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Acute Effect of Skill Random Practice Versus Cardiovascular Exercise on Motor Learning of a Golf Putting Task

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BACKGROUND: *Previous research has verified the role of acute cardiovascular exercise on improving motor learning. This study compares the effects of skill random practice and acute cardiovascular exercise on golf putting performance in college students. Method: 24 healthy adults (10 males, 14 females, aged 21.02±0.70 years) with no golf past experience participated in the study. They were randomized into two groups: skill random practice and acute cardiovascular exercise. A set of baseline, acquisition, and 24-hour retention tests were administered, including a 10-ft. golf putt task. A 3 (time periods) x 2 (groups) ANOVA was computed for further data analysis. Results: The performance in golf putts made was not improved immediately after the intervention; however, golf putts made were seen to improve 24 hours after practice compared to the baseline. However, no group difference was noted between skill random practice and acute cardiovascular exercise during acquisition and 24-hour retention tests.*

CONCLUSION: *Our findings suggested the temporal effects on motor learning of a golf putting task. Considering this is the first research effort that pairs skill random practice and acute cardiovascular exercise, there is need for further research to examine the role of exercise intensity and exercise modalities between acute exercise and early motor learning.*

KEY WORDS: Exercise, Contextual interference, Cognition, Memory, Motor learning, Motor performance.

Introduction

Several studies thus far have demonstrated that physical activity could lead to improvements in executive function and performance (Ludyga et al., 2016;

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Chen et al., 2020; Park & Etnier, 2019). Executive function is conceptualized as a high-order cognitive system that controls and manages other cognitive processes to achieve a goal (Hillman et al., 2008). In recent studies, attention has been placed on acute exercise effects of motor learning, measured through simple and choice reaction times, such as finger tapping and continuous tracking tasks, including discrete finger motor movements and other tasks involving complex arm movements (Draper et al., 2010; Hogervorst et al., 1996; Snow et al., 2016). Roig et al. (2012) found that a 15-min intense cycling exercise (11.77 ± 0.63 on the Borg Rating of Perceived Exertion scale) improved retention of visuomotor accuracy-tracking tasks of young adults during a period of 24 hours after practice and 7 days after practice, when compared to non-exercisers. However, the acquisition effect was not evident an hour after practice. Similarly, Mang et al. (2014) found that a 20-min high-intensity cycling protocol (90% maximum power output) enhanced young adults' motor performance in the retention test of a continuous tracking task skill, compared to a control condition when measured 24 hours following training. Skriver et al. (2014) not only found young adults improved their motor performance in the retention test of visuomotor tracking tasks 24 hours and 7 days after practice, but also noted that high concentrations of norepinephrine were associated with better retention 7 days after practice; lactate, on the other hand, correlated with better retention 24 hours and 7 days after practice. Thus, improvements in motor skill retention induced by acute cardiovascular exercise seem to be associated with increased concentrations of biomarkers involved in cognitive processes, which may facilitate long-term potentiation. Evidence for enhanced motor learning with acute exercise is rapidly growing; however, to the best of our knowledge, much of the reported research has been conducted using a motor test involving limited movements. Few studies have tested a motor skill in a real-life setting. Another goal in this research, therefore, is to examine the acute bouts of cardiovascular exercise that may create an optimized environment for young adults in a real-world activity. As such, the golf putting task was chosen for this study.

Past studies have recognized contextual interference as an important variable for maximizing motor skill learning (Kaipa & Mariam Kaipa, 2018; Kim et al., 2018). Randomly sequencing practice, compared to blocked practice throughout a training session has been shown to result in better motor performance on tests of retention and transfer, despite poorer performance during acquisition. It is assumed thus that random practice could enhance more cognitive activity because the learner continuously evaluates the changing visual and kinesthetic information derived from the performance of the same action with different parameters (Rendell et al., 2009). According to the elaboration and distinctiveness theory, it proposed the learner might be required an in-depth information processing strategy to differentiate the solutions of each task and further elaborate the memory representation (Lin et al., 2008). Hence, increased involvement of cognitive processing is expected to be necessary during random practice (Li & Wright, 2000). Fazeli et al. (2017) compared random and blocked practice for novice learners in a golf putting task. In addition to observing better putting in retention tests for the random practice group, when compared with the results for the blocked practice group, they found that the mental representation of putting in the random practice group was more structured. In another study, Aiken and Genter (2018) noted learners could improve their performance in golf chipping during the acquisition test regardless of the random and blocked practices. However, the random practice group significantly performed more accurately in chipping performance during the retention test. While the effectiveness of random practice has been observed in motor skill learning studies, golf is still a game that is typically practiced with blocked practice schedules (Weinman, 2015). This is a common phenomenon for novice learners when they just begin the sport. Therefore, more research is still needed in this field. This study would utilize random practice as the comparison measure for investigating what training method would be the most beneficial for novice learners in golf putting.

Taken together, the present study attempted to verify the role of skill random practice versus acute cardiovascular exercise in improving early stages of motor skill learning. We extended existing knowledge by employing a complex golf putting skill that involves the gradual control of the degrees of freedom around the arm segment, while simultaneously stabilizing other body parts. The present study was restricted to novice golfers since they relied extensively on their cognitive abilities to acquire and execute skills, when compared to trained golfers (Baumeister et al., 2008). A retention test of 24 hours after practice was added to evaluate early motor learning skills. The hypotheses of the present study were as follows: 1) golf putt accuracy would show during the retention test 24 hours after practice in acute cardiovascular exercise and skill random practice groups, and 2) group differences between skill random practice and acute cardiovascular exercise would be apparent.

Method

Participants

A total of 24 healthy college students participated in the present study (10 males and 14 females, 21.02 ± 0.70 years old). All participants were recruited from a southeastern university in the United States. Inclusion criteria for the research participants were as follows: (1) aged 18-24 years old; (2) right-handed; (3) no golf experience; and (4) no physical, cognitive, emotional, and/or neurological disorder. The interested participants signed an informed consent form and agreed to be part of the study before data collection. Participants were randomized into three groups: acute cardiovascular exercise (n = 12, aged 20.97 ± 0.74 years) and skill random practice (n = 12, aged 21.08 ± 0.68 years) groups. Each group had similar age, body mass index (BMI), and sex, as these variables might be associated with exercise performance (Baxi et al., 2018) and golf putt performance (Kaufman, 2007; Li, 2014). The Human Subject Institutional Review Board in the university approved the study protocol.

Procedure

The participants visited the laboratory one at a time. Upon arrival, the participants first completed demographic measures, including height, weight, age, golf experience, and handedness. Data collection for each participant was completed in two days. The first day included baseline, 30-min intervention, and acquisition. The second day involved a retention test 24 hour after practice.

The baseline period consisted of two working memory tests and 10 golf putts. Each participant watched a golf video instruction containing stance, grip, ball placement, and putting stroke demonstration. To remedy the variation of height among the participants, the researchers provided three putters with various lengths. Initially, participants were given familiarization and practice trials on the artificial turf. Thereafter, 10 golf putts were recorded as the performance during the baseline period. During the golf putting task, participants were asked to direct their focus of attention to the anticipated trajectory in order to control the potential impact on the performance outcome since the external focus of attention has been known as a possible moderator for golf performance (Brocken et al., 2016; Chen et al., 2021).

A 30-min intervention was implemented after the baseline period. Participants were randomized into either skill random practice or acute cardiovascular exercise group. There was an acquisition test immediately after the intervention. Another 10-ft golf putting task were administered to assess the intervention-induced effect. Lastly, participants were requested to visit the laboratory again 24 hours after practice. The golf putting task were administered as the retention test. Figure 1 provides a visual description of the procedure.

After each putting task, a post-manipulation check was conducted to confirm whether each participant actually focused on an anticipated trajectory line. Participants were asked to answer a question: "where did you focus on when you putted the golf ball?" with the answer options as follows: (1) anticipated trajectory line; (2) arm; (3) golf putter; (4) target, and (5) others.

Intervention

Acute Cardiovascular Exercise Group.

This group participated in a 30-min treadmill exercise, maintaining their heart rate between 65% and 85 % of their predicted maximum heart rate (HR_{max}). The 65-85 % of HR_{max} was adopted by Statton et al. (2015) and is considered as moderate intensity since it can be converted to 40 to 60 % of VO_2max (Swain et al., 1994), which the American College of Sports Medicine (2018) suggests as moderate intensity. The present study employed the

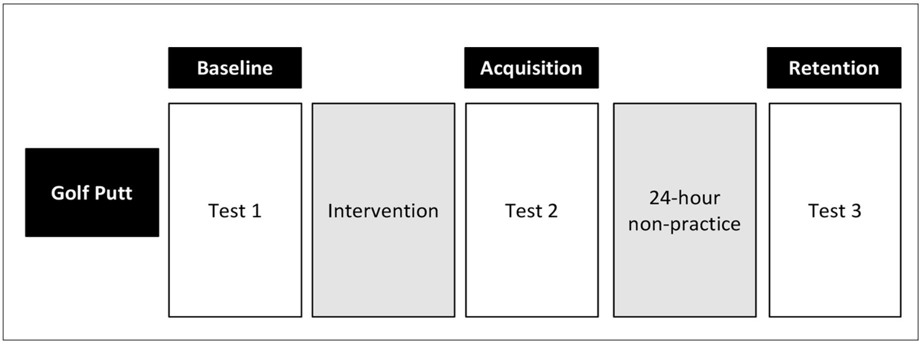

Fig. 1. - Visual description of the study design.
The present study had baseline, acquisition, and 24-hour retention. Each "Test" block in the golf putting task contains 10 putt strokes.

equation of age-predicted HR_{max} = 208 - (0.7 x age) to compute the target HR range for each participant (Tanaka et al., 2001). Also, an HR monitor was worn (Polar H10, Finland) to monitor the intensity of exercise through a Bluetooth connection with a mobile device. The intervention session began with a warm-up phase. During warm-up, the treadmill speed started at 1.0 mph and was gradually increased until the participants' HR reached the target heart rate zone. The duration of the warm-up phase was up to 5 minutes. Participants would start the main exercise session once their exercise HR reached the target range. The treadmill speed was manipulated as needed to maintain the participants' heart rate within the target range. The incline was set at 0% during the entire intervention period. After the 30-min exercise, participants were given another 5-min walking time at 1.0 mph for cool-down.

Skill Random Practice Group.

The skill random group practiced 3 blocks of 3 feet, 6 feet, and 9 feet putts. Each block had 10 trials of putting, so the total number of practice trials was 90. The distance of the putting was randomized, so the participants could not expect the putting distance for the upcoming practice block. In addition, the attentional focus during putt-practice was always directed at an anticipated trajectory line, which is the external focus of attention. The random practice was employed as the practice variability that is known to facilitate motor skill learning (Chua et al., 2019; Fazeli et al.,2017). The total time in skill random practice was about 30 minutes.

Measurement

Golf putt task.

The golf putting took place in a laboratory with a 15-ft long and 7-ft wide putting green made of artificial turf. The distance from a putting spot to a target was 10 feet. In the putting green, participants were asked to putt ten 10-ft putts into the target. During putting, participants were directed to focus on an external cue, i.e., an anticipated ball trajectory line with three references along the line (i.e., three marks at 1-, 4- and 7-feet distance from the target hole). The number of successful putts made was counted as the motor performance outcome.

Statistical Analysis

Statistical analysis was carried out using the SPSS 27.0 program. First, the independent t-test and chi-square (χ^2) test were computed to confirm demographic features across the groups.

Data from the golf putt task was analyzed by separate analyses of 3 (time periods) x 2 (groups) ANOVA. If the main effect analysis violated the Mauchly test of sphericity, as indicated by a *p* value of < .05, the corrected Greenhouse-Geisser F values for the main effect and the interactions between time periods and groups were reported.

The significant alpha level was set at .05 throughout the statistical analysis in the present study. Partial eta squared (η_p^2) was used in ANOVA to evaluate an effect size as follows: .01 to < .06 as small; .06 to < .14 as medium; and > .14 as a large effect size.

Results

Demographic Characteristics

As shown in Table 1, an independent t-test was conducted to compare age and BMI between the groups. Age: t (22) = -.373, p = .712, and BMI: t (22) = -.578, p = .573, were not significantly different. Also, according to chi-squared analysis, sex was not significantly different across the groups: χ^2 (1, N= 24) = .000, p = 1.00.

Exercise intensity

As for the exercise intensity, an average exercise HR among the participants in the acute cardiovascular group was 144.6 bpm, which was 74.9

Table I
Descriptive Statistics of Participants

	Intervention		***p* value**
	Skill Random Practice (n=12)	**Acute Cardiovascular Exercise (n=12)**	
Age (years)	21.08 ± 0.68	20.97 ± 0.74	.712
# of Females	7	7	1.00
BMI	27.20 ± 10.40	25.40 ± 2.87	.573

Note. BMI = Body Mass Index.

% of age predicted HR_{max}. Thus, the intensity was considered as moderate exercise intensity.

Post-Manipulation Check

the post-manipulation check was administered after the pre-, post-, and retention-putt tasks to ensure that participants followed the directed attentional focus while putting. The participants were directed to focus on the anticipated ball trajectory across the three testing sessions. 62.5 % focused on the anticipated trajectory during pre-putt task: χ^2 (3, N= 24) = 2.067, p = .559; 75.0 % focused on the anticipated trajectory during pre-putt task post-putt task: χ^2 (4, N= 24) = 3.333, p = .504; 83.3 % focused on the anticipated trajectory: χ^2 (2, N= 24) = 1.533, p = .465.

Golf Putts Made

A two-way repeated measures ANOVA was conducted to compare the effect of skill random practice versus cardiovascular exercise training on the performance in a 10-ft golf putting task. As noted in Figure 2, there was a

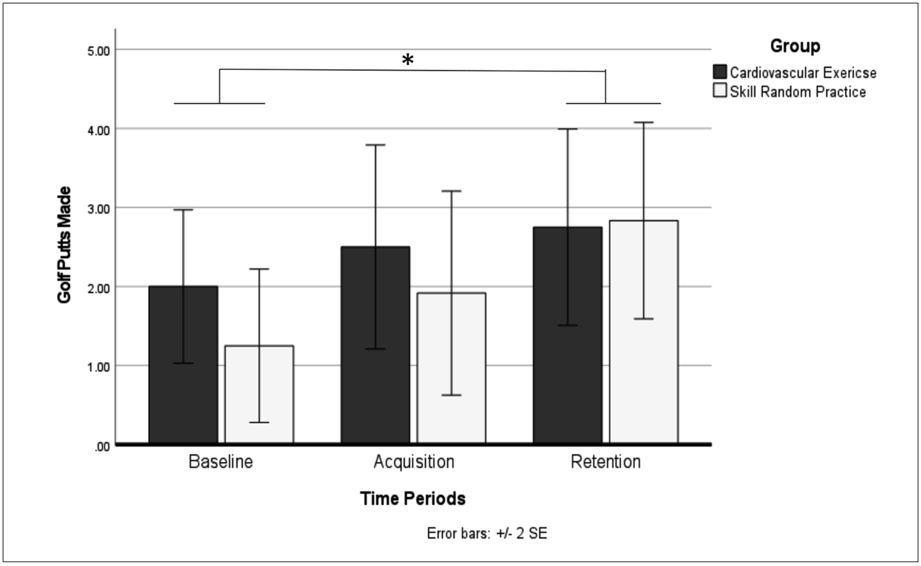

Fig. 2. - Acute effect of Exercise on golf putts made performance.

significant main effect of different time periods, $F(2, 44) = 4.083$, $p = .024$, $\eta^2=.157$. Pairwise comparisons with an LSD correction were used to make post hoc comparisons between time periods. They indicated that a significant difference existed in the retention period (M = 2.79) and the baseline period (M = 1.63), $p = .014$. Moreover, there was no interaction effect between different time periods and groups, $F(2, 44) = .583$, $p = .562$, $\eta^2 = .026$. There was also no significant main effect of groups, $F(1, 22) = .369$, $p = .550$, $\eta^2 = .017$.

Discussion

The purpose of the present study was to investigate the effect of skill random practice versus acute cardiovascular exercise on golf putts made. This is an important direction for future research because of our limited understanding of the time-dependent effect of two different exercise training regimens on motor learning. One of the important findings of the present study is that performance improvements in golf putting was observed after a delayed period. The acute cardiovascular exercise group achieved positive offline learning benefits in golf putts made. The underlying mechanism could be due to the fact that while walking on the treadmill, walking muscle movements in the lower extremities stimulated the motor cortex that was also responsible for the regulation of the upper extremities. The excitability in the neural level seemed to be sustained at least for a 24-hour period. Although some authors have demonstrated an increase in online learning of motor tasks after an acute cardiovascular exercise (Chartrand et al., 2015; Mang et al., 2014; Statton et al., 2015), the improvement in golf putts made was not evident immediately after acute exercise in the present study. It could be possible that the effect of the underlying fatigue in the low extremities on the treadmill may hinder the short-term recall of the motor memory and thus mask the movement regulation of upper extremities (i.e., golf grip, arm swing) later in the golf putting task. The coexistence of facilitative and hindering mechanisms from walking might explain why exercise did not enhance motor skill acquisition immediately. However, it is important to note that Roig et al. (2012) had utilized a 15-min high-intensity intervallic cycling and found intense exercise could enhance motor skill learning in 24-hour and 7-day retention tests. Similarly, Thomas et al. (2016) found the high intensity of exercise (HR = 173.6 bpm) performed better than moderate intensity exercise (HR = 132.5 bpm) in the 24-hour and 7-day retention tests. Given the discrepancy between these individual studies, it is suggested the intensity of exercise could play an important role in modulating the effect of a single bout of cardiovascular exercise. Further studies should explore the dose-relationship effect between exercise intensity and motor skill learning and add a 7-day retention test to explore long-term retention. Furthermore, the finding in the present study expanded the existing knowledge base to include complex motor skills (i.e., golf putting task). A single bout of cardiovascular exercise has the potential to improve different aspects of motor skill learning. More studies will be required to determine if our promising results can be extrapolated to other motor skills.

Interestingly, no group difference between skill random practice and cardiovascular exercise was found in the present study. Skill random practice resulted in a similar positive effect. While performing skill random practice in golf putting, participants generated a smaller change in energy metabolism than cardiovascular exercise but spent much time practicing fine and gross motor coordination, such as visual search, eye-hand coordination, balance, and spatial orientation. These motor abilities demand higher level cognitive processes and are likely to be related to attention and managing visual and spatial information. However, we did not have available physiological data that would allow investigating these mechanisms. For this, the values and details of the training session (e.g., HR, feelings) should be recorded in the future.

It was also noted that skill random practice improved the golf putts made in the 24-hour retention test. Landin and Hebert (1997) have recommended that a moderate level of practice schedule effect is more appropriate for novice learners in basketball free-throw tasks. Consistent with the study of Porter et al., (2007) in golf putting learning for novice learners, the present study provides a proper level of contextual interference that would offer participants the opportunity to make adjustments during practice and may be beneficial for learning motor skills. Future work should look at how random practice could improve movement patterns. Nevertheless, Pauwels et al. (2014) reported that the random practice group outperformed the blocked practice group in bimanual skill learning at immediate and retention tests, except for the most difficult bimanual task. Therefore, future work should also investigate the relationship between skill level and the effect of task complexity during practice.

It is important to consider the possible limitations accompanied that need to be addressed. First, although the results suggested several promising findings, adding a longer duration of retention test, such as a 7-day retention test, would enable subsequent studies to investigate this area of interest more thoroughly. Second, the estimated exercise intensity by age-predicted HRmax may not be the appropriate method to determine the effect of exercise that moderates motor learning and performance. Therefore, future work should expand these findings by evaluating high exercise intensity for a better understanding of the potential does-response relationship in a more rigorous manner. Additionally, this study should consider exercise modalities, levels of skill, and difficulty of motor tasks to comprehensively verify the association between acute exercise and complex motor skill learning.

Taken together, the present study is one of the pioneering studies that has attempted to pair acute cardiovascular exercise and complex motor skill learning. The evidence showed that there may be different temporal effects on golf putting learning. Skill random practice and moderate-intensity exercise seemed to result in an immediate increase in a delayed improvement in golf putt skills. There are numerous implications of these findings that could be applied to everyday settings, including the importance of daily physical activity for facilitating better learning and memory for young students, as well as motor rehabilitation for older adults.

REFERENCES

Aiken, C. A., & Genter, A. M. (2018). The effects of blocked and random practice on the learning of three variations of the golf chip shot. *International journal of performance analysis in sport, 18*(2), 339-349. https://doi.org/10.1080/24748668.2018.1475199

American College of Sports Medicine. (2018). *ACSM's Guidelines for Exercise Testing and Prescription: 10th Edition*. Wolters Kluwer.

Baumeister, J., Reinecke, K., Liesen, H., & Weiss, M. (2008). Cortical activity of skilled performance in a complex sports related motor task. *European journal of applied physiology, 104*(4), 625-631. https://doi.org/10.1007/s00421-008-0811-x

Baxi, G., Palekar, T., Nair, M., Basu, S., & Gohil, D. (2018). Effect of underwater treadmill training on cardiovascular responses in normal and overweight individuals. *National Journal of Integrated Research in Medicine*, *9*(4), 13-19.

Brocken, J. E. A., Kal, E. C., & van der Kamp, J. (2016). Focus of attention in children's motor learning: Examining the role of age and working memory. *Journal of Motor Behavior*, *48*(6), 527-534. https://doi.org/10.1080/00222895.2016.1152224

Chartrand, G., Kaneva, P., Kolozsvari, N., Li, C., Petrucci, A. M., Mutter, A. F., Daskalopoulou, S. S., Carli, F., Feldman, L. S., Fried, G. M., & Vassiliou, M. C. (2015). The effects of acute aerobic exercise on the acquisition and retention of laparoscopic skills. *Surgical endoscopy*, *29*(2), 474-480. https://doi.org/10.1007/s00464-014-3691-7

Chen, C.-C., Ryuh, Y., Luczak, T., & Lamberth, J. (2021). The effects of attentional focus and skill level on the performance of golf putting. *Journal of Motor Learning and Development, 9*(3), 371-382. https://doi.org/10.1123/jmld.2020-0072

Chen, F. T., Etnier, J. L., Chan, K. H., Chiu, P. K., Hung, T. M., & Chang, Y. K. (2020). Effects of exercise training interventions on executive function in older adults: a systematic review and meta-analysis. *Sports Medicine, 50*, 1451-1467.

Chua, L. K., Dimapilis, M. K., Iwatsuki, T., Abdollahipour, R., Lewthwaite, R., & Wulf, G. (2019). Practice variability promotes an external focus of attention and enhances motor skill learning. *Human movement science*, *64*, 307-319. https://doi.org/10.1016/j.humov.2019.02.015

Draper, S., McMorris, T., & Parker, J. K. (2010). Effect of acute exercise of differing intensities on simple and choice reaction and movement times. *Psychology of Sport and Exercise, 11*(6), 536-541. https://doi.org/10.1016/j.psychsport.2010.05.003

Fazeli, D., Taheri, H., & Saberi Kakhki, A. (2017). Random versus blocked practice to enhance mental representation in golf putting. *Perceptual and motor skills, 124*(3), 674-688. https://doi.org/10.1177/0031512517704106

Hogervorst, E., Riedel, W., Jeukendrup, A., & Jolles, J. (1996). Cognitive performance after strenuous physical exercise. *Perceptual and motor skills, 83*(2), 479-488. https://doi.org/10.2466/pms.1996.83.2.479

Hillman, C. H., Erickson, K. I., & Kramer, A. F. (2008). Be smart, exercise your heart: exercise effects on brain and cognition. *Nature reviews neuroscience, 9*(1), 58-65. https://doi.org/10.1038/nrn2298

Kaufman, S. B. (2007). Gender differences in mental rotation and spatial visualization ability: Can they be accounted for by differences in working memory capacity? *Intelligence*, *35*(3), 211-223. https://doi.org/10.1016/j.intell.2006.07.009

Kaipa, R. & Mariam Kaipa, R. (2018). Role of constant, random and blocked practice in an electromyography-based oral motor learning task. *Journal of motor behavior*, *50*(6), 599-613. https://doi.org/10.1080/00222895.2017.1383226

Kim, T., Chen, J., Verwey, W. B., & Wright, D. L. (2018). Improving novel motor learning through prior high contextual interference training. *Acta psychologica*, *182*, 55-64. https://doi.org/10.1016/j.actpsy.2017.11.005

Landin, D. & Hebert, E. P. (1997). A comparison of three practice schedules along the contextual interference continuum. *Research quarterly for exercise and sport*, *68*(4), 357-361. https://doi.org/10.1080/02701367.1997.10608017

Li, Y. & Wright, D. L. (2000). An assessment of the attention demands during random- and blocked-practice schedules. *Quarterly Journal of Experimental Psychology Section A, 53*(2), 591-606. https://doi.org/10.1080/713755890

Lin, C.-H., Fisher, B. E., Winstein, C. J., Wu, A. D., & Gordon, J. (2008). Contextual interference effect: Elaborative processing or forgetting-Reconstruction? A post hoc analysis of transcranial magnetic stimulation-Induced effects on motor learning. *Journal of Motor Behavior, 40*(6), 578-586. https://doi.org/10.3200/JMBR.40.6.578-586

Ludyga, S., Gerber, M., Brand, S., Holsboer-Trachsler, E., & Pühse, U. (2016). Acute effects of moderate aerobic exercise on specific aspects of executive function in different age and fitness groups: A meta-analysis. *Psychophysiology, 53*(11), 1611-1626.

Porter, J. M., Landin, D., Hebert, E. P., & Baum, B. (2007). The effects of three levels of contextual interference on performance outcomes and movement patterns in golf skills. *International journal of sports science & Coaching, 2*(3), 243-255. https://doi.org/10.1260/174795407782233100

Mang, C.S., Snow, N.J., Campbell, K.L., Ross, C.J., & Boyd, L.A. (2014). A single bout of high-intensity aerobic exercise facilitates response to paired associative stimulation and promotes sequence-specific implicit motor learning. *Journal of applied physiology*, *117*(11), 1325-1336. https://doi.org/10.1152/japplphysiol.00498.2014

Park, S. & Etnier, J. L. (2019). Beneficial effects of acute exercise on executive function in adolescents. *Journal of Physical Activity and Health, 16*(6), 423-429. https://doi.org/10.1123/jpah.2018-0219

Pauwels, L., Swinnen, S. P., & Beets, I. A. (2014). Contextual interference in complex bimanual skill learning leads to better skill persistence. *PloS one*, *9*(6), e100906. https://doi.org/10.1371/journal.pone.0100906

Rendell, M. A., Masters, R. S. W., & Farrow, D. (2009). The paradoxical role of cognitive effort in contextual interference and implicit motor learning. *International Journal of Sport Psychology, 40*(4), 636-648.

Roig, M., Skriver, K., Lundbye-Jensen, J., Kiens, B., & Nielsen, J. B. (2012). A single bout of exercise improves motor memory. *PloS one*, *7*(9), e44594. https://doi.org/10.1371/journal.pone.0044594

Skriver, K., Roig, M., Lundbye-Jensen, J., Pingel, J., Helge, J.W., Kiens, B., & Nielsen, J.B. (2014). Acute exercise improves motor memory: exploring potential biomarkers. *Neurobiology of learning and memory*, *116*, 46-58. https://doi.org/10.1016/j.nlm.2014.08.004

Snow, N.J., Mang, C S., Roig, M., McDonnell, M.N., Campbell, K L., & Boyd, L.A. (2016). The effect of an acute bout of moderate-intensity aerobic exercise on motor learning of a continuous tracking task. *PloS one*, *11*(2), e0150039. https://doi.org/10.1371/journal.pone.0150039

Statton, M.A., Encarnacion, M., Celnik, P., & Bastian, A.J. (2015). A single bout of moderate aerobic exercise improves motor skill acquisition. *PloS one*, *10*(10), e0141393. https://doi.org/10.1371/journal.pone.0141393

Swain, D. P., Abernathy, K. S., Smith, C. S., Lee, S. J., & Bunn, S. A. (1994). Target heart rates for the development of cardiorespiratory fitness. *Medicine and science in sports and exercise*, *26*(1), 112-116.

Tanaka, H., Monahan, K.D., & Seals, D.R. (2001). Age-predicted maximal heart rate revisited. *Journal of the American College of Cardiology*, *37*(1), 153-156. https://doi.org/10.1016/S0735-1097(00)01054-8

Thomas, R., Johnsen, L. K., Geertsen, S. S., Christiansen, L., Ritz, C., Roig, M., & Lundbye-Jensen, J. (2016). Acute exercise and motor memory consolidation: the role of exercise intensity. PloS one, 11(7), e0159589. https://doi.org/10.1371/journal.pone.0159589

Weinman, S. (2015, November). You've been practicing golf all wrong, and there's science to prove it. Golf Digest. Retrieved from https://www.golfdigest.com/story/youve-been-practicing-golf-all

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