Objective sleep duration in older adults: Results from The Irish Longitudinal Study on Ageing

Shortened version: Sleep duration in older adults in Ireland

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Abstract

Objective

This study assessed the distribution and correlates of objective sleep duration in the older population in Ireland.

Design

Cross-sectional study using population derived data from Wave 3 of the Irish Longitudinal Study on Ageing

Setting

Community dwelling adults

Participants

Adults aged 50 and older, who wore an accelerometer for at least four days (N=1,533).

Measurements

Sleep was measured for at least four days in 1,533 participants using a GENEActiv™ wrist-worn accelerometer device. Sleep parameters included total sleep time (TST) and self-reported sleep problems. TST was categorised as short and long sleep duration using US National Sleep Foundation guidelines. Linear and multinomial logistic regression models assessed socio-demographic, health and behavioural correlates of sleep duration.

Results

Mean TST for the sample was 463 minutes (SD, 72.6). 13.9% and 16.5% of participants measured short and long sleep duration respectively. TST decreased as sleep problems increased, as did durations recorded in Summer compared to Winter recordings. Advancing age was associated with longer sleep, as was anti-depressant use. Retired/Unemployed participants recorded longer TST, and were more likely to record long sleep compared to employed participants. Fair/poor self-rated health and separated/divorced participants were more likely to record short sleep. Those reporting moderate or high physical activity were less likely to record short or long sleep respectively compared to those reporting low physical activity. Participants reporting a limiting disability were less likely to record long sleep.

Conclusion

Average TST was within recommended guidelines, however, a significant subset of older adults recorded sleep duration outside of the guidelines. Independent demographic and health correlates of sub-optimal sleep were identified, many of which are modifiable. Patients and clinicians should be aware of factors potentially influencing sleep patterns. Longitudinal analyses to confirm directionality of relationships with potential risk factors are warranted.

Keywords: Sleep duration, GENEActiv, Accelerometer, Older population, Actigraphy

Introduction

Sleep duration decreases naturally as we age, but may become more variable in older adults.[1-3] Studies report a U shaped association with adverse health outcomes suggesting that both short and long sleep duration are risk factors for premature mortality, cardiovascular and chronic disease, and impairments in cognitive and mental health.[4-12] In 2015, the National Sleep Foundation released guidelines recommending 7-9 hours (420-540 minutes) of sleep for adults aged 26-64 years, and 7-8 (420-480 minutes) hours for adults aged 65 years and older.[13] Despite links to negative health outcomes and increased healthcare utilisation, sleep duration is not recognised as a public health concern.[14]

The gold standard for sleep measurement, laboratory-based polysomnography, is impractical outside of laboratory settings and of limited use in understanding the sleep patterns of large community-dwelling populations.[2] Self-reported sleep measures are the most commonly used method in large-scale surveys.[2] However, these may measure different sleep parameters than objective measurement.[15] Alternative objective methods such as accelerometry are becoming increasingly common.[16] Technological advances and access to cost-effective, user-friendly, non-invasive measurement devices such as wrist-worn monitors have made it feasible for large, community based population studies to incorporate accelerometry measurement.[17]

The Sleep Health Heart Study (SHHS) included home-based PSG[18], while The Study of Osteoporotic Fractures (SOF) and Osteoporotic Fractures in Men Study (MrOS) measured sleep parameters using both wrist accelerometers and home-based PSG.[19, 20] The CARDIA study included sleep measurement in young adults using wrist accelerometers.[21] These studies have expanded our knowledge on objectively measured sleep characteristics in adults while also exploring outcomes of sleep disorders, fragmented sleep and insufficient sleep duration.[20-27] SHHS, MRoS and SOF are, however, limited in their generalizability to other cohorts. SHHS is a multi-center cohort study designed to focus on sleep disorders as risk factors for cardiovascular disease[28], while SOF[19] and MRoS[29] are multi-centre prospective observational studies limited to female or male cohorts respectively.

Population studies have predominantly used self-reported survey questions for sleep research. There is a need for objective sleep analysis in generalizable population cohorts. Limited comparative data on European cohorts exists. The Whitehall II study of British civil servants recently included accelerometry.[30] These measurements have now been included in The English Longitudinal Study of Ageing[31] and The Irish Longitudinal Study on Ageing (TILDA)[32]. These population representative studies of community dwelling older adults follow an internationally comparable design modelled on the Health and Retirement Study. TILDA provides a unique opportunity to analyse sleep in a population derived randomly selected large sample of community dwelling older adults and thus further contribute to extant literature. The richness and complexity of the data available allows for comprehensive analyses while accounting for an extensive list of confounding factors covering social, economic and health domains.

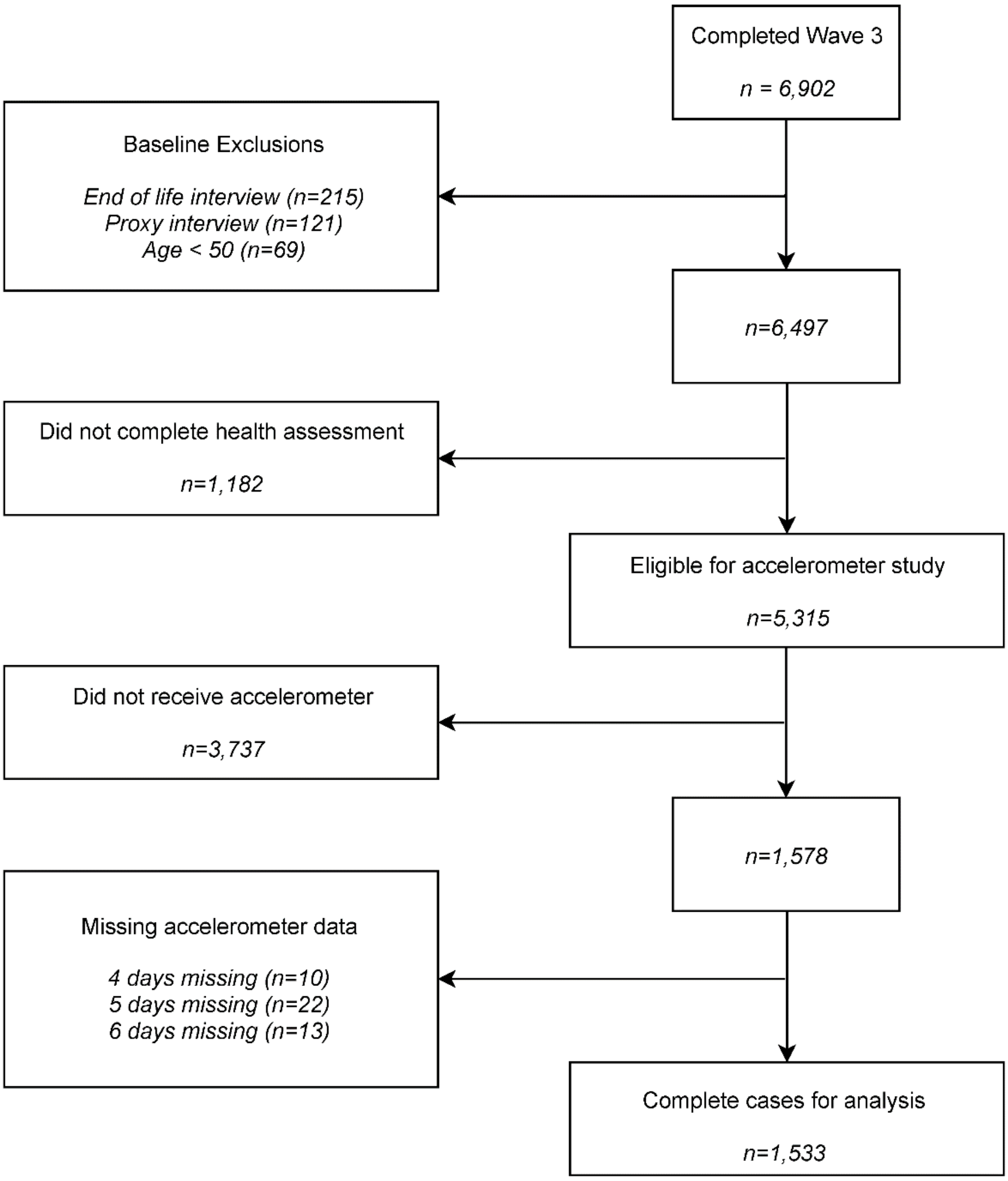
The aims of this study were to: 1) assess objective sleep duration in older adults in Ireland; 2) identify demographic and health related factors associated with sleep duration outside of the recommended ranges.

Methods

Data Collection

TILDA is a nationally representative study of community-dwelling adults aged 50 and over and their partners (of any age) in Ireland. The sampling procedure and study design have been described previously.[32, 33] Briefly, the sampling frame is the Irish Geodirectory, a comprehensive listing of all residential addresses in the Republic of Ireland. A randomly selected, clustered sample was drawn from this listing using the RANSAM sampling procedure[34] and all household residents aged ≥50 years were eligible to participate. 8,175 adults aged 50 and over took part in Wave 1. This study uses data from Wave 3 of TILDA, collected during 2014 and 2015. Participants completed a structured interview covering health, social and financial circumstances. From Wave 2, proxy interviews were offered where a participant could not complete the structured interview due to physical or cognitive impairment. 6,902 participants completed an interview in Wave 3[35] (Figure 1). Only participants aged 50 and older who had completed a self-interview were included in this study (n=6,497). Sleep data was collated during the structured interview (self reported sleep) and by accelerometry applied at the health assessment (objective sleep).

Figure 1. Flowchart of Sample



Participants were offered a comprehensive health assessment following the interview. This was carried out by qualified research nurses in a Health Assessment Centre (HAC). Where participants were unable or unwilling to travel, a modified home-based assessment was offered. 5,315 participants completed the objective assessment.

The Wave 3 health assessment included accelerometry measurement using a lightweight, non-invasive, wrist-worn GENEActiv™ accelerometer.[36] 190 accelerometer devices were available. This facilitated recruitment of a sub-sample of 1,578 (30%), attendees of the health assessment. Participants were asked to wear the accelerometer device on the non-dominant wrist for seven consecutive days immediately following health assessment.

The full seven days of data was not captured for 226 participants when participants reported that wearing the device for seven days was impractical, or the device experienced technical problems in the field. The majority of data loss was one day (61.1% n=138). A Spearman-Brown reliability analysis suggested four days or more were necessary to obtain a reliable estimate of sleep duration (see supplemental methods for details). Participants recording fewer than four days of sleep duration were excluded from analyses. 1,533 participants returned the accelerometer with at least four days of recorded sleep duration.

Activity Monitor

The GENEActiv™ wrist worn accelerometry-based activity device has a measurement range of ±8g with a maximum logging period of seven days at 100Hz. The device is lightweight and water-resistant, with an integrated body-temperature sensor which can confirm wear and non-wear periods.

Activity Processing

Data files were extracted from each accelerometer on return in a .bin and .csv format. Although the GENEActiv™ software package allows for assessment of sleep and activity, the company derived algorithm is manually operated and not suitable for larger samples. Sleep was assessed using a fully automated MEMS accelerometer classification algorithm devised for epidemiological studies.[37] The raw accelerometer data was split into three second epochs at F_s = 100Hz, producing 216000 epochs for a 1-week period (180 hours). This was further classified into sleep and wake cycles using automated threshold detection. To assess the accuracy of the sleep classification of this algorithm, a verification study was performed using a sample of participants in the English Longitudinal Study on Ageing. 99 participants had accelerometer recordings from a GENEActiv™ monitor matched to a sleep/wake diary completed by the participant. The algorithm showed a zero-mean difference from the diary reports, indicating that on average, the algorithm agrees closely with the diary reports.[37]

Sleep Parameters

Total sleep time (TST) is derived as the length of the classified major sleep period in each day, and presented in minutes.

Short sleep duration and long sleep duration were categorized using the recommended sleep periods as defined by the US National Sleep Foundation.[13] The recommended thresholds are determined using evidence drawn primarily from studies involving self reported sleep duration which is typically asked to the nearest hour.[13, 38] For comparability, TST was rounded to the nearest hour prior to categorization. Short sleep duration is defined as <7 hours for all participants. Long sleep duration is defined as >9 hours for participants aged up to 64, and >8 hours for participants aged 65 years and older.

Sleep Problems

Self-reported sleep problems were collected using items from the Jenkins Sleep Problems Scale.[39] Participants were asked three questions including how likely they were to doze off during the day with responses ranging from "would never doze" to "high chance of dozing" on a four-point Likert scale, how often they have trouble falling asleep, and how often they have trouble with waking up too early and not being able to fall asleep again, rated on a three-point Likert scale from "rarely or never" to "most of the time". Items were summed and treated as a continuous scale (range 0-7). Higher scores represented more sleep problems.

Covariates

Covariates known to impact sleep were included in the analysis. All covariates were self-reported:

Socio Demographic

Age was included as a continuous measure. Sex, educational attainment (primary, secondary, third level or higher), employment status (employed, retired, unemployed - includes unemployed, permanently sick or disabled, looking after home or family, or in education/training), marital status (married, not married, separated/divorced, widowed), location of residence (Dublin city or county, another town or city, a rural area) were also included.

Physical, Mental and Behavioural Health

Health covariates included self-rated health, physical activity groups (low, moderate, high) as measured by the International Physical Activity Questionnaire[40, 41], Body Mass Index (BMI), smoker status, self-reported pain, limiting disability determined by asking participants if they have any long term health problems, illness, disability or infirmity, including mental health problems, which would limit activities in any way, depressive symptoms as measured by scoring 9 or higher on the 8-item Center for Epidemiological Studies Depression Scale[42], doctor diagnosed cardiovascular conditions (hypertension, stroke, angina, heart attack, heart murmur, atrial fibrillation) and doctor diagnosed chronic conditions (lung disease, asthma, arthritis, osteoporosis, cancer, Parkinson's disease, stomach ulcer, varicose ulcer, liver disease, thyroid disease, kidney disease).

Medications

Medications known to impact sleep were included as covariates. Medications were classified using the Anatomical Therapeutic Chemical (ATC) classification codes. Sleep medication included ATC codes N05A (Antipsychotics), N05B (Anxiolytics), N05C (Hypnotics and Sedatives) and R06A (Antihistamines). Anti-hypertensive medication included ATC codes C02 (anti-adrenergic agents), C03 (diuretics), C07 (beta-blockers), C08 (calcium-channel blockers) and C09 (ACE inhibitors). Anti-depressant medication was classified by ATC code N06A.

Statistical analyses

Bivariate associations between TST and season, weekday/weekend, day of wear and between TST and sample characteristics, were analysed using *t*-tests and ANOVAs. Linear regression analyses were used to assess independent associations between sample characteristics and TST. For further interpretability, multinomial logistic regression of short and long sleep duration was undertaken to identify which groups were independently associated with measurement of categorised sub-optimal sleep duration. Statistical analyses were performed using Stata 15.1 (StataCorp., College Station, TX).

Results

Sample Characteristics

The characteristics of the accelerometer sample did not differ greatly from the health assessment sample, or the complete sample (Table 1). The Mean (SD) age of the accelerometer sample was 67.5 (9.1) years (range: 50-94 years). The largest discrepancy was found in employment status. 53.4% of the accelerometer sample reported being retired, compared to 46.4% of the health assessment sample and 45.8% of the complete sample. Self-reported sleep problems did not differ across the three samples (Mean±SD: 2.2±1.6).

Table 1. Characteristics of the Wave 3 Self-interview, health assessment and accelerometer samples

	Wave 3 self-interview[a] sample (n=6497)	Wave 3 Health assessment[b] sample (n=5315)	Wave 3 accelerometer[c] sample (n=1533)
	Mean (SD) or %	Mean (SD) or %	Mean (SD) or %
Sleep Problems Score	**2.2 (1.6)**	**2.2 (1.6)**	**2.2 (1.6)**
Sex			
Male	44.6	45.0	46.4
Female	55.4	55.0	53.6
Age	66.6 ± 9.2	66.4 ± 9.0	67.5 ± 9.1
Education			
None/Primary	25.5	23.6	25.4
Secondary	39.8	39.2	39.7
Third/Higher	34.7	37.2	34.8
Employment Status[d]			
Employed	33.0	33.2	26.5
Retired	45.8	46.4	53.4
Other	21.3	20.4	20.1
Marital Status			
Married	69.7	71.0	72.4
Never Married	8.5	7.8	7.7
Separated/Divorced	7.2	7.0	6.8
Widowed	14.6	14.2	13.1
Location			
Dublin city or county	24.1	25.6	28.4
Another town or city	27.8	27.1	27.1
A rural area	48.1	47.2	44.4
Self-Rated Health			
Excellent/Very Good/Poor	81.8	83.1	84.1
Fair/Poor	18.2	16.9	15.9
Physical Activity Groups			
Low	39.0	38.1	36.1
Moderate	34.8	35.7	36.5
High	26.1	26.2	27.4
BMI Category			
Normal Weight	22.4	22.4	23.4
Overweight	43.7	43.7	44.7
Obese	34.0	34.0	31.9
Current Smoker	12.9	11.7	10.7
Reported Pain	35.0	35.1	35.8
Limiting Disability[d]	25.7	25.1	25.1
Depressive Symptoms[d]	10.3	10.4	9.2
Medications: Sleep	9.1	9.0	8.4
Medications: Anti-Hypertensives	43.7	43.2	46.3
Medications: Anti-Depressants	9.2	9.2	9.4
≥1 Chronic Condition	54.1	54.2	56.0
≥1 Cardiovascular Condition	45.9	45.3	48.1

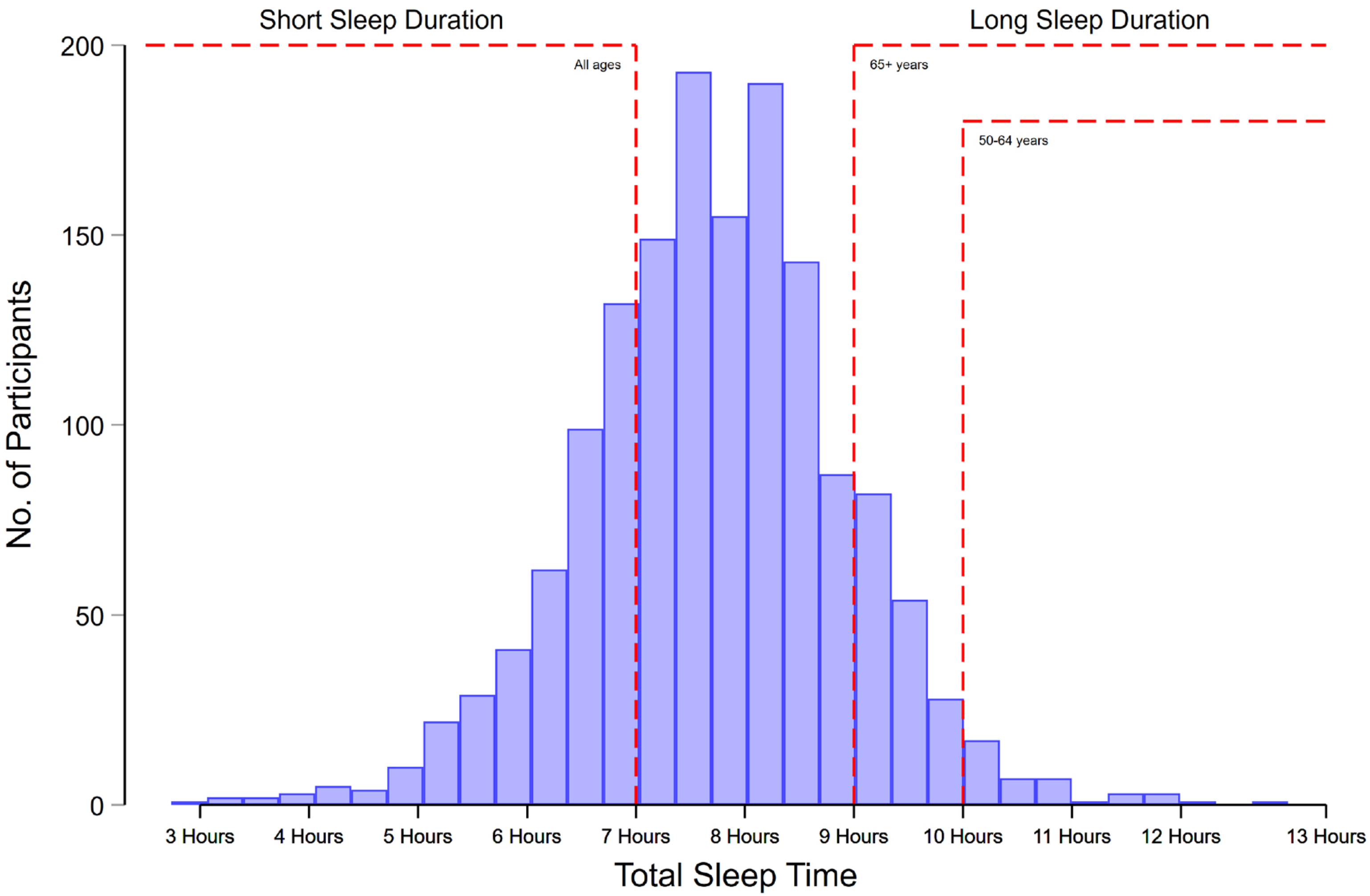
[a]Missing data: Sleep problems *n* = 18 (0.3%), Education *n* = 2 (0.03%,) Employment status *n* = 11 (0.2%), Self-rated health *n* = 1 (0.02%), Physical Activity Groups *n* = 315 (4.9%), Smoker *n* = 6 (0.1%), Reported pain *n* = 5 (0.1%) Limiting disability *n* = 3 (0.1%), Depressive symptoms *n*= 34 (0.5%)

[b]Sleep problems *n* = 12 (0.2%), Education *n* = 1 (0.02%,) Employment status *n* = 6 (0.1%), Self-rated health *n* = 1 (0.02%), Physical Activity Groups *n* = 256 (4.8%), BMI Category *n* = 78 (1.5%), Smoker *n* = 1 (0.02%) Reported pain *n* = 5 (0.1%) Limiting disability *n* = 2 (0.04%), Depressive symptoms *n*= 19 (0.4%)

[c]Missing data: Sleep problems *n* = 7 (0.5%), Employment status *n* = 4 (0.3%), Physical Activity Groups *n* = 17 (1.1%), BMI Category *n* = 17 (1.1%) Reported pain *n* = 4 (0.3%) Limiting disability *n* = 6 (0.4%), Depressive symptoms *n*= 6 (0.4)

Mean TST was 463±73 minutes with a range of 164-779 minutes (Figure 2). 80.2% of participants aged 50-64 were within the recommended range of 7-9 hours, with 15.0% sleeping 6 hours or less and 4.8% sleeping for 10 hours or more. Of those aged 65 years and older, 61.1% slept within the recommended time of 7-8 hours, with 13.0% sleeping 6 hours or less and 25.9% sleeping for 9 hours or more.

Figure 2: Histogram of Total Sleep Time



Supplementary Figure S1 shows mean TST by day of wear, week/weekend and season. Participants recorded longer mean TST on day of application of the device (483 minutes) compared to shorter means of 459-465 minutes for the remainder of wear. Significant variation in TST between seasons was recorded. TST recorded during spring and summer were shorter (Mean: 455 minutes) than winter and autumn (Mean: 470-472 minutes).

Table 2 shows the mean TST by sample characteristic groups. Participants who were retired (Mean: 468) or unemployed (Mean: 467) recorded almost 20 minutes longer TST compared to employed participants (Mean: 450 minutes). Anti-hypertensive medication users recorded longer TST compared to non-users (Mean: 467 minutes vs 459 minutes), as did anti-depressant users compared to non-users (Mean: 478 minutes vs 461 minutes).

Table 2. Total sleep time by sample characteristics

	Total Sleep Time[a] Mean ± SD (Range)	
Overall	463 ± 73 (164-779)	
Sex		
Male	460 ± 75 (164-726)	$p = 0.19$
Female	465 ± 70 (234-779)	
Education		
None/Primary	467 ± 78 (197-779)	
Secondary	464 ± 73 (191-705)	$p = 0.24$
Third/Higher	459 ± 68 (164-726)	
Employment Status[b]		
Employed	450 ± 63 (191-629)	
Retired	468 ± 75 (164-726)	$p < 0.001$
Unemployed	467 ± 76 (197-779)	
Marital Status		
Married	462 ± 68 (164-726)	
Never Married	451 ± 80 (197-701)	$p = 0.10$
Separated/Divorced	467 ± 72 (318-655)	
Widowed	471 ± 89 (234-779)	
Location		
Dublin city or county	459 ± 69 (209-672)	
Another town or city	465 ± 77 (191-779)	$p = 0.39$
A rural area	464 ± 72 (164-705)	
Self-Rated Health		
Excellent/Very Good/Poor	463 ± 70 (164-779)	$p = 0.82$
Fair/Poor	464 ± 84 (250-705)	
Physical Activity Groups[b]		
Low	465 ± 81 (164-779)	
Moderate	465 ± 69 (209-710)	$p = 0.26$
High	458 ± 66 (191-655)	
BMI Categories[b]		
Normal Weight	462 ± 68 (259-726)	
Overweight	465 ± 70 (191-779)	$p = 0.73$
Obese	461 ± 78 (164-710)	
Current Smoker		
No	463 ± 72 (164-779)	$p = 0.77$
Yes	465 ± 77 (282-658)	
Reported Pain[b]		
No	462 ± 74 (164-779)	$p = 0.46$
Yes	465 ± 70 (250-710)	
Limiting Disability[b]		
No	462 ± 71 (164-779)	$p = 0.09$
Yes	468 ± 77 (214-705)	
Depressive Symptoms[b]		
No	462 ± 72 (164-779)	$p = 0.22$
Yes	470 ± 80 (250-672)	

Medications: Sleep		
No	462 ± 72 (164-779)	$p = 0.07$
Yes	474 ± 77 (259-699)	
Medications: Anti-Hypertensives		
No	459 ± 69 (164-655)	$p < 0.03$
Yes	467 ± 76 (214-779)	
Medications: Anti-Depressants		
No	461 ± 70 (164-726)	$p < 0.01$
Yes	478 ± 93 (191-779)	
Chronic Conditions		
No Chronic Condition	463 ± 72 (164-726)	$p = 0.84$
≥1 Chronic Condition	463 ± 73 (197-779)	
Cardiovascular Conditions		
No Cardiovascular Condition	461 ± 69 (191-655)	$p = 0.20$
≥1 Cardiovascular Condition	465 ± 76 (164-779)	

[a]Presented as minutes
[b]Missing data: Sleep problems n = 7 (0.5%), Employment status n = 4 (0.3%), Physical Activity Groups n = 17 (1.1%), BMI Category n = 17 (1.1%) Reported pain n = 4 (0.3%) Limiting disability n = 6 (0.4%), Depressive symptoms n= 6 (0.4%)
p-values below 0.05 show statistically significant differences between groups

Figure 3A shows a multivariable linear regression model assessing associations between sample characteristics and TST. Figure 3B and 3C show the results of a multinomial logistic regression analysis which assessed predictors of short (n=213, 13.9%) and long sleep duration (n=253, 16.5%).

Self-reported sleep problems were associated with TST, and the likelihood of short sleep and long sleep durations. TST decreased as sleep problems increased (*B*=-3.58, 95% CI:-6.00,-1.17, $p<0.01$), with the risk of short sleep duration increasing (RRR=1.12 95% CI=1.01,1.23, $p<0.05$), and long sleep duration decreasing (RRR=0.89 95% CI=0.81,0.99, $p<0.05$) for each unit increase of sleep problems.

Associations between employment status and both TST and long sleep durations were found. Retired/unemployed participants recorded longer TST compared to employed participants (Retired: *B*=15.04, 95% CI: 4.22,25.85, $p<0.01$; Unemployed: *B*=12.60, 95% CI: 0.78,24.42, $p<0.05$). This was further reflected in a significant positive association with long sleep duration. Retired (RRR=3.36 95% CI=1.91,5.90, $p<0.001$) and Unemployed (RRR=2.64 95% CI=1.42,4.92, $p<0.01$) participants were more likely than employed participants to record long sleep duration.

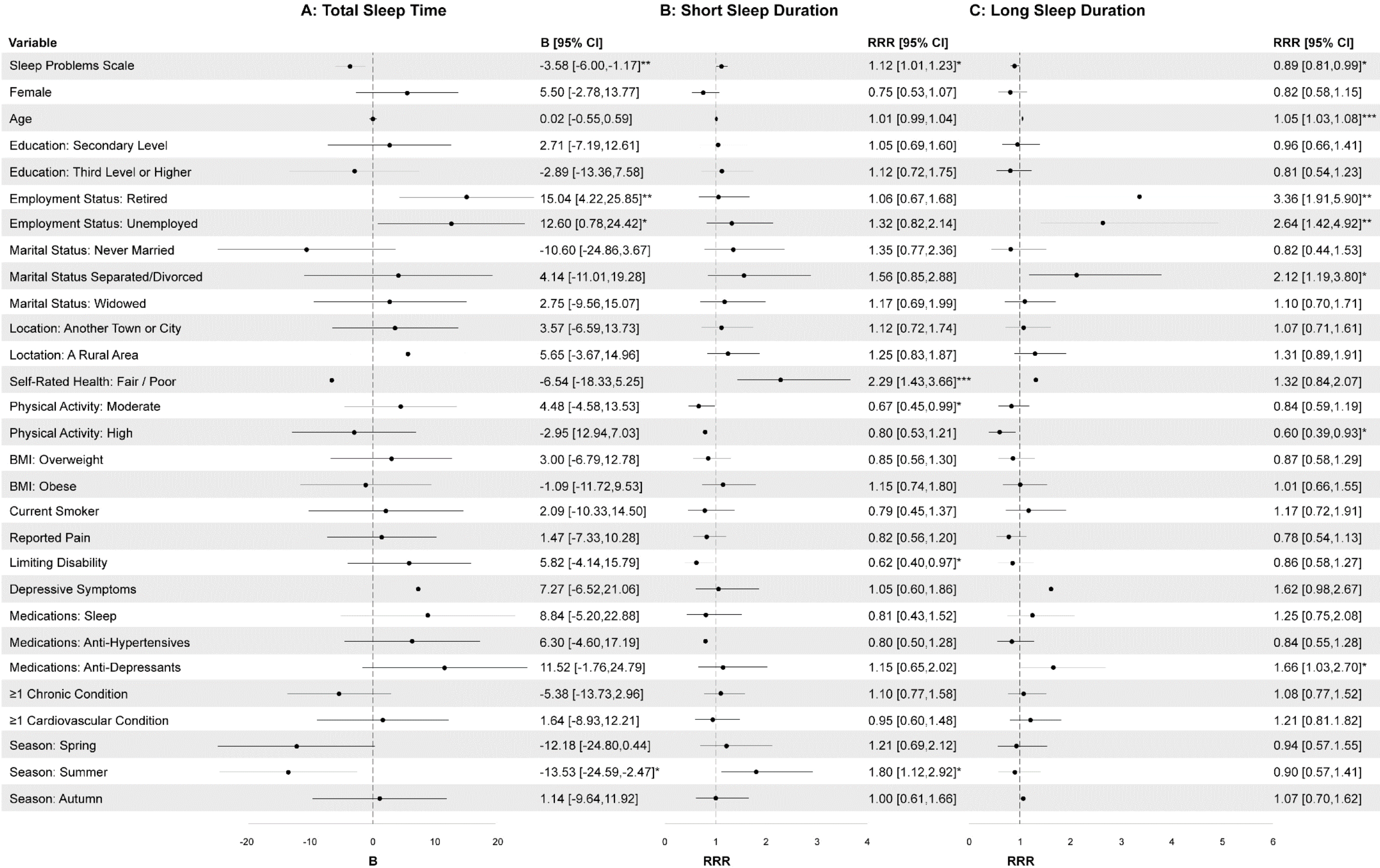
Season of recording was associated with TST and short sleep duration. Shorter TST was recorded in Summer compared to Winter (*B*=-13.53, 95% CI: -24.59,-2.47, $p<0.05$). Correspondingly, participants who had recordings taken in summer were more likely to record short sleep duration (RRR=1.80 95% CI=1.12,2.92, $p<0.05$) compared to Winter recordings.

Individual associations with both short and long sleep duration were also found. Participants who reported their health as fair/poor, compared to those who rated their health as excellent/very good/good, were more likely to record short sleep (RRR=2.29 95%

CI=1.43,3.66, $p<0.001$). Participants who were separated/divorced, compared to married participants, were also more likely to be short sleepers (RRR=2.12 95% CI=1.19,3.80, $p<0.05$). Age was positively associated with long sleep (RRR=1.05, 95% CI=1.03,1.08, $p<0.001$) as were anti-depressant medication users compared to non-users (RRR=1.66 95% CI=1.03,2.70, $p<0.05$).

Those reporting moderate physical activity were less likely (RRR=0.67 95% CI=0.45,0.99, $p<0.05$) to be short sleepers compared to those reporting low physical activity, as were those who reported a limiting disability compared to those who did not (RRR=0.62, 95% CI=0.40,0.95, $p<0.05$). Participants reporting high physical activity were less likely (RRR=0.60 95% CI=0.39,0.93, $p<0.05$) to be associated with long sleep duration than participants reporting low physical activity.

Figure 3. Regression models for predictors of A: Total Sleep Time, B: Short Sleep Duration, C: Long Sleep Duration
A: Linear Regression for total sleep time in minutes
B/C: Multinomial Regression for predictors of short and long sleep duration compared to recommended sleep duration



Discussion

This study assessed objective sleep duration in one of the largest samples to date of community-dwelling older adults, from different socio-economic backgrounds. Distributions of sleep duration were explored, and predictors of short and long sleep duration were identified. Whereas 69.6% of adults are sleeping within recommended guidelines, 13.9% and 16.5% report short or long sleep respectively. In other studies, these are known to be associated with negative health outcomes[4-12, 20, 43] Reported sleep problems and poorer self-rated health were associated with short sleep. Increasing age, separated/divorced participants and unemployment were positively associated with long sleep duration, as were common experiences with advancing age such as retirement, and anti-depressant use. Limiting disability and moderate physical activity were negatively associated with short sleep duration, while reported sleep problems and high physical activity were associated with long sleep duration.. Awareness of characteristics of people with altered sleep may alert attending health care professionals to high risk groups, suggesting monitoring of habitual changes in sleep during life-stage transitions and healthcare management may be warranted.

SHHS[3], SOF[44], MrOS[20] and CARDIA[24] have all shown that sleep duration is associated with increased health risks. MrOS provides an insight in older male adults, and SOF provide insight into older female adults. Both studies however are volunteer led multi-centre prospective observational studies, limited to male or female samples respectively, and note their findings have limited generalizability to other cohorts[19, 29]. SHHS is designed to investigate sleep disorders as risk factors for cardiovascular disease using in-home PSG[28], while CARDIA assesses sleep in a young adult cohort[21]. Although the Whitehall II study includes valid accelerometer data for 4,204 adults aged 60-83[30], data is collected from an occupational cohort and may not be considered representative of the general older population.[45] The TILDA accelerometer sample is a sub-sample of community dwelling adults in a large European cohort drawn from an internationally comparable survey design. The richness and complexity of the TILDA data enabled adjustment for many relevant confounders and identified sleep duration, socio-demographic, health and behavioural correlates of sleep duration. The design of TILDA has additionally allowed us to control for sources of methodological variation such as season. This study thus expands on existing reports.

Insomnia is closely related to sleep duration. TILDA included a number of questions assessing self-reported sleep problems drawn from a validated instrument.[39] These were included in models to assess the impact of sleep quality on measured sleep duration. Reporting more problems was strongly associated with short sleep. Inclusion of these measurements also allowed assessment of the effects of other factors on sleep duration independent of subjective experience.

Seasonal differences may be related to change in temperature or daylight hours.[46] Recordings taken during summer were associated with short sleep, potentially caused by longer daylight hours or higher temperatures.

Poorer general health was associated with short and long sleep duration. Participants who rated their health as fair/poor were more likely to record short sleep. Anti-depressants disrupt sleep, or improve it dependent upon the sedative properties of different drug classes.[47] Anti-depressant use was associated with long sleep in fully adjusted models which controlled for depressive symptoms.

Moderate and high physical activity showed negative associations with short and long sleep. Physical activity is known to attenuate the risk of sub-optimal sleep duration. In the MrOS study high levels of physical activity reduced the odds of becoming a short sleeper during 6-year follow.[23]

Age, employment status and marital status were all found to be related to TST. Our analysis showed age had a positive association with long sleep duration, but not with TST. Kurina et al. found increased TST of around 12 minutes per decade in adults aged 62-90.[2] The MrOS sample showed higher baseline age predicted increased odds of becoming a long sleeper.[23] However, findings from SHHS showed that TST decreased at older age, but sleep latency increased, an effect similar to our findings.[3] Transition to retirement leads to an increase in sleep duration.[48] Increased TST and a positive association with long sleep duration was found in our retired participants. A study of older adults in China showed an increased risk of short and long sleep duration in unmarried participants.[49] A US study reported better sleep characteristics in older married adults compared with unmarried participants.[50] Conversely, our findings showed participants who were separated/divorced experienced an association with long sleep duration.

Characteristics which were found to have associations with sub-optimal sleep duration may have clinical relevance, identifying groups potentially at risk of negative outcomes.

Strengths and Limitations

This is one of the largest studies of accelerometer measurement in a large population derived, community-dwelling cohort of older adults, to date.

The availability of TST coupled with the richness of data allow for a comprehensive assessment of sleep duration in older adults. The time span involved in collecting data during Wave 3 of TILDA additionally allowed for a summary of seasonal variation. Although this effect is cross-sectional and subject to individual variation, it has identified meaningful differences that should be considered as potential confounders.

Limitations were also present. The sample is relatively young (mean age: 67.5 years) and healthy. Accelerometer measurement is cross-sectional, limiting the ability to understand the temporal direction of these relationships. Further study is needed including longitudinal analyses to confirm directionality of relationships. Accelerometer measurements were only available for a sub-sample and though characteristically similar to the full cohort, it is not fully population representative. In wrist-worn monitors, activity measurement can be influenced by the height of the user. However, objectively measured height did not correlate with TST (-0.02) in this study (Supplementary Figure S2).

In conclusion, our findings show that the majority (69.6%) of older Irish adults sleep within the recommended range. This study has established baseline findings of sleep duration in a population derived sample of community dwelling older adults drawn from a large European cohort. Short and long sleep duration were found to be associated with socio-demographic and health characteristics, including employment status, marital status, self-rated health, limiting disability, physical activity and use of anti-depressants, many of which may be modifiable. Patients and clinicians should be aware of factors which influence undesirable sleep patterns.

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Researchers interested in using TILDA data may access the data for free from the following sites:

Irish Social Science Data Archive at University College Dublin (www.ucd.ie/issda/data/tilda/).

Interuniversity Consortium for Political and Social Research at the University of Michigan (http://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/34315).

Conflict of Interest: The authors declare no conflict of interest.

Author Contributions: SS: preparation of data, data analysis, drafting manuscript. RAK is the Principal investigator and responsible for overall and individual study design, data interpretation, content and dissemination. HN: significant contribution to preparation of data. SS, HN, MOC: study concept and design, interpretation of results, review and critical revision of manuscript for important intellectual content, final approval for submission.

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References

1. Ohayon MM, Carskadon MA, Guilleminault C, Vitiello MV. Meta-analysis of quantitative sleep parameters from childhood to old age in healthy individuals: developing normative sleep values across the human lifespan. *Sleep*. 2004;**27**: 1255-1273.

2. Kurina LM, Thisted RA, Chen J-H, McClintock MK, Waite LJ, Lauderdale DS. Actigraphic sleep characteristics among older Americans. *Sleep health*. 2015;**1**: 285-292.

3. Unruh ML, Redline S, An MW, *et al.* Subjective and objective sleep quality and aging in the sleep heart health study. *J Am Geriatr Soc*. 2008;**56**: 1218-1227.

4. Foley D, Ancoli-Israel S, Britz P, Walsh J. Sleep disturbances and chronic disease in older adults: results of the 2003 National Sleep Foundation Sleep in America Survey. *Journal of psychosomatic research*. 2004;**56**: 497-502.

5. Yaffe K, Falvey CM, Hoang T. Connections between sleep and cognition in older adults. *The Lancet Neurology*. 2014;**13**: 1017-1028.

6. Spira AP, Chen-Edinboro LP, Wu MN, Yaffe K. Impact of Sleep on the Risk of Cognitive Decline and Dementia. *Current opinion in psychiatry*. 2014;**27**: 478-483.

7. Spiegelhalder K, Scholtes C, Riemann D. The association between insomnia and cardiovascular diseases. *Nature and Science of Sleep*. 2010;**2**: 71-78.

8. Robert E. Roberts, Sarah J. Shema, George A. Kaplan, William J. Strawbridge. Sleep Complaints and Depression in an Aging Cohort: A Prospective Perspective. *American Journal of Psychiatry*. 2000;**157**: 81-88.

9. Nakakubo S, Makizako H, Doi T, *et al.* Long and Short Sleep Duration and Physical Frailty in Community-Dwelling Older Adults. *The journal of nutrition, health & aging*. 2018;**22**: 1066-1071.

10. Spira AP, Stone KL, Redline S*, et al.* Actigraphic Sleep Duration and Fragmentation in Older Women: Associations With Performance Across Cognitive Domains. *Sleep*. 2017;**40**: zsx073.

11. Kumari M, Green R, Nazroo J. Sleep duration and sleep disturbance. In: Banks J, Lessof C, Nazroo J, Rogers N, Stafford M, Steptoe A, eds. *Financial circumstances, health and well-being of the older population in England*. London: Institute for Fiscal Studies, 2010.

12. Gallicchio L, Kalesan B. Sleep duration and mortality: a systematic review and meta-analysis. *J Sleep Res*. 2009;**18**: 148-158.

13. Hirshkowitz M, Whiton K, Albert SM*, et al.* National Sleep Foundation's updated sleep duration recommendations: final report. *Sleep Health: Journal of the National Sleep Foundation*. 2015;**1**: 233-243.

14. Perry GS, Patil SP, Presley-Cantrell LR. Raising Awareness of Sleep as a Healthy Behavior. *Preventing Chronic Disease*. 2013;**10**: E133.

15. Hughes JM, Song Y, Fung CH*, et al.* Measuring Sleep in Vulnerable Older Adults: A Comparison of Subjective and Objective Sleep Measures. *Clinical gerontologist*. 2018;**41**: 145-157.

16. Sadeh A. The role and validity of actigraphy in sleep medicine: An update. *Sleep Medicine Reviews*. 2011;**15**: 259-267.

17. Marino M, Li Y, Rueschman MN*, et al.* Measuring Sleep: Accuracy, Sensitivity, and Specificity of Wrist Actigraphy Compared to Polysomnography. *Sleep*. 2013;**36**: 1747-1755.

18. Redline S, Sanders MH, Lind BK*, et al.* Methods for obtaining and analyzing unattended polysomnography data for a multicenter study. Sleep Heart Health Research Group. *Sleep*. 1998;**21**: 759-767.

19. Blackwell T, Redline S, Ancoli-Israel S*, et al.* Comparison of sleep parameters from actigraphy and polysomnography in older women: the SOF study. *Sleep*. 2008;**31**: 283-291.

20. Blackwell T, Yaffe K, Ancoli-Israel S, *et al.* Association of Sleep Characteristics and Cognition in Older Community-Dwelling Men: the MrOS Sleep Study. *Sleep*. 2011;**34**: 1347-1356.

21. Lauderdale DS, Knutson KL, Yan LL, *et al.* Objectively Measured Sleep Characteristics among Early-Middle-Aged Adults: The CARDIA Study. *American Journal of Epidemiology*. 2006;**164**: 5-16.

22. Rogers-Soeder TS, Blackwell T, Yaffe K, *et al.* Rest-Activity Rhythms and Cognitive Decline in Older Men: The Osteoporotic Fractures in Men Sleep Study. *J Am Geriatr Soc*. 2018;**66**: 2136-2143.

23. Smagula SF, Harrison S, Cauley JA, *et al.* Determinants of Change in Objectively Assessed Sleep Duration Among Older Men. *American Journal of Epidemiology*. 2017;**185**: 933-940.

24. Petrov MER, Kim Y, Lauderdale D, *et al.* Longitudinal Associations between Objective Sleep and Lipids: The CARDIA Study. *Sleep*. 2013;**36**: 1587-1595.

25. Shahar E, Whitney CW, Redline S, *et al.* Sleep-disordered breathing and cardiovascular disease: cross-sectional results of the Sleep Heart Health Study. *Am J Respir Crit Care Med*. 2001;**163**: 19-25.

26. Stone KL, Blackwell TL, Ancoli-Israel S, *et al.* Sleep Disturbances and Risk of Falls in Older Community-Dwelling Men: The Outcomes of Sleep Disorders in Older Men (MrOS Sleep) Study. *Journal of the American Geriatrics Society*. 2014;**62**: 299-305.

27. Blackwell T, Yaffe K, Ancoli-Israel S, *et al.* Associations between sleep architecture and sleep-disordered breathing and cognition in older community-dwelling men: the Osteoporotic Fractures in Men Sleep Study. *J Am Geriatr Soc*. 2011;**59**: 2217-2225.

28. Quan SF, Howard BV, Iber C, *et al.* The Sleep Heart Health Study: design, rationale, and methods. *Sleep*. 1997;**20**: 1077-1085.

29. Blank JB, Cawthon PM, Carrion-Petersen ML, *et al.* Overview of recruitment for the osteoporotic fractures in men study (MrOS). *Contemp Clin Trials*. 2005;**26**: 557-568.

30. van Hees VT, Sabia S, Anderson KN, *et al.* A Novel, Open Access Method to Assess Sleep Duration Using a Wrist-Worn Accelerometer. *PloS one*. 2015;**10**: e0142533.

31. Steptoe A, Breeze E, Banks J, Nazroo J. Cohort Profile: The English Longitudinal Study of Ageing. *International journal of epidemiology*. 2012;**42**: 1640-1648.

32. Kenny R, Whelan, BJ, Cronin, H, Kamiya, Y, Kearney, P, O'Regan, C, Ziegel, M. The Design of The Irish Longitudinal Study on Ageing. Dublin: The Irish Longitudinal Study on Ageing, 2010.

33. Kearney PM, Cronin H, O'Regan C, *et al.* Cohort profile: the Irish Longitudinal Study on Ageing. *International journal of epidemiology*. 2011;**40**: 877-884.

34. Whelan BJ. A National Random Sampling Design for Ireland. *Econ Soc Rev*. 1979;**10**: 169-174.

35. McGarrigle C, Donoghue, O, Scarlett, S, Kenny, RA. Health and Wellbeing: Active Ageing for Older Adults in Ireland. Dublin: The Irish Longitudinal Study on Ageing, 2017.

36. Donoghue OA, McGarrigle CA, Foley M, Fagan A, Meaney J, Kenny RA. Cohort Profile Update: The Irish Longitudinal Study on Ageing (TILDA). *International journal of epidemiology*. 2018;**47**: 1398-1398l.

37. Nolan H, Dunne, CL, Greene, L, Walsh, P, Kearney, PM, Kenny, RA, Finucane, C. SIGNAL PROCESSING FRAMEWORK FOR OBJECTIVE SLEEP AND PHYSICAL ACTIVITY MEASUREMENT USING ACCELEROMETRY IN POPULATION STUDIES OF OLDER ADULTS. *Age and Ageing*. 2013;**42**: iii15.

38. Lauderdale DS, Knutson KL, Yan LL, Liu K, Rathouz PJ. Self-reported and measured sleep duration: how similar are they? *Epidemiology*. 2008;**19**: 838-845.

39. Jenkins CD, Stanton B-A, Niemcryk SJ, Rose RM. A scale for the estimation of sleep problems in clinical research. *Journal of Clinical Epidemiology*. 1988;**41**: 313-321.

40. Fan M, Lyu J, He P. *Guidelines for data processing and analysis of the International Physical Activity Questionnaire (IPAQ).2005. URL: <*http://www.IPAQ.ki.se, 2014.

41. Craig CL, Marshall AL, Sjostrom M, *et al.* International physical activity questionnaire: 12-country reliability and validity. *Medicine and science in sports and exercise*. 2003;**35**: 1381-1395.

42. Briggs R, Carey D, O'Halloran AM, Kenny RA, Kennelly SP. Validation of the 8-item Centre for Epidemiological Studies Depression Scale in a cohort of community-dwelling older people: data from The Irish Longitudinal Study on Ageing (TILDA). *European Geriatric Medicine*. 2018;**9**: 121-126.

43. Irwin MR, Olmstead R, Carroll JE. Sleep Disturbance, Sleep Duration, and Inflammation: A Systematic Review and Meta-Analysis of Cohort Studies and Experimental Sleep Deprivation. *Biol Psychiatry*. 2016;**80**: 40-52.

44. Patel SR, Blackwell T, Redline S, *et al.* The association between sleep duration and obesity in older adults. *International Journal Of Obesity*. 2008;**32**: 1825.

45. Sabia S, van Hees VT, Shipley MJ, *et al.* Association Between Questionnaire- and Accelerometer-Assessed Physical Activity: The Role of Sociodemographic Factors. *American Journal of Epidemiology*. 2014;**179**: 781-790.

46. Friborg O, Bjorvatn B, Amponsah B, Pallesen S. Associations between seasonal variations in day length (photoperiod), sleep timing, sleep quality and mood: a comparison between Ghana (5 degrees) and Norway (69 degrees). *J Sleep Res*. 2012;**21**: 176-184.

47. Wichniak A, Wierzbicka A, Walecka M, Jernajczyk W. Effects of Antidepressants on Sleep. *Curr Psychiatry Rep*. 2017;**19**: 63.

48. Myllyntausta S, Salo P, Kronholm E, *et al.* Changes in Sleep Duration During Transition to Statutory Retirement: A Longitudinal Cohort Study. *Sleep*. 2017;**40**.
49. Gu D, Sautter J, Pipkin R, Zeng Y. Sociodemographic and health correlates of sleep quality and duration among very old Chinese. *Sleep*. 2010;**33**: 601-610.
50. Chen J-H, Waite LJ, Lauderdale DS. Marriage, Relationship Quality, and Sleep among U.S. Older Adults. *Journal of Health and Social Behavior*. 2015;**56**: 356-377.

Supplementary Methods. Spearman-Brown Reliability Analysis to determine minimum number of recorded days required for reliable measure of sleep duration

A two-way random effects model was used to calculate an intra-class correlation coefficient (ICC). Reliability was estimated using the formula;

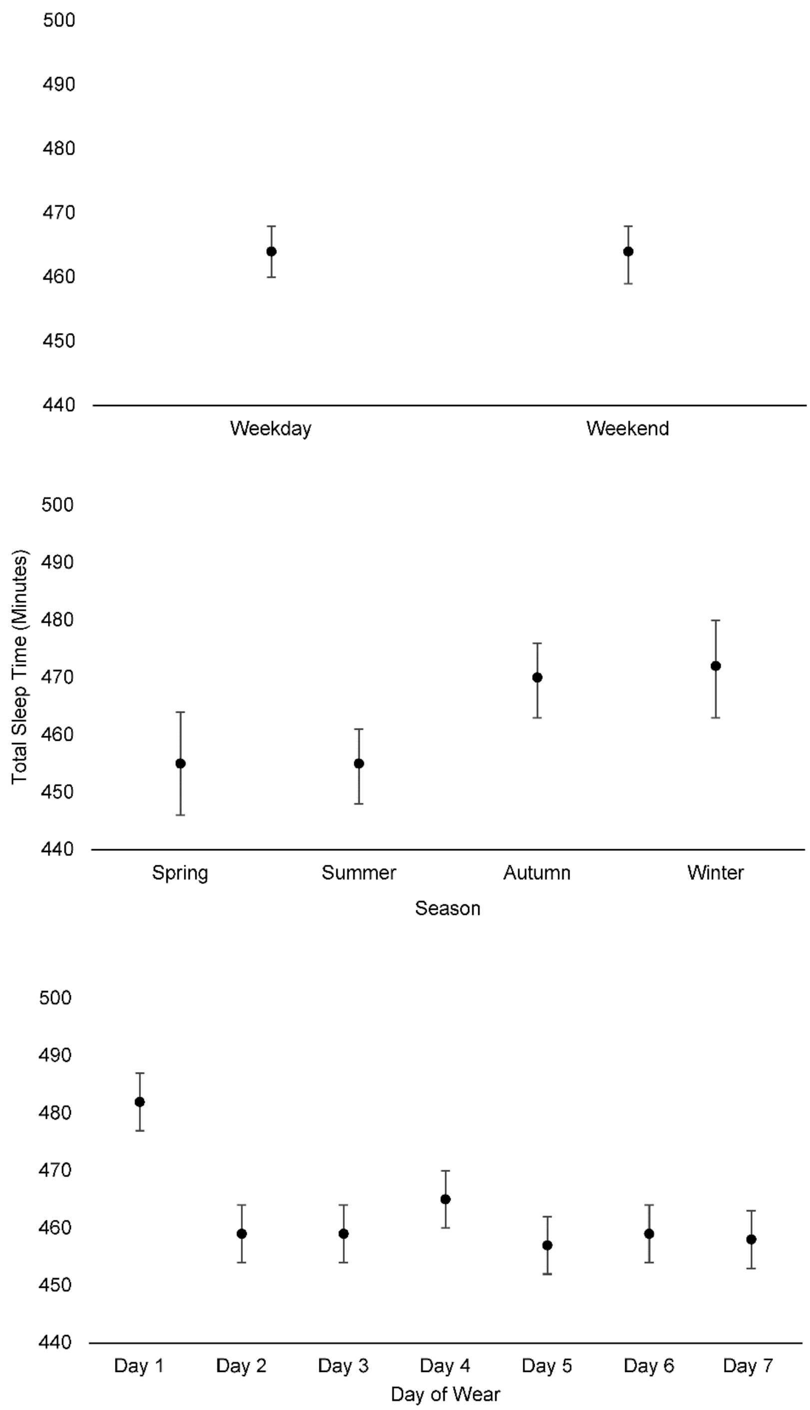
$$r_{sb} = \frac{n(\mathrm{ICC})}{1+(n-1)\mathrm{ICC}}$$

where *n* refers to the number of within person observations. In line with previous literature, ≥0.7 was used as the threshold for an acceptable reliability coefficient for the measurement of sleep parameters.[1,2] Four days or more of recorded sleep duration were needed to reach the reliability coefficient threshold in this sample (Supplementary Figure S3).

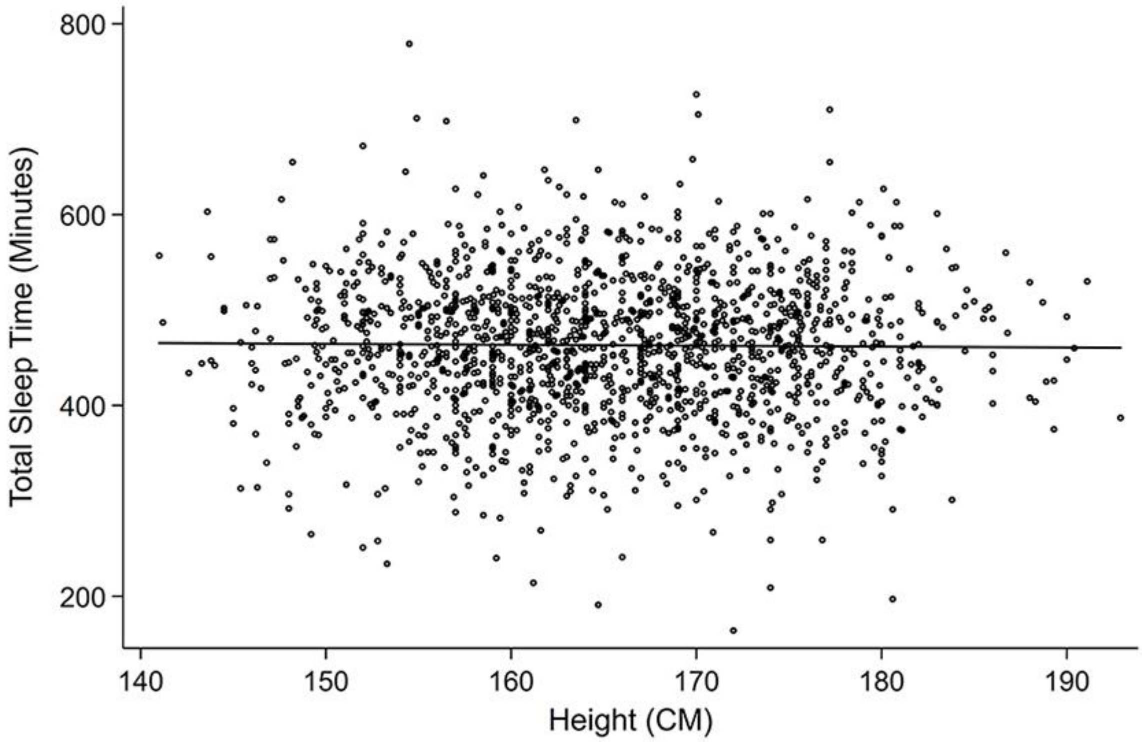
Supplementary References

1. Aili K, Åström-Paulsson S, Stoetzer U, Svartengren M, Hillert L. Reliability of Actigraphy and Subjective Sleep Measurements in Adults: The Design of Sleep Assessments. *Journal of clinical sleep medicine : JCSM : official publication of the American Academy of Sleep Medicine*. 2017;**13**: 39-47.
2. Acebo C, Sadeh A, Seifer R, *et al.* Estimating sleep patterns with activity monitoring in children and adolescents: how many nights are necessary for reliable measures? *Sleep*. 1999;**22**: 95-103

Supplementary Figure S1: Total Sleep Time by Day of Wear, Weekday/Weekend and Season



Supplementary Figure S2. Scatterplot of Total Sleep Time (Minutes) by Height (CM).



Supplementary Figure S3. Spearman Brown coefficients by number of recorded days of sleep duration.