

University of Mississippi

eGrove

Faculty and Student Publications

Health, Exercise Science, and Recreation
Management, Department of

1-1-2019

Association between habitual physical activity on episodic memory strategy use and memory controllability

Paul D. Loprinzi
University of Mississippi

Follow this and additional works at: https://egrove.olemiss.edu/hesrm_facpubs

Recommended Citation

Loprinzi, P. D. (2019). Association between habitual physical activity on episodic memory strategy use and memory controllability. *Health Promotion Perspectives*, 9(1), 65–70. <https://doi.org/10.15171/hpp.2019.08>

This Article is brought to you for free and open access by the Health, Exercise Science, and Recreation Management, Department of at eGrove. It has been accepted for inclusion in Faculty and Student Publications by an authorized administrator of eGrove. For more information, please contact egrove@olemiss.edu.

Original Article

Association between habitual physical activity on episodic memory strategy use and memory controllability

Paul D. Loprinzi*

Exercise & Memory Laboratory, Department of Health, Exercise Science and Recreation Management, The University of Mississippi, University, MS 38677, USA

ARTICLE INFO

Article History:

Received: 9 Oct. 2018
 Accepted: 15 Nov. 2018
 ePublished: 23 Jan. 2019

Keywords:

Episodic memory, Exercise, Movement, Perceptions, Self-efficacy

*Corresponding Author:

Paul D. Loprinzi, Ph.D.;
 Exercise & Memory
 Laboratory, Department of
 Health, Exercise Science, and
 Recreation Management,
 The University of Mississippi,
 229 Turner Center, University,
 MS 38677.
 Phone: 662-915-5561,
 Fax: 662-915-5521,
 Email: pdloprin@olemiss.edu

Abstract

Background: The primary objective of this study was to evaluate the association between habitual physical activity engagement and perceived controllability of memory function. Secondary objectives included the evaluation of physical activity on memory strategy use, and whether the latter mediates the relationship between physical activity on memory controllability.

Methods: Two-hundred and nine young adults ($M_{age}=25$ y) completed a brief survey evaluating physical activity (Physical Activity Vital Signs Questionnaire), memory strategy use (Memory Functioning Questionnaire), and memory controllability (Memory Controllability Inventory).

Results: Physical activity was not associated with memory strategy use ($\beta=0.68$; 95% CI: -1.25, 2.62; $P=0.48$), nor was memory strategy use associated with memory controllability. Physical activity was consistently associated with various attributes of memory controllability, including Present Ability ($\beta=1.10$; 95% CI: 0.07, 2.12; $P=0.03$), Potential Improvement ($\beta=0.84$; 95% CI: 0.05, 1.63; $P=0.03$), Effort Utility ($\beta=0.87$; 95% CI: 0.11, 1.61; $P=0.02$), Inevitable Decrement ($\beta=-1.19$; 95% CI: -2.19, -0.19; $P=0.02$) and Alzheimer's likelihood ($\beta=-1.21$; 95% CI: -2.29, -0.12; $P=0.02$).

Conclusion: Physical activity is consistently associated with greater perceptions of memory controllability. Future longitudinal and experimental work on this topic is warranted to evaluate if physical activity can foster an individual's ability to modify their behavior and cognitions to enhance and preserve memory function.

Citation: Loprinzi PD. Association between habitual physical activity on episodic memory strategy use and memory controllability. Health Promot Perspect. 2019;9(1):65-70. doi: 10.15171/hpp.2019.08.

Introduction

The field of memory function is not new, but the potential role of physical activity in subserving memory function is an emerging line of inquiry. Various laboratories,¹⁻⁵ including ours,⁶⁻¹⁴ has demonstrated that both acute and chronic engagement in physical activity may enhance memory function. From an acute exercise perspective, exercise may help to facilitate the recall of memories within a spatiotemporal context (episodic memory) from alterations in neuronal excitability, and ultimately, modulation of long-term potentiation and synaptic plasticity.¹⁰ Further, chronic exercise engagement may subserve memory function via the widespread adaptations from exercise, including neurogenesis, gliogenesis, and angiogenesis.^{10,15}

In addition to the importance of monitoring and

evaluating objective memory performance, it is also important to evaluate subjective memory outcomes (e.g., complaints made by individuals about their cognitive symptoms), as, for example, subjective memory complaints have been shown to predict negative memory outcomes.^{16,17} Even among young adult populations, subjective memory complaints are prevalent,¹⁸ and this population has also been identified as a point in time when objective memory function may start to decline.¹⁹

Individuals, even young adults, may employ various techniques to try and control, improve, or preserve their memory function. Among others, one cognitive technique may be the utilization of mnemonic strategies, which often includes techniques that involve organization, elaboration, and visual imagery (e.g., method of loci). Although experimental data suggests that acute and

chronic physical activity may help to improve memory performance on objective assessments, we have a limited understanding of whether habitual physical activity engagement is associated with an individual's perception of memory controllability. I hypothesize that higher levels of physical activity will be associated with greater perceptions of memory controllability (e.g., increased perception that their memory can be improved as well as preserved during aging). This hypothesis is plausible as prior work has shown that people believe that physical activity may be an effective behavior to help treat and prevent various cardiovascular and cognitive outcomes.²⁰ I also hypothesize that this potential relationship between physical activity and memory controllability may be influenced by the utilization of memory-based strategies, such as mnemonics. That is, higher levels of physical activity may be associated with greater memory controllability via memory strategy utilization. Such an effect is plausible as other work demonstrates that memory strategy use may play an important role in memory performance among healthy individuals.²¹

Couched within the above, the primary objective of this study was to evaluate the association between habitual physical activity engagement and perceived controllability of memory function. Secondary objectives included the evaluation of physical activity on memory strategy use, and whether the latter mediates the relationship between physical activity on memory controllability.

Materials and Methods

Study design and participants

A random sample of 1500 college students at the University of Mississippi were sent an e-mail inviting them to participate in a brief on-line survey. Thus, all variables were assessed via this on-line survey. This study was approved by the University of Mississippi's institutional review board. Completion of the survey provided voluntary participant consent. A total of 245 students completed the survey, and those who self-reported being pregnant, having a concussion in the past 30 days or having a diagnosis of a cognitive impairment, were excluded from the analyses. In total, 209 eligible participants provided complete data for all variables (list-wise deletion analysis used for missing data), constituting the analytic sample.

Exercise behavior

Subjective assessment of exercise was assessed using the two-item (days per week and minutes per day) physical activity vital signs (PAVS) questionnaire, indicating the number of minutes per week engaged in moderate-to-vigorous physical activity (MVPA). Meeting physical activity guidelines was defined as at least 150 min/wk of MVPA. This assessment has demonstrated evidence of validity.²²⁻²⁶ Notably, this self-report MVPA measure correlates with accelerometer-assessed MVPA ($r = 0.52$, $P < 0.001$).²³

Memory strategy use

Participants completed mnemonic usage questions from the Memory Functioning Questionnaire.²⁷ Specifically, 8 questions were employed. Participants were asked "how often do you use these techniques to remind yourself about things?" The different techniques included: keep an appointment book; write yourself reminder notes; make lists of things to do; make grocery lists; plan your daily schedule in advance; mental repetition; associations with other things; and keep things you need to do in a prominent place where you will notice them. For each of these 8 potential strategies, options ranged from 1 (always) to 7 (never). In the present sample, internal consistency for these 8 strategies, as measured by Cronbach's alpha, was 0.82.

Memory controllability

Memory controllability was evaluated using the Memory Controllability Inventory,²⁸ consisting of 19-items. This instrument includes 6 subscales, including Present Ability (3 items), Potential Improvement (3 items), Effort Utility (3 items), Inevitable Decrement (3 items), Independence (3 items), and Alzheimer's Likelihood (4 items). An example item for Present Ability is, "I can remember the things I need to." An example item for Potential Improvement is, "I can find ways to improve my memory." An example item for Effort Utility is, "If I work at it, I can improve my memory." An example item for Inevitable Decrement is, "There's not much I can do to keep my memory from going downhill." An example item for Independence is, "As I get older, I won't have to rely on others to remember things for me." Lastly, for Alzheimer's likelihood, an example item is, "I think there's a good chance I will get Alzheimer's disease." For all questions, response options ranged from 1 (strongly disagree) to 7 (strongly agree).

For each subscale, responses were summed for the respective items. For Present Ability, higher scores indicate a greater perceived present ability in memory. For Potential Improvement, higher scores indicate a greater perceived ability to improve their memory. For Effort Utility, higher scores indicate a greater perceived effort can help facilitate memory. For Inevitable Decrement, higher scores indicate that a decrement in memory is inevitable (i.e., not favorable). For Independence, higher scores indicate a greater perceived independence in their memory as they age. Lastly, for Alzheimer's Likelihood, higher scores indicate that the development of Alzheimer's disease is likely to happen to them (i.e., not favorable). For the present sample, internal consistency for this entire memory controllability inventory was 0.85.

Covariates

Self-reported covariates included age, gender, race-ethnicity, body mass index (from self-reported height and weight), and self-reported smoking status (current, former, never). These parameters were selected given their potential association with memory function.

Statistical analyses

All statistical analyses were computed in Stata (v. 12, College Station, TX, USA). Multivariable linear regression models were computed that examined the association between exercise and memory self-efficacy. Models were computed separately for memory strategy use, and similarly, models were computed separately for each of the subscales of the memory controllability inventory. In all models, covariates included age, gender, race-ethnicity, body mass index, and self-reported smoking status. Statistical significance was set at $\alpha=0.05$.

Table 1. Characteristics of the study sample (N = 209)

Variable	Point Estimate	SD
Age, mean years	25.4	8.8
Gender, % female	64.5	
Race-Ethnicity, % White	75.1	
Body mass index, mean kg/m ²	25.6	6.2
Current smoker, %	3.8	
MVPA, mean min/week	159.1	155.4
Meeting physical activity guidelines, %	42.1	
Strategy score, mean overall	22.7	6.9
Present ability, mean	15.9	3.5
Potential improvement, mean	16.2	2.7
Effort utility, mean	16.2	2.6
Independence, mean	13.8	3.1
Inevitable decrement, mean	10.0	3.4
Alzheimer's likelihood, mean	12.3	3.8

MVPA, Moderate-to-vigorous physical activity.

Meeting physical activity guidelines defined as at least 150 min/week of MVPA.

Results

Table 1 displays the characteristics of the sample. The mean (SD) age of the participants was 25 (8.8) years old, with the majority being female (64%) and non-Hispanic white (75%). Forty-two percent of the sample met physical activity guidelines.

Table 2 displays the multivariable regression results examining the association between physical activity on memory strategy use and memory controllability. Results are displayed for those meeting (vs. not) physical activity guidelines, as when physical activity was expressed as a continuous variable, results were similar (results not shown). Physical activity was not statistically significantly associated with memory strategy use when memory strategy use was expressed as a sum of the responses from the 8 memory strategy variables ($\beta = 0.68$; 95% CI: -1.25, 2.62; $P=0.48$). Notably, physical activity remained non-significantly associated with memory strategy use when results were evaluated for each separate memory strategy (results not shown).

Also shown in Table 2 are the results examining the association between physical activity and memory controllability. Physical activity was consistently associated with memory controllability (5 out of the 6 domains). Those who met physical activity guidelines (vs. not) had statistically significantly *higher* perceptions of Present Ability ($\beta = 1.10$; 95% CI: -0.07, 2.12; $P=0.03$), Potential Improvement ($\beta = 0.84$; 95% CI: 0.05, 1.63; $P=0.03$) and Effort Utility ($\beta = 0.87$; 95% CI: 0.11, 1.61; $P=0.02$), and also *lower* perceptions of Inevitable Decrement ($\beta = -1.19$; 95% CI: -2.19, -0.19; $P=0.02$) and Alzheimer's Likelihood ($\beta = -1.21$; 95% CI: -2.29, -0.12; $P=0.02$). Notably, additional models were evaluated that

Table 2. Multivariable regression results examining the association between physical activity on memory strategy use and memory controllability (N=209)

Model	Unstandardized Beta Coefficient	95% CI	P value
Memory Strategy Use			
Meeting MVPA guidelines vs. not	0.68	-1.25, 2.62	0.48
Memory Controllability			
Present Ability			
Meeting MVPA guidelines vs. not	1.10	0.07, 2.12	0.03
Potential Improvement			
Meeting MVPA guidelines vs. not	0.84	0.05, 1.63	0.03
Effort Utility			
Meeting MVPA guidelines vs. not	0.87	0.11, 1.61	0.02
Inevitable Decrement			
Meeting MVPA guidelines vs. not	-1.19	-2.19, -0.19	0.02
Independence			
Meeting MVPA guidelines vs. not	0.58	-0.31, 1.48	0.20
Alzheimer's likelihood			
Meeting MVPA guidelines vs. not	-1.21	-2.29, -0.12	0.02

MVPA, Moderate-to-vigorous physical activity.

Meeting physical activity guidelines defined as at least 150 min/wk of MVPA.

Each model controlled for age, gender, race-ethnicity, body mass index, and smoking status.

included memory strategy utilization as an independent variable, and for all models, memory strategy utilization was not associated ($P's > 0.05$) with any of the memory controllability measures (results not shown).

Discussion

The primary purpose of this study was to evaluate if, among a young adult sample, habitual engagement in physical activity was associated with memory controllability, and whether this potential association was influenced by memory strategy utilization. The motivation for this evaluation stemmed from previous work highlighting that both acute and chronic physical activity have been shown to improve objective measures of memory,²⁹ as well as other work suggesting that young adults believe that physical activity may be a useful behavior to help improve cognitive outcomes.²⁰ The main findings of this study were: (1) Physical activity was not associated with memory strategy utilization, (2) Memory strategy utilization was not associated with memory controllability, but (3) Physical activity was consistently associated with memory controllability.

Our null findings regarding memory strategy use may be a result of the limited number of memory strategies that were assessed. Perhaps a more comprehensive evaluation of memory strategy use would have increased the likelihood of observing a relationship between memory strategy use with physical activity and/or memory controllability. Although we restricted our memory strategy evaluation to commonly used mnemonic techniques, there are various learning strategies across multiple levels of cognitive processing (e.g., chaining/chunking, spatial clustering, affective clustering, overt rehearsal techniques, schema learning). However, we focused on commonly used mnemonic techniques, as these types of strategies may help to subserve memory function.³⁰⁻³⁶ Future research is needed to determine if indeed physical activity plays any role in influencing the utilization of memory strategies. Such a relationship is theoretically feasible. For example, executive functioning, known to be influenced by exercise,³⁷ may also influence memory strategy use.³⁸

A notable observation of this study was that, among this young adult population, habitual engagement in physical activity was favorably associated memory controllability. Although we did not objectively measure memory function, our observation of an association between physical activity and memory controllability could have been a result of a higher memory controllability effect among active individuals because of their potential greater memory function. However, not all studies demonstrate a memory enhancing effect from exercise,³⁹ and thus, there may be other possible explanations for our observations. One potential explanation is that, in theory, physical activity may foster an enhanced self-efficacy, or perceived controllability, in other domains. This transference paradigm (global self-efficacy) has been discussed in other behavioral domains, in that, physical activity is thought

to enhance one's self-efficacy to change other behaviors (e.g., diet and smoking) via improvements in executive functioning.⁴⁰⁻⁴² In the context of the present study, and although speculative, perhaps physically active individuals have enhanced global self-efficacy, and as a result, feel confident in modifying their lifestyle in a way that would be conducive to enhance and preserve their memory function. Such a transference paradigm is interesting and worthy of future exploration, as its implications have large individual and societal ramifications.

In conclusion, the purpose of this study was to evaluate the interrelationships between habitual physical activity, memory strategy use, and memory controllability. The main findings of this study suggest that physical activity is consistently associated with greater perceptions of memory controllability. Future work should overcome the limitations of this study (e.g., cross-sectional design, self-report measure of physical activity, limited study population). For example, longitudinal and experimental work on this topic is warranted to evaluate if, indeed, objectively-measured physical activity can foster an individual's ability to modify their behavior and cognitions to enhance and preserve memory function.

Ethical approval

This study was approved by the University of Mississippi's ethics committee (Protocol #18x-300).

Competing interests

The author declares no competing interest.

Funding

None.

Author's contribution

PDL conceived the study, collected the data and wrote the entire manuscript.

References

1. Roig M, Nordbrandt S, Geertsens SS, Nielsen JB. The effects of cardiovascular exercise on human memory: a review with meta-analysis. *Neurosci Biobehav Rev.* 2013;37(8):1645-66. doi: 10.1016/j.neubiorev.2013.06.012.
2. Roig M, Thomas R, Mang CS, Snow NJ, Ostadan F, Boyd LA, et al. Time-dependent effects of cardiovascular exercise on memory. *Exerc Sport Sci Rev.* 2016;44(2):81-8. doi: 10.1249/JES.0000000000000078.
3. Chang YK, Labban JD, Gapin JI, Etnier JL. The effects of acute exercise on cognitive performance: a meta-analysis. *Brain Res.* 2012;1453:87-101. doi: 10.1016/j.brainres.2012.02.068.
4. Etnier JL, Wideman L, Labban JD, Piepmeyer AT, Pendleton DM, Dvorak KK, et al. The effects of acute exercise on memory and brain-derived neurotrophic factor (BDNF). *J Sport Exerc Psychol.* 2016;38(4):331-40. doi: 10.1123/jsep.2015-0335.
5. Labban JD, Etnier JL. Effects of acute exercise on long-term memory. *Res Q Exerc Sport.* 2011;82(4):712-21. doi: 10.1080/02701367.2011.10599808.
6. Frith E, Sng E, Loprinzi PD. Randomized controlled trial

- evaluating the temporal effects of high-intensity exercise on learning, short-term and long-term memory, and prospective memory. *Eur J Neurosci*. 2017;46(10):2557-64. doi: 10.1111/ejn.13719.
7. Frith E, Sng E, Loprinzi PD. Randomized controlled trial considering varied exercises for reducing proactive memory interference. *J Clin Med*. 2018;7(6):147. doi: 10.3390/jcm7060147.
 8. Green D, Loprinzi PD. Experimental effects of acute exercise on prospective memory and false memory. *Psychol Rep*. 2018. doi: 10.1177/0033294118782466.
 9. Haynes IV JT, Frith E, Sng E, Loprinzi PD. The experimental effects of acute exercise on episodic memory function: Considerations for the timing of exercise. *Psychol Rep*. 2018. doi: 10.1177/0033294118786688.
 10. Loprinzi PD, Edwards MK, Frith E. Potential avenues for exercise to activate episodic memory-related pathways: a narrative review. *Eur J Neurosci*. 2017;46(5):2067-77. doi: 10.1111/ejn.13644.
 11. Siddiqui A, Loprinzi PD. Experimental investigation of the time course effects of acute exercise on false episodic memory. *J Clin Med*. 2018;7(7):E157. doi: 10.3390/jcm7070157.
 12. Sng E, Frith E, Loprinzi PD. Temporal effects of acute walking exercise on learning and memory function. *Am J Health Promot*. 2018;32(7):1518-1525. doi: 10.1177/0890117117749476.
 13. Sng E, Frith E, Loprinzi PD. Experimental effects of acute exercise on episodic memory acquisition: Decomposition of multi-trial gains and losses. *Physiol Behav*. 2018;186:82-4. doi: 10.1016/j.physbeh.2018.01.014.
 14. Wingate S, Crawford L, Frith E, Loprinzi PD. Experimental investigation of the effects of acute exercise on memory interference. *Health Promot Perspect*. 2018;8(3):208-214. doi: 10.15171/hpp.2018.28
 15. Loprinzi PD, Frith E. A brief primer on the mediational role of BDNF in the exercise-memory link. *Clin Physiol Funct Imaging*. 2019 Jan;39(1):9-14. doi: 10.1111/cpf.12522.
 16. Roberts JL, Clare L, Woods RT. Subjective memory complaints and awareness of memory functioning in mild cognitive impairment: a systematic review. *Dement Geriatr Cogn Disord*. 2009;28(2):95-109. doi: 10.1159/000234911.
 17. Steinberg SI, Negash S, Sammel MD, Bogner H, Harel BT, Livney MG, et al. Subjective memory complaints, cognitive performance, and psychological factors in healthy older adults. *Am J Alzheimers Dis Other Dement*. 2013;28(8):776-83. doi: 10.1177/1533317513504817.
 18. Pellicer-Porcar O, Mirete-Fructuoso M, Molina-Rodriguez S, Soto-Amaya J. Subjective memory complaints in young adults: the influence of the emotional state. *Rev Neurol*. 2014;59(12):543-50.
 19. Salthouse TA. When does age-related cognitive decline begin? *Neurobiol Aging*. 2009;30(4):507-14. doi: 10.1016/j.neurobiolaging.2008.09.023.
 20. Loprinzi PD, Darnell T, Hager K, Vidrine JJ. Physical activity-related beliefs and discrepancies between beliefs and physical activity behavior for various chronic diseases. *Physiol Behav*. 2015;151:577-82. doi: 10.1016/j.physbeh.2015.08.040.
 21. Hutchens RL, Kinsella GJ, Ong B, Pike KE, Clare L, Ames D, et al. Relationship between control beliefs, strategy use, and memory performance in amnesic mild cognitive impairment and healthy aging. *J Gerontol B Psychol Sci Soc Sci*. 2013;68(6):862-71. doi: 10.1093/geronb/gbt016.
 22. Greenwood JL, Joy EA, Stanford JB. The Physical Activity Vital Sign: a primary care tool to guide counseling for obesity. *J Phys Act Health*. 2010;7(5):571-6.
 23. Ball TJ, Joy EA, Goh TL, Hannon JC, Gren LH, Shaw JM. Validity of two brief primary care physical activity questionnaires with accelerometry in clinic staff. *Prim Health Care Res Dev*. 2015;16(1):100-8.
 24. Ball TJ, Joy EA, Gren LH, Cunningham R, Shaw JM. Predictive validity of an adult physical activity "Vital Sign" recorded in electronic health records. *J Phys Act Health*. 2016;13(4):403-408.
 25. Ball TJ, Joy EA, Gren LH, Shaw JM. Peer reviewed: concurrent validity of a self-reported physical activity "Vital Sign" questionnaire with adult primary care patients. *Prev Chronic Dis* 2016;13:150228. doi: 10.5888/pcd13.150228.
 26. Fowles JR, O'Brien MW, Wojcik WR, d'Entremont L, Shields CA. A pilot study: Validity and reliability of the CSEP-PATH PASB-Q and a new leisure time physical activity questionnaire to assess physical activity and sedentary behaviours. *Appl Physiol Nutr Metab*. 2017;42(6):677-80. doi: 10.1139/apnm-2016-0412.
 27. Gilewski MJ, Zelinski EM, Schaie KW. The Memory functioning questionnaire for assessment of memory complaints in adulthood and old age. *Psychol Aging*. 1990;5(4):482-90.
 28. Lachman ME, Bandura M, Weaver SL, Elliott E. Assessing memory control beliefs: The memory controllability inventory. *Aging and Cognition*. 1995;2:67-84.
 29. Loprinzi PD, Frith E, Edwards MK, Sng E, Ashpole N. The effects of exercise on memory function among young to middle-aged adults: systematic review and recommendations for future research. *Am J Health Promot*. 2018;32(3):691-704. doi: 10.1177/0890117117737409.
 30. McDaniel MA, Howard DC, Einstein GO. The read-recite-review study strategy: effective and portable. *Psychol Sci*. 2009;20(4):516-522. doi: 10.1111/j.1467-9280.2009.02325.x.
 31. Nguyen K, McDaniel MA. The JOIs of text comprehension: Supplementing retrieval practice to enhance inference performance. *J Exp Psychol Appl*. 2016;22(1):59-71. doi: 10.1037/xap0000066.
 32. Kole JA, Healy AF. Using prior knowledge to minimize interference when learning large amounts of information. *Mem Cognit*. 2007;35(1):124-37.
 33. Anderson MC, McCulloch KC. Integration as a general boundary condition on retrieval-induced forgetting. *J Exp Psychol Learn Mem Cogn*. 1999;25:608-29.
 34. Forcato C, Rodriguez ML, Pedreira ME, Maldonado H. Reconsolidation in humans opens up declarative memory to the entrance of new information. *Neurobiol Learn Mem*. 2010;93(1):77-84. doi: 10.1016/j.nlm.2009.08.006.
 35. van Kesteren MT, Rijpkema M, Ruiters DJ, Fernandez G. Consolidation differentially modulates schema effects on memory for items and associations. *PLoS One*. 2013;8(2):e56155. doi: 10.1371/journal.pone.0056155.
 36. van Kesteren MT, Rijpkema M, Ruiters DJ, Morris RG, Fernandez G. Building on prior knowledge: schema-dependent encoding processes relate to academic performance. *J Cogn Neurosci*. 2014;26(10):2250-2261. doi: 10.1162/jocn_a_00630.

37. Guiney H, Machado L. Benefits of regular aerobic exercise for executive functioning in healthy populations. *Psychon Bull Rev.* 2013;20(1):73-86. doi: 10.3758/s13423-012-0345-4.
38. Bebko JM, Ricciuti C, Bebko JM. Executive functioning and memory strategy use in children with autism: the influence of task constraints on spontaneous rehearsal. *Autism.* 2000;4(3):299-320.
39. Yanes D, Loprinzi PD. Experimental effects of acute exercise on iconic memory, short-term episodic, and long-term episodic memory. *J Clin Med.* 2018;7(6):E146. doi: 10.3390/jcm7060146.
40. Loprinzi PD, Herod SM, Walker JF, Cardinal BJ, Mahoney SE, Kane C. Development of a conceptual model for smoking cessation: physical activity, neurocognition, and executive functioning. *Res Q Exerc Sport.* 2015;86(4):338-346. doi: 10.1080/02701367.2015.1074152.
41. Loprinzi PD. Physical activity is the best buy in medicine, but perhaps for less obvious reasons. *Prev Med.* 2015;75:23-24. doi: 10.1016/j.ypmed.2015.01.033.
42. Loprinzi PD, Herod SM, Cardinal BJ, Noakes TD. Physical activity and the brain: a review of this dynamic, bi-directional relationship. *Brain Res.* 2013;1539:95-104. doi: 10.1016/j.brainres.2013.10.004.