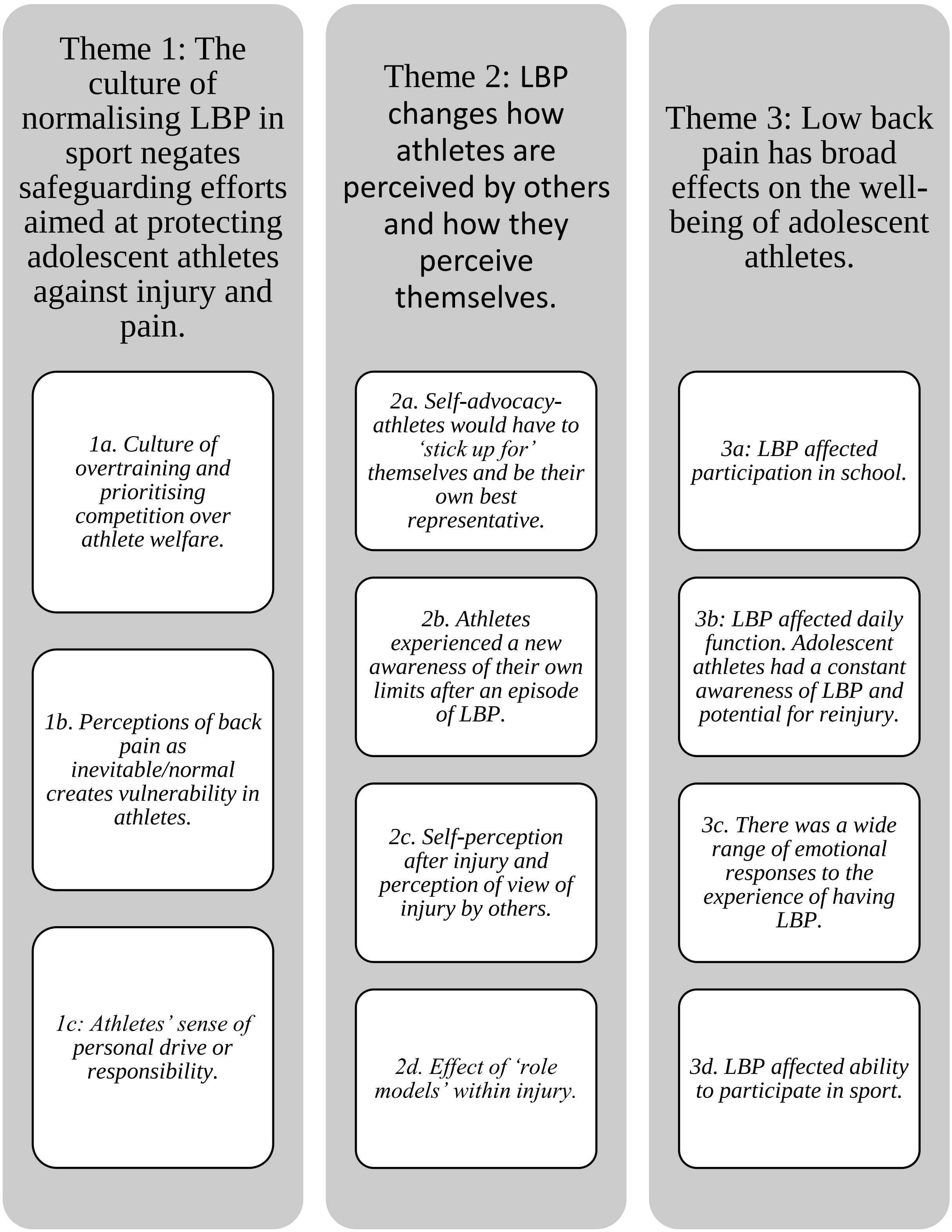


**Figure 4-3:** Themes and subthemes developed through thematic analysis.

Theme 1: The culture of normalising LBP in sport negates safeguarding efforts aimed at protecting adolescent athletes against injury and pain.

Several participants described a culture within their sport in which LBP was considered normal by coaches and other athletes. There are three subthemes within this theme.

*1a. Culture of high training load (described by athletes as overtraining) and prioritising competition over athlete welfare.*

After the development of LBP, some participants were encouraged to continue participating in sport despite pain. Several participants felt that their pain was not taken seriously, leading to a decreased sense of trust between the athlete and their coach. For instance, Participant 3 reflected on the context around the onset of their LBP. They commented that they were prescribed one of the most intense training regimens on the team by the coach:

> *"But to be honest, he probably did overtrain-train me and all my friends said it to me, and he said to me months later that in hindsight, it was probably like a bit much...."* (P3)

Participant 6 described how their LBP was not taken seriously by coaches:

> *"It was kind of bad management, not in a malicious way, but almost just- It's kind of the old lads who used to ... didn't think injury existed, was the thing so."* (P6)

Neither participant appeared to feel that their coach had purposefully contributed to their experience of LBP. However, Participant 6 described a scenario in which they heard what a coach had said about their injury to the team:

> *"And then there was, uh, one particular coach…he was worse for not thinking injury is really a thing. He was talking ... one of the days, I wasn't there, he was saying yeah and (Participant 6)'s thing. It's part-it's partly physical, but probably partly mental as well... I don't know how saying something like that would've transferred onto … people who were also injured at the time."* (P6)

Participant 6 felt that the underlying message about injury could be damaging to the team.

Two participants reported that their coach's reaction to their LBP impacted their trust in their coach. Participant 8 described a situation where they began to cry because they were so frustrated with the way their initial LBP episode was handled:

*"And that was the point I was … crying. And then, the head coach came in and she was like 'why are you crying?' and I'm like, 'My back really hurts. And you guys aren't letting me stop.'" (P8)*

Later, Participant 8 left the sport, in part because of the way the LBP episode was handled by the coaches. Participant 8 felt that trust in the coaches had been broken:

*"… I didn't really trust them, and I was just like, you don't care, like I was just mad … if I went back after I hurt my back, I just wouldn't be able to trust my coaches because I don't know, they would just like react in the same way." (P8)*

*1b. Perceptions of back pain as inevitable/normal creates vulnerability in athletes.*

All participants in this study described LBP as common or normal within their sport. For some, LBP was normalised to the point where it was not seen as a risk:

*"I think it's probably the biggest, most common risk with {sport}. And I think it is something that people should be careful of and maybe more careful of than they are."* (P1)

Some athletes felt that LBP was almost inevitable:

*"I've been told by pretty much everyone that back pain is part of {sport}, um, and that I'm just gonna have to live with it and that everybody gets a little bit of back pain. It's just part of the sport."* (P3)

Because of this 'part of the sport' mentality, some athletes no longer see LBP as a risk. For example, Participant 6 commented:

*"…it can be well managed when it's managed and it can really get bad when people start forgetting it's a problem."* (P6)

When asked whether this view of LBP was okay, Participant 3 felt that whether or not it is okay, there is no way to change the rate of LBP in their sport:

*"I mean, I don't think it's OK, but … if it's part of the sport, how could we help that? ... it is what it is, I suppose … if you get a little back pain, you're able to… sort of cope with it and deal with it. It's OK, but in the long run I guess it's not, especially for … young people. But um, overall, I wouldn't say it is, but … what can we do?"* (P3)

Participant 6 commented that the normalisation of LBP within sport may lead some athletes not to disclose LBP. Because it is seen as normal, some athletes did not feel that it was necessary to tell anyone about it:

*"…also people not really…feeling like injury is something worth saying anything about. It was always a thing where... It was quite-it's quite normal to be somewhat stiff, but no one, no one ever went through with {us} that it's a certain stage of back pain where it's not, not normal."* (P6)

*1c: Athletes' sense of personal drive or responsibility*

In conjunction with the pervading culture of LBP as normal, many of the athletes felt a personal responsibility to participate despite injury so as not to let their team down. Some felt that they could push through for a specific competition:

*"Personally, I know if I felt I was needed, there would always be that push of like, Oh well I can get through the next week of training… And if I go, then suddenly that's not gonna work anymore, like I'll let the team down and so on. ... Maybe the wise thing to do would be to step back or take a break or so on, but you often you can push yourself and end up making it worse. Out of obligation almost."* (P1)

Other athletes also described feeling apprehensive about their teammates' reaction to having to miss out on training and competition due to LBP. For instance:

*"I don't know, it's just … it's kind of a lot once you have the routine because you feel like, you know, people… your friends will get mad at you … so I feel like I was just nervous what… my teammates were gonna think of me."* (P8)

Other participants had a more internal sense of drive to make a particular team or to continue with their participation in sport. This was more internally located compared to those that were driven by responsibility to the team. For instance:

*"I mean, probably if I was, if I was heart set on getting into this {competition level} and I just really, really wanted to do it, I'd probably go 'Oh yeah, it's nothing. I'll be fine in a while' like I know I shouldn't in my mind, but I'm going if I really, really want to do it, I'm probably not going to try and, uh, possibly impact my chances of getting into the {competition level}."* (P4)

Like Participant 1, Participant 4 described knowing that they probably should not participate while injured but doing it anyway. Participant 6 also pushed through pain to participate in sport. For example:

*"And I was so desperate to stay with the {team} that I did it, and even though it kind of made me uncomfortable ... I think I just ignored the pain all the way through the next six months, 'cause I was just like I don't... I'm not putting it under pressure it's but it's still getting moved around quite often. So, I dealt with it, I think."* (P6)

Theme 2: LBP changes how athletes are perceived by others and how they perceive themselves.

Several athletes described a changed sense of athletic identity following an episode of LBP.

*2a: Self-advocacy- athletes would have to 'stick up for' themselves and be their own best representative.*

Following an episode of LBP, many athletes spoke of implementing prevention measures. Participant 6 described a 'campaign' that they underwent within their own sports club, including putting up copies of their own exercise programme:

> *"People were doing them {the exercises} 'cause they were afraid they'd end up in the same position and I kind of went on my own little campaign like guys, can you please look after your backs? There's no point three of us being like this, let alone just me. So, they were very open to doing that…they kind of knew what was going on."* (P6)

Similarly, when asked what advice might be given to others about LBP, Participant 8 spoke about self-advocating when injured or in pain:

> *"…if you notice that … your back is starting to hurt, even if it's … a little maybe just …tell your coaches and if they don't let you {stop} just be like no, like kind of … stand up for yourself."* (P8)

Further, Participant 8 regretted the way their first episode of LBP was handled. In hindsight, they said:

> *"…it's really hard to go through back pain and …I just …regret not … speaking up as much, I mean I definitely did, but I just wish I … took care of myself more. …. you just need to be … more … cautious I guess, if you ever feel pain and it's just … a really hard thing to go through."* (P8)

*2b. Athletes experienced a new awareness of their own limits after an episode of LBP.*

In addition to learning the importance of speaking up for themselves after an episode of LBP, the athletes had an increased awareness of their own limits. When asked about the advice about LBP they would give to others, Participant 3 spoke about knowing their own limits:

*"just knowing your body, … it definitely took me a while to know my body and know when I need to stop and just having those little … cue points for yourself, … knowing your limits and just looking after yourself, definitely. Like not overdoing it, … know when you need to stop."* (P3)

Participant 7 had a similar experience, speaking about knowing their own body's limits and their own relationship to having an injury:

*"It made me more aware of my body and the limits that I can push my body to, and what I can't push my body to. Um, it made me realise that… I shouldn't feel ashamed of having an injury and that it wasn't, I was very much blaming myself for getting that injury and that it wasn't, it wasn't, obviously it- I had to stop saying it was my fault, I- and just focus on the recovery process."* (P7)

*2c. Self-perception after injury and perception of view of injury by others*

Many of the athletes that participated in this study described the way they perceived themselves after the development of pain. For some, their self-perception had changed and remained changed for some time after injury:

*"I think you brand yourself constantly. I think once you've gotten injured once with back pain, you're constantly aware of it, like I'm constantly aware of it now, um, even though it has been more than six months since I have felt it in that particular area."* (P7)

This included pre-emptively acting in ways to conceal their pain for fear of how they would be perceived:

*"I didn't, I just didn't want to seem like I was … being lazy or I didn't want to just miss out over- miss out on the training or anything like that. So normally if I did feel a bit of back pain, it would take me a while to say it, or I wouldn't say it at all."* (P3)

The athletes' view of how their injury would be perceived by others also influenced how they felt about their own injury:

*"Well, I I- see, I never told the others about my injury ever because I knew that…. no one wants to admit it, but when you find out that another athlete is injured, it's kind of a one up. Oh, you know they're injured, I can take their spot, so you don't want to give that, uh, advantage away."* (P7)

*2d. Effect of 'role models' within injury*

In addition to perceiving how others might view their own injury, the adolescent athletes in this study also discussed how viewing others who had been injured impacted them. For some, coaches' reactions to previous teammates' injuries affected disclosure of their own LBP. Participant 3 mentioned awareness that injury might be viewed as an 'excuse':

*"…coaches sometimes … they would be- people can use injury as an excuse not to train and I always-I never wanted a coach to think that about me."* (P3)

For some adolescent athletes, previous experiences with injured teammates created a negative view of injury:

*"I mean, we've never had a coach say don't tell us if you're injured, in that way. But it's kind of in the way that anytime we would see someone get injured and you know, be out for a while, we'd see it not turn out so well for them because they'd be out of training for two weeks, and they wouldn't be in the running for a {competition} that would be a week later, so I don't know."* (P6)

*"I think I've seen people who have gotten injuries and just the frustration of the slow rehabilitation has led them to either… slowly kind of wither away and then and then disappear from the sport…"* (P7)

For others, however, previous experience with an injured team-mate created a positive view of injury and recovery potential:

*"...or I have seen … that-that girl, she had an amazing recovery, um, I just saw her stretching constantly… she was constantly on the bike doing different things to stay fit and active and then eventually she was able to get {back to the sport} again. So, I think it's really how you, how you approach the injury.'* (P7)

*"'cause there's been a lot of {teammates} who've had back pain recently, and kinda, she's been the one to tell us … to step back a bit and just focus on getting better before we overwork ourselves, and she's been a good influence on it."* (P5)

Theme 3: LBP has broad effects on the well-being of adolescent athletes.

Participants described effects that LBP had on them in sport, as well as on other aspects of their lives.

*3a: LBP affected participation in school*

There were several ways that LBP affected adolescent athletes' time at school. Some described a loss of concentration at school due to the pain they were experiencing:

> *"I've had to take days off school, so just from…Not being able to … fully…Um… almost like a kind of fog, or … irritability and so on that comes on from just being in a lot of pain sometimes."* (P1)

For others, the LBP they experienced was so severe that they were unable to go to school at all:

> *"Yeah, so the following … three days after that I didn't go to school."* (P4)

*3b: LBP affected daily function. Adolescent athletes had a constant awareness of LBP and potential for reinjury.*

Many of the adolescent athletes in this study described how having LBP affected their ability to move 'normally'. Several participants described differences in the way they would bend down to pick something up:

> *"But then sometimes if I was like reaching over to get something, like when my injury was at its … worst, I guess if I went to reach over for something I couldn't just … do it, I'd have to … be careful about doing it."* (P2)

For some participants, LBP affected everyday function. Participant 3 described a scenario where LBP affected the ability to sit:

*"So, for… a week and a half. I probably spent a lot of time on my floor, … I'd eat my dinner on the floor … lying down on my stomach doing my homework just because it was … an easier position for me. And then, just … sitting… Yeah, like sneezing and stuff {laughs} which is strange… yeah, I guess I always sort of was … cautious with doing different things so I was like oh, will this affect my back."* (P3)

Similarly, other participants felt that they still limited their activities because of having had LBP, although they were no longer experiencing LBP:

*"I limit… my activities if I feel like I'm gonna hurt my back."* (P8)

*"...obviously when you're injured you-you've a fear of... of increasing that injury and you also have a fear, even now, you know, a fear at the back of my head, 'Oh my God, what if this comes back.'"*"(P7)

The 'fear' of re-injury described by Participant 7 was common across many of the participants. There was a strong emotional component to the experience of LBP described by adolescent athletes.

*3c: There was a wide range of emotional responses to the experience of having LBP.*

At the time of first experiencing LBP, Participant 8 felt that their coaches did not take their LBP seriously. Despite the reports of LBP, the coaches asked Participant 8 to continue to participate in practice. Participant 8 felt that the success of the team was prioritised over them as an individual:

*"I was really angry, upset, I was stressed I was just … it just didn't make any sense to me…. they would act like they care but they just care about … winning and …their team, they don't really care about, … me as a person, or … anyone as a person I feel like. That's how it came off, at least."* (P8)

Participant 7 also described their emotional state at the time of first experiencing LBP, not knowing what the best course of action was:

*"I was quite concerned. I was concerned that…even though I was {participating in sport} through the injury and everything, I still wasn't {participating in sport} to my best without the injury …I was thinking, you know, is there any point in me {participating in sport} through this? Should I have stopped and just let it, um, let it heal itself or… should I've kept- should I have still kept {participating in sport} through it even though my performance wouldn't have been as good?"* (P7)

Participant 7 also felt strong emotion when experiencing LBP for the first time, saying:

*"...it kind of just made me feel like there was nothing really I could do."* (P9)

Similar to the fear of future reinjury previously described by Participant 7, Participant 3 said regarding their future in sport with LBP:

*"Honestly, it kind of scares me a bit 'cause I don't know what's going to happen."* (P3)

*3d: LBP affected ability to participate in sport*

LBP also had an impact on adolescent athletes' ability to participate in sport. For some, this meant missing a few training sessions. Others were unable to compete or described missed opportunities due to LBP:

*"I stopped training obviously and I said I've done something to my back, I need to stop. And the next week there was actually supposed to be…we were entered into a really high performance…competition. I pulled out of it because of it."* (P6)

For Participant 6, missing out on training and participating with teammates was worse than experiencing LBP itself:

*"So again, the pain didn't make things very hard, I think it was more everything that not being training did to me was the hardest part wasn't so much the actual pain itself."* (P6)

Similarly, Participant 9 had a reduced experience participating in sport because of LBP:

*"...it was completely limiting like my, my whole ability to play the sport or experience it."* (P9)

## 4.4 Discussion

In this study of adolescent athlete experiences of LBP, three main themes were developed: 1) The culture of normalising LBP in sport negates safeguarding efforts aimed at protecting adolescent athletes against injury and pain, 2) LBP changes how athletes are perceived by others and how they perceive themselves, and 3) LBP has broad effects on the well-being of adolescent athletes.

### 4.4.1 Approach to pain and injury within sport

Adolescent athletes in this study almost universally described a culture in sport where LBP was considered to be normal. Some participants reported feeling that because it is so normalised, athletes and coaches sometimes 'forgot' that LBP can be a problem for the athlete. In keeping with this, psychological and sociological research in sport supports a model in which an athlete's sports network (sportsnet)[330] or social group in sport can have a significant effect on an athlete's view of pain[331]**.** In a study of injured National Collegiate Athletic Association athletes, social support was consistently important throughout all stages of rehabilitation[332]. Participants in this study also reported discussing LBP with teammates on a routine basis, creating a sense of camaraderie around the shared experience of pain. In adolescents specifically, peer influence can have a greater impact on decision making, and adolescents may not yet understand the long-term implications of decisions they make[311]. In a setting where LBP is considered to be normal by peers, this could impact the athlete by encouraging the non-reporting of their pain.

While a robust social network can have positive effects on injured athletes, such as increased adherence to rehabilitation[333], an athlete's social network can also be a source of pressure[334] or constraint[311 335].

4.4.2 Coach-athlete relationship

The coach-athlete relationship is an important relationship within sport. Athletes are trained to have an athletic dependence on their coach and other members of their athletic team from a young age[336]. In young athletes, qualities attributed to the coach-athlete relationship can predict an adolescent's positive developmental experiences in sport, such as social and cognitive skills and goal setting[337 338]. Coaches who are attentive to athletes' needs are more likely to have a team with a better sense of psychological safety in the team, and better relationships[337].

It is possible that the coach-athlete relationship and sense of psychological safety could impact whether an athlete reports an episode of LBP. Coaches were reported as a source of external pressure to not report concussion according to a systematic review of concussion reporting in high school and college-aged athletes[334]. Furthermore, this pressure from coaches may be viewed by athletes as acceptable. In a study of athletes' perceptions of their human rights within sport, over half of the athletes surveyed agreed or were neutral in response to the statement '…it is sometimes ok for coaches to pressure me in any way.'.[339]

In this study, several participants discussed the perceived feelings of their coaches towards pain or injury. One participant described a situation in which the coach discussed their LBP with the team when she was not present. She expressed concern about how this would affect the team in relation to injuries of their own. An athlete's perception of how a coach may respond to pain or injury is important. The effects of perceived social support may be more influential than received social support on health outcomes[340 341].

Some of the athletes in this study discussed a sense of trust in their coach. For a few athletes, the trust in their coach was broken following the experience of LBP. One participant described a pattern of trusting their coaches followed by injury. This absolute trust in coaches' perceptions is common among young athletes. Young athletes often ‘transfer the control of their individual well-being onto the coach’, trusting that the coach will know when the athlete’s pain or training loads are too great[312 342]. However, research in young gymnasts has shown varying levels of knowledge around training load monitoring in coaches[31]. Coaches may also underestimate the willingness of an athlete to play through injury and conceal pain from the coach[31]. Some adolescent athletes in this study did not disclose injury or pain to their teammates or coaches. This is similar to what has been observed in adult rowers[153], where a culture of concealment was noted.

4.4.3 Athletic identity

In this study, some athletes exhibited a personal drive to continue to participate in sport despite injury. Some of these athletes wanted to fulfil personal goals, and others did not want to let teammates down. This is in keeping with other findings regarding athletic identity, which can form early in an athlete’s sport involvement[343]. In recreational basketball players, those with a higher sense of athletic identity expressed more positive attitudes towards playing through pain[344]. In a systematic review on concussion reporting, not wanting to let the team down and a strong sense of athletic identity were both linked to concussion non-reporting, although the sense of athletic identity was a less common reason[334]. Research in adolescent gymnasts has found that young gymnasts displayed an internal drive to continue to play in pain[345]. The external factors with the most influence on adolescent gymnasts included teammates and the media, similar to the adolescents in this study who did not want to let teammates down[345]. One participant described a feeling of being ‘branded’ by herself and others following an experience with LBP. This has been observed elsewhere, where athletes who have been injured take on an ‘injured role’[346], which is viewed more negatively within sports[347].

4.4.4 Self-efficacy, advocacy, and athlete well being

Several athletes in this study discussed a new sense of self-advocacy or knowing what is best for themselves after experiencing LBP. They discussed a new awareness of the limits of the body, and 'cue points' to know when they may be overtraining. This is in keeping with qualitative research on Olympic athletes, who reported a 'learning by doing' approach to injury prevention, where athletes learned from previous injury[348]. There has been reported behavioural change following injury[349], which is consistent with the findings of this study in which adolescent athletes had a new awareness of their limits after experiencing LBP. Furthermore, research into sports injury-related growth supports a model in which athletes recovering from injury are able to view injury as an opportunity for growth and development[350].

In contrast to these positive outcomes, many adolescent athletes in this study reported that LBP affected their participation in sport, as well as on other aspects of their lives including school, sleep, everyday function, and emotional well-being. There was a wide range of emotional responses that the athletes had to LBP, including anger, stress, fear, and helplessness. Research into the qualitative experiences of injured dancers shows that adult dancers similarly experience similar negative emotional consequences of pain of injury [351]. In a UK survey of athletes aged 15-18 years, 75% of participants reported experiencing emotional harm during sport[352].

Although LBP took a large emotional toll on the adolescent athletes in this study, some participants took action to address the impact that LBP had on them by advocating for themselves and others. Several participants in this study described efforts by themselves or by other previously injured teammates to implement exercise programmes or instil awareness about injury and pain in sport. It may be important to increase education and awareness about injury reporting to allow adolescent athletes to have a safe space to discuss pain and injury. Research has shown that young athletes (aged 15-18 years) have a low awareness of safe sport, and were not aware of where to report abuse allegations[352]. Similarly, in a study of adult athletes' knowledge of their rights within sport, almost 20% of respondents disagreed or were neutral in response to the statement '(When I am training and competing in my sport) if I experience behaviour that I deem inappropriate, I can seek assistance without fear of consequences or retaliation.'[339]. Women were less likely than men to believe that they could 'freely seek assistance without fear of consequences or retaliation.'[339]. This low knowledge of safe sport and rights within sport may be present in athletes from a young age, so it should be addressed early in their sporting career. Some athletes in this study also described not knowing the difference between 'normal' pain in sport and abnormal pain. Education and training for both coaches and athletes on the difference between good and bad pain in sports is needed. This will allow for increased self-management of injury risk from a young age.

4.4.5 Safeguarding adolescent athletes

Safeguarding in sport has been a major theme in recent policy making in sport. More recently, the idea of safeguarding in sport has changed and expanded to include all forms of violence in sport[353 354]. This includes non-intentional organisational violence[355]. In an updated International Olympic Committee (IOC) consensus statement, safeguarding in sport now includes safeguarding against systems that promote overtraining or competing with injury[354 356]. The athletes involved in this study spoke about a culture within sport of normalising LBP, which may have contributed to some athletes participating in sport with injury. Several participants reported playing or participating in sport through pain, as well as concealing or choosing not to disclose pain to a coach. Playing with pain or injury has been found to be common in sport[346 357]. Research in elite young athletes has found that up to one third of athletes have felt direct pressure to compete with pain or injury[357]. There can also be indirect pressure, such as the perception that absences due to injury may not be legitimate[358]. Alhough all athletes have a right to 'engage in safe sport', research has shown that athletes have an incomplete knowledge of their rights within a sporting context[359]. The socialisation and normalisation of LBP observed in adolescent sport in this study negates the efforts of safeguarding policy, as it creates an environment in which young athletes participate in sport despite pain.

4.4.6 Clinical implications and recommendations for future research

*Recommendations for coaches:*

- Create a safe space for pain and injury reporting.
- Provide education of 'normal' vs. abnormal thresholds of pain.
- Promote early disclosure of injury and pain for adolescent athletes.

*Recommendations for adolescent athletes:*

- Learn about the differences between normal and not normal levels of pain.
- Education about the impacts of concealing pain and injury.

4.4.7 Limitations

The recruitment settings for this study may have created a bias in those that volunteered for participation in this study. For example, the LBP experience of those that present to a Sports Medicine clinic may not be representative of the average adolescent athlete LBP experience. There were more participants involved in rowing in this study than other sports, which may impact the LBP experience. Participant reporting in this study could have been impacted by the necessary presence of parents/guardians during interviews.

## 4.6 Conclusion

The lived experience of LBP for adolescent athletes is impacted by a culture of tolerance of pain and injury in sport. Further steps should be taken to implement safeguarding measures in a way that adequately protects adolescent athletes who experience pain.

**What was already known?**

- LBP is common in adolescent athletes.
- LBP is the leading cause of disability worldwide and has large social and economic costs for adults.

**What this study adds:**

- For adolescent athletes, the LBP experience is impacted by a culture of tolerance of pain and injury in sport.
- LBP may change how an adolescent athlete perceives themself.
- LBP affects the wellbeing of an adolescent athletes in domains other than sport.

**How this study might affect research, practice, or policy:**

- In clinical practice, clinicians should be aware of the need for education about ‘normal’ vs. abnormal pain for adolescents participating in sport.
- Safeguarding policies in sport may need to expand to include specific implementation of a safe space for injury reporting.

**Figure 4-4:** Summary of Study III.

# Chapter 5: Healthcare professionals' assessment, management, and beliefs about low back pain in adolescent athletes

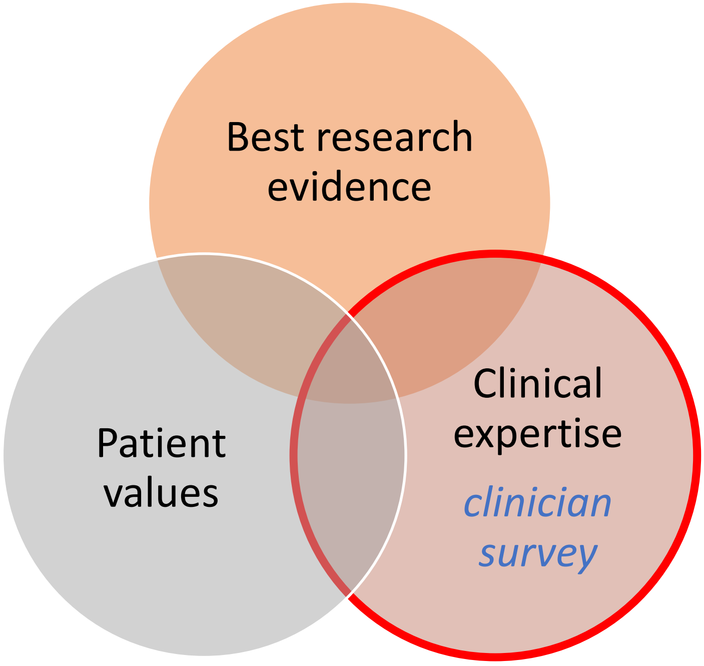


**Figure 5-1:** Sackett model of evidence-based medicine

## 5.1 Introduction

In the previous three chapters, we established that low back pain (LBP) is commonly experienced by adolescent athletes, that there are a wide range of associated morphologies, and that LBP can have wide-ranging impacts on an adolescent athlete's life. Despite this, existing LBP management guidelines are largely based on information from studies of LBP in adults[360]. There is less information currently available on treatment for athlete LBP in younger people, with only four randomised controlled trials (RCTs) on management included in a 2014 systematic review of child and adolescent LBP[137]. The absence of treatment guidelines specific to adolescent athletes overlooks the unique differences between adults and adolescents which may warrant alternative management strategies. For instance, for adolescents, the pain experience may be affected by parent/guardians and peers[63]. There are also important biological and physiological differences, including the growing skeleton and the onset of puberty and maturation during adolescence.

Even when published management guidelines exist, they can be of low quality[361], and there is often a disparity between recommendations and clinical practice[360]. For example, recommendations such as encouraging the provision of education, remaining active, and limited use of imaging are often not followed in practice[360]. One of the barriers to implementation of LBP guidelines has historically been low knowledge and misconceptions that clinicians have about the guidelines[360]. It is important to explore the current management practices for LBP in adolescent athletes to establish whether it follow best practice, and to allow for the future implementation of targeted management guidelines. Because of the absence of specific care pathways or guidelines for adolescent LBP, the authors will reference adult LBP guidelines throughout this study.

To assess the current management practices of LBP in adolescents, we designed a two-part survey. The survey tool was adapted from responses given in a Delphi study of clinicians treating adult rowers[362], along with adult LBP recommendations[360]. The first part of this survey assessed current practices for assessment and management of LBP in adolescent athletes. The second part of the survey focused on LBP beliefs of treating healthcare professionals. Beliefs and expectations about pain can shape the experience of pain[363]. Negative back pain beliefs in adults are linked to poorer outcomes in LBP[364], such as increased pain and disability. This is also true in adolescents; in 17-year-olds, negative LBP beliefs affected behaviour associated with LBP, including increased care seeking and activity modification[103].

Patient beliefs about LBP may be affected by LBP beliefs held by the healthcare professionals (HCPs) managing their LBP [365-367]. For instance, patient fear avoidance beliefs are in line with the fear avoidance beliefs of their treating HCP [365]. Even when LBP beliefs among HCPs differ by professional group, the beliefs of patients remain in line with their treating HCPs[367]. It is important to assess the beliefs about LBP held by HCPs to ensure that up-to-date and evidence-based information is conveyed to patients.

### 5.1.1 Aims and objectives

Aim: To explore current management of LBP in adolescent athletes, including the LBP beliefs of clinicians.

Objectives:

- To establish current assessment and management practices of HCPs managing LBP in adolescent athletes
- To establish the back pain beliefs of HCPs managing LBP in adolescent athletes
- To establish whether assessment, management, or beliefs varied based on geographical region or healthcare profession.
- To explore the components of adolescent LBP care that HCPs identify as differing from adult LBP care.

.

## 5.2 Methods

5.2.1 Study design

The design of this survey was a cross-sectional online survey consisting of open and closed end questions. Study recruitment took place from July to September 2022. Two forms of recruitment were used. The survey was disseminated on social media (Twitter; see Appendix 5-1) and via gatekeepers at various Irish healthcare professional organisations (Irish Nurses and Midwives Organisation, Athletic Rehabilitation Therapy Ireland, Irish Society of Physician Associates, Irish Society of Chartered Physiotherapists, Irish College of General Practitioners, and Chiropractic Association of Ireland). The study received ethical approval from the Trinity College Dublin School of Medicine Research Ethics Committee (application no: 20220505) (Appendix 5-2).

5.2.2 Participants

Participants were eligible to take part in this study if they fit the eligibility criteria listed below:

- They were a healthcare professional
- They had self-reported experience managing LBP in adolescent athletes (aged 10-19)
- They had at least one year of clinical experience and 1 year of experience managing LBP in adolescent athletes

Snowball sampling was used to recruit participants, which is a non-probability technique[368]. The goal study size was 40 responses. This is an exploratory study so there were no previous studies on which to base the expected study size.

5.2.3 Variables

Data was collected using a purpose-built survey on Qualtrics (Qualtrics, Provo, UT, https://www.qualtrics.com) (Appendix 5-3). The survey questions were based on a previous Delphi study of clinicians treating adult rowers[362]. Survey questions and response options were based on answers given in the Delphi study[362], best practice guidelines[360] and on clinician experience. To develop the survey, there were five rounds of editing with a team of clinicians experienced in musculoskeletal practice. For this survey, 'initial triage phase' was defined as first contact with a clinician. 'Acute phase' was defined as the first week of an acute episode of LBP. 'Subacute phase' was defined as partial return to sport. 'Rehabilitation phase' was defined as normal return to sport training load.

Part two of the survey was the 20-item version of the Back Pain Attitudes Questionnaire (BackPAQ) (Appendix 5-4)[369]. This version on the BackPAQ has good reliability[370]. It has previously been validated in general public and general practitioner populations and has high correlation with the original 34 item version[371].

### 5.2.4 Data analysis

For Part One of the survey, response options that received over 90% support were considered to have high agreement, and those that received under 15% support had low agreement. These cut-offs were decided using as recent Delphi study as a basis for high and low agreement, with some adaptation[372]. An upper limit of above 90% was agreed upon for high agreement, and a lower limit of below 15% for low agreement.

For open-ended question data analysis, the six-phase process of reflexive thematic analysis outlined by Braun and Clarke was chosen[320-323]. A realist ontological standpoint was used, as the aim was to document the current management techniques for adolescent athlete LBP, which assumes a 'knowable reality…waiting to be discovered'[320]. The epistemological standpoint for this study was realist, using a experiential qualitative framework, as the study sought to capture and describe clinicians' current management methods and experiences with treating adolescent athletes [320]. For this study, there was a deductive orientation to the data since the survey contained set questions, and the data was analysed within this framework[320]. The focus of meaning was entirely semantic. Since survey answers were provided in written form, there was little room for exploration of the meaning behind the data, and data analysis was of the explicitly stated ideas. Fitting with this, our theoretical framework was more essentialist/realist than relativist/constructionist, since the researchers aimed to capture the adolescent athletes' experiences as they were expressed[320].

Part Two of the survey was analysed using the scoring system for the BackPAQ[369 370]. Each item on the 20-item questionnaire is scored using a five-point Likert scale. Participants indicate their level of agreement with each item ('False', 'Possibly false', 'Unsure', 'Possibly true', 'True'). The response 'False' receives one point, and 'True' receives five points. For two items, (numbers 1 and 17), the direction of the scoring is reversed. Higher scores on the BackPAQ indicate unhelpful back pain beliefs.

## 5.3 Results

5.3.1 Characteristics of participants

There were 84 participants that consented to participation in this study. Of these, 80 provided their current profession. There were 69 physiotherapists, four chiropractors, three sports medicine physicians, one sports therapist, one surgeon, one physician assistant, and one emergency physician. Most participating clinicians (62) were currently practicing in Europe, followed by Oceania (7), Asia (2), and North America (2). There were no participants practicing in Africa or South America. Most clinicians currently work in private practice (46). More clinicians did not hold a sport-specific degree (44) than those who did (27), and most clinicians' highest qualification was a master's degree (34) or bachelor's degree (33). Most clinicians had between six and 25 years of clinical experience (50 respondents). Seventy-five participants had more than one year of experience managing LBP in adolescent athletes, and the majority had between one and 15 years of specific LBP experience (48 respondents). Most clinicians treated 5 or less adolescent athletes with LBP per month.

5.3.2 Survey Part One results

*5.3.2.1 Initial triage phase*

There were 64 participants answered the set of questions referring to the initial triage phase. These are summarised in Table 1.

| Question | Low agreement (under 15%) | Moderate agreement (15-89%) | High agreement (over 90%) |
|---|---|---|---|
| What subjective/interview questions guide your management of adolescent athlete low back pain in the initial triage phase? | None. | • Competition hours per month<br>• Goals for treatment<br>• Life stressors<br>• Pain quality and severity<br>• Year in school | • 24-hour pattern of pain<br>• Aggravating and easing factors<br>• History of current LBP episode<br>• Occurrence of pain with activities of daily living<br>• Past history of LBP<br>• Past medical history<br>• Recent changes to sport workload<br>• Red flags<br>• Sleep<br>• Sport type(s)<br>• Training hours per week, per sport<br>• Type/nature of pain |
| What objective/physical examination findings guide your management of adolescent athlete low back pain in the initial triage phase? | None. | • Functional tests<br>• Neurological testing<br>• Pain responses to palpation<br>• Posture/general observation<br>• Quality of movement | • Pain responses to lumbar range of movement/flexibility |
| What (non-pharmacological) treatment/management strategies and/or principles do you use in the initial triage phase of adolescent athlete low back pain? | • Acupuncture<br>• Brace/external support<br>• Surgical consult<br>• Tai chi<br>• Yoga | • Advice to stay active<br>• Avoidance of aggravating activities<br>• Balance exercises<br>• Communication with coach<br>• Consideration of psychological support where necessary<br>• Core specific exercise | • Communication with parent/guardian<br>• Education and reassurance about LBP<br>• Training load management |

| | | | |
|---|---|---|---|
| | | • Goal setting/expectation management<br>• Inclusion of athlete in treatment decision making<br>• Manual therapy<br>• Monitoring pain levels<br>• Pilates<br>• Range of movement/flexibility exercise<br>• Resistance exercise<br>• Rest/unloading | |

**Table 5-1:** Level of agreement for initial triage phase.

When asked to provide any other relevant information about the initial triage phase, participants discussed the following topics:

- Ice/cold therapy (one participant)
- Unload from aggravating activities (one participant)
- Growth spurts (one participant)
- Red flags and neurological signs (three participants)
- Referral to a nutritionist or dietician if needed (one participant)
- Communication with other healthcare providers (three participants)
- Surgical consult if indicated (three participants)
- Patient journey to date (one participant)
- Imaging (one participant)
- Pharmacological management (one participant)

*5.3.2.2 Acute phase*

There were 46 participants who answered the set of questions referring to the acute phase. These are summarised in Table 2.

| **Question** | **Low agreement (under 15%)** | **Moderate agreement (15-89%)** | **High agreement (over 90%)** |
|---|---|---|---|
| What subjective/interview questions guide your management of adolescent athlete low back pain in the acute phase? | None. | • 24-hour pattern of pain<br>• Ability to complete activities of daily living<br>• Athlete confidence in improvement in low back pain and function<br>• Competition hours per month<br>• Goals for treatment<br>• History of current LBP episode<br>• Improvement of symptoms<br>• Level of pain with ADLs<br>• Life stressors<br>• Pain quality and severity<br>• Past history of LBP<br>• Past medical history<br>• Red flags<br>• Response to medication<br>• Responses to rest and activity<br>• Sleep<br>• Sport type(s)<br>• Training hours per week, per sport<br>• Year in school | • Aggravating and easing factors.<br>• Recent changes to sport workload.<br>• Type/nature of pain. |
| What objective/physical examination findings guide your | None. | • Functional tests<br>• Neurological testing | • Quality of movement |

| | | | |
|---|---|---|---|
| management of adolescent athlete low back pain in the acute phase? Please select all that apply. | | • Pain responses to lumbar range of movement/flexibility<br>• Pain responses to palpation<br>• Posture/general observation<br>• Sitting tolerance<br>• Sport-specific ranges of motion | |
| What (non-pharmacological) treatment/management strategies and/or principles do you use in the acute phase of adolescent athlete low back pain? | • Acupuncture<br>• Avoid axial load through the spine<br>• Brace/external support<br>• Surgical consult<br>• Tai chi | • Address/alleviate athlete concerns<br>• Advice to stay active<br>• Avoidance of aggravating activities<br>• Coach/family/friend support<br>• Communication with coach<br>• Consideration of psychological support where necessary<br>• Cross-training<br>• Exercise<br>• Expectation management<br>• Functional exercise rehabilitation programme<br>• Inclusion of athlete in treatment decision making | • Communication with parent/guardian<br>• Education about LBP |

| | | | |
|---|---|---|---|
| | | • Involving athlete in treatment planning<br>• Isometric trunk exercises<br>• Manual therapy<br>• Massage<br>• Mindfulness techniques<br>• Monitoring pain levels<br>• No sport-specific training<br>• Ongoing use of medication<br>• Pilates<br>• Progression towards sport-specific spinal load requirements<br>• Psychology services<br>• Rest/unloading<br>• Sport-specific exercise<br>• Training load management<br>• Yoga | |

**Table 5-2:** Levels of agreement for acute phase.

When asked to provide any other relevant information about the acute phase, participants discussed the following topics:

- Reassurance and education around the timeline for recovery (1 participant)
- High degree of suspicion for stress fractures (1 participant)
- Addressing negative beliefs (1 participant)

#### *5.3.2.3 Subacute phase*

There were 39 participants who answered the set of questions referring to the subacute phase. These are summarised in Table 3.

| **Question** | **Low agreement (under 15%)** | **Moderate agreement (15-89%)** | **High agreement (over 90%)** |
|---|---|---|---|
| What subjective/interview questions guide your management of adolescent athlete low back pain in the subacute phase? | None. | • 24-hour pattern of pain.<br>• Ability to complete activities of daily living.<br>• Aggravating and easing factors.<br>• Athlete confidence in improvement in low back pain and function.<br>• Competition hours per month.<br>• Goals for treatment.<br>• History of current low back pain episode.<br>• Level of athlete's confidence in progress.<br>• Level of morning stiffness or generalised stiffness.<br>• Level of pain during sport.<br>• Level of pain with cross-training modalities.<br>• Life stressors.<br>• Pain quality and severity.<br>• Past history of low back pain.<br>• Past medical history.<br>• Red flags.<br>• Reduction in medication.<br>• Response to medication.<br>• Responses to rest and activity.<br>• Sleep.<br>• Sport type(s). | • Improvement of symptoms.<br>• Recent changes to sport workload. |

| | | | |
|---|---|---|---|
| | | • Training hours per week, per sport.<br>• Type/nature of pain.<br>• Year in school. | |
| What objective/physical examination findings guide your management of adolescent athlete low back pain in the subacute phase? | None. | • Neurological testing.<br>• Pain levels during activities of daily living.<br>• Pain levels during sport.<br>• Pain responses to lumbar range of movement/flexibility.<br>• Pain responses to palpation.<br>• Posture/general observation.<br>• Quality of movement.<br>• Sitting tolerance.<br>• Sport-specific ranges of motion.<br>• Trial return to sport. | • Functional tests. |
| What (non-pharmacological) treatment/management strategies and/or principles do you use in the subacute phase of adolescent athlete low back pain? | • Acupuncture (2 participants)<br>• Avoid axial load through the spine (0 participants)<br>• Brace/external support (1 participants)<br>• No sport-specific training (4 participants)<br>• Surgical consultation (1 participant)<br>• Tai chi (0 participants) | • Coach/friend/family support.<br>• Cross-training.<br>• Functional exercise rehabilitation programme.<br>• Involvement of a strength and conditioning coach.<br>• Involvement of athlete in treatment planning.<br>• Manual therapies. | None. |

| | | | |
|---|---|---|---|
| | | • Massage.<br>• Mindfulness techniques.<br>• Ongoing use of medication.<br>• Pilates.<br>• Progression towards sport-specific spinal load requirements.<br>• Psychology services.<br>• Progression towards sport-specific range of movement.<br>• Return to sport in a gradual re-loading programme.<br>• Return to sport without pain.<br>• Short sport-specific exercise.<br>• Soft tissue treatment.<br>• Technical coaching.<br>• Yoga. | |

**Table 5-3:** Levels of agreement for subacute phase.

When asked to provide any other relevant information about the subacute phase, participants discussed the following topics:

- More emphasis on returning to sport with no pain for adolescents compared to adults (one participant)
- Age-dependent interventions (one participant)

*5.3.2.4 Rehabilitation phase*

There were 33 participants who answered the set of questions referring to the rehabilitation phase. These are summarised in Table 4.

| Question | Low agreement (under 15%) | Moderate agreement (15-89%) | High agreement (over 90%) |
|---|---|---|---|
| What subjective/interview questions guide your management of adolescent athlete low back pain in the rehabilitation phase? | None. | • 24-hour pattern of pain.<br>• Ability to complete activities of daily living.<br>• Aggravating and easing factors.<br>• Athlete confidence in improvement in low back pain and function.<br>• Competition hours per month.<br>• Goals for treatment.<br>• History of current low back pain episode.<br>• Improvement of symptoms.<br>• Level of morning stiffness or generalised stiffness.<br>• Level of pain after sport.<br>• Level of pain during sport.<br>• Level of pain with activities of daily living.<br>• Pain quality and severity.<br>• Past history of low back pain.<br>• Past medical history.<br>• Red flags.<br>• Reduction in medication.<br>• Response to medication. | • Recent changes to sport workload. |

| | | | |
|---|---|---|---|
| | | • Response to rest and activity.<br>• Sleep.<br>• Sport type(s).<br>• Training hours per week, per sport.<br>• Type/nature of pain.<br>• Year in school. | |
| What objective/physical examination findings guide your management of adolescent athlete low back pain in the rehabilitation phase? | None. | • Functional tests<br>• Trial return to sport<br>• Pain levels during sport<br>• Sitting tolerance<br>• Pain response to palpation<br>• Neurological testing | None. |
| What (non-pharmacological) treatment/management strategies and/or principles do you use in the rehabilitation phase of adolescent athlete low back pain? | • No sport- specific training<br>• Massage<br>• Brace/external support<br>• Avoid axial load through the spine<br>• Acupuncture<br>• Yoga<br>• Tai chi<br>• Surgical consultation<br>• Pilates | • Address risk factors with coach and athlete.<br>• Assessment of quality of movement during sport.<br>• Biomechanics.<br>• Coach/family/friend support.<br>• Communication with coach.<br>• Communication with parent/guardian.<br>• Cross-training.<br>• Education and reassurance about low back pain. | • Education and reassurance about low back pain.<br>• Return to sport in a gradual re-loading programme.<br>• Planned programme for full return to training |

| | | | |
|---|---|---|---|
| | | • Functional exercise rehabilitation programme.<br>• Individualised strength and mobility programme.<br>• Involvement of a strength and conditioning coach.<br>• Involvement of athlete in treatment planning.<br>• Manual therapies.<br>• Mindfulness techniques.<br>• Participation in sport with no pain.<br>• Progression toward sport-specific spinal load requirements<br>• Return to sport without pain.<br>• Psychology services.<br>• Pilates.<br>• Self-management by athlete.<br>• Short sport-specific exercise.<br>• Soft tissue treatment.<br>• Technical coaching.<br>• Yoga. | |

**Table 5-4:** Levels of agreement for subacute phase.

When asked to provide any other relevant information about the rehabilitation phase, one participant discussed getting the parent/guardian and coach on the same page as the adolescent athlete and physiotherapist.

*5.3.2.5 Patient-reported outcome measures*

There were 33 participants who provided a response to the question *What patient-reported outcome measures/questionnaires do you use to assess low back pain? (select all that apply).* No questionnaires received over 90% support, but the questionnaire with the highest amount of support was the Visual Analogue Scale (25 participants chose this response). There were nine questionnaires with under 15% support (Figure 5-2).

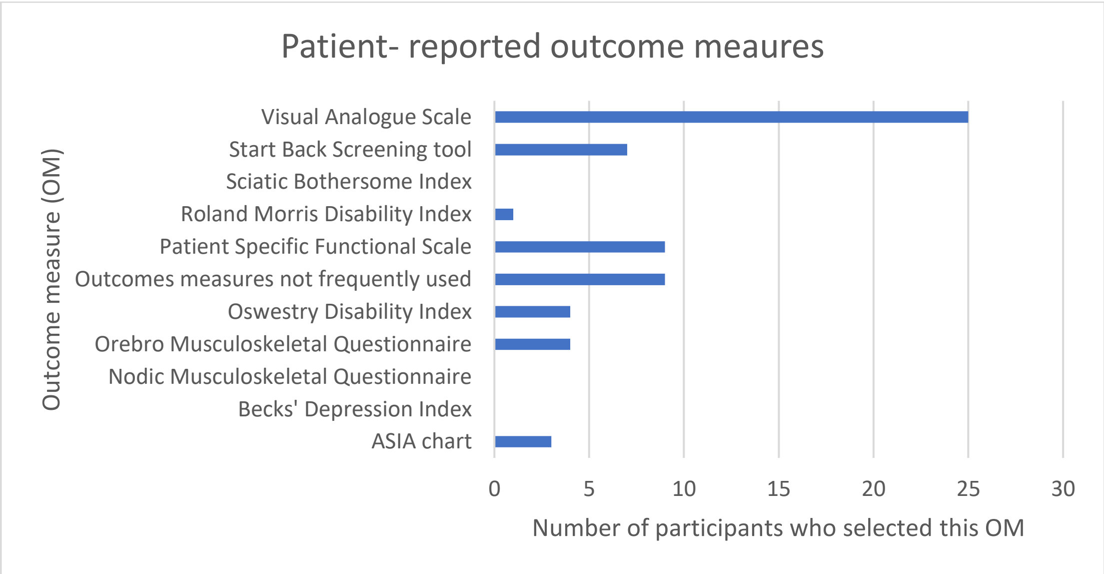


**Figure 5-2:** Number of participants who selected each outcome measure.

*5.3.2.6 Psychosocial factors*

There were 33 participants that provided a response to the question *What yellow flags/psychosocial components of adolescent athlete low back pain do you typically consider throughout all phases? Please select all that apply.*

There was only one response option, anxiety, which received over 90% support. There were no responses which had under 15% support. There was one response added by a participant, which was *parental pressure, personal high expectations and pressure put on oneself.*

*5.3.2.7 Differences between adult and adolescent athletes*

Of 31 respondents, 28 answered *yes* to the question *If you also treat adult athletes, are there any physical differences between adult and adolescent athletes that affect your management of low back pain?* From the answers provided about these differences, several common themes were developed 1) the impact of growth and the adolescent growth spurt 2) an increased awareness of spondylolysis in this age group 3) the possibility of overtraining or high training loads in adolescent athletes. See Table 5-1 for quotations supporting each theme.

| **Theme 1:** the impact of growth and the adolescent growth spurt | |
|---|---|
| *Example Quotation* | *Participant number* |
| "If a patient is still growing then it is important to identify if some of the discomfort can be due to growth patterns." | 3 |
| "Adolescent athletes may be growing, this can change relative flexibility and strength and requires energy." | 6 |
| "Recent growth spurts. Strength deficits as the body adapts to recent growth." | 7 |
| "Rapid growth in height and muscle mass in teens and to a lesser extent primary school children." | 32 |

| **Theme 2:** an increased awareness of spondylolysis in this age group | |
|---|---|
| *Quotation* | *Participant number* |
| "Frequency of spondylolysis in adolescents." | 25 |
| "Higher incidence of bone stress injuries in certain adolescent athlete categories. Lower threshold for investigation of bone stress injuries in adolescents." | 27 |
| "Skeletal maturation. Always aware of potential for pars defect / Spondylolysis in immature skeleton, may image extension based back pain more quickly in adolescents." | 34 |
| **Theme 3:** the possibility of overtraining or high training loads in adolescent athletes. | |
| *Quotation* | *Participant number* |
| "In my experience, a combination of growth spurts and increased sport loading can contribute to trigger an episode of lower back pain." | 29 |
| "Often overtraining if talented in their sport e.g., playing for multiple teams different ages. May compete against children with much higher body weight increases risk of injury in contact sport." | 32 |
| "Adolescent training/ competition hours often excessive as may be involved in number of sports" | 42 |

**Table 5-5:** Quotations to support themes regarding physical differences between adult and adolescent athletes.

Of 28 respondents, 22 answered *yes* to the question *If you also treat adult athletes, are there any psychosocial differences between adult and adolescent athletes that affect your management of low back pain?* From the answers provided about these differences, two themes were developed: 1) decreased adolescent experience and understanding of LBP and 2) external pressure from family and coaches. See Table 5-2 for quotations supporting each theme.

| **Theme 1:** decreased adolescent experience and understanding of LBP | |
|---|---|
| *Quotation* | *Participant number* |
| 'I try to keep my explanations with young athletes as simple as possible, I want to make sure that they understand their back pain and how their body moves. They may not have the maturity to take ownership of their recovery. Getting buy-in from their parents is crucial for me to help them make a full return to sport.' | 1 |
| 'Often adolescents may be experiencing their first episode of low back pain or their very first injury, they need education to alleviate fear' | 6 |
| 'Maturity/experience and their ability to understand their clinical presentation, fear of pain.' | 7 |
| 'Adolescents may have more an external control of the demands of their sport and are not as able to voice their concerns or appreciate when things are going too far for their bodies at a particular time point (less experience with their body, higher demands of the sport and acceptable outcomes).' | 9 |
| **Theme 2:** external pressure from family and coaches. | |
| *Quotation* | *Participant number* |
| 'Pressure from parents and team to resume ASAP' | 25 |
| 'Undue pressure to perform by parent/guardian and/or coach' | 28 |
| 'Adults are generally more autonomous, adolescents come under more coach pressure/ influence' | 42 |

**Table 5-6:** Quotations to support themes regarding psychosocial differences between adult and adolescent athletes.

*5.3.2.8 Pharmacological management*

There were 28 participants that provided an answer to the question *If applicable to your profession, what pharmacological management techniques would be included in the management of adolescent athlete low back pain? (please select all that apply).*

For 17 participants, this question was not applicable. The three response options with the most support were non-steroidal anti-inflammatories (11 participants selected this response), oral paracetamol/acetaminophen (11 participants), and muscle relaxants (4 participants). Topical analgesics (3 participants), steroids (2 participants), narcotics (0 participants), and injection (0 participants) received the least support.

5.3.3 Survey Part Two results

In Part Two of the survey, 30 participants fully completed the BackPAQ. There were 27 physiotherapists, 2 chiropractors, and one sports medicine physician. Scores on the BackPAQ ranged from 20-61. The mean score was 37.6 (SD: 9.6), and the median score was 37. There were four participants with scores above 50 (three physiotherapists and one chiropractor). There were six participants with scores between 20 and 29 (all physiotherapists). One participant (3.33%) had the lowest score possible (20 out of 100).

There were no significant differences in mean scores when compared using one-way analysis of variance (ANOVA) by years of clinical experience (f=.205, p=.892), years of experience managing adolescent athletes with LBP (f=.198, p=.897), number of adolescents with LBP seen per month (f=.460, p=.636), or geographic region (f=0.223, p=.801) (see Tables 5, 6, 7 and 8). Analysis by clinician type was not possible as it was not sufficiently powered. Table 9 shows the percentage of participants who chose True or Possibly True for each question. This table is based on previous reporting of BackPAQ results in a study on bending and lifting beliefs in people with LBP[373].

**Report**

Score

| Years clinical experience | Mean | N | Std. Deviation |
|---|---|---|---|
| 1-5 years | 39.0 | 3 | 6.6 |
| 16-25 years | 38.3 | 12 | 10.4 |
| 25+ years | 38.6 | 7 | 12.2 |
| 6-15 years | 35.3 | 8 | 7.9 |
| Total | 37.6 | 30 | 9.6 |

**ANOVA**

Score

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 61.7 | 3 | 20.6 | .21 | .89 |
| Within Groups | 2609.5 | 26 | 100.4 | | |
| Total | 2671.2 | 29 | | | |

**Table 5-7:** Mean scores (left) and ANOVA results (right) for years of clinical experience.

**Report**

Score

| Years Mx Adolescent LBP | Mean | N | Std. Deviation |
|---|---|---|---|
| 1-5 years | 38.3 | 7 | 4.9 |
| 16-25 | 40.0 | 6 | 8.3 |
| 25+ years | 36.3 | 4 | 16.7 |
| 6-15 years | 36.5 | 13 | 10.3 |
| Total | 37.6 | 30 | 9.6 |

**ANOVA**

Score

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 59.8 | 3 | 19.9 | .19 | .89 |
| Within Groups | 2611.4 | 26 | 100.4 | | |
| Total | 2671.2 | 29 | | | |

**Table 5-8:** Mean scores (left) and ANOVA results (right) for years of experience managing adolescent athlete low back pain.

**Report**

Score

| Geographic region | Mean | N | Std. Deviation |
|---|---|---|---|
| Europe | 37.5 | 23 | 10.7 |
| North America | 44.0 | 1 | . |
| Oceania | 37.0 | 6 | 4.8 |
| Total | 37.6 | 30 | 9.6 |

**ANOVA**

Score

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 43.5 | 2 | 21.7 | .22 | .80 |
| Within Groups | 2627.7 | 27 | 97.3 | | |
| Total | 2671.2 | 29 | | | |

**Table 5-9:** Mean scores (left) and ANOVA results (right) for geographic region.

**Report**

Score

| Number seen per month | Mean | N | Std. Deviation |
|---|---|---|---|
| 11-30 | 34.0 | 1 | . |
| 5 or less | 38.8 | 20 | 10.7 |
| 6-10 | 35.3 | 9 | 7.2 |
| Total | 37.6 | 30 | 9.6 |

**ANOVA**

Score

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between groups | 88.0 | 2 | 44.0 | .46 | .64 |
| Within groups | 2583.2 | 27 | 95.7 | | |
| Total | 2671.2 | 29 | | | |

**Table 5-10:** Mean scores (left) and ANOVA results (right) for number of adolescent athletes seen per month.

| Item | Percentage true** | N (total) | Mean score (1-5) | Mode score (1-5) |
|---|---|---|---|---|
| 1. Bending your back is good for it*. | 90.1%* | 29 (32) * | 1.31* | 1* |
| 2. It is easy to injure your back. | 18.8% | 6 (32) | 2.09 | 1 |
| 3. If you overuse your back, it will wear out. | 12.5% | 4 (32) | 1.56 | 1 |
| 4. If an activity or movement causes back pain, you should avoid it in future. | 6.3% | 2 (32) | 1.59 | 1 |
| 5. You could injure your back if you are not careful. | 34.4% | 11(32) | 2.3 | 1 |
| 6. Back pain means that you have injured your back. | 9.4% | 3 (32) | 1.6 | 1 |
| 7. A twinge in your back can be the first sign of a serious injury. | 9.7% | 3(31) | 1.6 | 1 |
| 8. Having back pain makes it difficult to enjoy life. | 59.4% | 19(32) | 3.1 | 4 |
| 9. It is worse to have pain in your back than your arms or legs. | 6.3% | 2(32) | 1.8 | 1 |
| 10. It is hard to understand what back pain is like if you have never had it yourself. | 62.5% | 20(32) | 3.25 | 4 |
| 11. If your back hurts, you should take it easy until the pain goes away. | 25% | 8 (32) | 2.22 | 1 |
| 12. If you ignore back pain, you may cause damage to your back. | 34.4% | 11 (32) | 2.41 | 4 |
| 13. It is important to see a health professional when you have back pain. | 75.0% | 24 (32) | 3.72 | 4 |
| 14. To effectively treat back pain, you need to know exactly what is wrong. | 21.9% | 7 (32) | 1.97 | 1 |
| 15. If you have back pain, you should avoid exercise. | 0.0% | 0 (32) | 1.13 | 1 |
| 16. When you have back pain the risks of vigorous exercise outweigh the benefits. | 15.6% | 5 (32) | 2.03 | 2 |
| 17. If you have back pain, you should try to stay active*. | 100%* | 32 (32) * | 1.00* | 1* |

| | | | | |
|---|---|---|---|---|
| 18. Once you have had back pain there is always a weakness. | 12.5% | 4 (32) | 1.66 | 1 |
| 19. There is a high chance that an episode of back pain will not resolve. | 6.51% | 2 (31) | 1.34 | 1 |
| 20. Once you have a back problem, there is not a lot you can do about it. | 0.0% | 0 (31) | 1.03 | 1 |

**Table 5-11:** percentage of participants who chose True or Possibly True for each question.

*Indicates reverse direction of scoring.

** ‘True’ refers to selections corresponding to 4 and 5 points on the BackPAQ scoring scale.

## 5.4 Discussion

### 5.4.1 Subjective and objective assessment

Overall, there was low agreement on subjective and objective items included in a LBP assessment. This was true across all phases, except subjective interview questions in the initial triage phase, in which all but four items received high agreement. It is possible that this lack of agreement could be due to variation in LBP conditions[267]. When asked to provide additional information about the initial triage phase, one clinician wrote "This is very variable depending how the patient presents at the time, how severe and irritable the patient is and how close and important the competition is". In LBP guidelines, there are recommendations for diagnostic triage using general history taking and physical examination, but no specific details on items included in subjective or objective examination, fitting with the results of this survey[292]. Similarly, assessment of psychosocial factors is recommended[292], but only one item (anxiety) received over 90% support, showcasing the wide variation in assessment techniques. Overall, subjective and objective examination techniques used across all phases appeared to be dependent on patient presentation.

### 5.4.2 Non-pharmacological management of adolescent athlete LBP

In questions regarding non-pharmacological management, only a few items received over 90% support from the participant group. In the initial triage and acute phases, the focus was on communication and education, as well as training load management in the initial triage phase. This is consistent with management recommendations that consistently advocate for patient education about LBP, reassurance that symptoms will improve, and advice to stay active[292 360]. A recent systematic review of LBP treatment in adult athletes, however, found that reassurance and advice to stay active was not included in the treatment of sport-related LBP[150]. In the subacute phase, there was no agreement over 90% on any non-pharmacological management technique. In the rehabilitation phase, the two items that received over 90% support were about return to training. This is consistent with the athlete LBP recovery focus of this survey but is not included in general LBP guidelines. The same systematic review of LBP management for adult athletes also found that there is little evidence regarding the effect of LBP management on return to sport[150].

In questions regarding non-pharmacological management across all phases, there was consistent low support for the options brace/external support, acupuncture, tai chi, and surgical consultation. The low support for braces/external supports is consistent with existing evidence. Back supports are generally not recommended[360], however this advice is from guidelines aimed at those aged over 16 years old. As discussed in Chapter 3, the role of external bracing in adolescent athletes is controversial. Although the use of bracing may allow for a slightly faster return to sport[297], it appears that there are no long-term effects on functional outcomes (such as recurrence, pain, and functional ability)[123 299].

Acupuncture also consistently received low support from the clinician sample. This is in line with current recommendations, where acupuncture is recommended only as a second line or adjunctive treatment. There is some disagreement in guidelines about passive treatments like acupuncture[292]. Some guidelines do not recommend them, while others may consider them for patients whose LBP does not respond to other treatments[360].

The management option ‘surgical consultation’ received low support across all phases, although many participants stipulated that this is dependent on red flags. This is also consistent with existing management guidelines, in which the role of surgery is limited and not consistent[360].

The low support for tai chi as a management option is also consistent with existing management guidelines. In a 2018 overview of guidelines, all included guidelines recommended exercise therapy, but there was no consistency regarding type of exercise programme[292]. Tai chi was included as a recommendation in some guidelines, but others recommended other types of exercises such as yoga or aquatic exercise[292]. There is a lack of specific recommendations for those that already participate in exercise, such as adolescents participating in sport. A recent systematic review on LBP treatment in adult athletes called for more research on the effect of LBP treatments on athletes specifically [150].

Overall, clinician responses to questions about non-pharmacological management followed existing management guidelines. The low number of items that received over 90% support suggests that adolescent athlete LBP necessitates an individualised management programme based on athlete presentation.

5.4.3 Pharmacological management of adolescent athlete LBP

In management recommendation guidelines from the American College of Physicians, non-pharmacological care is now recommended as the first line of treatment for LBP[374]. This reflects the changing understanding of LBP management, with emphasis on a biopsychosocial management model rather than the traditional biomedical model[360]. The use of medication, however, still sometimes has a place in the management of LBP. There were eleven participants to whom the question about pharmacological management was applicable. Of these, all eleven participants chose both oral paracetamol/acetaminophen and non-steroidal anti-inflammatories (NSAIDs). Both US[374] and UK[375] guidelines now recommend against the use of paracetamol, with the use of NSAIDs recommended instead[374]. There is still controversy about this, as in a 2018 overview of LBP management guidelines, eight of 14 included guidelines recommended paracetamol, while five recommended against its use[292]. The most recent guidelines in this group did not recommend paracetamol[292]. In some LBP guidelines, opioid use is not recommended for LBP[360], although some guidelines recommend the use of weak opioids for short periods of time, if NSAIDs are ineffective[292]. No participants in this survey selected narcotics as an option for pharmacological management.

Research suggests that analgesic use is common in young athletes (aged 15-24)[376]. Approximately one in two youth athletes reported the use of NSAIDs in this study[376], a similar use rate to that of elite/senior athletes[377]. Although guidelines suggest that analgesics should not be used for pain prevention, some youth athletes reported using analgesics to prevent pain to enable participation in sport[376]. It has been suggested that existing evidence is not sufficient to guide clinicians in the use of analgesic management[376 377]. Considering the risks to adolescent athletes that analgesic use can present, clinicians should consider the benefits and risks of analgesic use, along with the reasons for analgesic use in adolescent athletes.

### 5.4.4 Patient-reported outcome measures

In the question regarding the use of patient- reported outcome measures, the Visual Analogue Scale (VAS), received the most support from participants (25 participants). Although the VAS is useful to examine pain levels and is commonly used in LBP assessment/management, it omits other dimensions of LBP that are important to assess, such as function[378]. A clinical practice guideline from the American Physical Therapy Association (APTA) recommends the use of other measures, such as the Roland Morris Disability Questionnaire or the Oswestry Disability Index, to assess LBP[378]. In this survey, there was low support for these measures. Only one participant selected the RMDQ, and four participants selected the ODI as an outcome measure they use to assess LBP.

### 5.4.5 Physical differences between adults and adolescent athletes

There were three themes developed from responses regarding physical differences between adolescent and adult athletes. The impact of growth on adolescent athletes was discussed by several participants. This is an important consideration in adolescents, as adolescents can be at increased risk of injury during a growth spurt[28 33]. Beyond the direct musculoskeletal effects of growth, such as articular surfaces that can withstand lower stress thresholds[28-30], there may also be interactions between growth and increased sport workload because of the timing of the adolescent growth spurt[29]. This also ties in with another theme developed from participant responses: the possibility of overtraining or high training loads in adolescent athletes. Because the adolescent growth spurt can take place at a time when sport workload is increasing, this can lead to increased susceptibility to injury. Maximum growth occurs in the middle years of adolescence (12 years for girls, 14 years old for boys), and continues into older adolescence (16-20 years old)[164]. During development, an adolescent's bone growth outpaces the growth of muscles, leading to decreased flexibility and increased injury risk[293]. These predisposing factors combined with the sport-specific risks such as poor technique or overtraining can lead to injury[293].

A potential reason for high training loads in adolescent athletes is the increasing emphasis on sport specialisation in young athletes[287]. Sport specialisation involves an athlete focusing exclusively on one sport, often year-round[287 288]. Often, athletes choose to specialise as they, their parents, or their coaches aspire to reach elite performance levels. In most sports, specialisation has not been shown to increase elite status, and has many deleterious effects on the athlete, such as increased risk of injury and psychological stress[288].

There was also an increased awareness of spondylolysis in this age group. In previous chapters of this thesis, spondylolysis was identified as the most commonly reported specific diagnosis across 13 studies that reported specific LBP-related diagnoses (Chapter 2)[266], and the most common LBP diagnosis after non-specific LBP in a retrospective review of 400 charts. The pathophysiology of spondylolysis is thought to be a result of repetitive mechanical stress[120]. During adolescence, ossification of the posterior spinal column may be incomplete, leaving the pars interarticularis more susceptible to injury [164]. Adolescent athletes may be at higher risk of developing symptomatic spondylolysis because of this repetitive strain on the immature spine experienced during sport. Thus, spondylolysis may be a modifiable effect of loading during the growth period. Since it is known that spondylolysis is common in adolescents who play sport, it is important to evaluate techniques for assessment and management of this condition, to allow for positive outcomes for adolescent athletes.

5.4.6 Psychosocial differences between adolescent and adult athletes

There were two themes developed from responses about psychosocial differences between adolescent and adult athletes. Many participants discussed the decreased adolescent experience and understanding of LBP. As some participants pointed out, for some adolescent athletes, this may be their first experience of LBP. These clinicians felt that they would spend more time explaining and educating the patient about LBP because of this. As discussed above, education is a first-line recommended treatment for individuals with LBP[292 360]. Research shows that structured patient education can reassure patients, with effects lasting for up to a year[379]. This can, however, vary by type of healthcare practitioner providing education[379] and format of education provided[380]. The information included in patient education may also affect patient outcomes; for instance, interventions focusing on pain biology may reduce catastrophising more effectively than other educational interventions[381 382]. Factors specific to adolescent athletes may be important to include in educational interventions to allow for maximum impact. There has been some research on LBP education for adolescent athletes, with one multi-dimensional intervention study examining the effectiveness of an LBP education session with a physiotherapist for adolescent rowers[383]. Overall, the intervention was found to reduced incidence of LBP[383]. Although this study utilised  group seminar format for LBP education, it is thought that clinicians can provide individually tailored educational interventions to best address an adolescent's LBP[384].

In addition to LBP education for adolescent athletes, the second theme developed was external pressure experienced by adolescent athletes from family and coaches. Participants mentioned pressure to resume sport from parents and team, and another mentioned pressure to perform from parent/guardians or coaches. This is similar to the influence of the coach-athlete relationship discussed in Chapter 4. In previous concussion research, coaches were reported as a source of external pressure to not report concussion[334]. This pressure from coaches may be viewed by athletes as acceptable. In a study of athletes' perceptions of their human rights within sport, over half of the athletes surveyed agreed or were neutral in response to the statement '…it is sometimes ok for coaches to pressure me in any way'[339]. Clinicians in this study recognised the pressures that adolescent athletes are under. It may be important for clinicians to address this directly with adolescent athletes. Discussions with coaches/parents?

5.4.7 Back Pain Beliefs

Overall, participants demonstrated more helpful than unhelpful back pain beliefs. There were three items with mean scores over 3, which indicated more unhelpful beliefs on these items. The three items with high mean scores were 8,10, and 13. The highest mean score was 3.72 on the item *It is important to see a health professional when you have back pain*. 75% of participants answered *True* or *Possibly true* on this item. This belief contrasts with what is known about LBP. Most experiences of acute LBP are self-limiting and will resolve within four to eight weeks[385]. The belief that all LBP necessitates medical care could possibly contribute to overmedicalisation of LBP and increased healthcare costs associated with LBP. It may be especially important to prevent the overmedicalisation of LBP for adolescents, since it may be their first instance of LBP and may set expectations for possible future episodes.

There has been an overall increase in unnecessary LBP care[386], although most people with LBP require little or no formal care and most instances of uncomplicated LBP can be self-managed[386 387]. In some cases, healthcare exposure can actually have harmful consequences[387], such as negative LBP beliefs derived from healthcare professionals[388].

There were two items on which participants had 100% agreement. On item number 17, *If you have back pain you should try to stay active*, 100% of participants answered *True* to item on staying active. Item 17 one of the two items with a reversed scoring direction, and the mean score out of 5 was 1.00. Similarly, 0% of participants answered True for item 15, *If you have back pain you should avoid exercise*, with a mean score of 1.13. As discussed above, advice to stay active is recommended in all existing LBP care guidelines[292 360].

For over half of the BackPAQ items, however, at least one participant responded with the most unhelpful LBP beliefs response choice. There were five items with modes higher than one:

- Having back pain makes it difficult to enjoy life (mode: 4)
- It is hard to understand what back pain is like if you have never had it yourself (mode: 4)
- If you ignore back pain, you may cause damage to your back (mode: 4)
- It is important to see a health professional when you have back pain (mode: 4)
- When you have back pain the risks of vigorous exercise outweigh the benefits (mode: 2)

This suggests that there may need to be ongoing clinician education to dispel myths about LBP. Since healthcare professional LBP beliefs can affect patient LBP beliefs, education for clinicians around LBP beliefs will benefit both clinicians and patients[365].

5.4.8 <u>Clinical implications and future research directions</u>

The development of LBP guidelines specific to adolescent athletes, which consider the unique differences between adults and adolescents will benefit that management of this condition. There should also be ongoing clinician education about LBP beliefs to ensure that the most accurate, up-to-date, and beneficial information is conveyed to patients.

5.4.9 Limitations

There was likely a recruitment bias in this study since it was advertised on social media. Participants may have been more likely to respond if they treat LBP in adolescent athletes and if they already have an interest in this topic. There is also the possibility of selection bias (i.e., people who chose to take the survey may be more experienced for example). This was addressed by asking about experience; however, it could still potentially influence the results of this survey. The novelty of this study meant that the survey design was not validated. Furthermore, because of the pilot nature of this study, the goal sample size could not be confirmed. Lastly, there was under-representation of clinicians other than physiotherapists who responded to this survey.

## 5.6 Conclusion

Current clinician management of LBP in adolescent athletes is generally in line with existing guidance, although no guideline or care pathways specific to adolescent athletes exist. There was low agreement on assessment and management techniques, suggesting that adolescent athlete LBP may necessitate an individualised management programme based on athlete presentation. Clinicians recognised important physical and psychological differences in the management of adults and adolescents presenting with LBP. Clinician beliefs about LBP were largely helpful, although there were still some unhelpful LBP beliefs held by this participant group. Ongoing clinician education regarding LBP is needed.

**What was already known?**

- LBP is common in adolescent athletes, has a wide range of associated morphologies, and has wide-ranging impacts on the lives of adolescent athletes.
- Current LBP management guidelines are based on LBP in adults.
- There is often a disparity between clinical guidance and practice for LBP.
- Patient LBP beliefs can be affected by clinician LBP beliefs.

**What this study adds:**

- Current clinician management of adolescent athlete LBP is generally in line with existing guidance.
- The management of LBP in adolescent athletes may necessitate tailored, individualised management and includes an understanding of the physical and psychosocial differences between adults and adolescents.
- Clinician beliefs about LBP were largely helpful in this cohort.

**How this study might affect research, practice, or policy:**

- In clinical practice, clinicians should be aware of common negative beliefs about LBP and engage in ongoing education regarding LBP beliefs.
- Management of LBP in adolescent athletes would benefit from the development of specific guidelines for adolescent LBP.

**Figure 5-3:** Summary of Study IV.

# Chapter 6: Discussion

## 6.1 Overview

Low back pain is a symptom that can affect people of all ages[267]. It can disrupt an individual's life, either for a short period of time, or for a continued period[103]. Previous LBP can predict future LBP[69 80 81], so it is important to mitigate episodes of LBP early in life to prevent potential future pain later in life. LBP can also impact physical activity and sport participation. In adolescent athletes, this can affect their sense of identity and ability to form positive lifelong habits of exercise and sport. Prior to the work presented in this thesis, there was little information available on LBP in this specific population. The primary aim of this thesis was to characterise LBP in adolescent athletes, to enhance understanding of LBP in this population and potentially improve management strategies. Since each study chapter contained a Discussion section, this chapter serves to summarise key findings of each study (Figure 6-1) and discuss these findings in context.

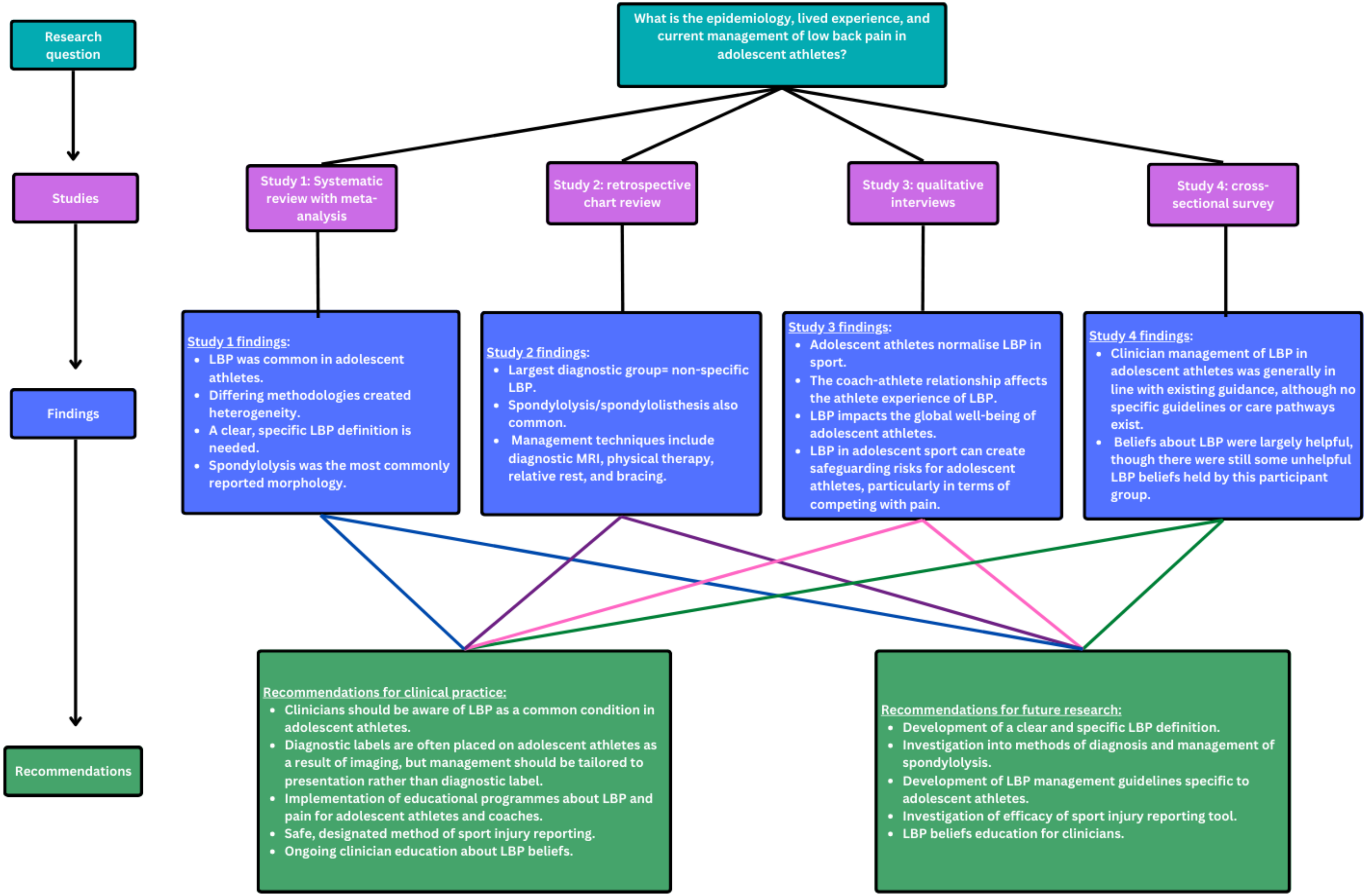


**Figure 6-1:** Thesis summary flowchart.

## 6.2 Overview of studies

The key characteristics of adolescent athlete LBP that were chosen for exploration in this thesis were selected in line with the Sackett model of evidence-based medicine (Figure 6-2)[166]. Study I was designed to address epidemiology, Study II to address clinical presentation and management, Study III to explore lived experience, and Study IV delved further into clinician management and beliefs. In the Sackett model, Study I represents best research evidence, Studies II and IV address clinical expertise, and Study III addresses patient values.


**Figure 6-2:** Sackett model for evidence-based medicine as it was implemented in this thesis.

## 6.3 Analysis of key findings

6.3.1 Study I (presented in Chapter 2) key findings

There were 80 studies included. The pooled incidence estimate of LBP in adolescent athletes was 11% (95% CI 8-13, $I^2$=0%) for two-year[202 242], 36.0% (95% CI 4-68, $I^2$=99.3%) for 12-month[184 185 215 244] and 14% (95% CI 7-22, $I^2$= 76%) for six-month[177 180 182 187]. incidence estimates. The pooled prevalence estimate of LBP in adolescent athletes was 50% for lifetime (95% CI 39-60, $i^2$ 99.5%) [98 173 195 196 204 207-209 211 218 219 222 224 225 227 228 230 237], 42% (95% CI 29-55, $I^2$=96.6%) for the previous 12 months[122 172 178 181 195 222 225 227 228 231 241], 46% (95% CI 41.0-52, $I^2$=56%) for the previous three months[118 205 220 228], and 16% (95% CI 9-23, $I^2$=98.3%) for point prevalence[181 196 200 201 203 210 218 219 222 224-228 230 232-236 245 246]. Potential risk factors were sport participation[118 172 173 225 227 230 240 246], sport volume/intensity[195 201 207 213 219 225 227 231 247], concurrent lower extremity pain[232 235 236], overweight/high BMI[209 218 248], older adolescent age[203 207 221 222], female sex.[98 207 216 218 227 238 246], and family history of LBP[207 221 222 238]. The most common morphology reported was spondylolysis. Methodological quality was deemed high in 73% of cross-sectional studies and in 30% of cohort studies. Common reasons for downgrading at quality assessment were use of non-validated survey instruments and imprecision or absence of LBP definition.

6.3.2 Study II (Presented in Chapter 3) key findings

Non-specific LBP was the largest diagnostic group in adolescent athletes, followed by spondylolysis or spondylolisthesis. There were some associations between female sex and facet-based pain or SI-joint pain compared to spondylolysis or spondylolisthesis. There were twice as many single sport athletes compared to multi-sport athletes, suggesting the possibility that sport specialisation may play a role in adolescent athlete LBP. Commonly used management techniques in this cohort were diagnostic MRI, physical therapy, relative rest, and bracing. There was a high rate of imaging used, although there is no consensus on imaging for spondylolysis in adolescent athletes.

### 6.3.3 Study III (presented in Chapter 4) key findings

Through the reflexive thematic analysis process, three themes were developed from the dataset of participant transcripts. The main themes were 1) The culture of normalising LBP in sport negates safeguarding efforts aimed at protecting adolescent athletes against injury and pain, 2) LBP changes how athletes are perceived and perceive themselves, and 3) Low back pain has broad effects on the well-being of adolescent athletes. Overall, the lived experience of LBP for adolescent athletes showed that the normalisation of LBP in adolescent sport can create safeguarding risks for adolescent athletes, particularly in terms of competing with pain[354]. Coaches and sport organisations should create a space for injury reporting, and adolescent athletes should be educated on differences between 'normal' and non-normal pain.

### 6.3.4 Study IV (presented in Chapter 5) key findings

Current clinician management of LBP in adolescent athletes was generally in line with existing guidance, although no guidelines or care pathways specific to adolescent athletes exist. There was low agreement on assessment and management techniques, suggesting that adolescent athlete LBP may necessitate an individualised management programme based on athlete presentation. Clinicians recognised important physical and psychological differences in the management of adults and adolescents presenting with LBP. Clinician beliefs about LBP were largely helpful, although there were still some beliefs which were not supported by evidence held by this participant group. Ongoing clinician education about LBP would be beneficial to ensure that patients received accurate and current information.

## 6.4 Relationships between findings

The results from Study I provided a basis for the subsequent work completed in this thesis. Because of varying methodologies and LBP definitions, analysis of LBP prevalence by sport type was not possible. In Study II, the aim was to analyse LBP diagnoses by sport type, age, sex, and BMI. There were no associations between diagnoses and sport type. One of the main findings from Study II was a high rate of imaging, especially in spondylolysis. This was also a finding in Study I, with MRI being the most used method of confirming diagnosis. In Study II, MRI was also commonly used to assess for spondylolysis, despite there being no clinical consensus for the use of imaging in spondylolysis. Study III was designed to include the adolescent athlete voice, which had been missing from the thesis in Studies I and II. While Study I found that LBP in adolescent athletes is common, Study III described the effects of this high rate of LBP on adolescent athletes. The normalisation of LBP led to wide reaching effects on the lives of adolescent athletes including and beyond sport. In Study III, it was clear that LBP can change how an athlete perceives themselves. The findings regarding MRI usage in Study I and Study II must be examined carefully, as it is possible that the over-medicalisation of adolescent athlete LBP could contribute to this altered self-perception. Study IV examined the current management techniques of clinicians managing adolescent athlete LBP. Although there are no LBP guidelines or care pathways specifically designed for adolescent athletes, clinician management broadly follows adult LBP guidelines. The highest mean score on any item was 3.72 on '*It is important to see a health professional when you have back pain'*. Although LBP in adolescents warrants assessment, it is possible that the emphasis on health professional involvement in management reinforces the possibility explored in Studies I and II that the management of LBP in adolescent athletes is at risk of over-medicalisation. Similar to some of the findings in Study III regarding the coach-athlete relationship, clinicians in Study IV highlighted important differences in the treatment of adolescent and adult LBP, including the increased influence of parents and coaches on the adolescent's experience.

6.4.1 Strengths and weaknesses

The work from this thesis overall provides a robust basis for future research in this area. The range of quantitative and qualitative research methodologies involved in this work benefitted this research, as it allowed for exploration across four specific areas within LBP research. Further, the international aspect of this thesis, with research conducted in both Ireland and the United States, allowed for a broader application of results from this work, and exploration into different medical systems.

Study I was bolstered by a comprehensive search strategy designed by an expert librarian. As such, it included all current studies on adolescent athlete LBP prevalence and incidence. The high number of included papers allowed for a thorough meta-analysis and meta-regression. In addition to this, Study I was peer-reviewed by experts in the subject area, allowing for confidence in the conclusions from this study. Study I was limited by differing methodologies in included studies and a low number of high-quality studies. Study I contributed a new synthesis of adolescent athlete LBP incidence and prevalence that was previously not present in the existing evidence base in this area. There were some findings from this study that may be of interest to the field but were beyond the scope of this thesis, including further exploration of risk factors for LBP in adolescent athletes.

Study II allowed for further exploration into current management of adolescent LBP across a variety of sports. It also broadened the scope of the research through providing an international perspective. Study II was limited by the information present in the medical charts and would have benefitted from a larger sample size to allow for exploration of specific sports. This was not possible within the timing and scope of the PhD research. It also would have been beneficial to explore the impact of maturation on injury type, but this information was not available. Study II highlighted the possible impacts of a high rate of MRI usage, and the importance of developing guidelines for MRI usage and interpretation.

Study III provided important information on the adolescent athlete voice within research in this area. This has not previously been done in the area of adolescent athlete LBP. Study III highlighted the importance of monitoring safeguarding techniques for adolescent athletes to ensure that athletes are adequately protected. The results from Study III may be used to affect current safeguarding policy in regard to playing through pain or injury. Interview responses may have been affected by the necessary presence of parents/guardians during interviews. Further areas for exploration that were not possible within the scope of this PhD research include the parent perspective on adolescent athlete LBP, and cultural differences in management and experiences of LBP.

Study IV aimed to gather further information on the clinician perspective, addressing unanswered questions from Studies II and III. Study IV was limited by clinician responses, with mainly physiotherapists currently practicing in Europe responding. It may have been beneficial to limit this survey to Irish clinicians, to control for the effect of differing medical systems across Europe and other continents. Further, the number of responses to each item in the survey decreased throughout the survey, limiting the generalisability of findings.

Overall, the work from this thesis contributed to an under-researched area in the field of Sports Medicine. The international nature of this research between Ireland and the United States increased the scope and impact of the results. The results of this body of work contributed to an increased understanding of how LBP affects adolescents participating in sport, making an original contribution to LBP management.

## 6.5 Findings in the context of previous work

Study I found that most studies investigating LBP in adolescent athletes were of low methodological quality. Common reasons for downgrading at quality assessment were use of non-validated survey instruments and imprecision or absence of LBP definition. In a recent systematic review of adult athletes, there was a similar finding in that an athlete-specific definition of LBP may improve research in this population[146].

The findings from Study II were consistent with what is known about LBP in the general population. In Study II, the most common diagnosis among 400 adolescent athletes with LBP was non-specific LBP (NS-LBP). In the general population, it is thought that up to 90% of all LBP is non-specific[290]. In a retrospective chart review of 106 adolescents, NS-LBP was also found to be the most common diagnosis associated with LBP[389], although this review included participants aged 8-17 years old. The frequency of NS-LBP in Study II was lower, 34%, compared to 58.4% in the general adolescent chart review study[389]. As discussed in Chapter 3, this may be in part due to the high rate of imaging seen in Study II. Because spondylolysis is thought to be common in adolescent athletes specifically as compared to other populations, it is possible that it may be considered and diagnosed more frequently than in other groups.

There were some similarities between Study III and previous qualitative work in adult athletes. A grounded theory interview study of adult rowers found that participants reported similar feelings to the adolescent athletes, considering LBP almost inevitable[153]. They also discussed the impact on their lives and jobs[153], similar to what adolescents described about the impact of LBP on their school and home lives. The culture of sport was similarly discussed between adolescent and adult athletes. This demonstrates that the negative aspects of sports injury culture can begin as early as adolescence, and many athletes grow up surrounded by this mentality. A qualitative study of 14 high level adolescent athletes found that some participants believed their injury was caused by training with pain, and one of the themes developed from this study was ‘hazardous sports practice’[390]. This is similar to the finding from Study III in which many participants continued to participate in sport despite LBP- either because of internal drive to participate, or a sense of duty to their team. Another study investigating sport-related concussion in adolescent athletes described the effects of others’ perceptions of their injury[391]. This is similar to the effect of perception and self-perception described by the young athletes in Study III. These similarities with other studies in adolescent athletes demonstrate that some aspects of the experiences of adolescent athletes with LBP are shared with other injured athletes.

Study IV found that while clinician LBP beliefs were largely helpful, there were three specific items on which unhelpful beliefs were more prevalent. Moreover, in 11 of the 20 items, at least one participant selected the most unhelpful belief. It is important to consider the implications of this finding, as previous research has shown that healthcare provide LBP beliefs can affect the beliefs of their patient[365 366].

## 6.6 Limitations

Specific limitations for each study are discussed in their respective chapters (Chapters 2-5), however there are some common limitations across all studies presented here. Prospective, longitudinal assessments would have been preferable over the retrospective chart review and cross-sectional survey designs of Studies II and IV. However, there are time and funding limitations associated with PhD research that did not allow for this study design. Study I was a broad systematic review encapsulating several research questions. Further, more targeted, reviews would be beneficial to explore specific risk factors for LBP in adolescent athletes. In Study IV, a survey closing date determined the study size, as the pilot nature of the study did not allow for an a priori sample size calculation. Overall participant recruitment in this thesis may have been subject to participation bias, since Studies III and IV both used social media as a main form of recruitment. There were restrictions and adaptations throughout all studies included in this thesis due to necessary constraints implemented during the Covid-19 pandemic.

## 6.7 Contributions of this research to the field of sports medicine

The results of this body of work contributed to an increased understanding of how LBP affects adolescents participating in sport, making an original contribution to LBP management.

6.7.1 Recommendations for clinical practice

1. Clinicians should be aware of LBP as a common condition in adolescent athletes.

   This may allow for further recognition of LBP as a potential issue affecting adolescent athletes. Although LBP is recognised as a common condition for adults[290], pain in adolescents and children is still often under-recognised[53].

2. Clinicians should exercise caution with the use of diagnostic labels for management of LBP in adolescent athletes.

   It is known that the majority of LBP is non-specific[290]. The use of imaging to define specific diagnoses may overlook or simplify the specific presentation of adolescents with LBP, as discussed in Studies I and II.

3. Education about LBP for coaches and athletes should be implemented.

   This would take some burden off adolescent athletes, as coaches may have a better understand of injury mechanisms and healing times. It would also allow for adolescent athletes to best advocate for their needs. This could include (but is not limited to) pain neuroscience education, the dual nature of pain in sport, ‘normal’ vs. abnormal pain, and when to report pain or injury.

4. A safe, designated method of sport injury reporting should be implemented within sport groups/clubs.

With this in place, athletes would be able to disclose pain or injury without fear of repercussions from their coach, as some of the athletes described in Study III.

5. There should be ongoing clinician education about LBP beliefs.

This would ensure that the most accurate and up-to-date information is conveyed to patients, since it is known that HCP LBP beliefs can affect the beliefs of their patients[365-367]. As discussed in Study IV, some clinicians still hold unhelpful LBP beliefs, which could affect the patient experiences of LBP.

6.7.2 Recommendations for research

1. Clear and specific LBP definition.

In future, a definition of LBP specific to adolescent athletes would be useful for research in this population. In the meta-regression analyses in Study I, LBP definition accounted for most of the heterogeneity in studies of cohort design and all heterogeneity in cross-sectional studies reporting 3-month prevalence. The lack of standardised definition of LBP may affect the overall prevalence reported. A definition of LBP more specific to adolescent athletes may improve assessment of LBP in this group.

2. Methods of diagnosis and management of spondylolysis.

The results of Study I also suggest that further investigation into the methods of diagnosis and treatment of spondylolysis in adolescent athletes is warranted. It is not clear currently whether spondylolysis in this population is a normal consequence of loading on the growing spine. Study II also brought forward the idea that methods of diagnosis of spondylolysis need further investigation, as spondylolysis was the most common specific diagnosis in the adolescent athlete population.

3. LBP management guidelines specific to adolescent athletes.

Studies II and IV highlighted the need for management guidelines specific to LBP in adolescent athletes, to take into consideration their specific differences. This would necessitate further research to ensure that these management guidelines are safe and appropriate.

4. Efficacy of sport injury reporting tool.

As discussed in Section 6.7.1, it may also be useful to implement a safe, designated method of injury reporting, so the adolescent athlete feels heard and able to disclose injury. Further research on the efficacy of such a tool and best methods of implementation would be needed.

5. LBP beliefs education for clinicians.

As discussed in section 6.7.1, Study IV illustrated the need for ongoing clinician education about LBP beliefs to ensure that the most accurate, up-to-date, and beneficial information is conveyed to patients. Research into methods of implementation would be needed.

6.7.3 Recommendations for policy

1. Further work is needed to ensure that safeguarding policies are adequately implemented to protect adolescent athletes. Although safeguarding in sport now includes safeguarding against systems that promote overtraining or competing with injury[354 356], the athletes involved in Study II reported playing or participating in sport through pain, as well as concealing or choosing not to disclose pain to a coach.
2. Policy addressing adolescent sport should consider LBP specifically as a common source of pain for adolescent athletes.

## 6.8 Conclusion

The results of this thesis indicate that LBP is common in adolescent athletes, and further research is needed to ensure optimal management of this condition. Adolescent athletes with LBP indicate that LBP is normalised in sport and can impact their global wellbeing. Future research is needed in this area to adequately address the needs of adolescent athletes who experience LBP.  The definition of LBP used for research in this population varies widely and can impact on report incidence and prevalence. Spondylolysis appears to be the most common specific morphology in adolescent athletes, although it is not clear whether this is a normal response to loading in an immature spine. Non-specific LBP is the most common type of LBP overall in this population. Because of this, it may be more important to tailor management to individual presentation rather than diagnostic label. It is important to note that there are no guidelines specific to this population, and the development of such guidelines may guide clinical practice in this area.

Adolescent athletes reported playing through pain or injury because of the normalisation of LBP in their respective sports. This carries risks for athletes and can affect their lives outside of sport. A re-framing of LBP in sport is needed to adequately protect adolescent athletes from the myriad risks associated with LBP during adolescence. This could start with education about pain for coaches and athletes, and the development of a safe and impartial injury reporting method for adolescent athletes. The described culture within sport of tolerance of pain will need consistent scrutiny to ensure that positive change is being undertaken in the coming years.

Overall, the work from this thesis has potential to affect or direct policy in regard to safe sport for adolescent athletes. There were many research areas which could not be explored during the scope of this PhD, but may serve as a basis for future work. The work from this thesis will be disseminated through peer-reviewed publications and conference presentations to add to the evidence-based literature investigating LBP in adolescent athletes.

# Chapter 7: References


1. Adolescent Health: World Health Organization; [Available from: https://www.who.int/health-topics/adolescent-health/.

2. van Mechelen W, Hlobil H, Kemper HCG. Incidence, Severity, Aetiology and Prevention of Sports Injuries. Sports Medicine. 1992;14:82-99.

3. Guthold R, Stevens GA, Riley LM, et al. Global trends in insufficient physical activity among adolescents: a pooled analysis of 298 population-based surveys with 1·6 million participants. The Lancet Child & Adolescent Health. 2020;4:23-35.

4. Guddal MH, Stensland SØ, Småstuen MC, et al. Physical activity and sport participation among adolescents: associations with mental health in different age groups. Results from the Young-HUNT study: a cross-sectional survey. BMJ Open. 2019;9:e028555-e.

5. Murphy J, Sweeney MR, McGrane B, editors. Physical Activity and Sports Participation in Irish Adolescents and Associations with Anxiety, Depression and Mental Wellbeing. Findings from the Physical Activity and Wellbeing (Paws) Study2020.

6. Kumar B, Robinson R, Till S. Physical activity and health in adolescence. Clin Med (Lond). 2015;15:267-72.

7. Hallal PC, Victora CG, Azevedo MR, et al. Adolescent Physical Activity and Health. Sports Medicine. 2006;36:1019-30.

8. Jewett R, Sabiston CM, Brunet J, et al. School Sport Participation During Adolescence and Mental Health in Early Adulthood. Journal of Adolescent Health. 2014;55:640-4.

9. Ukogu C, Patterson D, Sarosi A, et al. Epidemiology of youth sports injury: a review of demographic and sports-related risk factors for injury. Annals of Joint. 2017;2.

10. Adirim TA, Cheng TL. Overview of injuries in the young athlete. Sports Med. 2003;33:75-81.

11. Piercy KL, Dorn JM, Fulton JE, et al. Opportunities for public health to increase physical activity among youths. Am J Public Health. 2015;105:421-6.

12. Barber Foss KD, Myer GD, Hewett TE. Epidemiology of basketball, soccer, and volleyball injuries in middle-school female athletes. Phys Sportsmed. 2014;42:146-53.

13. DiFiori JP, Benjamin HJ, Brenner JS, et al. Overuse injuries and burnout in youth sports: a position statement from the American Medical Society for Sports Medicine. British Journal of Sports Medicine. 2014;48:287.

14. Harrison CB, Gill ND, Kinugasa T, et al. Development of Aerobic Fitness in Young Team Sport Athletes. Sports Medicine. 2015;45:969-83.

15. Eime RM, Young JA, Harvey JT, et al. A systematic review of the psychological and social benefits of participation in sport for children and adolescents: informing development of a conceptual model of health through sport. International Journal of Behavioral Nutrition and Physical Activity. 2013;10:98.

16. Haynes A, McVeigh J, Hissen SL, et al. Participation in sport in childhood and adolescence: Implications for adult fitness. Journal of Science and Medicine in Sport. 2021;24:908-12.

17. Tammelin T, Näyhä S, Hills AP, et al. Adolescent participation in sports and adult physical activity. American Journal of Preventive Medicine. 2003;24:22-8.

18. Children HSEaDoHa. Physical Activity Guidelines: Health Service Executive; [Available from: https://www.hse.ie/eng/about/who/healthwellbeing/our-priority-programmes/heal/physical-activity-guidelines/.

19. Services UDoHaH. Physical Activity Guidelines for Americans [2:[Available from: https://health.gov/sites/default/files/2019-09/Physical_Activity_Guidelines_2nd_edition.pdf.

20. Crane J, Temple V. A systematic review of dropout from organized sport among children and youth. European Physical Education Review. 2014;21:114-31.

21. Sabo DaV, P. Go out and Play: Youth Sports in America. East Meadow, NY: Women's Sports Foundation 2008.

22. Adolescent Girls Get Active. Dublin, Ireland: Sport Ireland; 2021.

23. McKay CD, Rollo S, Dillon K, et al. The Mental Impact of Sports Injury. McKay, Carly D. ed2021.

24. Kisser R, Bauer R. The burden of sport injuries in the European Union. Research report D2h of the project “Safety in Sports”. Vienna: Austrian Road Safety Board (Kuratorium fur Verkehrssicherheit); 2012.

25. Sheu Y, Chen L-H, Hedegaard H. Sports- and Recreation-related Injury Episodes in the United States, 2011–2014 Centers for Disease Control and Prevention; 2016.

26. Räisänen AM, Kokko S, Pasanen K, et al. Prevalence of adolescent physical activity-related injuries in sports, leisure time, and school: the National Physical Activity Behaviour Study for children and Adolescents. BMC Musculoskeletal Disorders. 2018;19:58.

27. Brukner P, Clarsen B, Cook J, et al. Brukner & Khan’s Clinical Sports Medicine: Injuries, Volume 1, 5e. Sydney, Australia: McGraw-Hill Education; 2017.

28. Patel DR, Kinsella E. Evaluation and management of lower back pain in young athletes. Transl Pediatr. 2017;6:225-35.

29. McKay CD, Cumming SP, Blake T. Youth sport: Friend or Foe? Best Practice & Research Clinical Rheumatology. 2019;33:141-57.

30. Caine D, DiFiori J, Maffulli N. Physeal injuries in children's and youth sports: reasons for concern? Br J Sports Med. 2006;40:749-60.

31. Patel TS, McGregor A, Fawcett L, et al. Coach awareness, knowledge and practice in relation to growth and maturation and training load in competitive, young gymnasts. International Journal of Sports Science & Coaching. 2020;16:528-43.

32. Soliman A, De Sanctis V, Elalaily R, et al. Advances in pubertal growth and factors influencing it: Can we increase pubertal growth? Indian J Endocrinol Metab. 2014;18:S53-S62.

33. Arnold A, Thigpen CA, Beattie PF, et al. Overuse Physeal Injuries in Youth Athletes: Risk Factors, Prevention, and Treatment Strategies. Sports Health. 2017;9:139-47.

34. Bergeron MF, Mountjoy M, Armstrong N, et al. International Olympic Committee consensus statement on youth athletic development. British Journal of Sports Medicine. 2015;49:843.

35. Romann M, Javet M, Fuchslocher J, editors. Coaches’ eye as a valid method to assess biological maturation in youth elite soccer2017.

36. Brown KA, Patel DR, Darmawan D. Participation in sports in relation to adolescent growth and development. Transl Pediatr. 2017;6:150-9.

37. Malisoux L, Frisch A, Urhausen A, et al. Monitoring of sport participation and injury risk in young athletes. Journal of Science and Medicine in Sport. 2013;16:504-8.

38. Dolan MG, Fourchet F, Horobeanu C, et al. Foot, Ankle, and Lower Leg Injuries in Young Male Track and Field Athletes. International Journal of Athletic Therapy and Training. 2011;16:19-23.

39. Rejeb A, Johnson A, Farooq A, et al. Sports injuries aligned to predicted mature height in highly trained Middle-Eastern youth athletes: a cohort study. BMJ Open. 2019;9:e023284.

40. Johnson A, Doherty PJ, Freemont A. Investigation of growth, development, and factors associated with injury in elite schoolboy footballers: prospective study. Bmj. 2009;338:b490.

41. Lacroix AE, Gondal H, Shumway KR, et al. Physiology, Menarche. StatPearls [Internet]. Treasure Island, FL: StatPearls Publishing; 2022.

42. Emmonds S, Heyward O, Jones B. The Challenge of Applying and Undertaking Research in Female Sport. Sports Med Open. 2019;5:51.

43. Sport readiness in children and youth. Paediatr Child Health. 2005;10:343-4.

44. Wachholz F, Tiribello F, Mohr M, et al. Adolescent Awkwardness: Alterations in Temporal Control Characteristics of Posture with Maturation and the Relation to Movement Exploration. Brain Sci. 2020;10.

45. Ackland T, Elliott B, Richards J. Growth in body size affects rotational performance in women's gymnastics. Sports Biomech. 2003;2:163-76.

46. John C, Rahlf AL, Hamacher D, et al. Influence of biological maturity on static and dynamic postural control among male youth soccer players. Gait & Posture. 2019;68:18-22.

47. Brewer BW, Van Raalte JL, Linder DE. Athletic identity: Hercules' muscles or Achilles heel? International Journal of Sport Psychology. 1993;24:237-54.

48. McKay C, Campbell T, Meeuwisse W, et al. The role of psychosocial risk factors for injury in elite youth ice hockey. Clinical Journal of Sport Medicine. 2013;23:216-21.

49. Kentää G, Podlog L, Johnson U, et al., editors. Athletic identity as a predictor of overtraining and injury among elite Swedish athletes. 14th European Congress of Sport Psychology; 2015; Bern, Switzerland.

50. Wiese-bjornstal DM, Smith AM, Shaffer SM, et al. An integrated model of response to sport injury: Psychological and sociological dynamics. Journal of Applied Sport Psychology. 1998;10:46-69.

51. Peck DM. Apophyseal injuries in the young athlete. Am Fam Physician. 1995;51:1891-5, 7-8.

52. Raja SN, Carr DB, Cohen M, et al. The revised International Association for the Study of Pain definition of pain: concepts, challenges, and compromises. Pain. 2020;161:1976-82.

53. Pain in Children: Management: International Association for the Study of Pain; 2021 [Available from: https://www.iasp-pain.org/resources/fact-sheets/pain-in-children-management/.

54. Harrison LE, Pate JW, Richardson PA, et al. Best-Evidence for the Rehabilitation of Chronic Pain Part 1: Pediatric Pain. J Clin Med. 2019;8.

55. Pancekauskaitė G, Jankauskaitė L. Paediatric Pain Medicine: Pain Differences, Recognition and Coping Acute Procedural Pain in Paediatric Emergency Room. Medicina (Kaunas). 2018;54:94.

56. Stinson JN, Kavanagh T, Yamada J, et al. Systematic review of the psychometric properties, interpretability and feasibility of self-report pain intensity measures for use in clinical trials in children and adolescents. Pain. 2006;125:143-57.

57. Walco GA, Cassidy RC, Schechter NL. Pain, Hurt, and Harm -- The Ethics of Pain Control in Infants and Children. New England Journal of Medicine. 1994;331:541-4.

58. Kamper SJ, Dissing KB, Hestbaek L. Whose pain is it anyway? Comparability of pain reports from children and their parents. Chiropractic & Manual Therapies. 2016;24:24.

59. Haraldstad K, Sørum R, Eide H, et al. Pain in children and adolescents: prevalence, impact on daily life, and parents' perception, a school survey. Scandinavian Journal of Caring Sciences. 2011;25:27-36.

60. Ross DM, Ross SA. Assessment of Pediatric Pain: An Overview. Issues in Comprehensive Pediatric Nursing. 1988;11:73-91.

61. Engel George L. The Need for a New Medical Model: A Challenge for Biomedicine. Science. 1977;196:129-36.

62. Bailen NH, Green LM, Thompson RJ. Understanding Emotion in Adolescents: A Review of Emotional Frequency, Intensity, Instability, and Clarity. Emotion Review. 2018;11:63-73.

63. Merlijn VPBM, Hunfeld JAM, van der Wouden JC, et al. Psychosocial factors associated with chronic pain in adolescents. PAIN. 2003;101.

64. 4, The Psychology of Adolescence. Washington (DC): Institute of Medicine (US) and National Research Council (US) Committee on the Science of Adolescence. 2011.

65. Eccleston C, Wastell S, Crombez G, et al. Adolescent social development and chronic pain. Eur J Pain. 2008;12:765-74.

66. Logan DE, Simons LE, Stein MJ, et al. School impairment in adolescents with chronic pain. J Pain. 2008;9:407-16.

67. Groenewald CB, Essner BS, Wright D, et al. The economic costs of chronic pain among a cohort of treatment-seeking adolescents in the United States. J Pain. 2014;15:925-33.

68. Swain MS, Henschke N, Kamper SJ, et al. An international survey of pain in adolescents. BMC Public Health. 2014;14:447-.

69. Hestbaek L, Leboeuf-Yde C, Kyvik KO. Is comorbidity in adolescence a predictor for adult low back pain? A prospective study of a young population. BMC Musculoskelet Disord. 2006;7:29.

70. Weston G, Zeltzer L. Misuse of Adult Framework for Pediatric Pain Management. Practical Pain Management.22.

71. Hoy D, Bain C, Williams G, et al. A systematic review of the global prevalence of low back pain. Arthritis & Rheumatism. 2012;64:2028-37.

72. Dionne CE, Dunn KM, Croft PR, et al. A consensus approach toward the standardization of back pain definitions for use in prevalence studies. Spine (Phila Pa 1976). 2008;33:95-103.

73. Koes BW, van Tulder MW, Thomas S. Diagnosis and treatment of low back pain. BMJ (Clinical research ed). 2006;332:1430-4.

74. Rubin DI. Epidemiology and Risk Factors for Spine Pain. Neurologic Clinics. 2007;25:353-71.

75. Hwang J, Louie PK, Phillips FM, et al. Low back pain in children: a rising concern. European Spine Journal. 2019;28:211-3.

76. Jones GT, Macfarlane GJ. Epidemiology of low back pain in children and adolescents. 2005;90:312-6.

77. Calvo-Muñoz I, Gómez-Conesa A, Sánchez-Meca J. Prevalence of low back pain in children and adolescents: a meta-analysis. BMC Pediatr. 2013;13:14-.

78. Silva MROGCM, Badaró AFV, Dall'Agnol MM. Low back pain in adolescent and associated factors: A cross sectional study with schoolchildren. Braz J Phys Ther. 2014;18:402-9.

79. Calvo-Muñoz I, Gómez-Conesa A, Sánchez-Meca J. Physical therapy treatments for low back pain in children and adolescents: a meta-analysis. BMC Musculoskeletal Disorders. 2013;14:55.

80. Hestbaek L, Leboeuf-Yde C, Kyvik KO, et al. The course of low back pain from adolescence to adulthood: eight-year follow-up of 9600 twins. Spine (Phila Pa 1976). 2006;31:468-72.

81. Hestbaek L, Leboeuf-Yde C, Manniche C. Low back pain: what is the long-term course? A review of studies of general patient populations. Eur Spine J. 2003;12:149-65.

82. Grotle M, Brox JI, Vøllestad NK. Functional status and disability questionnaires: what do they assess? A systematic review of back-specific outcome questionnaires. Spine (Phila Pa 1976). 2005;30:130-40.

83. Longo UG, Loppini M, Denaro L, et al. Rating scales for low back pain. British Medical Bulletin. 2010;94:81-144.

84. Outcome Measures, British Pain Society, Faculty of Pain Medicine, Royal College of Anaesthetists; 2019.

85. Fritz JM, Clifford SN. Low back pain in adolescents: a comparison of clinical outcomes in sports participants and nonparticipants. J Athl Train. 2010;45:61-6.

86. Crawford JO. The Nordic Musculoskeletal Questionnaire. Occupational Medicine. 2007;57:300-1.

87. Legault ÉP, Cantin V, Descarreaux M. Assessment of musculoskeletal symptoms and their impacts in the adolescent population: adaptation and validation of a questionnaire. BMC Pediatr. 2014;14:173.

88. Oliveira CB, Pinto RZ, Damato TM, et al. Daily activity limitations and physical activity encouragement influence adolescents seeking health care for neck and low back pain. Musculoskeletal Science and Practice. 2021;54:102385.

89. MacDonald JP, d'Hemecourt PA, Micheli LJ. The Reliability and Validity of a Pediatric Back Outcome Measure. Clinical Journal of Sport Medicine. 2016;26.

90. O'Sullivan PB, Straker LM, Smith A, et al. Carer Experience of Back Pain Is Associated With Adolescent Back Pain Experience Even When Controlling for Other Carer and Family Factors. The Clinical Journal of Pain. 2008;24.

91. O'Sullivan PB, Beales DJ, Smith AJ, et al. Low back pain in 17 year olds has substantial impact and represents an important public health disorder: a cross-sectional study. BMC Public Health. 2012;12:100.

92. Watson KD, Papageorgiou AC, Jones GT, et al. Low back pain in schoolchildren: occurrence and characteristics. Pain. 2002;97:87-92.

93. Masiero S, Carraro E, Celia A, et al. Prevalence of nonspecific low back pain in schoolchildren aged between 13 and 15 years. Acta Paediatrica. 2008;97:212-6.

94. Skaggs DL, Early SD, D'Ambra P, et al. Back Pain and Backpacks in School Children. Journal of Pediatric Orthopaedics. 2006;26.

95. Mohseni-Bandpei MA, Bagheri-Nesami M, Shayesteh-Azar M. Nonspecific low back pain in 5000 Iranian school-age children. J Pediatr Orthop. 2007;27:126-9.

96. Olsen TL, Anderson RL, Dearwater SR, et al. The epidemiology of low back pain in an adolescent population. Am J Public Health. 1992;82:606-8.

97. Hershkovich O, Friedlander A, Gordon B, et al. Associations of Body Mass Index and Body Height With Low Back Pain in 829,791 Adolescents. American Journal of Epidemiology. 2013;178:603-9.

98. Harreby M, Nygaard B, Jessen T, et al. Risk factors for low back pain in a cohort of 1389 Danish school children: an epidemiologic study. Eur Spine J. 1999;8:444-50.

99. Sano A, Hirano T, Watanabe K, et al. Body mass index is associated with low back pain in childhood and adolescence: a birth cohort study with a 6-year follow-up in Niigata City, Japan. European Spine Journal. 2015;24:474-81.

100. Jones GT, Watson KD, Silman AJ, et al. Predictors of Low Back Pain in British Schoolchildren: A Population-Based Prospective Cohort Study. Pediatrics. 2003;111:822.

101. Lynch AM, Kashikar-Zuck S, Goldschneider KR, et al. Psychosocial Risks for Disability in Children With Chronic Back Pain. The Journal of Pain. 2006;7:244-51.

102. Diepenmaat ACM, van der Wal MF, de Vet HCW, et al. Neck/Shoulder, Low Back, and Arm Pain in Relation to Computer Use, Physical Activity, Stress, and Depression Among Dutch Adolescents. Pediatrics. 2006;117:412.

103. O'Sullivan P, Smith A, Beales D, et al. Understanding Adolescent Low Back Pain From a Multidimensional Perspective: Implications for Management. Journal of Orthopaedic & Sports Physical Therapy. 2017;47:741-51.

104. Smith AJ, O'Sullivan PB, Beales D, et al. Back Pain Beliefs Are Related to the Impact of Low Back Pain in 17-Year-Olds. Physical Therapy. 2012;92:1258-67.

105. Burton KA, Clarke RD, McClune TD, et al. The Natural History of Low Back Pain in Adolescents. Spine. 1996;21:2323-8.

106. Sato T, Ito T, Hirano T, et al. Low back pain in childhood and adolescence: a cross-sectional study in Niigata City. Eur Spine J. 2008;17:1441-7.

107. Balagué F, Skovron M-L, Nordin M, et al. Low Back Pain in Schoolchildren A Study of Familial and Psychological Factors. Spine. 1995;20.

108. Sheir-Neiss GI, Kruse RW, Rahman T, et al. The Association of Backpack Use and Back Pain in Adolescents. Spine. 2003;28.

109. Siambanes D, Martinez JW, Butler EW, et al. Influence of School Backpacks on Adolescent Back Pain. Journal of Pediatric Orthopaedics. 2004;24.

110. Yamato TP, Maher CG, Traeger AC, et al. Do schoolbags cause back pain in children and adolescents? A systematic review. British Journal of Sports Medicine. 2018;52:1241.

111. Haselgrove C, Straker L, Smith A, et al. Perceived school bag load, duration of carriage, and method of transport to school are associated with spinal pain in adolescents: an observational study. Australian Journal of Physiotherapy. 2008;54:193-200.

112. Leo N, Amity C, Angus B, et al. Spinal Kinematics of Adolescent Male Rowers with Back Pain in Comparison with Matched Controls During Ergometer Rowing. Journal of Applied Biomechanics. 2015;31:459-68.

113. Auvinen JP, Tammelin TH, Taimela SP, et al. Is insufficient quantity and quality of sleep a risk factor for neck, shoulder and low back pain? A longitudinal study among adolescents. European spine journal :

official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society. 2010;19:641-9.

114. Perry MC, Straker LM, Oddy WH, et al. Spinal pain and nutrition in adolescents - an exploratory cross-sectional study. BMC Musculoskeletal Disorders. 2010;11:138.

115. Kędra A, Plandowska M, Kędra P, et al. Physical activity and low back pain in children and adolescents: a systematic review. European Spine Journal. 2021;30:946-56.

116. Heneweer H, Vanhees L, Picavet HS. Physical activity and low back pain: a U-shaped relation? Pain. 2009;143:21-5.

117. Bento TPF, Cornelio GP, Perrucini PO, et al. Low back pain in adolescents and association with sociodemographic factors, electronic devices, physical activity and mental health. J Pediatr (Rio J). 2020;96:717-24.

118. Skoffer B, Foldspang A. Physical activity and low-back pain in schoolchildren. Eur Spine J. 2008;17:373-9.

119. Clifford SN, Fritz JM. Children and Adolescents With Low Back Pain: A Descriptive Study of Physical Examination and Outcome Measurement. Journal of Orthopaedic & Sports Physical Therapy. 2003;33:513-22.

120. Standaert CJ, Herring SA. Spondylolysis: a critical review. British journal of sports medicine. 2000;34:415-22.

121. McDonald BT HA, Lucas JA. Spondylolysis. Treasure Island, FL: StatsPearls Publishing; 2020.

122. Sweeney EA, Daoud AK, Potter MN, et al. Association Between Flexibility and Low Back Pain in Female Adolescent Gymnasts. Clin J Sport Med. 2019;29:379-83.

123. Klein G, Mehlman CT, McCarty M. Nonoperative Treatment of Spondylolysis and Grade I Spondylolisthesis in Children and Young Adults: A Meta-analysis of Observational Studies. Journal of Pediatric Orthopaedics. 2009;29.

124. Micheli LJ, Wood R. Back pain in young athletes. Significant differences from adults in causes and patterns. Arch Pediatr Adolesc Med. 1995;149:15-8.

125. Lonstein JE. Spondylolisthesis in Children: Cause, Natural History, and Management. Spine. 1999;24.

126. Hresko MT. Idiopathic Scoliosis in Adolescents. New England Journal of Medicine. 2013;368:834-41.

127. Théroux J, Le May S, Fortin C, et al. Prevalence and management of back pain in adolescent idiopathic scoliosis patients: A retrospective study. Pain Res Manag. 2015;20:153-7.

128. Sato T, Hirano T, Ito T, et al. Back pain in adolescents with idiopathic scoliosis: epidemiological study for 43,630 pupils in Niigata City, Japan. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society. 2011;20:274-9.

129. Balagué F, Pellisé F. Adolescent idiopathic scoliosis and back pain. Scoliosis and Spinal Disorders. 2016;11:27.

130. Mansfield JT, Bennett M. Scheuermann Disease Treasure Island (FL): StatPearls Publishing; 2020 [Available from: https://www.ncbi.nlm.nih.gov/books/NBK499966/.

131. Ristolainen L, Kettunen JA, Heliövaara M, et al. Untreated Scheuermann's disease: a 37-year follow-up study. European spine journal : official publication of the European Spine Society, the European Spinal Deformity Society, and the European Section of the Cervical Spine Research Society. 2012;21:819-24.

132. Kumar R, Kumar V, Das NK, et al. Adolescent lumbar disc disease: findings and outcome. Child's Nervous System. 2007;23:1295-9.

133. Kjaer P, Leboeuf-Yde C, Sorensen JS, et al. An Epidemiologic Study of MRI and Low Back Pain in 13-Year-Old Children. Spine. 2005;30.

134. Koes BW, van Tulder MW, Thomas S. Diagnosis and treatment of low back pain. BMJ. 2006;332:1430.

135. Combs JA, Caskey PM. Back pain in children and adolescents: a retrospective review of 648 patients. South Med J. 1997;90:789-92.

136. MacDonald J, Stuart E, Rodenberg R. Musculoskeletal Low Back Pain in School-aged Children: A Review. JAMA Pediatrics. 2017;171:280-7.

137. Michaleff ZA, Kamper SJ, Maher CG, et al. Low back pain in children and adolescents: a systematic review and meta-analysis evaluating the effectiveness of conservative interventions. European Spine Journal. 2014;23:2046-58.

138. Jones MA, Stratton G, Reilly T, et al. A school ‐ based survey of recurrent non ‐ specific low ‐ back pain prevalence and consequences in children. Health Education Research. 2004;19:284-9.

139. Salminen JJ, Pentti J, Terho P. Low back pain and disability in 14-year-old schoolchildren. Acta Paediatr. 1992;81:1035-9.

140. Watson KD, Papageorgiou AC, Jones GT, et al. Low back pain in schoolchildren: occurrence and characteristics. PAIN. 2002;97:87-92.

141. Harreby M, Neergaard K, Hesselsøe G, et al. Are radiologic changes in the thoracic and lumbar spine of adolescents risk factors for low back pain in adults? A 25-year prospective cohort study of 640 school children. Spine (Phila Pa 1976). 1995;20:2298-302.

142. Jones GT, Macfarlane GJ. Predicting persistent low back pain in schoolchildren: A prospective cohort study. Arthritis Care & Research. 2009;61:1359-66.

143. Mortazavi J, Zebardast J, Mirzashahi B. Low Back Pain in Athletes. Asian J Sports Med. 2015;6:e24718-e.

144. Ball JR, Harris CB, Lee J, et al. Lumbar Spine Injuries in Sports: Review of the Literature and Current Treatment Recommendations. Sports Medicine - Open. 2019;5:26.

145. Trompeter K, Fett D, Platen P. Prevalence of Back Pain in Sports: A Systematic Review of the Literature. Sports Med. 2017;47:1183-207.

146. Wilson F, Ardern CL, Hartvigsen J, et al. Prevalence and risk factors for back pain in sports: a systematic review with meta-analysis. British Journal of Sports Medicine. 2020:bjsports-2020-102537.

147. Greene HS, Cholewicki J, Galloway MT, et al. A history of low back injury is a risk factor for recurrent back injuries in varsity athletes. Am J Sports Med. 2001;29:795-800.

148. Moradi V, Memari A-H, ShayestehFar M, et al. Low Back Pain in Athletes Is Associated with General and Sport Specific Risk Factors: A Comprehensive Review of Longitudinal Studies. Rehabil Res Pract. 2015;2015:850184-.

149. Trompeter K, Fett D, Brüggemann GP, et al. Prevalence of Back Pain in Elite Athletes. Deutsche Zeitschrift für Sportmedizin. 2018;69:240-6 doi.

150. Thornton JS, Caneiro JP, Hartvigsen J, et al. Treating low back pain in athletes: a systematic review with meta-analysis. British Journal of Sports Medicine. 2020:bjsports-2020-102723.

151. Petering RC, Webb C. Treatment options for low back pain in athletes. Sports Health. 2011;3:550-5.

152. Hoy D, Brooks P, Blyth F, et al. The Epidemiology of low back pain. Best Pract Res Clin Rheumatol. 2010;24:769-81.

153. Wilson F, Ng L, Sullivan K, et al. You're the best liar in the world': a grounded theory study of rowing athletes' experience of low back pain. British Journal of Sports Medicine. 2021;55:327.

154. Andersen MB, Williams JM. A Model of Stress and Athletic Injury: Prediction and Prevention. Journal of Sport and Exercise Psychology. 1988;10:294-306.

155. Williams JM, Andersen MB. Psychosocial antecedents of sport injury: Review and critique of the stress and injury model'. Journal of Applied Sport Psychology. 1998;10:5-25.

156. Brewer BW. The role of psychological factors in sport injury rehabilitation outcomes. International Review of Sport and Exercise Psychology. 2010;3:40-61.

157. Walsh NP. Recommendations to maintain immune health in athletes. Eur J Sport Sci. 2018;18:820-31.

158. Robinson H, Norton S, Jarrett P, et al. The effects of psychological interventions on wound healing: A systematic review of randomized trials. British Journal of Health Psychology. 2017;22:805-35.

159. Petlichkoff LM. Youth Sport Participation and Withdrawal: Is It Simply a Matter of FUN? Pediatric Exercise Science. 1992;4:105-10.

160. Stenner BJ, Buckley JD, Mosewich AD. Reasons why older adults play sport: A systematic review. Journal of Sport and Health Science. 2020;9:530-41.

161. Molanorouzi K, Khoo S, Morris T. Motives for adult participation in physical activity: type of activity, age, and gender. BMC Public Health. 2015;15:66.

162. Perkins DF, Jacobs JE, Barber BL, et al. Childhood and Adolescent Sports Participation as Predictors of Participation in Sports and Physical Fitness Activities During Young Adulthood. Youth & Society. 2004;35:495-520.

163. Houle JL, Brewer BW, Kluck AS. Developmental trends in athletic identity: a two-part retrospective study. Journal of Sport Behaviour. 2010;33.

164. Purcell L, Micheli L. Low back pain in young athletes. Sports Health. 2009;1:212-22.

165. Theisen D, Malisoux L, Seil R, et al. Injuries in Youth sports: Epidemiology, Risk Factors and Prevention. Deutsche Zeitschrift für Sportmedizin. 2014;65:248-52.

166. Sackett DL, Rosenberg WMC, Gray JAM, et al. Evidence based medicine: what it is and what it isn't. BMJ. 1996;312:71.

167. d'Hemecourt PA, Gerbino PG, Micheli LJ. BACK INJURIES IN THE YOUNG ATHLETE. Clinics in Sports Medicine. 2000;19:663-79.

168. Moher D, Liberati A, Tetzlaff J, et al. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. BMJ. 2009;339:b2535.

169. Viechtbauer W. Conducting meta-analyses in R with the metafor package. Journal of Statistical Software. 2010;36:1-48.

170. Leboeuf-Yde C, Lauritsen JM. The prevalence of low back pain in the literature. A structured review of 26 Nordic studies from 1954 to 1993. Spine (Phila Pa 1976). 1995;20:2112-8.

171. Walker BF. The prevalence of low back pain: a systematic review of the literature from 1966 to 1998. J Spinal Disord. 2000;13:205-17.

172. Hutchinson MR. Low back pain in elite rhythmic gymnasts. Medicine & Science in Sports & Exercise. 1999;31:1686.

173. Sato T, Ito T, Hirano T, et al. Low back pain in childhood and adolescence: assessment of sports activities. Eur Spine J. 2011;20:94-9.

174. Kuorinka I, Jonsson B, Kilbom A, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl Ergon. 1987;18:233-7.

175. Clarsen B, Myklebust G, Bahr R. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire. British Journal of Sports Medicine. 2013;47:495.

176. Aoki H, Kohno T, Fujiya H, et al. Incidence of injury among adolescent soccer players: a comparative study of artificial and natural grass turfs. Clin J Sport Med. 2010;20:1-7.

177. Bayne H, Elliott B, Campbell A, et al. Lumbar load in adolescent fast bowlers: A prospective injury study. Journal of Science and Medicine in Sport. 2016;19:117-22.

178. Cejudo A, Ginés-Díaz A, Rodríguez-Ferrán O, et al. Trunk Lateral Flexor Endurance and Body Fat: Predictive Risk Factors for Low Back Pain in Child Equestrian Athletes. Children (Basel). 2020;7.

179. Cezarino LG, Grüninger BLdS, Scattone Silva R. Injury Profile in a Brazilian First-Division Youth Soccer Team: A Prospective Study. Journal of Athletic Training. 2020;55:295-302.

180. Dennis RJ, Finch CF, Farhart PJ. Is bowling workload a risk factor for injury to Australian junior cricket fast bowlers? British Journal of Sports Medicine. 2005;39:843.

181. Farahbakhsh F, Akbari-Fakhrabadi M, Shariat A, et al. Neck pain and low back pain in relation to functional disability in different sport activities. J Exerc Rehabil. 2018;14:509-15.

182. Gregory PL, Batt ME, Wallace WA. Comparing injuries of spin bowling with fast bowling in young cricketers. Clin J Sport Med. 2002;12:107-12.

183. Hjelm N, Werner S, Renstrom P. Injury profile in junior tennis players: a prospective two year study. Knee Surg Sports Traumatol Arthrosc. 2010;18:845-50.

184. Iwamoto J, Abe H, Tsukimura Y, et al. Relationship between Radiographic Abnormalities of Lumbar Spine and Incidence of Low Back Pain in High School and College Football Players:A Prospective Study. The American Journal of Sports Medicine. 2004;32:781-6.

185. Iwamoto J, Abe H, Tsukimura Y, et al. Relationship between radiographic abnormalities of lumbar spine and incidence of low back pain in high school rugby players: a prospective study. Scand J Med Sci Sports. 2005;15:163-8.

186. Lee I, Jeong HS, Lee SY. Injury Profiles in Korean Youth Soccer. Int J Environ Res Public Health. 2020;17:5125.

187. Linek P, Noormohammadpour P, Mansournia MA, et al. Morphological changes of the lateral abdominal muscles in adolescent soccer players with low back pain: A prospective cohort study. Journal of Sport and Health Science. 2018.

188. Palmer-Green DS, Stokes KA, Fuller CW, et al. Training activities and injuries in English youth academy and schools rugby union. Am J Sports Med. 2015;43:475-81.

189. Rossi MK, Pasanen K, Heinonen A, et al. Incidence and risk factors for back pain in young floorball and basketball players: A Prospective study. Scand J Med Sci Sports. 2018;28:2407-15.

190. O' Connor S, McCaffrey N, Whyte EF, et al. Epidemiology of injury in male adolescent Gaelic games. J Sci Med Sport. 2016;19:384-8.

191. Shah T, Cloke DJ, Rushton S, et al. Lower Back Symptoms in Adolescent Soccer Players: Predictors of Functional Recovery. Orthop J Sports Med. 2014;2:2325967114529703.

192. Shimozaki K, Nakase J, Yoshioka K, et al. Incidence rates and characteristics of abnormal lumbar findings and low back pain in child and adolescent weightlifter: A prospective three-year cohort study. PLoS One. 2018;13:e0206125.

193. Smoljanovic T, Bojanic I, Hannafin JA, et al. Traumatic and overuse injuries among international elite junior rowers. Am J Sports Med. 2009;37:1193-9.

194. Sommerfield LM, Harrison CB, Whatman CS, et al. A prospective study of sport injuries in youth females. Physical Therapy in Sport. 2020;44:24-32.

195. McMeeken J, Tully E, Stillman B, et al. The experience of back pain in young Australians. Man Ther. 2001;6:213-20.

196. Kaldau NC, Kerr S, McCaig S, et al. Training and injuries among world elite junior badminton players – Identifying the problems. Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology. 2021;26:21-6.

197. Fouasson-Chailloux A, Mesland O, Menu P, et al. Soccer injuries documented by F-MARC guidelines in 13- and 14-year old national elite players: A 5-year cohort study. Science & Sports. 2020;35:145-53.

198. Gamboa JM, Roberts LA, Maring J, et al. Injury Patterns in Elite Preprofessional Ballet Dancers and the Utility of Screening Programs to Identify Risk Characteristics. Journal of Orthopaedic & Sports Physical Therapy. 2008;38:126-36.

199. Hickey GJ, Fricker PA, McDonald WA. Injuries of young elite female basketball players over a six-year period. Clin J Sport Med. 1997;7:252-6.

200. Abe T, Kamada M, Kitayuguchi J, et al. Is being a regular player with fewer teammates associated with musculoskeletal pain in youth team sports? A cross-sectional study. BMC Musculoskeletal Disorders. 2017;18:105.

201. Kamada M, Abe T, Kitayuguchi J, et al. Dose-response relationship between sports activity and musculoskeletal pain in adolescents. Pain. 2016;157:1339-45.

202. Mueller S, Mueller J, Stoll J, et al. Incidence of back pain in adolescent athletes: a prospective study. BMC Sports Sci Med Rehabil. 2016;8:38.

203. Müller J, Müller S, Stoll J, et al. Back pain prevalence in adolescent athletes. Scand J Med Sci Sports. 2017;27:448-54.

204. Zaina F, Donzelli S, Lusini M, et al. Tennis is not dangerous for the spine during growth: results of a cross-sectional study. Eur Spine J. 2016;25:2938-44.

205. Alricsson M, Werner S. Self-reported health, physical activity and prevalence of complaints in elite cross-country skiers and matched controls. J Sports Med Phys Fitness. 2005;45:547-52.

206. Alricsson M, Werner S. Young elite cross-country skiers and low back pain—A 5-year study. Physical Therapy in Sport. 2006;7:181-4.

207. Balagué F, Nordin M, Skovron ML, et al. Non-specific low-back pain among schoolchildren: a field survey with analysis of some associated factors. J Spinal Disord. 1994;7:374-9.

208. Brown EW, Kimball RG. Medical history associated with adolescent powerlifting. Pediatrics. 1983;72:636-44.

209. Cupisti A, D'Alessandro C, Evangelisti I, et al. Low back pain in competitive rhythmic gymnasts. Journal of Sports Medicine and Physical Fitness. 2004;44:49-53.

210. Hagiwara Y, Yabe Y, Sekiguchi T, et al. Upper Extremity Pain Is Associated with Lower Back Pain among Young Basketball Players: A Cross-Sectional Study. The Tohoku Journal of Experimental Medicine. 2020;250:79-85.

211. Hoskins W, Pollard H, Daff C, et al. Low back pain in junior Australian rules football: a cross-sectional survey of elite juniors, non-elite juniors and non-football playing controls. BMC musculoskeletal disorders. 2010;11:241-.

212. Kujala UM, Salminen JJ, Taimela S, et al. Subject characteristics and low back pain in young athletes and nonathletes. Med Sci Sports Exerc. 1992;24:627-32.

213. Kujala UM, Taimela S, Erkintalo M, et al. Low-back pain in adolescent athletes. Medicine & Science in Sports & Exercise. 1996;28:165-70.

214. Kujala UM, Taimela S, Oksanen A, et al. Lumbar mobility and low back pain during adolescence. A longitudinal three-year follow-up study in athletes and controls. Am J Sports Med. 1997;25:363-8.

215. Kujala UM, Taimela S, Salminen JJ, et al. Baseline anthropometry, flexibility and strength characteristics and future low-back pain in adolescent athletes and nonathletes. Scandinavian Journal of Medicine & Science in Sports. 1994;4:200-5.

216. Legault É P, Descarreaux M, Cantin V. Musculoskeletal symptoms in an adolescent athlete population: a comparative study. BMC Musculoskelet Disord. 2015;16:210.

217. Mogensen AM, Gausel AM, Wedderkopp N, et al. Is active participation in specific sport activities linked with back pain? Scand J Med Sci Sports. 2007;17:680-6.

218. Muntaner-Mas A, Palou P, Ortega FB, et al. Sports participation and low back pain in schoolchildren. J Back Musculoskelet Rehabil. 2018;31:811-9.

219. Ng L, Perich D, Burnett A, et al. Self-reported prevalence, pain intensity and risk factors of low back pain in adolescent rowers. J Sci Med Sport. 2014;17:266-70.

220. Noll M, de Avelar IS, Lehnen GC, et al. Back Pain Prevalence and Its Associated Factors in Brazilian Athletes from Public High Schools: A Cross-Sectional Study. PLoS One. 2016;11:e0150542.

221. Pasanen K, Rossi M, Heinonen A, et al. LOW BACK PAIN IN YOUNG TEAM SPORT PLAYERS: A RETROSPECTIVE STUDY. British Journal of Sports Medicine. 2014;48:651.

222. Pasanen K, Rossi M, Parkkari J, et al. Low Back Pain in Young Basketball and Floorball Players. Clinical Journal of Sport Medicine. 2016;26:376-80.

223. Peterhans L, Fröhlich S, Stern C, et al. High Rates of Overuse-Related Structural Abnormalities in the Lumbar Spine of Youth Competitive Alpine Skiers: A Cross-sectional MRI Study in 108 Athletes. Orthopaedic Journal of Sports Medicine. 2020;8:2325967120922554.

224. Rossi M, Pasanen K, Kokko S, et al. Low back and neck and shoulder pain in members and non-members of adolescents' sports clubs: the Finnish Health Promoting Sports Club (FHPSC) study. BMC Musculoskelet Disord. 2016;17:263.

225. Schmidt CP, Zwingenberger S, Walther A, et al. Prevalence of low back pain in adolescent athletes - an epidemiological investigation. Int J Sports Med. 2014;35:684-9.

226. Sekiguchi T, Hagiwara Y, Momma H, et al. Youth baseball players with elbow and shoulder pain have both low back and knee pain: a cross-sectional study. Knee Surg Sports Traumatol Arthrosc. 2018;26:1927-35.

227. Sundell CG, Bergström E, Larsén K. Low back pain and associated disability in Swedish adolescents. Scand J Med Sci Sports. 2019;29:393-9.

228. Swain CTV, Bradshaw EJ, Whyte DG, et al. Life history and point prevalence of low back pain in pre-professional and professional dancers. Phys Ther Sport. 2017;25:34-8.

229. Swain CTV, Bradshaw EJ, Whyte DG, et al. The prevalence and impact of low back pain in pre-professional and professional dancers: A prospective study. Phys Ther Sport. 2018;30:8-13.

230. Thoreson O, Kovac P, Swärd A, et al. Back pain and MRI changes in the thoraco-lumbar spine of young elite Mogul skiers. Scand J Med Sci Sports. 2017;27:983-9.

231. van Hilst J, Hilgersom NF, Kuilman MC, et al. Low back pain in young elite field hockey players, football players and speed skaters: Prevalence and risk factors. J Back Musculoskelet Rehabil. 2015;28:67-73.

232. Yabe Y, Hagiwara Y, Sekiguchi T, et al. High prevalence of low back pain among young basketball players with lower extremity pain: a cross-sectional study. BMC Sports Sci Med Rehabil. 2020;12:40.

233. Yabe Y, Hagiwara Y, Sekiguchi T, et al. Knee pain is associated with lower back pain in young baseball players: a cross-sectional study. Knee Surg Sports Traumatol Arthrosc. 2019;27:985-90.

234. Sogi Y, Hagiwara Y, Yabe Y, et al. Association between trunk pain and lower extremity pain among youth soccer players: a cross-sectional study. BMC sports science, medicine & rehabilitation. 2018;10:13-.

235. Yabe Y, Hagiwara Y, Sekiguchi T, et al. Association between lower back pain and lower extremity pain among young volleyball players: A cross-sectional study. Phys Ther Sport. 2020;43:65-9.

236. Yabe Y, Hagiwara Y, Sekiguchi T, et al. Low Back Pain in School-Aged Martial Arts Athletes in Japan: A Comparison among Judo, Kendo, and Karate. Tohoku J Exp Med. 2020;251:295-301.

237. Farahbakhsh F, Rostami M, Noormohammadpour P, et al. Prevalence of low back pain among athletes: A systematic review. J Back Musculoskelet Rehabil. 2018;31:901-16.

238. Vanti C, M G, F M, et al. Low Back Pain in adolescent gymnasts. Prevalence and risk factors. Scienza Riabilitativa. 2010;12:45-50.

239. Auvinen JP, Tammelin TH, Taimela SP, et al. Musculoskeletal pains in relation to different sport and exercise activities in youth. Med Sci Sports Exerc. 2008;40:1890-900.

240. Balagué F, Dutoit G, Waldburger M. Low back pain in schoolchildren. An epidemiological study. Scand J Rehabil Med. 1988;20:175-9.

241. Mizoguchi Y, Akasaka K, Otsudo T, et al. Factors associated with low back pain in elite high school volleyball players. J Phys Ther Sci. 2019;31:675-81.

242. Ogon M, Riedl-Huter C, Sterzinger W, et al. Radiologic Abnormalities and Low Back Pain in Elite Skiers. Clinical Orthopaedics and Related Research®. 2001;390:151-62.

243. Schoeb T, Peterhans L, Fröhlich S, et al. Health problems in youth competitive alpine skiing: A 12-month observation of 155 athletes around the growth spurt. Scandinavian Journal of Medicine & Science in Sports. 2020;30:1758-68.

244. Son B, Cho YJ, Jeong HS, et al. Injuries in Korean Elite Taekwondo Athletes: A Prospective Study. Int J Environ Res Public Health. 2020;17:5143.

245. HA D, Takemura M, Nagai S, et al. Prevalence of Low Back Pain of South Korean Baseball Players in Childhood and Adolescence: 1496 Board #171 June 1 8: 00 AM - 9: 30 AM. Medicine & Science in Sports & Exercise. 2017;49:418-9.

246. Kikuchi R, Hirano T, Watanabe K, et al. Gender differences in the prevalence of low back pain associated with sports activities in children and adolescents: a six-year annual survey of a birth cohort in Niigata City, Japan. BMC Musculoskelet Disord. 2019;20:327.

247. Grimmer K, Williams M. Gender-age environmental associates of adolescent low back pain. Appl Ergon. 2000;31:343-60.

248. Kountouris A, Portus M, Cook J. Quadratus lumborum asymmetry and lumbar spine injury in cricket fast bowlers. J Sci Med Sport. 2012;15:393-7.

249. Burnett AF, Khangure MS, Elliott BC, et al. Thoracolumbar disc degeneration in young fast bowlers in cricket: a follow-up study. Clinical Biomechanics. 1996;11:305-10.

250. Kamper SJ, Yamato TP, Williams CM. The prevalence, risk factors, prognosis and treatment for back pain in children and adolescents: An overview of systematic reviews. Best Practice & Research Clinical Rheumatology. 2016;30:1021-36.

251. Jeffries LJ, Milanese SF, Grimmer-Somers KA. Epidemiology of adolescent spinal pain: a systematic overview of the research literature. Spine (Phila Pa 1976). 2007;32:2630-7.

252. Hill JJ, Keating JL. Risk factors for the first episode of low back pain in children are infrequently validated across samples and conditions: a systematic review. Journal of Physiotherapy. 2010;56:237-44.

253. Junge T, Wedderkopp N, Boyle E, et al. The natural course of low back pain from childhood to young adulthood – a systematic review. Chiropractic & Manual Therapies. 2019;27:10.

254. Milanese S, Grimmer-Somers K. What is adolescent low back pain? Current definitions used to define the adolescent with low back pain. J Pain Res. 2010;3:57-66.

255. Fredrickson BE, Baker D, McHolick WJ, et al. The natural history of spondylolysis and spondylolisthesis. JBJS. 1984;66:699-707.

256. Syrmou E, Tsitsopoulos PP, Marinopoulos D, et al. Spondylolysis: a review and reappraisal. Hippokratia. 2010;14:17-21.

257. Brinjikji W, Luetmer PH, Comstock B, et al. Systematic literature review of imaging features of spinal degeneration in asymptomatic populations. AJNR Am J Neuroradiol. 2015;36:811-6.

258. Boden SD, Davis DO, Dina TS, et al. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects. A prospective investigation. J Bone Joint Surg Am. 1990;72:403-8.

259. Kalichman L, Kim DH, Li L, et al. Computed tomography-evaluated features of spinal degeneration: prevalence, intercorrelation, and association with self-reported low back pain. Spine J. 2010;10:200-8.

260. Wiesel SW, Tsourmas N, Feffer HL, et al. A study of computer-assisted tomography. I. The incidence of positive CAT scans in an asymptomatic group of patients. Spine (Phila Pa 1976). 1984;9:549-51.

261. Tofte JN, CarlLee TL, Holte AJ, et al. Imaging Pediatric Spondylolysis: A Systematic Review. Spine (Phila Pa 1976). 2017;42:777-82.

262. Bartley EJ, Fillingim RB. Sex differences in pain: a brief review of clinical and experimental findings. Br J Anaesth. 2013;111:52-8.

263. Tracy LM. Psychosocial factors and their influence on the experience of pain. Pain Rep. 2017;2:e602-e.

264. Rollman GB, Abdel-Shaheed J, Gillespie JM, et al. Does past pain influence current pain: biological and psychosocial models of sex differences. Eur J Pain. 2004;8:427-33.

265. McNair P, Lewis G. Levels of evidence in medicine. Int J Sports Phys Ther. 2012;7:474-81.

266. Wall J, Meehan WP, Trompeter K, et al. Incidence, prevalence and risk factors for low back pain in adolescent athletes: a systematic review and meta-analysis. British Journal of Sports Medicine. 2022;56:1299.

267. Low Back Pain Fact Sheet: National Institute of Neurological Disorders and Stroke; 2020 [updated April 27, 2020. Available from: https://www.ninds.nih.gov/Disorders/Patient-Caregiver-Education/Fact-Sheets/Low-Back-Pain-Fact-Sheet.

268. Clifford SN, Fritz JM. Children and adolescents with low back pain: a descriptive study of physical examination and outcome measurement. J Orthop Sports Phys Ther. 2003;33:513-22.

269. Gearing RE, Mian IA, Barber J, et al. A methodology for conducting retrospective chart review research in child and adolescent psychiatry. J Can Acad Child Adolesc Psychiatry. 2006;15:126-34.

270. Hess DR. Retrospective studies and chart reviews. Respir Care. 2004;49:1171-4.

271. Boyd NF, Pater JL, Ginsburg AD, et al. Observer variation in the classification of information from medical records. Journal of Chronic Diseases. 1979;32:327-32.

272. Allen G, Galer BS, Schwartz L. Epidemiology of complex regional pain syndrome: a retrospective chart review of 134 patients. Pain. 1999;80:539-44.

273. Rajeev J, Srinath S, Girimaji S, et al. A systematic chart review of the naturalistic course and treatment of early-onset bipolar disorder in a child and adolescent psychiatry center. Compr Psychiatry. 2004;45:148-54.

274. Hospital BCs. Boston Children's Hospital- About Us: Boston Children's Hospital; [Available from: https://www.childrenshospital.org/about-us.

275. Hospital BCs. Boston Children's Hospital Website- Sports Medicine Division: Boston Children's Hospital; [Available from: https://www.childrenshospital.org/departments/sports-medicine.

276. Harris PA, Taylor R, Minor BL, et al. The REDCap consortium: Building an international community of software platform partners. Journal of Biomedical Informatics. 2019;95:103208.

277. Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support. Journal of Biomedical Informatics. 2009;42:377-81.

278. Holm S. A Simple Sequentially Rejective Multiple Test Procedure. Scandinavian Journal of Statistics. 1979;6:65-70.

279. Clarsen B, Rønsen O, Myklebust G, et al. The Oslo Sports Trauma Research Center questionnaire on health problems: a new approach to prospective monitoring of illness and injury in elite athletes. British Journal of Sports Medicine. 2014;48:754.

280. Clarsen B, Steffen K, Berge HM, et al. Methods, challenges and benefits of a health monitoring programme for Norwegian Olympic and Paralympic athletes: the road from London 2012 to Tokyo 2020. British Journal of Sports Medicine. 2021:bjsports-2020-103717.

281. Moseid CH, Myklebust G, Fagerland MW, et al. The prevalence and severity of health problems in youth elite sports: A 6-month prospective cohort study of 320 athletes. Scand J Med Sci Sports. 2018;28:1412-23.

282. Bahr R, Clarsen B, Derman W, et al. International Olympic Committee consensus statement: methods for recording and reporting of epidemiological data on injury and illness in sport 2020 (including STROBE Extension for Sport Injury and Illness Surveillance (STROBE-SIIS)). British Journal of Sports Medicine. 2020;54:372.

283. Organization WH. Orientation programme on adolescent health for health-care providers. 2006.

284. Kuczmarski RJ, Ogden CL, Grummer-Strawn LM, et al. CDC growth charts: United States. Adv Data. 2000:1-27.

285. Swain MS, Henschke N, Kamper SJ, et al. An international survey of pain in adolescents. BMC Public Health. 2014;14:447.

286. Kalichman L, Kim DH, Li L, et al. Spondylolysis and spondylolisthesis: prevalence and association with low back pain in the adult community-based population. Spine. 2009;34:199-205.

287. Brenner JS. Sports Specialization and Intensive Training in Young Athletes. Pediatrics. 2016;138:e20162148.

288. Jayanthi N, Pinkham C, Dugas L, et al. Sports specialization in young athletes: evidence-based recommendations. Sports Health. 2013;5:251-7.

289. Abernethy L, Bleakley C. Strategies to prevent injury in adolescent sport: a systematic review. Br J Sports Med. 2007;41:627-38.

290. Maher C, Underwood M, Buchbinder R. Non-specific low back pain. The Lancet. 2017;389:736-47.

291. Chou R, Qaseem A, Snow V, et al. Diagnosis and treatment of low back pain: a joint clinical practice guideline from the American College of Physicians and the American Pain Society. Ann Intern Med. 2007;147:478-91.

292. Oliveira CB, Maher CG, Pinto RZ, et al. Clinical practice guidelines for the management of non-specific low back pain in primary care: an updated overview. European Spine Journal. 2018;27:2791-803.

293. Purcell L. Causes and prevention of low back pain in young athletes. Paediatr Child Health. 2009;14:533-8.

294. Hainline B, Derman W, Vernec A, et al. International Olympic Committee consensus statement on pain management in elite athletes. British Journal of Sports Medicine. 2017;51:1245.

295. d'Hemecourt Pierre A, Zurakowski D, Kriemler S, et al. Spondylolysis: Returning the Athlete to Sports Participation With Brace Treatment. Orthopedics. 2002;25:653-7.

296. Steiner ME, Micheli LJ. Treatment of symptomatic spondylolysis and spondylolisthesis with the modified Boston brace. Spine (Phila Pa 1976). 1985;10:937-43.

297. Ibiebele A, Scott D, D'Hemecourt P, et al. The use of bracing in the management of lumbar spondylolysis. PM&R. 2022;14:604-10.

298. Boyd ED, Mundluru SN, Feldman DS. Outcome of Conservative Management in the Treatment of Symptomatic Spondylolysis and Grade I Spondylolisthesis. Bull Hosp Jt Dis (2013). 2019;77:172-82.

299. Selhorst M, Fischer A, Graft K, et al. Long-Term Clinical Outcomes and Factors That Predict Poor Prognosis in Athletes After a Diagnosis of Acute Spondylolysis: A Retrospective Review With Telephone Follow-up. Journal of Orthopaedic & Sports Physical Therapy. 2016;46:1029-36.

300. Williamson OD, Cameron P. The Global Burden of Low Back Pain: International Association for the Study of Pain; 2021 [Available from: https://www.iasp-pain.org/resources/fact-sheets/the-global-burden-of-low-back-pain/.

301. Organization WH. Years of healthy life lost due to disability (YLD) 2022 [Available from: https://www.who.int/data/gho/indicator-metadata-registry/imr-details/160.

302. Hartvigsen J, Hancock MJ, Kongsted A, et al. What low back pain is and why we need to pay attention. Lancet. 2018;391:2356-67.

303. Ahlqwist A, Sällfors C. Experiences of low back pain in adolescents in relation to physiotherapy intervention. Int J Qual Stud Health Well-being. 2012;7:10.3402/qhw.v7i0.15471.

304. Podlog L, Wadey R, Stark A, et al. An adolescent perspective on injury recovery and the return to sport. Psychology of Sport and Exercise. 2013;14:437-46.

305. Bearden DJ, Feinstein A, Cohen LL. The influence of parent preprocedural anxiety on child procedural pain: mediation by child procedural anxiety. J Pediatr Psychol. 2012;37:680-6.

306. Braams BR, Davidow JY, Somerville LH. Developmental patterns of change in the influence of safe and risky peer choices on risky decision-making. Developmental Science. 2019;22:e12717.

307. Van Hoorn J, Crone EA, Van Leijenhorst L. Hanging Out With the Right Crowd: Peer Influence on Risk-Taking Behavior in Adolescence. Journal of Research on Adolescence. 2017;27:189-200.

308. Ciranka S, van den Bos W. Social Influence in Adolescent Decision-Making: A Formal Framework. Frontiers in Psychology. 2019;10.

309. Tomé G, Matos M, Simões C, et al. How can peer group influence the behavior of adolescents: explanatory model. Glob J Health Sci. 2012;4:26-35.

310. Nixon HL. EXPLAINING PAIN AND INJURY ATTITUDES AND EXPERIENCES IN SPORT IN TERMS OF GENDER, RACE, AND SPORTS STATUS FACTORS. Journal of Sport and Social Issues. 1996;20:33-44.

311. The Mental Impact of Sports Injury. 1 ed: Routledge; 2021.

312. Bekker S, Bolling C, H Ahmed O, et al. Athlete health protection: Why qualitative research matters. Journal of Science and Medicine in Sport. 2020;23:898-901.

313. Bittencourt NFN, Meeuwisse WH, Mendonça LD, et al. Complex systems approach for sports injuries: moving from risk factor identification to injury pattern recognition—narrative review and new concept. British Journal of Sports Medicine. 2016;50:1309.

314. Bekker S, Clark AM. Bringing complexity to sports injury prevention research: from simplification to explanation. British Journal of Sports Medicine. 2016;50:1489.

315. Hulme A, Finch CF. From monocausality to systems thinking: a complementary and alternative conceptual approach for better understanding the development and prevention of sports injury. Injury Epidemiology. 2015;2:31.

316. Bolling C. "Who me? I thought you would never ask!" Applying qualitative methods in sports injury prevention research (PhD Academy Award). British Journal of Sports Medicine. 2021;55:125.

317. Verhagen E, Bolling C. We dare to ask new questions. Are we also brave enough to change our approaches? TRANSLATIONAL SPORTS MEDICINE. 2018;1:54-5.

318. Sackett DL, Straus SE, Richardson WS, et al. Evidence-based medicine: How to practice and teach EBM. 2 ed. New York: Churchill Livingstone; 2000.

319. Staniszewska S, Crowe S, Badenoch D, et al. The PRIME project: developing a patient evidence-base. Health Expectations. 2010;13:312-22.

320. Braun V, Clarke V. Thematic Analysis: A Practical Guide: SAGE Publishing; 2021.

321. Braun V, Clarke V. Using thematic analysis in psychology. Qualitative Research in Psychology. 2006;3:77-101.

322. Braun V, Clarke V. Reflecting on reflexive thematic analysis. Qualitative Research in Sport, Exercise and Health. 2019;11:589-97.

323. Terry G, Hayfield N, Clarke V, et al. Thematic analysis. In C. Willig, & W. Stainton Rogers (Eds.), The SAGE Handbook of Qualitative Research in Psychology (17-37). (2nd). 2nd ed: SAGE Publications; 2017.

324. Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. International Journal for Quality in Health Care. 2007;19:349-57.

325. Braun V, Clarke V. To saturate or not to saturate? Questioning data saturation as a useful concept for thematic analysis and sample-size rationales. Qualitative Research in Sport, Exercise and Health. 2021;13:201-16.

326. Vianin M. Psychometric properties and clinical usefulness of the Oswestry Disability Index. J Chiropr Med. 2008;7:161-3.

327. Grönblad M, Hupli M, Wennerstrand P, et al. Intel-correlation and Test-Retest Reliability of the Pain Disability Index (PDI) and the Oswestry Disability Questionnaire (ODQ) and Their Correlation with Pain Intensity in Low Back Pain Patients. The Clinical Journal of Pain. 1993;9.

328. Silsbury Z, Goldsmith R, Rushton A. Systematic review of the measurement properties of self-report physical activity questionnaires in healthy adult populations. BMJ Open. 2015;5:e008430.

329. Craig CL, Marshall AL, Sjöström M, et al. International physical activity questionnaire: 12-country reliability and validity. Med Sci Sports Exerc. 2003;35:1381-95.

330. Nixon HL. A Social Network Analysys of Influences On Athletes To Play With Pain and Injuries. Journal of Sport and Social Issues. 1992;16:127-35.

331. Deroche T, Woodman T, Stephan Y, et al. Athletes' inclination to play through pain: a coping perspective. Anxiety, Stress, & Coping. 2011;24:579-87.

332. Clement D, Arvinen-Barrow M, Fetty T. Psychosocial responses during different phases of sport-injury rehabilitation: a qualitative study. J Athl Train. 2015;50:95-104.

333. Goddard K, Roberts C-M, Byron-Daniel J, et al. Psychological factors involved in adherence to sport injury rehabilitation: a systematic review. International Review of Sport and Exercise Psychology. 2021;14:51-73.

334. Clark R, Stanfill AG. A Systematic Review of Barriers and Facilitators for Concussion Reporting Behavior Among Student Athletes. Journal of Trauma Nursing | JTN. 2019;26.

335. Iñigo MM, Podlog L, Hall MS. Why Do Athletes Remain Committed to Sport After Severe Injury? An Examination of the Sport Commitment Model. The Sport Psychologist. 2015;29:143-55.

336. Burke M. Obeying Until It Hurts: Coach-Athlete Relationships. Journal of the Philosophy of Sport. 2001;28:227-40.

337. Gosai J, Jowett S, Nascimento-Júnior JRAD. When leadership, relationships and psychological safety promote flourishing in sport and life. Sports Coaching Review. 2021:1-21.

338. Vella SA, Oades LG, Crowe TP. The relationship between coach leadership, the coach–athlete relationship, team success, and the positive developmental experiences of adolescent soccer players. Physical Education and Sport Pedagogy. 2013;18:549-61.

339. Tuakli-Wosornu YA, Goutos D, Ramia I, et al. 'Knowing we have these rights does not always mean we feel free to use them': athletes' perceptions of their human rights in sport. BMJ Open Sport & Exercise Medicine. 2022;8:e001406.

340. Haber MG, Cohen JL, Lucas T, et al. The relationship between self-reported received and perceived social support: A meta-analytic review. American Journal of Community Psychology. 2007;39:133-44.

341. Lakey B, Orehek E. Relational regulation theory: a new approach to explain the link between perceived social support and mental health. Psychol Rev. 2011;118:482-95.

342. Thiel A, Schubring A, Schneider S, et al. Health in Elite Sports ? a ?Bio-Psycho-Social? Perspective. Deutsche Zeitschrift für Sportmedizin. 2015;66:241-7 doi.

343. Brewer BW, Van Raalte JL, Linder DE. Athletic identity: Hercules' muscles or Achilles heel? International Journal of Sport Psychology. 1993;24:237-54.

344. Weinberg R, Vernau D, Horn T. Playing Through Pain and Injury: Psychosocial Considerations. Journal of Clinical Sport Psychology. 2013;7:41-59.

345. Nippert AH. "I have four months to compete, eight months to heal": Playing through pain and injuries in girls' interscholastic gymnastics [Ph.D.]. Ann Arbor: University of Minnesota; 2005.

346. Roderick M, Waddington I, Parker G. PLAYING HURT: Managing Injuries in English Professional Football. International Review for the Sociology of Sport. 2000;35:165-80.

347. Hammond LE, Lilley JM, Pope GD, et al. 'We've just learnt to put up with it': an exploration of attitudes and decision-making surrounding playing with injury in English professional football. Qualitative Research in Sport, Exercise and Health. 2014;6:161-81.

348. Bonell Monsonís O, Verhagen E, Kaux J-F, et al. 'I always considered I needed injury prevention to become an elite athlete': the road to the Olympics from the athlete and staff perspective. BMJ Open Sport & Exercise Medicine. 2021;7:e001217.

349. Verhagen EALM, van Stralen MM, van Mechelen W. Behaviour, the Key Factor for Sports Injury Prevention. Sports Medicine. 2010;40:899-906.

350. Roy-Davis K, Wadey R, Evans L. A grounded theory of sport injury-related growth. Educational Publishing Foundation; 2017. p. 35-52.

351. McEwen K, Young K. Ballet and pain: reflections on a risk-dance culture. Qualitative Research in Sport, Exercise and Health. 2011;3:152-73.

352. Mountjoy M, Vertommen T, Greinig S, et al. “Nothing About Us, Without Us”: Empowering the Youth Athlete Voice in #SafeSport. Clinical Journal of Sport Medicine. 2022;32.

353. Bekker S, Posbergh A. Safeguarding in sports settings: unpacking a conflicting identity. Qualitative Research in Sport, Exercise and Health. 2022;14:181-98.

354. Mountjoy M, Rhind DJ, Tiivas A, et al. Safeguarding the child athlete in sport: a review, a framework and recommendations for the IOC youth athlete development model. Br J Sports Med. 2015;49:883-6.

355. Roberts V, Sojo V, Grant F. Organisational factors and non-accidental violence in sport: A systematic review. Sport Management Review. 2020;23:8-27.

356. Kavanagh EJ. The Dark side of sport: athlete narratives on maltreatment in high performance environments: Bournemouth University; 2014.

357. Mayer J, Giel KE, Malcolm D, et al. Compete or rest? Willingness to compete hurt among adolescent elite athletes. Psychology of Sport and Exercise. 2018;35:143-50.

358. Mayer J, Thiel A. Presenteeism in the elite sports workplace: The willingness to compete hurt among German elite handball and track and field athletes. International Review for the Sociology of Sport. 2016;53:49-68.

359. Goutos D, Bekker S, Galea N, et al. 394 Preventing intentional injury (harassment and abuse) in sport: assessing athletes’ knowledge, attitudes, and beliefs about their human rights in the olympic and paralympic movements. British Journal of Sports Medicine. 2021;55:A150-A.

360. Foster NE, Anema JR, Cherkin D, et al. Prevention and treatment of low back pain: evidence, challenges, and promising directions. The Lancet. 2018;391:2368-83.

361. Arnau JM, Vallano A, Lopez A, et al. A critical review of guidelines for low back pain treatment. Eur Spine J. 2006;15:543-53.

362. Wilkie K, Thornton JS, Vinther A, et al. Clinical management of acute low back pain in elite and subelite rowers: a Delphi study of experienced and expert clinicians. Br J Sports Med. 2021;55:1324-34.

363. Atlas LY, Wager TD. How expectations shape pain. Neuroscience Letters. 2012;520:140-8.

364. Grøn S, Jensen RK, Jensen TS, et al. Back beliefs in patients with low back pain: a primary care cohort study. BMC Musculoskeletal Disorders. 2019;20:578.

365. Darlow B, Fullen BM, Dean S, et al. The association between health care professional attitudes and beliefs and the attitudes and beliefs, clinical management, and outcomes of patients with low back pain: a systematic review. Eur J Pain. 2012;16:3-17.

366. Darlow B, Dowell A, Baxter GD, et al. The enduring impact of what clinicians say to people with low back pain. Ann Fam Med. 2013;11:527-34.

367. Werner EL, Ihlebæk C, Skouen JS, et al. Beliefs About Low Back Pain in the Norwegian General Population: Are They Related to Pain Experiences and Health Professionals? Spine. 2005;30.

368. Leo AG. Snowball Sampling. The Annals of Mathematical Statistics. 1961;32:148-70.

369. Darlow B, Perry M, Mathieson F, et al. The development and exploratory analysis of the Back Pain Attitudes Questionnaire (Back-PAQ). BMJ Open. 2014;4:e005251.

370. Krägeloh C, Medvedev ON, Dean S, et al. Rasch analysis of the Back Pain Attitudes Questionnaire (Back-PAQ). Disability and Rehabilitation. 2022;44:3228-35.

371. University of Otago WDoHS. Back Pain Attitude Questionnaire (Back-PAQ): University of Otago; [Available from: https://www.otago.ac.nz/wellington/departments/primaryhealthcaregeneralpractice/research/otago656643.html#Use_in_research.

372. Dijkstra HP, Mc Auliffe S, Ardern CL, et al. Oxford consensus on primary cam morphology and femoroacetabular impingement syndrome: part 1—definitions, terminology, taxonomy and imaging outcomes. British Journal of Sports Medicine. 2022:bjsports-2022-106085.

373. Caneiro J, O'Sullivan P, Lipp OV, et al. Evaluation of implicit associations between back posture and safety of bending and lifting in people without pain. Scandinavian Journal of Pain. 2018;18:719-28.

374. Qaseem A, Wilt TJ, McLean RM, et al. Noninvasive Treatments for Acute, Subacute, and Chronic Low Back Pain: A Clinical Practice Guideline From the American College of Physicians. Ann Intern Med. 2017;166:514-30.

375. National Guideline C. National Institute for Health and Care Excellence: Guidelines. Low Back Pain and Sciatica in Over 16s: Assessment and Management. London: National Institute for Health and Care Excellence (NICE). Copyright © NICE, 2016.; 2016.

376. Pedersen JR, Andreucci A, Thorlund JB, et al. Prevalence, frequency, adverse events, and reasons for analgesic use in youth athletes: A systematic review and meta-analysis of 44,381 athletes. Journal of Science and Medicine in Sport. 2022;25:810-9.

377. Harle CA, Danielson EC, Derman W, et al. Analgesic Management of Pain in Elite Athletes: A Systematic Review. Clinical Journal of Sport Medicine. 2018;28.

378. Delitto A, George SZ, Van Dillen L, et al. Low Back Pain. Journal of Orthopaedic & Sports Physical Therapy. 2012;42:A1-A57.

379. Traeger AC, Hübscher M, Henschke N, et al. Effect of Primary Care–Based Education on Reassurance in Patients With Acute Low Back Pain: Systematic Review and Meta-analysis. JAMA Internal Medicine. 2015;175:733-43.

380. Henrotin YE, Cedraschi C, Duplan B, et al. Information and Low Back Pain Management: A Systematic Review. Spine. 2006;31.

381. Moseley GL, Butler DS. Fifteen Years of Explaining Pain: The Past, Present, and Future. J Pain. 2015;16:807-13.

382. Moseley GL, Nicholas MK, Hodges PW. A Randomized Controlled Trial of Intensive Neurophysiology Education in Chronic Low Back Pain. The Clinical Journal of Pain. 2004;20.

383. Perich D, Burnett A, O'Sullivan P, et al. Low back pain in adolescent female rowers: a multi-dimensional intervention study. Knee Surgery, Sports Traumatology, Arthroscopy. 2011;19:20-9.

384. O'Sullivan K, O'Keeffe M, Forster BB, et al. Managing low back pain in active adolescents. Best Practice & Research Clinical Rheumatology. 2019;33:102-21.

385. Dixit R. Chapter 47 - Low Back Pain. In: Firestein GS, Budd RC, Gabriel SE, McInnes IB, O'Dell JR, editors. Kelley and Firestein's Textbook of Rheumatology (Tenth Edition): Elsevier; 2017. p. 696-716.

386. Traeger AC, Buchbinder R, Elshaug AG, et al. Care for low back pain: can health systems deliver? Bull World Health Organ. 2019;97:423-33.

387. Buchbinder R, van Tulder M, Öberg B, et al. Low back pain: a call for action. The Lancet. 2018;391:2384-8.

388. Lin IB, Sullivan PB, Coffin JA, et al. Disabling chronic low back pain as an iatrogenic disorder: a qualitative study in Aboriginal Australians. BMJ Open. 2013;3:e002654.

389. Illeez OG, Akpinar P, Bahadir Ulger FE, et al. Low back pain in children and adolescents: Real life experience of 106 patients. North Clin Istanb. 2020;7:603-8.

390. Timpka T, Fagher K, Bargoria V, et al. 'The Little Engine That Could': A Qualitative Study of Medical Service Access and Effectiveness among Adolescent Athletics Athletes Competing at the Highest International Level. Int J Environ Res Public Health. 2021;18.

391. Valovich McLeod T, Wagner AJ, Parsons JT, et al. Adolescent athletes' social perspectives following a sport-related concussion. British Journal of Sports Medicine. 2017;51:A46.

# Chapter 8: Appendices

## Appendix 2-1: Differences between protocol and review

In the protocol, methodological quality of the included studies was going to be assessed using the Newcastle Ottawa scale in addition to the LBP-specific quality appraisal tool developed by Lebeouf-Yde and Lauritsen. Only the LBP-specific tool was used. KT and JW were the reviewers who assessed for quality, not FW and JW as listed.

# Appendix 2-2: Search strategy

**Medline**

1. Low Back Pain/ OR Sciatica/
2. (low* adj3 (back pain* OR back ache* OR backache* OR back injur*)).ti,ab.
3. ((Lumbal OR lumbar OR lumbosacral OR lumbosacroiliac) adj2 (pain* OR ache* OR syndrome OR strain* OR injur*)).ti,ab.
4. (Lumbago OR lumbodynia OR lumbalgesia OR lumbalgia OR Sciatica).ti,ab.
5. or/1-4
6. ATHLETES/ OR Athletic Injuries/ OR BASEBALL/ OR BICYCLING/ OR HOCKEY/ OR Racquet Sports/ OR WRESTLING/ exp sports/
7. (Rowing OR rower* OR sculling OR athlet* OR gymnast* OR cricket OR bowler* OR pitcher* OR wrestl* OR hockey OR baseball OR golf OR kayak* OR canoei* OR hammer throw* OR martial art* OR basketball OR bowling OR football OR lacrosse OR racquetball OR rugby OR soccer OR softball OR squash OR tennis OR volleyball).ti,ab.
8. (Sport* adj3 injur*).ti,ab.
9. or/6-8
10. Epidemiologic studies/
11. Exp case control studies/
12. Exp cohort studies/
13. Case control.tw.
14. (cohort adj (study or studies)).tw.
15. Cohort analy$.tw.
16. (Follow up adj (study or studies)).tw.
17. (observational adj (study or studies)).tw.
18. Longitudinal.tw.
19. Retrospective.tw.
20. Cross sectional.tw.
21. Cross-sectional studies/
22. or/9-20
23. and/5,9,22

**Embase**

1. 'low back pain'/exp OR 'sciatica'/exp
2. (low* NEAR/3 (‘back pain*’ OR ‘back ache*’ OR ‘backache*’ OR ‘back injur*’)):ti,ab
3. ((Lumbal OR lumbar OR lumbosacral OR lumbosacroiliac) NEAR/2 (pain* OR ache* OR syndrome OR strain* OR injur*)):ti,ab
4. (Lumbago OR lumbodynia OR lumbalgesia OR lumbalgia OR sciatica):ti,ab
5. #1 OR #2 OR #3 OR #4
6. 'athlete'/exp OR 'sport injury'/exp OR 'sport'/exp OR 'athletics'/exp OR 'baseball'/exp OR 'cricket (sport)'/exp OR 'cycling'/exp OR 'hockey'/exp OR 'ice hockey'/exp OR 'racquet sport'/exp
7. (Rowing OR rower* OR sculling OR athlet* OR gymnast* OR cricket OR bowler* OR pitcher* OR wrestl* OR hockey OR

baseball OR golf OR kayak* OR canoei* OR ‘hammer throw*’ OR ‘martial art*’ OR basketball OR bowling OR football OR lacrosse OR racquetball OR rugby OR soccer OR softball OR squash OR tennis OR volleyball):ti,ab

8. (Sport* NEAR/3 injur*):ti,ab
9. #6 OR #7 OR #8
10. 'clinical study'/de
11. 'case control study'/exp
12. 'family study'/exp
13. 'longitudinal study'/exp
14. 'retrospective study'/exp
15. 'prospective study'/exp
16. 'randomized controlled trial'/exp
17. #14 NOT #15
18. 'cohort analysis'/exp
19. (Cohort NEAR/1 (study or studies)):ti,ab
20. (‘Case control’ NEAR/1 (study or studies)):ti,ab
21. (‘follow up’ NEAR/1 (study or studies)):ti,ab
22. (observational NEAR/1 (study or studies)):ti,ab
23. (epidemiologic* NEAR/1 (study or studies)):ti,ab
24. (‘cross sectional’ NEAR/1 (study or studies)):ti,ab
25. #10 OR #11 OR #12 OR #13 OR #14 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24
26. #5 AND #9 AND #25

**CINAHL**

1. (MH "Low Back Pain") OR (MH "Sciatica")
2. TI (low* N3 (“back pain*” OR “back ache*” OR “backache*” OR “back injur*”)) OR AB (low* N3 (“back pain*” OR “back ache*” OR “backache*” OR “back injur*”))
3. TI ((Lumbal OR lumbar OR lumbosacral OR lumbosacroiliac) N2 (pain* OR ache* OR syndrome OR strain* OR injur*)) OR AB ((Lumbal OR lumbar OR lumbosacral OR lumbosacroiliac) N2 (pain* OR ache* OR syndrome OR strain* OR injur*))
4. TI (Lumbago OR lumbodynia OR lumbalgesia OR lumbalgia OR sciatica) OR AB (Lumbago OR lumbodynia OR lumbalgesia OR lumbalgia OR sciatica)
5. S1 OR S2 OR S3 OR S4
6. (MH "Rowing") OR (MH "Athletes+") OR (MH "Athletic Injuries") OR (MH "Baseball Injuries") OR (MH "Basketball Injuries") OR (MH "Cricket Injuries") OR (MH "Cycling Injuries") OR (MH "Fencing Injuries") OR (MH "Golf Injuries") OR (MH "Gymnastics Injuries") OR (MH "Hockey Injuries") OR (MH "Racquet Sports Injuries") OR (MH "Baseball") OR (MH "Cricket (Sports)") OR (MH "Cycling") OR (MH "Hockey") OR (MH "Racquet Sports") OR (MH "Sports+")
7. TI (Rowing OR rower* OR sculling OR athlet* OR gymnast* OR cricket OR bowler* OR pitcher* OR wrestl* OR hockey OR baseball OR golf OR kayak* OR canoei* OR “hammer throw*” OR “martial art*” OR basketball OR bowling OR football OR lacrosse OR racquetball OR rugby OR soccer OR softball OR squash OR tennis OR volleyball) OR AB (Rowing OR rower* OR

sculling OR athlet* OR gymnast* OR cricket OR bowler* OR pitcher* OR wrestl* OR hockey OR baseball OR golf OR kayak* OR canoei* OR “hammer throw*” OR “martial art*” OR basketball OR bowling OR football OR lacrosse OR racquetball OR rugby OR soccer OR softball OR squash OR tennis OR volleyball)

8. TI(Sport* N3 injur*) OR AB (Sport* N3 injur*)
9. S6 OR S7 OR S8
10. (MH "Prospective Studies")
11. (MH "Case Control Studies+")
12. (MH "Correlational Studies")
13. (MH "Nonconcurrent Prospective Studies")
14. (MH "Cross Sectional Studies")
15. TI (cohort N1 (study OR studies)) OR AB (cohort N1 (study OR studies))
16. TI (epidemiologic* N1 (study or studies)) OR AB (epidemiologic* N1 (study or studies))
17. TI (“follow up” N1 (study or studies)) OR AB (“follow up” N1 (study or studies))
18. TI (observational N1 (study or studies)) OR AB (observational N1 (study or studies))
19. TI (“cross sectional” N1 (study or studies)) OR AB (“cross sectional” N1 (study or studies))
20. S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18 OR S19
21. S5 AND S9 AND S20

**Web of Science**

TS =(((low* NEAR/3 (“back pain*” OR “back ache*” OR “backache*” OR “back injur*”)) OR ((Lumbal OR lumbar OR lumbosacral OR lumbosacroiliac) NEAR/2 (pain* OR ache* OR syndrome OR strain* OR injur*)) OR (Lumbago OR lumbodynia OR lumbalgesia OR lumbalgia OR sciatica)) **AND** ((Cohort OR “Case control” OR epidemiologic* OR “follow up” OR observational OR “cross sectional”) NEAR/1 (study or studies)) **AND** (Rowing OR rower* OR sculling OR athlet* OR gymnast* OR cricket OR bowler* OR pitcher* OR wrestl* OR hockey OR baseball OR golf OR kayak* OR canoei* OR “hammer throw*” OR “martial art*” OR basketball OR bowling OR football OR lacrosse OR racquetball OR rugby OR soccer OR softball OR squash OR tennis OR volleyball) OR (sport* NEAR/3 injur*))

**Scopus**

TITLE-ABS(((low* W/3 (“back pain*” OR “back ache*” OR “backache*” OR “back injur*”)) OR ((Lumbal OR lumbar OR lumbosacral OR lumbosacroiliac) W/2 (pain* OR ache* OR syndrome OR strain* OR injur*)) OR (Lumbago OR lumbodynia OR lumbalgesia OR lumbalgia OR sciatica)) **AND** ((Cohort OR “Case control” OR epidemiologic* OR “follow up” OR observational OR “cross sectional”) W/1 (study or studies)) **AND** (Rowing OR rower* OR sculling OR athlet* OR gymnast* OR cricket OR bowler* OR pitcher* OR wrestl* OR hockey OR baseball OR golf OR kayak* OR canoei* OR “hammer throw*” OR “martial art*” OR basketball OR bowling OR football OR lacrosse OR racquetball OR rugby OR soccer OR softball OR squash OR tennis OR volleyball) OR (sport* W/3 injur*))

## Appendix 2-3: Study methodological quality appraisal tool

| |
|---|
| **A: Is the final sample representative of the target population?** |
| 1. At least one of the following must apply to the study: an entire target population, randomly selected sample, or sample stated to represent the target population |
| 2. At least one of the following: reasons for nonresponse described, non-responders described, comparison of responders and non-responders, or comparison of sample and target population |
| 3. Response rate and, if applicable, drop-out rate reported |
| **B: Quality of the data?** |
| 4. Were the data primary data of back pain or were they taken from a survey not specifically designed for that purpose? |
| 5. Were the data collected from each adult directly or were they collected from a proxy? |
| 6. Was the same mode of data collection used for all subjects? |
| 7. At least one of the following in the case of a questionnaire: a validated questionnaire or at least tested for reproducibility |
| 8. At least one of the following in the case of an interview: interview validated, tested for reproducibility, or adequately described and standardized |
| 9. At least one of the following in the case of an examination: examination validated, tested for reproducibility, or adequately described and standardized |
| **C: Definition of back pain** |
| 10. Was there a precise anatomic delineation of the back area or reference to an easily obtainable article that contains such specification? |
| 11. Was there further useful specification of the definition of back pain, or question(s) put to study subjects quoted such as the frequency, duration, or intensity, and character of the pain. Or was there reference to an easily obtainable article that contains such specification? |
| 12. Were recall periods clearly stated: e.g., 1 week, 1 month, or lifetime? |

# Appendix 2-4: Study reporting explanation

During data extraction, it appeared that there was dual (or multiple) publishing by some studies. The study by Pasanen et al. from 2016, the conference abstract by Pasanen et al. from 2014, and the study by Rossi et al. from 2018 are reported as Rossi et al. 2018 (a), (b), and (c). The first authors for these papers were contacted, and it was confirmed that the 2014 conference abstract reported preliminary results for the 2016 paper, and the 2018 paper included a follow up of the same participants.

The studies by Kujala et al. 1992, 1994, 1996, and 1997 will be reported under the study heading Kujala et al. 1997 (a), (b), (c), (d). The first author was contacted, and it was confirmed that Kujala et al. 1992 reported baseline associations, and each of the subsequent studies reported results from follow ups of the initial cohort.

The studies by Swain et al. 2017 and 2018 will be reported under the study heading Swain et al. 2017 (a) and (b). Attempts to contact the authors for clarification were unsuccessful. For the purposes of this review, it was assumed that the two studies used the same participant group, given similarities in participant numbers and demographic data.

The studies by Sekiguchi et al. 2018 and Yabe et al. 2019 will be reported under the study heading Sekiguchi et al. 2018 (a) and (b). Attempts to contact the authors for clarification were unsuccessful. For the purposes of this review, it was assumed that the two studies used the same participant group, given similarities in participant numbers and demographic data.

The study by Hutchinson 1999 included both a prospective and retrospective component. The prospective component will be reported as Hutchinson 1999 (a), and the retrospective component Hutchinson 1999 (b).

There were three studies by the same first author in the year 2020. These will be reported as Yabe et al. 2020 (a), (b), and (c).

The studies by Hagiwara et al. 2020 and Yabe et al. 2020 (a) will be reported under the study heading Yabe et al. 2020 (a) and (1a). Attempts to contact the authors for clarification were unsuccessful. For the purposes of this review, it was assumed that the two studies used the same participant group, given similarities in participant numbers and demographic data.

# Appendix 2-5: meta-regression results

**Cohort six-month risk**

Mixed-Effects Model (k = 4; $tau^2$ estimator: DL)

$tau^2$ (estimated amount of residual heterogeneity): 0 (SE = 0.00)
tau (square root of estimated $tau^2$ value): 0
$I^2$ (residual heterogeneity / unaccounted variability): 0.00%
$H^2$ (unaccounted variability / sampling variability): 1.00
$R^2$ (amount of heterogeneity accounted for): 100.00%

Test for Residual Heterogeneity:
QE(df = 2) = 1.34, p-val = 0.51

Test of Moderators (coefficient 2):
QM(df = 1) = 8.59, p-val = 0.00

Model results**:**

| | **Estimate** | **Confidence interval** | **P-value** |
|---|---|---|---|
| **Intercept** | 0.35 | 0.28 to 0.41 | <.0001 |
| **Methodological quality** | 0.30 | 0.10 to 0.51 | 0.00 |

**Cohort 12-month risk**

Mixed-Effects Model (k = 4; $tau^2$ estimator: DL)

$tau^2$ (estimated amount of residual heterogeneity): 0.00 (SE = 0.00)
tau (square root of estimated $tau^2$ value): 0.00
$I^2$ (residual heterogeneity / unaccounted variability): 4.27%
$H^2$ (unaccounted variability / sampling variability): 1.04
$R^2$ (amount of heterogeneity accounted for): 99.98%

Test for Residual Heterogeneity:
QE(df = 1) = 1.04, p-val = 0.31

Test of Moderators (coefficients 2:3):
QM(df = 2) = 431.55, p-val < .0001

Model results:

| | **Estimate** | **Confidence interval** | **P-value** |
|---|---|---|---|
| **Intercept** | 0.24 | 0.18 to 0.31 | <.0001 |
| **LBP definition** | 0.68 | 0.61 to 0.75 | <.0001 |
| **Methodological quality** | -0.59 | -0.69 to -0.48 | <.0001 |

**Cross-sectional point prevalence (high quality studies)**

Mixed-Effects Model (k = 15; $tau^2$ estimator: DL)

$tau^2$ (estimated amount of residual heterogeneity): 0.01 (SE = 0.01)
tau (square root of estimated $tau^2$ value): 0.09
$I^2$ (residual heterogeneity / unaccounted variability): 96.30%
$H^2$ (unaccounted variability / sampling variability): 27.00
$R^2$ (amount of heterogeneity accounted for): 45.86%

Test for Residual Heterogeneity:
QE(df = 9) = 242.98, p-val < .0001

Test of Moderators (coefficients 2:6):
QM(df = 5) = 19.42, p-val = 0.002

Model results:

| | Estimate | Confidence interval | P-value |
|---|---|---|---|
| **Intercept** | -0.41 | -0.99 to 0.17 | 0.17 |
| **LBP definition** | 0.23 | -0.005 to 0.47 | 0.05 |
| **N** | -0.0001 | -0.00 to -0.00 | 0.02 |
| **Sport2** | 0.03 | -0.15 to 0.041 | <.0001 |
| **Sex** | 0.21 | -0.03 to 0.44 | 0.07 |
| **Outcome** | -0.16 | -0.33 to 0.01 | 0.06 |

**Cross-sectional three-month prevalence (high quality studies)**
Mixed-Effects Model (k = 4; $tau^2$ estimator: DL)
$tau^2$ (estimated amount of residual heterogeneity): 0 (SE = 0.00)
tau (square root of estimated $tau^2$ value): 0
$I^2$ (residual heterogeneity / unaccounted variability): 0.00%
$H^2$ (unaccounted variability / sampling variability): 1.00
$R^2$ (amount of heterogeneity accounted for): 100.00%

Test for Residual Heterogeneity:
QE(df = 2) = 1.1613, p-val = 0.5595

Test of Moderators (coefficient 2):
QM(df = 1) = 6.3593, p-val = 0.0117

Model results:

| | Estimate | Confidence interval | P-value |
|---|---|---|---|
| **Intercept** | 0.71 | 0.66 to 0.76 | <.0001 |
| **LBP definition** | 0.08 | 0.02 to 0.15 | 0.01 |

**Cross-sectional 12-month prevalence (high quality studies)**
Mixed-Effects Model (k = 7; $tau^2$ estimator: DL)
$tau^2$ (estimated amount of residual heterogeneity): 0.10 (SE = 0.15)
tau (square root of estimated $tau^2$ value): 0.32
$I^2$ (residual heterogeneity / unaccounted variability): 98.23%
$H^2$ (unaccounted variability / sampling variability): 56.37
$R^2$ (amount of heterogeneity accounted for): 0.00%

Test for Residual Heterogeneity:
QE(df = 1) = 56.37, p-val < .0001

Test of Moderators (coefficients 2:6):
QM(df = 5) = 1.15, p-val = 0.95

Model results:

| | Estimate | Confidence interval | P-value |
|---|---|---|---|
| **Intercept** | -0.08 | -2.02 to 1.87 | 0.94 |
| **LBP definition** | 0.31 | -0.69 to 1.32 | 0.54 |
| **Number of participants** | 0.00 | -0.00 to .00 | 0.96 |
| **Sport** | 0.01 | -0.07 to 0.09 | 0.77 |
| **Sex** | 0.30 | -0.54 to 1.13 | 0.49 |
| **Data collection mode** | -0.07 | -0.48 to 0.31 | 0.71 |

# Appendix 3-1: Institutional Review Board exemption

Boston Children's Hospital
**Institutional Review Board (IRB)**
300 Longwood Avenue
Mailstop BCH 3164
Boston, MA 02115
Tel: (617) 355-7052
Fax: (617) 730-0226
www.bostonchildrens.org/research/irb

**Principal Investigator** William Meehan, MD

**Protocol Number** IRB-P00035872

**Protocol Title** Low Back Pain Etiologies and Presentation in Adolescent Athletes

**Date:** July 17, 2020

## NOTICE OF EXEMPTION

**IRB Exemption Date: 7/9/2020**

Please Note: The initiation or continuation of clinical research activities must follow the Boston Children's Hospital (BCH) advisories or policies. The IRB is continuing to review protocols; **however BCH is currently restricting the conduct of clinical research in response to the COVID-19 crisis.** Details of these restrictions and an IRB Q&A document are available at http://www.childrenshospital.org/research/IRB and both will be updated as changes are implemented. Please contact the IRB Office with any questions you may have.

---

The Institutional Review Board (IRB) has reviewed the above referenced protocol and determined that it qualifies as exempt from the requirements of 45 CFR 46.

This protocol was determined to be exempt because it is limited to research activities in which the only involvement of human subjects will be in the following category described in 45 CFR 46.104 (d):

(4) Secondary research for which consent is not required: Secondary research uses of identifiable private information or identifiable biospecimens, if at least one of the following criteria is met:

> (iii) The research involves only information collection and analysis involving the investigator's use of identifiable health information when that use is regulated under 45 CFR parts 160 and 164, subparts A and E, for the purposes of "health care operations" or "research" as those terms are defined at 45 CFR 164.501 or for "public health activities and purposes" as described under 45 CFR 164.512(b);

Sincerely,

Theresa Williams, IRB Administrator
For the Institutional Review Board

Tell us how we are doing! https://www.surveymonkey.com/s/irbsatisfactionsurvey

# Appendix 3-2: Customised data extraction form

**Demographic data**

MRN

Date of birth

Sex

Height

Weight

BMI

Primary Sport
- Baseball
- Basketball
- Cheerleading
- Crew
- Cross Country
- Dance
- Diving
- Fencing
- Field Hockey
- Football
- Golf
- Gymnastics
- Ice hockey
- Lacrosse
- Rugby
- Sailing
- Skiing
- Squash
- Soccer
- Softball
- Swimming
- Tennis
- Track and Field
- Volleyball
- Water polo
- Wrestling
- Other

Primary position

Level of competition
- Junior varsity
- Varsity
- Club/travel
- College club

College varsity
High school (unspecified)
College (unspecified)
Middle School
Not specified in chart

Does the chart contain data on volume of primary sport participation? Y/N

Secondary sport
Baseball
Basketball
Cheerleading
Crew
Cross Country
Dance
Diving
Fencing
Field Hockey
Football
Golf
Gymnastics
Ice hockey
Lacrosse
Rugby
Sailing
Skiing
Squash
Soccer
Softball
Swimming
Tennis
Track and Field
Volleyball
Water polo
Wrestling
Other

Primary position

Level of competition
Junior varsity
Varsity
Club/travel
College club
College varsity
High school (unspecified)
College (unspecified)
Middle School
Not specified in chart

Does the chart contain data on volume of secondary sport participation? Y/N

Tertiary sport

- Baseball
- Basketball
- Cheerleading
- Crew
- Cross Country
- Dance
- Diving
- Fencing
- Field Hockey
- Football
- Golf
- Gymnastics
- Ice hockey
- Lacrosse
- Rugby
- Sailing
- Skiing
- Squash
- Soccer
- Softball
- Swimming
- Tennis
- Track and Field
- Volleyball
- Water polo
- Wrestling
- Other

Primary position

Level of competition

- Junior varsity
- Varsity
- Club/travel
- College club
- College varsity
- High school (unspecified)
- College (unspecified)
- Middle School
- Not specified in chart

Does the chart contain data on volume of secondary sport participation? Y/N

Other demographic notes

**Initial visit**

Date of initial clinic visit

Age at initial visit

Modalities used for diagnosis
- Clinical (no imaging)
- X ray
- MRI
- Ultrasound

Date initial onset of symptoms

Onset type
- Acute
- Insidious

Mechanism of injury

Time of season during onset
- In-season
- Pre-season
- Off-season
- Not specified in chart

Sporting activity at onset
- Practice
- Competition
- Strength training
- Not sport-related
- Not specified in chart

Does the pain radiate?
- Yes
- No
- Not specified in chart

Aggravating activities

Easing activities

Does the pain affect the patient's sleep?
- Yes
- No
- Not specified in chart

Investigations and findings

Primary diagnosis
- Spondylolysis
- Spondylolisthesis

Disc disease
Apophysitis
Facet joint dysfunction
Infection
Inflammation
Malignancy
Sacroiliitis
Sprain
Strain
Non-specific LBP
Other

Secondary diagnosis
Spondylolysis
Spondylolisthesis
Disc disease
Apophysitis
Facet joint dysfunction
Infection
Inflammation
Malignancy
Sacroiliitis
Sprain
Strain
Non-specific LBP
Other

Diagnosis during initial visit? Y/N

Pain level at initial visit

Pain descriptor
Achy
Burning
Dull
Sharp
Stabbing
Other
Not specified in the chart

Management/treatment
Rest
Activity modulation (Relative rest)
Physical therapy
Injection (type of injection)
Surgery
Rest from sport
Medication (type of medication)
MRI
Bracing
Other

Level of function

- Unrestricted
- Participating in sport with modifications
- No participation in sport; engaging in other functional activities
- ADLs only
- Severely restricted
- Not specified in chart

Management described

Additional notes

**Follow-up visit**

Date of follow-up clinic visit

Age at follow-up visit

New diagnosis? Y/N

Are they currently experiencing back pain? Y/N

Does the pain radiate?

- Yes
- No
- Not specified in chart

Aggravating activities

Easing activities

Does the pain affect the patient's sleep?

- Yes
- No
- Not specified in chart

Investigations and findings

Primary diagnosis

- Spondylolysis
- Spondylolisthesis
- Disc disease
- Apophysitis
- Facet joint dysfunction
- Infection
- Inflammation
- Malignancy
- Sacroiliitis
- Sprain
- Strain
- Non-specific LBP
- Other

Secondary diagnosis

- Spondylolysis
- Spondylolisthesis
- Disc disease
- Apophysitis
- Facet joint dysfunction
- Infection
- Inflammation
- Malignancy
- Sacroiliitis

Sprain
Strain
Non-specific LBP
Other

Diagnosis during initial visit? Y/N

Pain level at initial visit

Pain descriptor
- Achy
- Burning
- Dull
- Sharp
- Stabbing
- Other
- Not specified in the chart

Management/treatment
- Rest
- Activity modulation (Relative rest)
- Physical therapy
- Injection (type of injection)
- Surgery
- Rest from sport
- Medication (type of medication)
- MRI
- Bracing
- Other

Level of function
- Unrestricted
- Participating in sport with modifications
- No participation in sport; engaging in other functional activities
- ADLs only
- Severely restricted
- Not specified in chart

Management described

Additional notes

# Appendix 4-1: Trinity College Dublin Faculty of Health Sciences Research Ethics Committee Ethics Approval

Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Ollscoil Átha Cliath | The University of Dublin

**Julia Wall**
**Department of Physiotherapy,**
**Trinity Centre for Health Sciences,**
**St. James's Hospital,**
**James's Street,**
**Dublin 8**

**2nd March 2020**

**Ref: 2020109**

**Title of Study:** **Sport related low back pain in adolescent athletes: the need for increased knowledge.**

**Dear Julia,**

**Further to a meeting of the Faculty of Health Sciences Ethics Committee held in February 2020. We are pleased to inform you that the above project has ethical approval to proceed.**

**This study has been ethically approved. We would advise you to seek review and comments on your DPIA from the DPO if required prior to study commencement'**

**As a researcher you must ensure that you comply with other relevant regulations, including DATA PROTECTION and HEALTH AND SAFETY.**

**Yours sincerely,**

**Prof. Jacintha O'Sullivan**
**Chairperson**
**Faculty Research Ethics Committee**

Dámh na nEolaíochtaí Sláinte
Foirgneamh na Ceimice,
Coláiste na Tríonóide,
Ollscoil Átha Cliath,
Baile Átha Cliath 2, Éire.

Faculty of Health Sciences
Chemistry Building,
Trinity College Dublin,
The University of Dublin,
Dublin 2, Ireland.

www.healthsciences.tcd.ie

# Appendix 4-2: Boston Children's Hospital Institutional Review Board Approval

Boston Children's Hospital

**Institutional Review Board (IRB)**
300 Longwood Avenue
Mailstop BCH 3164
Boston, MA 02115
Tel: (617) 355-7052
Fax: (617) 730-0226
www.bostonchildrens.org/research/irb

| | |
|---|---|
| **Principal Investigator** | William Meehan, MD |
| **Protocol Number** | IRB-P00037036 |
| **Protocol Title** | Sport-related low back pain in adolescent athletes: the lived experience of adolescent athletes |

**Date:** May 10, 2021

## NOTICE OF EXPEDITED APPROVAL

**IRB Approval Date: 3/23/2021**
**IRB Activation/Release Date: 5/10/2021**

---

Please Note: The initiation or continuation of clinical research activities must follow the Boston Children's Hospital (BCH) advisories or policies. The IRB is continuing to review protocols; **however, BCH is currently restricting the conduct of clinical research in response to the COVID-19 crisis.** Details of these restrictions and an IRB Q&A document are available at https://www.childrenshospital.org/research/institutional-review-board/latest-resources-and-references and both will be updated as changes are implemented. Please contact the IRB Office with any questions you may have.

The Institutional Review Board (IRB) has approved the above referenced protocol through expedited review procedures in accordance with federal regulation 45 CFR 46.110 (b) (1), under Categories 5 and 7. We are now able to release this approval to you since you have adequately responded to the IRB's questions and concerns.

### RISK/BENEFIT ASSESSMENT

This study has been approved under HHS Regulations 45 CFR 46.404 for the inclusion of children. Risks were determined to be minimal with no potential for direct benefit

### INFORMED CONSENT, ASSENT, PARENTAL PERMISSION AND HIPAA AUTHORIZATIONS

The IRB has approved a waiver for the requirement to obtain informed consent and HIPAA authorization to use protected health information to identify potential research subjects.

The IRB has determined that only one parent/guardian is required to provide permission for their child to participate in this study and provide authorization for the use and/or disclosure of protected health information in the conduct of this research.

Assent is required from those subjects capable of understanding the research and its ramifications. If you determine a particular child is not capable of providing assent, you will need to provide justification on the informed consent after the parental signatures.

The approved consent/assent document(s) are available on-line through the BCH the Informed Consent Library. To obtain the consent form, please go to the CHeRP IRB website and select "IC Library." Please note that the ICLibrary is accessible only through internal access and available only to those with a BCH web account. The IC Library

# Appendix 4-3: Twitter Poster

## HAVE YOU HAD LOW BACK PAIN?

### Are you a junior athlete?


Researchers from the Discipline of Physiotherapy, Trinity College Dublin want to hear about your experience of having low back pain.

### Participants will be asked to:

- Participate in one interview with researchers about the participant's experience of low back pain (via Microsoft Teams).
- Fill out two questionnaires via Microsoft Forms. One questionnaire is about low back pain, the other is about the participant's physical activity levels.

### Am I eligible?

Participants must:

- Have had low back pain within the past year.
- Be otherwise healthy persons aged between 10 and 19 years old.
- Be an athlete, defined by participation or competing in organised sport at least three times per week.
- Be fluent in English.
- Be able to give informed consent (if over 18) or accompanied by a parent or guardian who can provide consent if under 18 years.

**For more information, please contact Julia Wall, PhD Student.**

EMAIL: WALLJU@TCD.IE

# Appendix 4-4: Participant Information Leaflet

**Sport related low back pain: the lived experience of adolescent athletes**

| Site | Online |
|---|---|
| Principal Investigator(s) and Co-Investigator(s) (insert names, titles and contact details) | Lead Investigator: Ms. Julia Wall wallju@tcd.ie<br>Co-investigators:<br>Dr. Fiona Wilson wilsonf@tcd.ie<br>Dr. William Meehan william.meehan@childrens.harvard.edu |
| Data Controllers | Trinity College Dublin<br>The Micheli Center for Sports Injury Prevention at Boston Children's Hospital |
| Data Protection Officer | Data Protection Officer<br>Secretary's Office<br>Trinity College Dublin<br>Dublin 2 |

You are being invited to take part in a research study that is being done through Trinity College Dublin in association with the Micheli Center for Sports Injury Prevention at Boston Children's Hospital. The lead investigator is Ms. Julia Wall. The study will take place online via Microsoft Teams.

Before you decide whether you wish to take part, please read this information sheet carefully. Ask Ms. Wall any questions. Don't feel rushed or under pressure to make a quick decision. You should understand the risks and benefits of taking part in this study so that you can make a decision that is right for you. You may wish to discuss it with your family, friends or GP.

This leaflet has four main parts:

Part 1 – The Study

Part 2 – Data Protection

Part 3 – Costs, Funding and Approval

Part 4 –Further Information

## Part 1 – The Study

### Why is this study being done?

- Exercise is vital for adolescents' physical and mental health in adolescence. Many adolescents get exercise by participating in sport, but this comes with risk. An under-researched risk of participation in sport is low back pain (LBP). LBP in this study is defined as pain, ache, or discomfort in the area from the bottom of the ribcage to the gluteal folds whether or not it extends to one or both legs. LBP in adolescence can lead to an adolescent athlete taking time off sport or leaving sport entirely. Since the greatest predictor of low back pain in adults is a previous episode of low back pain, LBP in adolescence puts the athlete at risk for future LBP. Despite the numerous problems presented by LBP in adolescent athletes, there has been limited research into this condition. It is necessary to understand the presentation of LBP in adolescent athletes to develop evidence-based management and prevention approaches. The proposed research will contribute to the development of this evidence base.

*This study is being conducted to develop the evidence base for low back pain in adolescent athletes.*

### Who can participate?

- You have been invited to take part in this study because you are an adolescent athlete who has experienced low back pain.
- To be included in this study, you must:
  - Have had low back pain in the past year
  - Be aged between 10 and 19
  - Be an athlete, defined by participation and competing in organised sport
  - Be fluent in English
  - Be free of intellectual disability or cognitive impairment that would impair or impede the ability to give informed consent (if over 18) or are accompanied by a parent or guardian who can provide consent if under 18 years.

**Do I have to take part?  Can I withdraw?**

You do not have to take part in this study.  It is entirely voluntary. If you decide not to take part, it will not affect your current or future medical care or athletic participation. You can change your mind about taking part in the study and opt out at any time even if the study has started. If you decide to opt out, it won't affect your current or future medical care or athletic participation. You don't have to give a reason for not taking part or for opting out. If you wish to opt out, please contact Ms. Julia Wall, lead investigator (email wallju@tcd.ie) who will be able to organise this for you.

If you choose not to take part anymore, you will be asked to fill in a withdrawal form. If you wish, you can ask for your data stored to be destroyed. If you request this, we will destroy all data that are still in our possession. We will no longer use or share your data for research from this point onwards. However, it will not be possible to destroy samples and data already used in research studies prior to this time.

**Are there any benefits to taking part in this research?**

Taking part in this study will not directly benefit you. However, research performed with your questionnaire responses may help us to better understand low back pain in adolescent athletes and may result in new treatment approaches. This is a long-term research project, so the benefits of the research may not be seen for several years. By participating, you are helping to advance science and medicine for future generations.

**Are there any risks to me or others if I take part?**

- Due to the nature of the questionnaire and interview, some of the information discussed could be sensitive/upsetting, as it relates to your experience of pain. The interviewer is a chartered physiotherapist and investigators are experienced clinicians. Advice will be provided regarding pain management and referral options if it is required.
- There is a risk that a connection to your identity could be made. Great care will always be taken to ensure the confidentiality of all data and the risk to participants of a breach of confidentiality is considered very low.

**How will the study be carried out?**

Below is a general overview of the study

- **When**: July 2020 to December 2021
- **Where**: You will be asked to be available to be online for a Microsoft Teams interview on one occasion at a time that suits you. Prior to the online interview, you will be asked to fill out a Patient Information Sheet and two short questionnaires on Microsoft Forms. You will only need be available once and the whole process should last approximately one hour.
- **What will happen:**
    - You will have a conversation with the investigators via Microsoft Teams regarding your experience of having back pain. This will be recorded (audio and video) so that the interviewers can use your interview responses for research.
    - After the interview on Microsoft Teams, you will be asked to fill out a Patient Information Sheet on Microsoft Forms, which will ask about your age, sex, height, weight, and sports you participate in.
    - You will be asked to fill out an International Physical Activity Questionnaire on Microsoft Forms, which will ask questions about your weekly physical activity.

    - You will be asked to fill out the Modified Oswestry Disability Questionnaire on Microsoft Forms, which will ask about your low back pain.
    - There will also be an open text box on Microsoft Forms, where you will be asked to outline a typical week of sporting activity at the time of LBP onset.
    - If you are under the age of 18, it will be necessary to have a parent/guardian sign the formal consent form and be present for the Microsoft Teams interview.

- The study investigators are hoping to recruit approximately 30 participants.
- There will be no long-term monitoring or follow-up.

**Will I be told the outcome of the study? Will I be told the results of any tests or investigations performed as part of this study that relate to me?**

The results of the study will be reported in medical/scientific journals and disclosed at medical/scientific conferences. No information which reveals your identity will be disclosed.

## Part 2 – Data Protection

**What information about me (personal data) will be used as part of this study? Will my medical records be accessed?**

Personal data that will be collected and used include:

- Your name (this will be pseudo anonymised)
- Your age
- Your sport(s), training details at time of LBP onset, and level of physical activity
- Your questionnaire responses
- Your interview responses will be recorded and transcribed via Microsoft Teams. Interview recordings will be retained for a maximum period of one week on the Microsoft Stream cloud platform. Recordings will then be downloaded to local storage on a Trinity-provided laptop owned by Julia Wall.
- Your medical records will not be accessed.

**What will happen to my personal data?**

- Personal data will be processed only as is necessary to achieve the objective of the health research and will not be processed in a way that damage or distress will be caused to the participant.
- Consent forms will be kept for 7 years, at which time they will be destroyed by the Research Supervisor.
- Interview recordings will be retained for a maximum period of one week on the Microsoft Stream cloud platform. Recordings will then be downloaded to local storage on a Trinity-provided laptop owned by Julia Wall.
- Raw data will only be processed by the lead investigator and supervisors, the data processors for this study.

**Who will access and use my personal data as part of this study?**

- Only the Lead Investigator and Research Supervisors on the research team will have access to your personal data. Your personal data will not be shared with anyone outside of the research team at Trinity College Dublin and Boston Children's Hospital. The data controllers (the organisation responsible for keeping your information safe) for this study are Trinity College Dublin and Boston Children's Hospital. The Lead Investigator and Research Supervisor have undergone training in data protection law and practice, prior to starting this research. The researchers in this project are bound by our Professional Code of Conduct to maintain confidentiality regarding all data gained during this research. The data processors for this study are Ms. Julia Wall, Dr. Fiona Wilson, and Dr. William Meehan.

**Will my personal data be kept confidential? How will my data be kept safe?**

Your privacy is important to us. We take many steps to make sure that we protect your confidentiality and keep your data safe. Here are some examples of how we do this:

- Online access to data collection forms, questionnaires, and participant consent forms will only be accessible to the lead investigator, Julia Wall, and supervisor, Fiona Wilson.

- Information and records in electronic form will be stored on a password-protected and encrypted USB stick locked securely in a filing cabinet at the Trinity Centre for Health Sciences, and accessible only to the research team.

- Interview recordings will be retained for a maximum period of one week on the Microsoft Stream cloud platform. Recordings will then be downloaded to local storage on a Trinity-provided laptop owned by Julia Wall.

- All data we collect from you during the study will be coded with a number ID to maintain your confidentiality. The key to this code will be kept securely locked in the filing cabinet, separate from all other data we have collected.

- Only data required to achieve the aims of this study will be collected.

- Your name and personal details will never be published or disclosed to anyone outside the research team. All information relating to you in hard-copy form will be stored in a locked filing cabinet in a secure office accessible only by the research team.
- Your study information and results will be retained for 7 years, in keeping with good research practice standards and data protection legislation. It will be destroyed after this time (electronic data will be erased,).

- Under Article 46 (2)(c), there will be a data sharing agreement between Trinity College Dublin and the Micheli Center for Sports Injury Prevention to ensure adequate data protection for international data transfers. The persons carrying out the research are bound by a contractual code of secrecy and have been provided with training in data protection law.

- A Data Protection Impact Assessment was carried out and the level of risk identified was low.

**How will my data be used during this study?**

Your data will be used for health research, which is in the public interest. The information collected in this study will be analysed, and the overall findings of this study may be published in international peer reviewed journals and shared at research conferences.

However, your data will remain coded throughout and your personal identifiers will never be published or disclosed to anyone outside of this research team.

All online participant information forms, consent forms, questionnaire and interview responses will only be accessible to Julia Wall, lead investigator, and Fiona Wilson, primary supervisor.

Names and contact information of participants will be taken upon participation. Number identification codes will be given to each participant and documented onto the coding sheet at this time by the lead investigator. All other data collection will be pseudonymised using this code, with no personal identifiers written on the data collection sheets or on soft-copy data stored on the USB key.

If a participant requests to edit or delete their data, this request will be reviewed and completed by the Lead Investigator, as soon as the request has been made. In the case of the request occurring after a significant period (during which the Lead Investigator may no longer study at Trinity College Dublin) the request will be completed by the research Supervisor, Dr. Fiona Wilson.

Data will be shared with Trinity College Dublin, Department of Physiotherapy and Boston Children's Hospital, Sports Medicine Division as they are partners in this research.

**What is the lawful basis to use my personal data?**

Your data will be processed under the lawful basis according to the following Articles of the EU General Data Protection Act 2016: Article 6(1)(e), where the processing is carried out in the public interest, and Article 9(2)(j), where processing is necessary for archiving in the public interest, scientific or historical research purposes, or statistical purposes.

We will also ask for your explicit consent to process your data as a requirement of the Irish Health Research Regulations 2018.

**What are my rights?**

You are entitled to:

- The right to access to your data and receive a copy of it
- The right to restrict or object to processing of your data
- The right to object to any further processing of the information we hold about you (except where it is de-identified)
- The right to have inaccurate information about you corrected or deleted
- The right to receive your data in a portable format and to have it transferred to another data controller
- The right to request deletion of your data

By law you can exercise the following rights in relation to your personal data unless the request would make it impossible or very difficult to conduct the research.

You can exercise these rights by contacting your study lead investigator, Ms. Julia Wall. Email: wallju@tcd.ie. If you are not satisfied with how your data is being used, you can also lodge a complaint to the Data Protection Commissioner (Phone: +353 57 8684800 or +353 (0)761 104 800; website: http://www.dataprotection.ie; address: Office of the Data Protection Commission, 21 Fitzwilliam Square South, Dublin 2).

## Part 3 – Costs, Funding and Approval

**Has this study been approved by a research ethics committee?**

Yes, this study received ethical approval on 10th July 2020 from the Faculty of Health Sciences Research Ethics Committee, Trinity College Dublin. Email: ethicscommittee@tcd.ie

**Who is organising and funding this study? Will the results be used for commercial purposes? Will I be paid?**

This research project is self-funded by the Discipline of Physiotherapy, Trinity College Dublin, as part of postgraduate PhD research. The results will not be used for commercial purposes. You will not receive payment or reimbursement for your participation in this research

## Part 4 – Further Information

**Who should I contact for information or complaints?**

For more information about the study, your participation, and your rights, please contact the research team:

**Research Supervisor**: Dr Fiona Wilson, Associate Professor, Discipline of Physiotherapy, Trinity College Dublin

Contact: Tel (01) 8963534, E-mail: wilsonf@tcd.ie

**Research Supervisor:** Dr. Bill Meehan, Director, the Micheli Center for Injury Prevention

Contact: Tel (781) 216-1328, Email: william.meehan@childrens.harvard.edu

**Lead Investigator:** Ms. Julia Wall, Research PhD Student, Trinity College Dublin

Contact: Tel (01) 8963613, E-mail: wallju@tcd.ie

**Data Controller:** Trinity College Dublin

For information regarding your rights under data protection law, please contact:

**Data Protection Officer, Trinity College Dublin:** Contact E-mail: dataprotection@tcd.ie Website: http://www.tcd.ie/privacy, Address: Secretary's Office, Trinity College Dublin, Dublin

**Will I be contacted again?**

We do not intend to contact you following your participation in the study.

If you would like to take part in this study, you will be asked to sign the Consent Form on the next page. You will be given a copy of this information leaflet and the signed Consent Form to keep.

# Appendix 4-5: Consent Form (Participants under age 18)

| |
|---|
| **Study name:** Sport related low back pain in adolescent athletes: the lived experience of adolescent athletes<br>**Location:** Interviews will be conducted via Microsoft Teams and questionnaires will be given via Microsoft Forms |

**There are 2 sections in this form. Each section has a statement and asks you to initial if you agree. The end of this form is for the researchers to complete.**

**Please ask <u>any</u> questions you may have when reading each of the statements.**

**Thank you for participating.**

**Please <u>Initial</u> the box if you agree with the statement. Please feel free to ask questions if there is something you do not understand.**

| **Section 1: General Information** | **Initial** |
|---|---|
| I confirm I have read and understood the **Participant Information Leaflet** for the above study. The information has been fully explained to me and my child/ward and I have been able to ask questions, all of which have been answered to my satisfaction. My child/ward has been able to ask questions, all of which have been answered to his/her satisfaction. | |
| I understand that this study **is entirely voluntary, and if I or my child/ward decide that they do not want to take part, they can stop taking part in this study at any time without giving a reason**. I understand that deciding not to take part will not affect my child/ward's future medical care. | |
| I understand that my child/ward **will not be paid for taking part in this study.** | |
| I know how to contact the research team if I need to. | |
| I agree to that my child/ward may take part in this research study having been fully informed of the **risks, benefits and alternatives** which are set out in full in the information leaflet that I have been provided with. | |
| I agree to being contacted by researchers by email/phone as part of this research study | |
| I agree to my child/ward's interview being recorded on Microsoft Teams. Interview recordings will be retained for a maximum period of one week on the Microsoft Stream cloud platform before being downloaded to local storage on a Trinity-provided laptop owned by Julia Wall. The recording will be transcribed. The recording will be retained for the duration of the study. | |

| **Section 2: Data processing** | **Initial** |
|---|---|
| I agree to allow personal information about my child/ward to be shared with third parties including; The Micheli Center for Sport Injury Prevention, Sport Ireland, and Trinity College Dublin for the purpose of low back pain in adolescent athlete research, as described in the Patient Information leaflet. | |
| I understand that personal information about my child/ward, including the transfer of this personal information about my child/ward outside of the EU, will be protected in accordance with the General Data Protection Regulation. | |
| I understand that there are **no direct benefits to my child/ward** from participating in this study. I understand that **results from analysis of my child/ward's personal information will not be given to me**. | |
| I understand that **my child/ward can stop taking part in this study** at any time without giving a reason and this will not affect my child/ward's future medical care or athletic participation. | |
| I understand that I can request at any time that my child/ward's personal data will be deleted and not used (except where the data has already been analysed/published or has been anonymised). | |
| I understand that my child's/ward's data will be stored for 7 years in compliance with legal and regulatory obligations. Interview recordings will be retained for a maximum period of one week on the Microsoft Stream cloud platform before being downloaded to local storage on a Trinity-provided laptop owned by Julia Wall. The recording will be transcribed. The recording will be retained for one month in local storage. | |

---------------------------------------------------------------------------------------------------------------------

Participant Name (Block Capitals)     Participant Signature                    Date

---------------------------------------------------------------------------------------------------------------------

Parent/Guardian Name (Block Capitals)     Parent/Guardian Signature     Date

-------------------------------------------------- ---------------------------------------------------------------

Witness Name (Block Capitals) Witness Signature Date

**To be completed by the Principal Investigator or nominee.**

I, the undersigned, have taken the time to fully explain to the above patient the nature and purpose of this study in a way that they could understand. I have explained the risks and possible benefits involved. I have invited them to ask questions on any aspect of the study that concerned them.

I have given a copy of the information leaflet and consent form to the participant with contacts of the study team

Researcher name

Researcher Title and qualifications

Researcher Signature

Date

# Appendix 4-6: Assent Form (Participants aged 16-17)

**Study name:** Sport related low back pain in adolescent athletes: the lived experience of adolescent athletes

**Location:** Interviews will be conducted via Microsoft Teams; questionnaires will be given via Microsoft Forms.

Before signing this Assent Form, please read the Patient Information Leaflet provided and ask us any questions you have.

We are doing a research study about **athletes who are between the ages of 10 and 19, who have low back pain.**

If you decide that you want to be part of this study, you will be asked to be available online for an interview on Microsoft Teams and to fill out a patient information sheet and two questionnaires online via Microsoft Forms. The whole process should last one hour. Since you are under the age of 18, your parent/guardian needs to be present for the interview. The interview will be recorded and transcribed to allow the interviewers to use your interview responses in their research.

No one who participates in this study will directly benefit, but you will be helping the researchers to find out more information about low back pain in athletes your age. After we are finished with the study, we will write a report about what we learned from the study. This report will not include your name.

You do not have to participate in this study if you do not want to. You can also decide to stop after we begin. Your parent/guardians know about the study and your participation in it.

If you decide you want to be in this study, please sign your name.

I, ________________________________, want to be part of this research study.

________________________________ ______

(Sign your name here) (Date)

# Appendix 4-7: Assent Form (Participants aged 10-15)

I agree that I would like to take part in this study about low back pain in adolescent athletes. I agree that the researchers can record and transcribe my interview on Microsoft Teams. I read the information given to me about this study and asked any questions I had. I understand that I do not have to be a part of this study, and that I can stop at any time.

____________________________________________________________

My signature Today’s date

____________________________________________________________

My parent/guardian’s signature Today’s date

# Appendix 4-8: Modified Oswestry Disability Index (ODI)

**Modified Oswestry Low Back Pain Disability Questionnaire**

Name:____________________________________________ Date: _____/_____/______

**Please Read:**
This questionnaire has been designed to give your doctor/therapist information as to how your back pain has affected your ability to manage everyday life. Please answer every section, and mark in each section only the **one** box that best describes your condition today.

We realize you may feel that two of the statements in any one section relate to you, but please just mark the box which most closely describes your current condition

**Section 1 – Pain Intensity**
- ☐ I can tolerate the pain I have without having to use pain medication.
- ☐ The pain is bad but I manage without having to take pain medication.
- ☐ Pain medication provides me complete relief from pain.
- ☐ Pain medication provides me moderate relief from pain.
- ☐ Pain medication provides me little relief from pain.
- ☐ Pain medication has no effect on the pain.

**Section 2 – Personal Care (Washing, Dressing, etc.)**
- ☐ I can take care of myself normally without causing increased pain.
- ☐ I can take care of myself normally but it increases my pain.
- ☐ It is painful to take care of myself and I am slow and careful.
- ☐ I need help but I am able to manage most of my personal care.
- ☐ I need help every day in most aspects of my care.
- ☐ I do not get dressed, wash with difficulty and stay in bed.

**Section 3 – Lifting**
- ☐ I can lift heavy weights without increased pain.
- ☐ I can lift heavy weights but it causes increased pain.
- ☐ Pain prevents me from lifting heavy weights off the floor, but I can manage if weights are conveniently positioned, e.g. on a table.
- ☐ Pain prevents me from lifting heavy weights but I can manage light to medium weights if they are conveniently positioned.
- ☐ I can lift only very light weights.
- ☐ I cannot lift or carry anything at all.

**Section 4 - Walking**
- ☐ Pain does not prevent me walking any distance.
- ☐ Pain prevents me walking more than 1 mile.
- ☐ Pain prevents me walking more than ½ mile
- ☐ Pain prevents me walking more than ¼ mile
- ☐ I can only walk using crutches or a cane.
- ☐ I am in bed most of the time and have to crawl to the toilet.

**Section 5 - Sitting**
- ☐ I can sit in any chair as long as I like.
- ☐ I can only sit in my favorite chair as long as I like.
- ☐ Pain prevents me sitting more than 1 hour.
- ☐ Pain prevents me from sitting more than ½ hour.
- ☐ Pain prevents me from sitting more than 10 mins.
- ☐ Pain prevents me from sitting at all.

**Section 6 – Standing**
- ☐ I can stand as long as I want without increased pain.
- ☐ I can stand as long as I want but increases my pain.
- ☐ Pain prevents me from standing for more than 1 hour.
- ☐ Pain prevents me from standing for more than ½ hour.
- ☐ Pain prevents me from standing for more than 10 mins.
- ☐ Pain prevents me from standing at all.

**Section 7 – Sleeping**
- ☐ Pain does not prevent me from sleeping well.
- ☐ I can sleep well only by using pain medication.
- ☐ Even when I take pain medication, I sleep less than 6 hours.
- ☐ Even when I take pain medication, I sleep less than 4 hours.
- ☐ Even when I take pain medication, I sleep less than 2 hours.
- ☐ Pain prevents me from sleeping at all

**Section 8 – Social Life**
- ☐ My social life is normal and does not increase my pain.
- ☐ My social life is normal, but it increases my level of pain.
- ☐ Pain prevents me from participating in more energetic activities (ex sports, dancing, etc.
- ☐ Pain prevents me from going out very often.
- ☐ Pain has restricted my social life to my home.
- ☐ I have hardly any social life because of my pain.

**Section 9 – Traveling**
- ☐ I can travel anywhere without increased pain.
- ☐ I can travel anywhere but it increases my pain.
- ☐ Pain restricts travel over 2 hours.
- ☐ Pain restricts travel over 1 hour.
- ☐ Pain restricts my travel to short necessary journeys under ½ hour.
- ☐ Pain prevents all travel except for visits to the doctor/therapist or hospital.

**Section 10 – Employment/Homemaking**
- ☐ My normal homemaking/job activities do not cause pain.
- ☐ My normal homemaking/job activities increase my pain, but I can still perform all that is required of me.
- ☐ I can perform most of my homemaking/job duties, but pain prevents me from performing more physically stressful activities (ex. Lifting, vacuuming).
- ☐ Pain prevents me from doing anything but light duties.
- ☐ Pain prevents me from doing even light duties.
- ☐ Pain prevents me from performing any job/homemaking chores.

# Appendix 4-9: International Physical Activity Questionnaire (IPAQ)

## INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

1. During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

_____ **days per week**

☐ No vigorous physical activities ➔ ***Skip to question 3***

2. How much time did you usually spend doing **vigorous** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

3. During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

_____ **days per week**

☐ No moderate physical activities ➔ ***Skip to question 5***

4. How much time did you usually spend doing **moderate** physical activities on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you have done solely for recreation, sport, exercise, or leisure.

5. During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ **days per week**

☐ No walking ➔ ***Skip to question 7***

6. How much time did you usually spend **walking** on one of those days?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, while doing course work and during leisure time. This may include time spent sitting at a desk, visiting friends, reading, or sitting or lying down to watch television.

7. During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

_____ **hours per day**

_____ **minutes per day**

☐ Don't know/Not sure

# Appendix 4-10: Additional Information About Sport Activity

Please outline a typical week of sports activity at the time of LBP onset. Include information such as: number of days per week, length of exercise sessions, type of exercise, etc.

# Appendix 4-11: Code Evolution Example

| **Raw data:** | **Initial code** | **Stage 2 code** | **Subtheme** |
|---|---|---|---|
| *'I've been told by pretty much everyone that back pain is part of {sport}, um, and that I'm just gonna have to live with it and that everybody gets a little bit of back pain. It's just part of the sport.'* (P3) | Inevitability of back pain | The view of back pain as normal/inevitable creates vulnerability in adolescent athletes | Perceptions of back pain as normal/inevitable creates vulnerability in adolescent athletes. |

# Appendix 5-1: Twitter poster

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

Researchers from the Discipline of Physiotherapy, Trinity College Dublin are conducting a research survey of healthcare professionals who are involved in the management of adolescent athletes with low back pain.

**Participants will be asked to:**

- Fill out a survey on Qualtrics. The questionnaire will ask about assessment, management, and beliefs about low back pain.
- This questionnaire should take no longer than 30 minutes to complete.


## Am I eligible?

Participants must:

- Be a healthcare professional.
- Have experience managing low back pain in adolescent athletes (aged 10-19 years old).
- Have at least one year of clinical experience.

**For more information, please contact Julia Wall**
**Email: wallju@tcd.ie**

# Appendix 5-2: TCD School of Medicine Research Ethics Committee Approval

Title: 'Healthcare Professionals' Assessment, Management, and Beliefs about Low Back Pain in Adolescent Athletes'
Applicant Name: Julia Wall
Submitted by: Julia Wall
Academic Supervisor: Fiona Wilson
Application Number: 20220505

Result of the REC Meeting: Approved

# Appendix 5-3: Survey

Thank you for taking the time to complete this survey. Full details about this survey can be found in the Participant Information Leaflet [link to PIL].

[1]**Part 1** of this survey explores the management (including assessment) of low back pain in adolescent athletes. For the purposes of this survey, the adolescent age range is defined as 10-19 years old.
[3]*Low back pain definition:* Low back pain is a symptom that can result from several different known or unknown abnormalities or diseases. It is defined by the location of pain, typically between the lower rib margins and the buttock creases. In some cases, it may be accompanied by pain in one or both legs and some people with low back pain have associated neurological symptoms in the lower limbs. Sport-related low back pain is pain that affects an athlete, that is because of or exacerbated by sport or sport-related training, resulting in a need to modify or stop scheduled activities.

[2]**Part 2** of this survey assesses low back pain beliefs/attitudes of healthcare professionals and is assessed using the Back Pain Attitudes Questionnaire.
We are inviting any healthcare professional with more than one year of experience managing low back pain in adolescent athletes to participate in this survey. All responses are anonymous, and you may exit the survey at any time. This survey should take no more than [ten] minutes to complete.
Thank you for your participation.


*References:*

[1] **Part 1** developed using a Delphi study as a framework: Wilkie K, Thornton JS, Vinther A, Trease L, McDonnell SJ, Wilson F. Clinical management of acute low back pain in elite and subelite rowers: a Delphi study of experienced and expert clinicians. Br J Sports Med. 2021 Dec;55(23):1324-1334. doi: 10.1136/bjsports-2020-102520. Epub 2021 Jan 11. PMID: 33431498.
[2] **Part 2:** Darlow B, Perry M, Mathieson F, Stanley J, Melloh M, Marsh R, Baxter GD, Dowell A: The development and exploratory analysis of the Back Pain Attitudes Questionnaire (Back-PAQ). BMJ Open 2014, 4(5).
[3] **Low back pain definition adapted from:** Wilson F, Thornton JS, Wilkie K, *et al*2021 consensus statement for preventing and managing low back pain in elite and subelite adult rowers *British Journal of Sports Medicine* 2021;**55:**893-899.


**I confirm that I have read and understood the Information Leaflet for this study, and I consent to participate in this survey.**

¨ Yes

¨ No

**Part 1**

Part 1 of this survey explores the management (including assessment) of low back pain in adolescent athletes (1). For the purposes of this survey, the adolescent age range is defined as 10-19 years old.

1. Part 1 developed using a Delphi study as a framework: Wilkie K, Thornton JS, Vinther A, Trease L, McDonnell SJ, Wilson F. Clinical management of acute low back pain in elite and subelite rowers: a Delphi study of experienced and expert clinicians. Br J Sports Med. 2021 Dec;55(23):1324-1334. doi: 10.1136/bjsports-2020-102520. Epub 2021 Jan 11. PMID: 33431498.

1. What is your current profession?

    ¨ Physiotherapist

    ¨ Sports medicine physician

    ¨ General practitioner

    ¨ Osteopath

    ¨ Chiropractor

    ¨ Athletic trainer

    ¨ Sports therapist

    ¨ Surgeon

    ¨ Nurse practitioner

    ¨ Physician assistant

    ¨ Other (please specify)

2. How many years of overall clinical experience do you have?

    ¨ 1-5 years

    ¨ 6-15 years

    ¨ 16-25 years

    ¨ 25+ years

3. Do you have more than one year of experience treating adolescent athletes (aged 10-19) with low back pain?

    ¨ Yes

    ¨ No

If yes, How many years of experience managing adolescent athlete low back pain do you have?

¨ 1-5 years

¨ 6-15 years

¨ 16-25 years

¨ 25+ years

4. On average, how many adolescent athletes with low back pain do you see per month?

5. What is your highest level of qualification?

¨ Bachelor's degree

¨ Master's degree

¨ Postgraduate diploma

¨ Doctorate

6. Do you hold sports medicine-specific qualifications? E.g., UKSCA, MSc (Sports Medicine)

¨ Yes

¨ No

7. In which area do you practice?

¨ Hospital

¨ Community

¨ Sports medicine clinic

¨ Private practice

¨ Team

Other (please state)

8. In which geographical region do you currently practice?

¨Africa

¨Asia

¨Europe

¨North America

¨South America

¨Oceania

**The following questions are about the initial triage phase. This is defined as the first contact with a clinician.**

9. What subjective/interview questions guide your management of adolescent athlete low back pain in the **initial triage phase**? Please select all that apply.

¨ Type/nature of pain

¨ History of current low back pain episode

¨ Past history of low back pain

¨ Past medical history

¨ Pain quality and severity

¨ 24-hour pattern of pain

¨ Aggravating and easing factors

¨ Sleep

¨ Occurrence of pain with activities of daily living

¨ Recent changes related to sport workload

¨ Red flags

¨ Year in school

¨ Life stressors

¨ Sport type(s)

¨ Training hours per week, per sport

¨ Competition hours per month

¨ Goals for treatment

¨ Other (please specify)

10. What objective/physical examination findings guide your management of adolescent athlete low back pain in the **initial triage phase**? Please select all that apply.

¨ Posture/general observation

¨ Functional tests e.g., gait

¨ Neurological testing; reflexes, sensation, muscle power, neural sensitivity

¨ Quality of movement

¨ Pain responses to lumbar range of movement/flexibility

¨ Pain responses to palpation

¨ Other (please specify)

11. What (non-pharmacological) treatment/management strategies and/or principles do you use in the **initial triage phase** of adolescent athlete low back pain?

¨ Manual therapy

¨ Exercise (please specify type)

¨ Advice to stay active

¨ Training load management

¨ Monitoring pain levels

¨ Education and reassurance about low back pain

¨ Inclusion of athlete in treatment decision making

¨ Communication with coach

¨ Avoidance of aggravating activities

¨ Consideration of psychological support where necessary

¨ Goal setting/expectation management

¨ Rest/unloading

¨ Resistance exercise

¨ Core specific exercise

¨ Range of movement/flexibility exercise

¨ Balance exercises

¨ Acupuncture

¨ Tai Chi

¨ Yoga

¨ Pilates

¨ Surgical consult

¨ Brace/external support

¨ Other (please specify)

12. Please add any additional information about the **initial triage phase** here.

**The following questions are about the acute phase. This is defined as the first week of an acute episode of low back pain.**

13. What subjective/interview questions guide your management of adolescent athlete low back pain in the **acute phase**? Please select all that apply

¨ Type/nature of pain

¨ History of current low back pain episode

¨ Past history of low back pain

¨ Past medical history

¨ Pain quality and severity

¨ 24-hour pattern of pain

¨ Aggravating and easing factors

¨ Sleep

¨ Occurrence of pain with activities of daily living

¨ Recent changes related to sport workload

¨ Red flags

¨ Year in school

¨ Life stressors

¨ Sport type(s)

¨ Training hours per week, per sport

¨ Competition hours per month

¨ Goals for treatment

¨ Improvement of symptoms

¨ Responses to rest and activity

¨ Athlete confidence in improvement in low back pain and function

¨ Ability to complete activities of daily living

¨ Response to medication

¨ Level of pain with activities of daily living

¨ Recent changes related to sport workload

¨ Other (please specify)

14. What objective/physical examination findings guide your management of adolescent athlete low back pain in the **acute phase**? Please select all that apply.

¨ Posture/general observation

¨ Functional tests e.g., gait

¨ Neurological testing; reflexes, sensation, muscle power, neural sensitivity

¨ Quality of movement

¨ Pain responses to lumbar range of movement/flexibility

¨ Pain responses to palpation

¨ Sitting tolerance

¨ Sport-specific ranges of motion

¨ Other (please specify)

15. What (non-pharmacological) treatment and management strategies and/or principles do you use in the **acute phase**?

¨ Manual therapy

¨ Exercise (please specify type)

¨ Advice to stay active

¨ Training load management

¨ Monitoring pain levels

¨ Education and reassurance about low back pain

¨ Inclusion of athlete in treatment decision making

¨ Communication with coach

¨ Avoidance of aggravating activities

¨ Consideration of psychological support where necessary

¨ Goal setting/expectation management

¨ Rest/unloading

¨ Resistance exercise

¨ Core specific exercise

¨ Range of movement/flexibility exercise

¨ Balance exercises

¨ Progression toward sport-specific spinal load requirements

¨ Functional exercise rehabilitation programme

¨ Cross-training

¨ Short sport-specific exercise

¨ Mindfulness techniques

¨ Coach/friend/family support

¨ Ongoing use of medication

¨ No sport-specific training

¨ Avoid axial load through the spine

¨ Acupuncture

¨ Tai Chi

¨ Yoga

¨ Pilates

¨ Surgical consult

¨ Brace/external support

¨ Other (please specify)

16. Please add any additional information about the **acute phase**.

**The following questions are about the subacute phase. This is defined as partial return to sport.**

17. What subjective/interview findings guide your management of adolescent athlete low back pain in the **subacute phase**? Please select all that apply

- ¨ Type/nature of pain
- ¨ History of current low back pain episode
- ¨ Past history of low back pain
- ¨ Past medical history
- ¨ Pain quality and severity
- ¨ 24-hour pattern of pain
- ¨ Aggravating and easing factors
- ¨ Sleep
- ¨ Occurrence of pain with activities of daily living
- ¨ Recent changes related to sport workload
- ¨ Red flags
- ¨ Year in school
- ¨ Life stressors
- ¨ Sport type(s)
- ¨ Training hours per week, per sport
- ¨ Competition hours per month
- ¨ Goals for treatment
- ¨ Improvement of symptoms
- ¨ Responses to rest and activity
- ¨ Athlete confidence in improvement in low back pain and function
- ¨ Ability to complete activities of daily living
- ¨ Response to medication
- ¨ Level of pain with activities of daily living
- ¨ Recent changes related to sport workload
- ¨ Level of pain with cross-training modalities

¨ Level of morning stiffness

¨ Reduction in medication or generalised stiffness

¨ Level of athlete's confidence to progress

¨ Level of pain during sport

¨ Other

18. What objective/examination findings guide your management of adolescent athlete low back pain in the **subacute phase**? Please select all that apply.

¨ Posture/general observation

¨ Functional tests e.g., gait

¨ Neurological testing; reflexes, sensation, muscle power, neural sensitivity

¨ Quality of movement

¨ Pain responses to lumbar range of movement/flexibility

¨ Pain responses to palpation

¨ Sitting tolerance

¨ Sport-specific ranges of motion

¨ Reassessment of objective findings from initial triage phase

¨ Reassessment of objective findings from acute phase

¨ Trial return to sport

¨ Pain levels during activities of daily living

¨ Pain levels during sport

¨ Other

19. What treatment and management strategies and/or principles do you use in the **subacute phase**?

¨ Manual therapy

¨ Exercise (please specify type)

¨ Advice to stay active

¨ Training load management

¨ Monitoring pain levels

¨ Education and reassurance about low back pain

¨ Inclusion of athlete in treatment decision making

¨ Communication with coach

¨ Avoidance of aggravating activities

¨ Consideration of psychological support where necessary

¨ Goal setting/expectation management

¨ Rest/unloading

¨ Resistance exercise

¨ Core specific exercise

¨ Range of movement/flexibility exercise

¨ Balance exercises

¨ Progression toward sport-specific spinal load requirements

¨ Functional exercise rehabilitation programme

¨ Cross-training

¨ Short sport-specific exercise

¨ Mindfulness techniques

¨ Coach/friend/family support

¨ Ongoing use of medication

¨ No sport-specific training

¨ Avoid axial load through the spine

¨ Return to sport without pain

¨ Biomechanical assessment

¨ Technical coaching

¨ Restoration of sport-specific ROM

¨ Maintenance or improvement in mobility

¨ Return to sport with a gradual reloading programme

¨ Involvement of a strength and conditioning coach

¨ Acupuncture

¨ Tai Chi

¨ Yoga

¨ Pilates

¨ Surgical consult

¨ Brace/external support

¨ Other (please specify)

20. Please add any additional information about the **subacute phase** here.

**The following questions are about the rehabilitation phase. This is defined as a return to normal training load.**

21. What subjective/interview findings guide your management of adolescent athlete low back pain in the **rehabilitation phase**? Please select all that apply

¨ Type/nature of pain

¨ History of current low back pain episode

¨ Past history of low back pain

¨ Past medical history

¨ Pain quality and severity

¨ 24-hour pattern of pain

¨Aggravating and easing factors

¨ Sleep

¨ Occurrence of pain with activities of daily living

¨ Recent changes related to sport workload

¨ Red flags

¨ Year in school

¨ Life stressors

¨ Sport type(s)

¨ Training hours per week, per sport

¨ Competition hours per month

¨ Goals for treatment

¨ Improvement of symptoms

¨ Responses to rest and activity

¨ Athlete confidence in improvement in low back pain and function

¨ Ability to complete activities of daily living

¨ Response to medication

¨ Level of pain with activities of daily living

¨ Recent changes related to sport workload

¨ Level of pain with cross-training modalities

¨ Level of morning stiffness

¨ Reduction in medication or generalised stiffness

¨ Level of athlete's confidence to progress

¨ Level of pain during sport

¨ Other

22. What objective/physical/examination findings guide your management of adolescent athlete low back pain in the **rehabilitation phase**? Please select all that apply

¨ Posture/general observation

¨ Functional tests e.g., gait

¨ Neurological testing; reflexes, sensation, muscle power, neural sensitivity

¨ Quality of movement

¨ Pain responses to lumbar range of movement/flexibility

¨ Pain responses to palpation

¨ Sitting tolerance

¨ Sport-specific ranges of motion

¨ Trial return to sport

¨ Pain levels during activities of daily living

¨ Pain levels during sport

¨ Other (please specify)

23. What treatment and management strategies and/or principles do you use in the **rehabilitation phase**?

¨ Manual therapy

¨ Exercise (please specify type)

¨ Advice to stay active

¨ Training load management

¨ Monitoring pain levels

¨ Education and reassurance about low back pain

¨ Inclusion of athlete in treatment decision making

¨ Communication with coach

¨ Avoidance of aggravating activities

¨ Consideration of psychological support where necessary

¨ Goal setting/expectation management

¨ Rest/unloading

¨ Resistance exercise

¨ Core specific exercise

¨ Range of movement/flexibility exercise

¨ Balance exercises

¨ Progression toward sport-specific spinal load requirements

¨ Functional exercise rehabilitation programme

¨ Cross-training

¨ Short sport-specific exercise

¨ Mindfulness techniques

¨ Coach/friend/family support

¨ Ongoing use of medication

¨ No sport-specific training

¨ Avoid axial load through the spine

¨ Return to sport without pain

¨ Biomechanical assessment

¨ Technical coaching

¨ Restoration of sport-specific ROM

¨ Maintenance or improvement in mobility

¨ Return to sport with a gradual reloading programme

¨ Involvement of a strength and conditioning coach

¨ Participation in sport with no pain

¨ Assessment of quality of movement during sport

¨ Address risk factors with coach and athlete

¨ Individualised strength and mobility programme

¨ Self-management by athlete

¨ Sports psychology

¨ Education about low back pain

¨ Reassurance about low back pain

¨ Acupuncture

¨ Tai Chi

¨ Yoga

¨ Pilates

¨ Surgical consult

¨ Brace/external support

¨ Other (please specify)

24. Please add any additional information about the **rehabilitation phase** here.

**The following questions are about adolescent athlete low back pain in general.**

25. What guides the use of imaging in your management of adolescent athletes with low back pain?

26. What patient-reported outcome measures/questionnaires do you use to assess adolescent athlete low back pain? (Select all that apply)

¨ Visual Analogue Scale

¨ Patient Specific Functional Scale

¨ Orebro Musculoskeletal Screening Questionnaire

¨ ASIA chart

¨ Start Back Screening tool

¨ Sciatic Bothersome Index

¨ Roland Morris Disability Index

¨ Oswestry Disability Index

¨ Becks' Depression Index

¨ Nordic Musculoskeletal Questionnaire

¨ Outcome measures not frequently used

¨ Other (please specify)

27. What yellow flags/psychosocial components of adolescent athlete low back pain do you typically consider throughout all phases? Please select all that apply.

¨ Catastrophising

¨ Anxiety

¨ Life stressors

¨ Stressors in sport

¨ Diagnosed mental health disorder

¨ Expectations for recovery

¨ Expectations for return to sport

¨ Sleep

¨ Fear avoidance beliefs

¨ Pressure from coach

¨ Mood

¨ Fear of specific movement patterns

¨ Coping strategies

¨ Recurrent history of failing to progress

¨ Symptoms in excess of clinical presentation

¨ Other (please specify)

28. If you also treat adult athletes, are there any physical differences between adult and adolescent athletes that affect your management of low back pain?

¨ Yes

¨ No

29. What are the key physical differences in management between adult and adolescent athletes?

30. If you also treat adult athletes, are there any psychosocial differences between adult and adolescent athletes that affect your management of low back pain?

¨ Yes

¨ No

31. What are the key psychosocial differences in management between adult and adolescent athletes?

32. If applicable to your profession, what pharmacological management techniques would be included in the management of adolescent athlete low back pain? (please select all that apply).

¨ Non-steroidal anti-inflammatories

¨ Oral paracetamol

¨ Topical analgesics

¨ Muscle relaxants

¨ Injection (specify type)

¨ Other (please specify

¨ Not applicable to my profession

**Part 2**

The aim of Part 2 of this questionnaire is to assess your own beliefs/attitudes using the Back Pain Attitudes Questionnaire.
Source: Darlow B, Perry M, Mathieson F, Stanley J, Melloh M, Marsh R, Baxter GD, Dowell A: The development and exploratory analysis of the Back Pain Attitudes Questionnaire (Back-PAQ). BMJ Open 2014, 4(5).

33. These questions are about your own back. Please rate each statement as false, possibly false, unsure, possibly true, true.

| | **False** | **Possibly false** | **Unsure** | **Possibly true** | **True** |
|---|---|---|---|---|---|
| Bending your back is good for it | | | | | |
| It is easy to injure your back | | | | | |
| If you overuse your back, it will wear out | | | | | |
| If an activity or movement causes back pain, you should avoid it in future | | | | | |
| You could injure your back if you are not careful | | | | | |
| Back pain means that you have injured your back | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| A twinge in your back can be the first sign of serious injury | | | | | |
| Having back pain makes it difficult to enjoy life | | | | | |
| It is worse to have pain in your back than in your arms or legs | | | | | |
| It is hard to understand what back pain is like if you have never had it yourself | | | | | |

34. These questions are about recovering from back pain. Please rate each statement as false, possibly false, unsure, possibly true, true.

| | **False** | **Possibly false** | **Unsure** | **Possibly true** | **True** |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| If your back hurts, you should take it easy until the pain goes away | | | | | |
| If you ignore back pain, you may cause damage to your back | | | | | |
| It is important to see a health professional when you have back pain | | | | | |
| To effectively treat back pain, you need to know exactly what is wrong | | | | | |
| If you have back pain, you should avoid exercise | | | | | |
| When you have back pain the risks of vigorous exercise outweigh the benefits | | | | | |
| If you have back pain, you should try to stay active | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Once you have back pain there is always a weakness | | | | | |
| There is a high chance than an episode of back pain will not resolve | | | | | |
| Once you have a back problem, there is not a lot you can do about it | | | | | |

We thank you for your time spent taking this survey.

Your response has been recorded.

# Appendix 5-4: Back Pain Attitudes Questionnaire

**Back Pain Attitudes Questionnaire – 20 item**

THESE QUESTIONS ARE ABOUT YOUR OWN BACK

| | *Please rate each statement as* | False | Possibly False | Unsure | Possibly True | True |
|---|---|---|---|---|---|---|
| 1 | **Bending your back is good for it** | | | | | |
| 2 | **It is easy to injure your back** | | | | | |
| 3 | **If you overuse your back, it will wear out** | | | | | |
| 4 | **If an activity or movement causes back pain, you should avoid it in the future** | | | | | |
| 5 | **You could injure your back if you are not careful** | | | | | |
| 6 | **Back pain means that you have injured your back** | | | | | |
| 7 | **A twinge in your back can be the first sign of a serious injury** | | | | | |
| 8 | **Having back pain makes it difficult to enjoy life** | | | | | |
| 9 | **It is worse to have pain in your back than your arms or legs** | | | | | |
| 10 | **It is hard to understand what back pain is like if you have never had it yourself** | | | | | |

THESE QUESTIONS ARE ABOUT RECOVERING FROM BACK PAIN

| | *Please rate each statement as:* | False | Possibly False | Unsure | Possibly True | True |
|---|---|---|---|---|---|---|
| 11 | **If your back hurts, you should take it easy until the pain goes away** | | | | | |
| 12 | **If you ignore back pain, you may cause damage to your back** | | | | | |
| 13 | **It is important to see a health professional when you have back pain** | | | | | |
| 14 | **To effectively treat back pain you need to know exactly what is wrong** | | | | | |
| 15 | **If you have back pain you should avoid exercise** | | | | | |
| 16 | **When you have back pain the risks of vigorous exercise outweigh the benefits** | | | | | |
| 17 | **If you have back pain you should try to stay active** | | | | | |
| 18 | **Once you have had back pain there is always a weakness** | | | | | |
| 19 | **There is a high chance that an episode of back pain will not resolve** | | | | | |
| 20 | **Once you have a back problem, there is not a lot you can do about it** | | | | | |

This questionnaire is taken from: Krageloh C, Medvedev O, Dean S, Stanley J, Dowell A, Darlow B (2020) Rasch analysis of the Back Pain Attitudes Questionnaire. *Disability and Rehabilitation. https://doi.org/10.1080/09638288.2020.1861484*