ORIGINAL ARTICLE

Exercise and Cognitive Function: A Randomized Controlled Trial Examining Acute Exercise and Free-Living Physical Activity and Sedentary Effects

Paul D. Loprinzi, PhD, and Christy J. Kane, PhD

Abstract

Objective: To simultaneously examine the effects of acute exercise intensity and free-living physical activity and sedentary behavior on cognitive function in young, healthy adults.

Patients and Methods: Using a counterbalanced, crossover, randomized controlled design, 87 young adults (mean age, 21.4 years) completed various cognitive assessments with and without an acute bout of exercise preceding the assessment. Participants were randomized into 1 of 4 groups to complete a 30-minute bout of acute exercise: control (no exercise), light intensity (40%-50% of predicted maximum heart rate [HR_{max}]), moderate intensity (51%-70% of predicted HR_{max}), or vigorous intensity (71%-85% of predicted HR_{max}). Subjectively and objectively determined (accelerometry) physical activity and sedentary behavior were assessed to examine the association between these free-living behaviors and cognitive function. The study duration was August 26, 2013, to September 11, 2014.

Results: Concentration-related cognition (mean ± SD Feature Match test score) was significantly higher after a 30-minute acute bout of moderate-intensity exercise (145.1±26.9) compared with cognitive assessment without exercise (121.3±19.2; P=.004). Furthermore, questionnaire-determined sedentary behavior was inversely associated with visual attention and task switching (Trail Making Test A score) (β=−0.23; P=.04). Last, estimated cardiorespiratory fitness (volume of maximum oxygen consumption) was positively associated with reasoning-related cognitive function (Odd One Out test score) (β=0.49; P=.05); when adding metabolic equivalent of task minutes per week to this model, the results were not significant (β=0.47; P=.07).

Conclusion: These findings provide some support for acute moderate-intensity exercise, sedentary behavior, and cardiorespiratory fitness being associated with executive functioning–related cognitive function in young, healthy adults.

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From the Department of Health, Exercise Science, and Recreation Management, School of Applied Sciences, Center for Health Behavior Research, The University of Mississippi, University (P.D.L.); and Department of Respiratory Therapy, Donna and Allan Lansing School of Nursing and Health Sciences, Bellarmine University, Louisville, KY (C.J.K.).

Emerging research is starting to find neuroprotective effects of physical activity (PA) on the brain,[1] particularly in youth[2] and older adults,[3,4] with fewer investigations in young, healthy adults.[5] There is also some evidence indicating that some aspects of cognitive function may start to decline in the early adult years (ie, 20s).[6] The underlying mechanisms through which PA may improve cognition are likely a result of PA-induced changes at the systemic, molecular, and cellular levels.[1,3] For example, PA may influence neural systems (eg, improved information processing and memory encoding) involved in attention, learning, and memory[7]; increase molecular mediators (eg, brain-derived neurotrophic factor) by which PA affects cognition; and promote a cellular environment that enhances cognition through PA-induced neurogenesis and vascular function.[3,8]

In addition to the need for further studies in young, healthy adults, delineating the effects of different exercise intensity levels on cognition is important; some evidence suggests a differential effect of exercise intensity on cognition. For example, studies have reported that lower-intensity exercise may be more beneficial regarding brain protection and restoration[9,10] compared with vigorous-intensity exercise, which may result in much larger increases in catecholamine levels, ultimately inducing neural noise and inhibiting exercise-induced cognitive changes.[11] Furthermore, high-intensity exercise may require greater activation of the premotor and supplementary motor areas of the brain, which may result in less cognitive adaption as these areas of the brain will be activated at the expense of the prefrontal cortex. Moderate-intensity exercise should, in theory, facilitate cognition because this intensity should be high enough to elicit changes in brain neurotransmitters but low enough to prevent large increases in catecholamine levels that may be induced during vigorous-intensity PA.

In addition to the potential differential effects of exercise intensity on cognition, forced vs voluntary/habitual exercise may have differential effects on brain function. Forced exercise is often defined as exercise that is augmented mechanically to assist the individual in achieving or maintaining a given heart rate (HR).[12] Forced exercise has been found to have neurotransmitter-sparing effects.[13] However, there is also some evidence suggesting that habitual free-living PA, compared with forced exercise, has a greater ability to elicit higher concentrations of brain-derived neurotrophic factor and to induce less of a corticosterone stress response.[14] In contrast, other studies[15] have found that forced exercise, compared with habitual PA, may be more beneficial in increasing cerebral blood flow and cerebral glycolysis. Most of the human intervention studies examining the effect of exercise on cognition have used a forced exercise model, often consisting of acute exercise followed by cognitive testing. We are aware of no studies that have simultaneously considered acute exercise and free-living PA and their potential relationships with cognition.

To address these gaps in the literature, the primary purposes of this study were to examine the effects of exercise on cognitive function in young, healthy adults and, specifically, to address the role of exercise intensity and acute vs habitual exercise on cognition. Furthermore, we examined whether exercise is associated with cognition independent of mood and anxiety because it is unclear whether the effects of exercise on cognition are independent of changes in mood and anxiety. That is, it is unclear whether exercise-induced effects on cognition are due to exercise-induced changes in affect or whether separate neural systems mediate these effects.

METHODS

Sample and Design

Participants were eligible for the study if they were 35 years or younger, were "ready" to engage in PA as determined by the Physical Activity Readiness Questionnaire, spoke English, and provided written informed consent. Participants were excluded from the study if they perceived having any difficulty completing all the tests or had a current illness. No recruited participants were excluded. The study was conducted between August 26, 2013, and September 11, 2014.

Eighty-seven young (mean ± SD age, 21.4±2.1 years) (Table 1), healthy (as determined by the Physical Activity Readiness Questionnaire) adults were recruited to participate, with all the participants providing informed consent; all the study procedures were approved by Bellarmine University's institutional review board. Participants were recruited by the student researchers using a nonprobability convenience sampling approach at Bellarmine University (ie, student researchers proposed the study to students enrolled in university courses). Participants completed 2 visits (at approximately the same time of day; ±30 minutes) approximately 1 week apart. Participants were asked not to exercise and not to consume any stimulants (eg, caffeine and cigarettes) within 3 hours of the visit. Of the 87 participants, 86 (99%) complied and did not exercise within 3 hours of testing, and 75 (86%) did not consume any stimulants within 3 hours of testing. Initial analyses were computed that statistically controlled for whether participants complied with these stipulations, as well as analyses that excluded these participants, and the results were unchanged; therefore, these participants were included in the analyses.

During both visits (for test-retest reliability), participants completed a variety of questionnaires, including an assessment of self-reported PA, sedentary behavior, and affect (see later herein for further details). Height and weight were measured during the first visit to calculate body mass index (BMI; calculated as the weight in kilograms divided by the height in meters squared). During the first visit, participants