LETTER

Failure to demonstrate that memory improvement is due either to aerobic exercise or increased hippocampal volume

We read with interest the article in PNAS, "Exercise training increases size of hippocampus and improves memory" by Erickson et al. (1). It is a noteworthy finding that over a 1-y period anterior hippocampal volume increased by 2% in the aerobic exercise group, whereas it decreased by 1.4% in the stretching control group. However, contrary to both the title and abstract, there is virtually no evidence in this article that exercise improved memory. After 1 y there were no differences between the exercise and control groups. "Both groups showed improvements in memory, as demonstrated by significant increases in accuracy between the first and last testing sessions for the aerobic exercise [$t(2,51) = 2.08$; $P < 0.05$] and the stretching control [$t(2,54) = 4.41$; $P < 0.001$] groups. Response times also became faster for both groups between the baseline and postintervention sessions (all $P < 0.01$), indicating that improvements in accuracy were not caused by changes in speed–accuracy tradeoff. However, the aerobic exercise group did not improve performance above that achieved by the stretching control group, as demonstrated by a nonsignificant Time × Group interaction [$F(1,102) = 0.67$; $P < 0.40$]." In addition, "change in aerobic fitness levels from baseline to after intervention was not related to improvements in memory for either the entire sample ($r = 0.15$; $P < 0.12$) or when considering each group separately (both $P > 0.05$). Furthermore, changes in BDNF were not associated with improvements in memory function for either group ($r < 0.15$; $P > 0.20$)." The authors then "reasoned that increased hippocampal volume after the exercise intervention should translate to improved memory function." To support this hypothesis they correlated aerobic exercise group hippocampal volume increase and memory improvement and found statistically significant correlations, which are small. For left hippocampus $r = 0.23$ ($P < 0.05$), accounting for 5% variance, and for right hippocampus $r = 0.29$ ($P < 0.02$), accounting for 8% variance. They concluded that "this indicates that increases in hippocampal volume after 1 y of exercise augments memory function in late adulthood." However, association cannot be assumed to indicate causality. Furthermore, it is clear that although the aerobic exercise group improved on the memory task, so did the stretching control group in whom hippocampal volume decreased, further undermining any assumed link between hippocampal volume and improved memory. However, just such a link was explicitly drawn in the abstract, which states "here we show, in a randomized controlled trial with 120 older adults, that aerobic exercise training increases the size of the anterior hippocampus, leading to improvements in spatial memory." Unfortunately both the title and abstract are misleading and a major overstatement of the findings. A similar lack of precision in reporting is evident elsewhere in the research literature, making it difficult to evaluate what the real evidence is in relation to cognitive enhancement interventions and aging. This clouds the picture for the scientific community and is misleading for the general public. It behooves us all to ensure rigor in our scientific reporting.

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1. Erickson KI, et al. (2011) Exercise training increases size of hippocampus and improves memory. *Proc Natl Acad Sci USA* 108:3017–3022.

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