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Impact of acute aerobic exercise on motor learning and executive function in adults with intellectual disabilities

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As motor learning in individuals with intellectual disabilities (ID) has been poorly elucidated, this study aimed to apply an acute aerobic exercise (AE), well-known intervention favorable to motor learning in typically developing individuals, to assist people with ID in motor learning, and examine its underlying mechanisms via EF and EEG assessments.

17 adults with ID (11 males, aged 31.41 ± 9.7, & mental aged 7.69 ± 3.06) participated in this within-group counterbalanced study. They participated in 2 interventions, a vigorous treadmill walking (AE) or seated rest (CON) condition, with having a month of wash-out period in between interventions. The pre-test, post-test, 24-hour retention test, and 7-day retention test was administered, and each testing phase administered a golf putt performance under both original (i.e., with guideline) and transfer putt tasks (i.e., without guideline), EF (i.e., Knock and Tap test, forward and backward Digit span test, forward and backward Corsi block test), and resting EEG assessment.

Golf putting accuracy in post-test was not significantly different from the pre-test; however, the putt accuracy under the transfer putt task indicated an interaction effect at 24-hour retention test phase compared to pre-test, $F(1, 32) = 5.26$, $p = .03$, $\eta_p^2 = .14$, and paired t-test

indicated a near significant improvement in putt accuracy in AE (p = .07), but not in CON condition (p = .23). The pre-test and 7-day retention phases did not indicate a significant effect on golf putt skill. As EF variables and resting EEG temporal alpha asymmetry (TAA) remained unchanged throughout the procedure, underlying mechanisms of change in putt skill need to be further investigated.

This study revealed a trend that the AE positively influenced golf putt accuracy and offline motor memory consolidation at 24-hour retention phase, but the effects were not statistically significant. Given that the study procedure did not include practice blocks, the observed positive impact of AE on golf putt accuracy is promising; thus, a future study is recommended to further verify the benefit of AE on motor learning in individuals with ID, as well as with rigorous EF and EEG measures to elucidate possible underlying mechanisms of AE-dependent improvement in motor skill.

DEDICATION

For Poram.

Thank you, my love, for your unconditional support, dedication, endless encouragement, and belief in myself.

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CHAPTER I

INTRODUCTION

Intellectual disability (ID) is a condition that exhibits significant limitations in intellectual functioning and adaptive behavior, which originates before the age of 18 years (Schalock et al., 2010). In addition to the primary condition, people with ID experience health disparity compared to their typically developing counterparts (Tracy & McDonald, 2015), and especially young adults with ID experience poor health care transition in the perspective of parents (Franklin et al., 2019) as well as caregivers (Bhaumik et al., 2011). The poor health status in individuals with ID could be partially attributed to the low motor skill competence, according to a model of interrelationship (Robinson et al., 2015). Behavioral evidence also pointed out that individuals with ID exhibited relatively poor motor skills (Frey & Chow, 2006; Vuijk, Hartman, Scherder, & Visscher, 2010). Therefore, given that the estimated prevalence of ID as approximately 1% in the world (Maulik, Mascarenhas, Mathers, Dua, & Saxena, 2011) and 1.22% in the United States (Maenner et al., 2016), enhancing motor skill competence in individuals with ID is important to reduce the health disparity.

The study area of motor learning is to elucidate the process of the relatively permanent attainments in motor skills associated with practice or experience (Magill, 2010; Schmidt, Lee, Winstein, Wulf, & Zelaznik, 2018). To date, a growing number of researchers have focused on motor memory to understand the underlying memory processes inducing changes in motor skills (Chen, Zheng et al., 2019; Dal Maso, Desormeau, Boudrias, & Roig, 2018; Jo, Chen, Riechman, Roig, & Wright, 2019; Kantak & Winstein, 2012). Literatures have been accumulated over the decades regarding the motor learning and memory processes in typically developing individuals (Dal Maso et al., 2018; Jo et al., 2019; Roig, Skriver, Lundbye-Jensen, Kiens, & Nielsen, 2012). Also, motor learning theories and techniques have been extensively applied in typically developing populations (Anguera et al., 2012; Buszard & Masters, 2018; Wulf, Lewthwaite, Cardozo, & Chiviacowsky, 2017). However, the studies regarding the motor skill learning in individuals with ID have been poorly documented; only a few studies applied the emerging motor learning knowledge to people with ID without Down Syndrome (DS; Capio, Poolton, Sit, Eguia, & Masters, 2013; Chiviacowsky, Wulf, & Ávila, 2013; Gillespie, 2003).

To date, converging evidence indicated that an acute bout of Aerobic Exercise (AE) has a positive impact on motor learning. The acute AE protocol has been utilized as an effective avenue to promote motor learning in typically developing individuals (Roig et al., 2012; Skriver et al., 2014; Statton, Encarnacion, Celnik, & Bastian, 2015; Thomas et al., 2016). Importantly, many studies reported that the AE was exclusively effective in the retention test phase, including 24 hours and 7 days after the practice, but not immediately after or 1 hour after (Roig et al., 2012; Thomas et al., 2016). The favorable effect of the AE on a delayed retention test, but not post-test, can be explained by the notion of motor memory consolidation (Roig et al. 2012; Robertson, 2009). According to a motor behavior-memory framework (Kantak & Winstein, 2012), motor learning is divided into several phases: motor memory encoding that occurs during practice, a consolidation that occurs during the offline non-practice period, and retrieval that occurs during the original and transfer test phase. The reason that the AE is not effective on the motor memory encoding phase might be that the impact of AE on motor learning typically takes at least 4 to 6 hours following practice (Fischer, Nitschke, Melchert, Erdmann, & Born, 2005;

Kantak & Winstein, 2012; Skriver et al., 2014). However, to our best knowledge, there is no study applied to the knowledge mentioned above induced by an acute bout of AE to assist individuals with ID in motor learning. The present study, thus, employed an acute bout of AE to assist adults with ID in learning a novel motor skill. In addition, the present study captured the motor memory encoding, consolidation, and retrieval in individuals with ID via administering multiple testing phases, including post-intervention, 24-hour retention, and 7-day retention test phases.

As there is limited evidence regarding the AE-dependent motor learning status in individuals with ID, an executive function (EF) and resting electroencephalography (EEG) measures were also as possible underlying mechanisms that might explain the motor skill learning process. First, EF has recently been indicated to be associated with motor skill performance in individuals with ID (Casey, Tottenham, Liston, & Durston, 2005; Hartman et al., 2010; Marvel, Morgan, & Kronemer, 2019). The findings from the studies suggested that, if we can improve EF in individuals with ID, the improved EF would facilitate motor learning. Among the EF constructs, it has been documented that inhibitory control and working memory (WM) are involved in early stages of the motor learning process (Anguera, Seidler, & Gehring, 2009; Buszard & Masters, 2018; Chan et al., 2011; Kerns et al., 2004; Maxwell, Masters, & Eves, 2003; Zhu et al., 2015). Furthermore, evidence revealed a transient increase in EF performance was observed following an acute AE bout in not only typically developing individuals (Chang, Labban, Gapin, & Etnier, 2012; Lambourne & Tomporowski 2010) but also individuals with ID (Vogt, Schneider, Abeln, Anneken, & Strüder, 2012; Vogt, Schneider, Anneken, & Strüder, 2013). For this reason, the present study assessed EF to examine the possible association with motor learning and AE. Also, EEG assessment was employed to capture the brain response to reflect the motor learning status. As temporal cortex area has been known to reflect the performers' motor skill proficiency (Haufler, Spalding, Santa Maria, & Hatfield 2000; Janelle & Hatfield, 2008; Kericket al., 2001; Wolf et al., 2015), the present study also focused temporal cortex area. Taken together, the present study added the EF (i.e., inhibition and WM) and resting EEG (i.e., TAA) measures to elucidate the underlying mechanisms of motor learning. To our best knowledge, the present study is the first study to integrate EEG analysis into AE and motor learning in individuals with ID.

The purpose of the present study was to examine the effect of an acute AE on motor learning and its underlying mechanisms, including the EF and EEG temporal alpha power. To do that, this study employed a treadmill walking protocol because it has been documented as one of the most popular and easy-accessible activities in an adapted physical activity as well as activities in daily living among adults with ID (Temple, 2007). In addition, a golf putting was adopted as a motor skill in the present study since, first, it is a self-paced skill that enabled the researchers to easily connect the motor performance with EF and EEG profile and, secondly, it enables to expand the existing body of knowledge from simple motor skills employed in the previous research, such as serial reaction time task (Bo et al., 2011), visuomotor tracking task (Anguera et al., 2012), and isometric finger pinch task (Statton et al., 2015), to a more complex motor skill which is arguably more similar to activities in daily living. The golf putt skill learning was comprehensively captured each distinctive motor learning phase based on the motor behavior-memory framework (Kantak & Winstein 2012); thus, the motor memory encoding, consolidation, and retrieval were all assessed by administering a post-test, and 24-hour and 7-day delayed retention tests. In addition, the performance in EF tasks (i.e., Knock and Tap test, forward and backward Digit span test, and forward and backward Corsi block test) as well as resting EEG activity were recorded to elucidate the change in golf putt performance induced by AE over a time period. The present study hypothesized that: 1) golf putt accuracy and consistency in the AE condition, but not the no-exercise control (CON) condition, would be improved in 24-hour and 7-day retention tests, but not immediately after, 2) the AE condition, compared with the CON condition, would indicate greater offline motor memory consolidation, 3) The AE condition, but not the CON condition, would exhibit an improvement in the EF performances immediately after the intervention, but not in the 24-hour and 7-day retention test phases, and 4) EEG activity would be altered in the AE, but not the CON, condition.

CHAPTER II

LITERATURE REVIEW

Motor Learning

Conceptual Framework

Motor learning can be defined as the process of acquiring motor skills (Magill, 2010), and the motor learning is known to be closely associated with memory structure as the acquired memory related to a particular motor skill needs to be encoded, stored, consolidated, and retrieved so that the learned motor skill can be executed (Magill, 2010; Robertson, 2009). Extensive evidence recently accumulated refers to the memory process during the motor learning as a motor memory that is conceptualized as a procedural, or non-verbal, skill memory that is a representation of motor action acquired through practice or experience (Foster, 1996). Therefore, the study of motor learning is often thought to an understanding of the motor memory representation process induced by practice and experience (Kantak & Winstein, 2012). To date, Kantak and Winstein (2012) proposed a motor memory-behavior framework which was made upon the motor behavior and neuroscience literature. The framework divided the time course of change in the motor memory process into the acquisition phase, the post-acquisition period, and the delayed original and transfer phase. Motor memory encoding primarily occurs during the acquisition phase, and the consolidation takes place during the non-practice retention interval. Lastly, performers retrieve the motor memory at the delayed retention/transfer test phase.

The encoding phase involves a considerable amount of cognitive resources as performers within the encoding phase focuses on information processing related to connecting a task goal, movement planning, execution, and movement outcomes (Robertson, 2009). Typically, the encoding phase exhibits a large magnitude of the error and a relatively rapid improvement (Fitts & Poster, 1967). Motor memory encoding typically assessed using an immediate post-test or tracking performance during the practice. Motor memory consolidation is a time-dependent process that the motor representation of a particular motor skill becomes more stable over the offline retention interval. The motor memory consolidation is important in that it strengthens the memory representation as well as increases resistance to interference from a secondary task (Robertson, 2009; Robertson & Cohen, 2006). Existing literature indicated that the motor memory consolidation process requires a sufficient amount of time period to be stabilized of 4 to 6 hours following practice (Shadmehr & Holcomb, 1997; Walker & Stickgold, 2004). That is, an immediate post-test typically assesses only a memory representation before the consolidation phase has stabilized the acquired memory. In the research platform, memory consolidation often inferred using a change score between the practice and retention test phase (Snow et al., 2016; Statton et al., 2015). Lastly, the motor memory retrieval phase is critical not only in our daily life as well as in motor performance and learning as the encoded and consolidated memory must be successfully retrieved to be used. It typically measured in research using delayed retention/transfer tests.

Motor Performance in ID

Although deficits in motor function are reported as one of the major limitations that individuals with ID possess (Pratt & Greydanus, 2007), there is a relatively small body of research in the area of motor learning and performance in this population. Nevertheless, several studies documented a motor function profile in individuals with ID compared with their typically developing counterparts (Frey & Chow 2006; Vuijk et al., 2010). For example, Frey and Chow (2006) indicated that children and adolescents with ID, aged from 6 to 18 years old, showed poorer Test of Gross Motor Development-2 (TGMD-2) scores, including locomotor and object control function, relative to the peers without ID. Similarly, Vuijk et al. (2010) recruited children with mild and borderline ID and assessed the Movement Assessment Battery for Children (MABC) to compare the standardized norm with the children with ID who participated in this study. They found that both groups of children with mild and borderline ID exhibited a substantially poorer motor performance, especially manual dexterity, compared to the norm. Further, children with mild ID showed more pronounced motor deficits that their counterparts with borderline intellectual functioning, which suggests that there might be an association between the degree of ID and motor function.

The compromised motor function seems to be associated with compromised EF in individuals with ID (Chen, Ringenbach, Albert, & Semken, 2014; Hartman et al., 2010; Wuang, Wang, Huang, & Su, 2008). Specifically, a cognitive planning component of EF, assessed by the Tower of London task, exhibited a notable association with fine motor skills among individuals with DS (Chen, Ringenbach et al. 2014). Similarly, Hartman et al. (2010) found that the children with ID's cognitive planning component of EF, measured by the Tower of London task, and gross motor skill, measured by TGMD-2, were highly correlated with each other. Moreover, Wuang et al. (2008) recruited children with mild ID and assessed motor proficiency, visual-motor integration, sensory integration, and intellectual functioning. The result indicated that children with mild ID impaired not only motor and intellectual functioning but also all types of sensorimotor integration. The findings suggested that the limited cognitive development also negatively affects motor control as the development of motor control is thought to be an interaction among cognitive, sensory, and motor systems in the human brain (Casey et al., 2005). Diamond (2000) supported the connection between cognitive and motor impairment via an extensive review of brain imaging studies regarding the relationship between the cerebellum and prefrontal cortex. The study found that the cerebellum and prefrontal cortex showed a parallel development while performing many types of cognitive tasks. Considering that the cerebellum and prefrontal cortex are the representative brain regions responsible for motor and executive function, respectively, the findings might suggest that motor and executive function may be interrelated with each other. That is, the poor motor function in individuals with ID might result from the low EF. Taken together, the studies mentioned above are all indicating that the EF and motor function appears to be interrelated with each other. Given that the population with ID exhibits an impaired cognitive function, including EF, it is suggested that an improvement in EF might be able to enhance motor skill proficiency in individuals with ID as well.

Motor Learning in ID

Within a small body of literature, several studies indicated that verified intervention to enhance motor learning in typically developing individuals could be applied to the motor learning in the individuals with ID as well (Chiviacowsky et al., 2013; Chen, Ryuh, Fang, Lee, & Kim, 2019; Gillespie, 2003). First, Chiviacowsky et al. (2013) documented that individuals with ID yielded greater motor learning effects under the external focus condition (i.e., beanbag) than internal focus condition (i.e., hand) in a beanbag throwing accuracy at 24-hour original and transfer test phase. The positive impact of the external focus of attention over an internal focus in motor skill performance and learning has been extensively studied in typically developing populations (Kal et al., 2013; Wulf, Dufek, Lozano, & Pettigrew, 2010; Wulf & Su, 2007).

Similar to typically developing individuals, the children with mild ID under the external focus instruction group also improved the bean bag throwing accuracy a day after practice measured by retention and transfer tests. There was no focus instruction during the 24-hour retention and transfer test sessions. The findings from the Chiviacowsky et al. (2013) suggested that attentional focus appears to be similarly affecting motor performance and learning in both people with and without ID. Moreover, while Wulf et al. (2017) stated that practice with enhanced expectancy is in favor of motor learning in typically developing population, Capio et al. (2012) indicated that the practicing under the reduced-error condition (i.e., an easier condition so less likely to make errors) also benefits motor learning in individuals with ID. Further, Gillespie (2003) recruited individuals with ID, and compared golf putt skill learning between a group that received the knowledge of result (KR) in every trial and the other group that received the summarized KR in every 5 trials. The study administered 50 acquisition trials, 25 24-hour retention trials, and 25 7-day retention trials to capture the change in golf putt skill from practice to the 7-day retention period. The result of the study indicated that, similar to the KR-effect in typically developing individuals (Anderson, Magill, Sekiya, & Ryan, 2005; Winstein & Schmidt, 1990), the every-trial KR group performed better in the acquisition phase than the summary KR group. Oppositely, the summary KR group outperformed the every-trial KR group at both retention phases. It also suggested that the motor learning technique effective to typically developing individuals can also be applied to the people with ID. Lastly, Chen, Yan, Yin, Pan, and Chang (2014) administered a regular-based inclusive soccer intervention, moderate-intensity exercise, to examine whether the motor practice with individuals with and without ID together would benefit motor learning via facilitating peer support, thereby promoting active participation. As a result, both groups with and without ID improved both EF and sports skills.

There are several methods reported to enhance motor learning in individuals with ID, and it is mainly to reduce conscious cognitive processing during the practice such as providing an external focus of attention (Chiviacowsky et al., 2013), providing practice trials under the reduced-error condition (Capio et al., 2013), and manipulating the frequency of KR (Gillespie, 2003). However, only a few studies, including the aforementioned literature, have been documented to assist motor learning in individuals with ID. Moreover, none of the existing literature considered the role of EF on motor learning in individuals with ID. To date, acute AE is another emerging remedy to facilitate motor learning, as discussed above. However, this area of study as well has not yet been expanded to the people with ID. Therefore, applying the knowledge regarding the AE-motor learning connection to the individuals with ID would be worthwhile for this population.

AE on Motor Learning

Extensive evidence including neuroscience (Chen, Zheng et al., 2019; Dal Maso et al., 2018) and behavioral literature (Roig et al., 2012; Skriver et al., 2014) supports the notion that the AE enhances motor learning. First, Chen, Zheng et al. (2019) documented evidence of a synaptic adaptation when it comes to motor learning using mice model. The researchers employed a treadmill exercise with a hypothesis that the treadmill exercise would enhance functional plasticity that would yield a better motor memory process until retrieval. Specifically, a mechanistic target of rapamycin (mTOR) was a substance of interest in this study in that the mTOR is known to contribute from motor memory encoding to the retrieval process in a molecular pathway. Motor memory is known to be encoded and stored in the form of cortical spine plasticity (Hayashi-Takagi et al., 2015), and an up-regulating brain-derived neurotrophic factor (BDNF) stabilizes the dendritic spines, thus, contribute to motor memory representation process (Chen et al., 2017). Converging evidence indicated that exercise contributes to the expression of the BDNF (Piepmeier & Etnier, 2015), and the BDNF proposed to activate the mTOR that functions as a trigger to activate molecular mechanisms to activate motor memory process (Autry et al., 2011). This study confirmed the hypothesis that the mTOR strengthened postsynaptic densities in the motor cortex, neurogenesis in spinal dendrites (spinogenesis), and increased axonal myelination. Therefore, Chen et al. (2019) documented a molecular effect of the AE on motor learning. Del Maso et al. (2018) adopted EEG and EMG analysis to further understand the underlying mechanisms of motor memory consolidation after the AE bout. Participants practiced a visuomotor tracking task and performed an AE following the practice. The study found that the participants who engaged in a single bout of AE resulted in better visuomotor tracking performance after the 24-hour retention period, and the skill improvement was positively associated with a brain activation over the bilateral sensorimotor cortex area. Although the connection between motor memory/learning and AE remains poorly understood, the studies investigated an underlying neuronal mechanism that sheds light on elucidating the area of interest.

In addition to the neural mechanisms, behavioral literature also indicated that the AE contributed to motor memory, especially consolidation process (Jo et al., 2019; Roig et al., 2012; Skriver et al., 2014; Snow et al., 2016; Statton et al., 2015; Thomas et al., 2016). First, Statton et al., (2015) documented a moderate-intensity AE intervention (65 – 85% HR_{max}), both single and multiple sessions, led to an immediate improvement in isometric pinch task accuracy, but the motor skill retention and offline motor memory consolidation captured by the change score before and after the 24-hour rest was not noticed. Similarly, Snow et al. (2016) assessed the motor learning comprehensively, including immediate acquisition, 24-hour delayed motor learning, and 24-hour offline motor memory consolidation, in a continuous tracking task using fingers after the moderate-intensity cycling exercise (60% peak O_2 uptake), and the study indicated maintenance of motor performance during the practice in the AE condition, compared with resting condition. However, 24-hour motor learning and offline motor memory consolidation were not notably altered after the AE bout. Thus, these aforementioned studies indicated that a moderate-intensity AE did not notably influence a relatively long-term motor learning and memory consolidation. In contrast, studies adopted vigorous AE indicated a favorable impact on motor retention tests (Roig et al., 2012; Skriver et al., 2014; Thomas et al., 2016). Roig et al. (2012) documented that a single bout of 20-min vigorous cycling exercise (90% VO_2peak) improved visuomotor accuracy-tracking task performance, using the right hand to follow the target line accurately, after 24 hours and 7 days of practice, but not 1 hour after. The findings supported the notion that the motor memory consolidation requires a sufficient amount of time reported as 4 to 6 hours from the previous study (Shadmehr & Holcomb, 1997; Walker & Stickgold, 2004). Further, Skriver et al. (2014) revealed potential biomarkers that might be associated with motor memory consolidation in the visuomotor tracking task performance at 1 hour, 24 hours, and 7 days after 20-min intense cycling exercise. As a result, the findings indicated that higher concentrations of BDNF and norepinephrine were interrelated with better motor learning and memory consolidation until 7 days after the practice. Moreover, Thomas et al. (2016) even proposed a possible dose-response relationship between the intensity of AE and motor learning. Specifically, both exercise groups under 90% and 45% maximal power output outperformed a visuomotor tracking task than a control group at 24-hour retention phase; however, at 7-day retention phase, the exercise group under the 90% of maximal power output outperformed the visuomotor task than the others including an exercise group under 45%

power output and control group. Therefore, given that the up-to-date evidence regarding the positive effect of AE on motor learning and memory consolidation, it is logical to speculate that the vigorous exercise intensity could exhibit a motor learning effect in a relatively long period.

Executive Function

Conceptual Framework

A sufficient amount of cognitive resources are required for daily living activities as well as motor skill acquisition, and such goal-directed cognitive processes are collectively called EF. There are at least 30 or more constructs, including attentional control, cognitive and response inhibition, WM, problem-solving, cognitive planning, and cognitive flexibility or set-shifting, have been included under the umbrella term EF (Diamond 2013; Miyake & Friedman 2012), and it is unrealistic to extract one specific construct from EFs to explain a specific action. Indeed, researchers indicated that each construct of EFs interconnected (Miyake et al. 2000). Therefore, yet the models that range from one to multiple constructs to define the concept of EF varies among many researchers, there is a general agreement that there are 3 basic constructs within the concept of EF: cognitive flexibility, which is the ability to shift between tasks or mental sets; WM, a capability to control attention to hold and manipulate information that is necessary for achieving a certain task goal (Repovš & Baddeley, 2006); and inhibitory control, suppressing unnecessary information to focus on the information related to achieving a particular goal (Nigg, 2000) that includes behavioral inhibition and selective attention (Miyake & Friedman, 2012). Thus, higher-order EFs are thought to utilize multiple basic EF constructs simultaneously, so individuals can execute his/her behaviors toward to the chosen goals (Davidson, Amso, Anderson, & Diamond 2006; Diamond, 2013).

Inhibitory control and WM. Converging evidence indicated the WM and inhibitory control were involved in the early stage of motor learning of a golf putt task (Beilock, Bertenthal, McCoy, & Carr, 2004; Brocken, Kal, & Van der Kamp, 2016). First, inhibitory control allows individuals to achieve a goal by doing what is more appropriate than automatic or familiar responses. That is, this function is vital to achieving a certain goal by suppressing unnecessary response from the stimuli that was irrelevant to the purpose. Nigg (2000) proposed a model that is one of the rare overarching models of inhibitory control (Bexkens, Ruzzano, Collot d'Escury-Koenigs, Van der Molen, & Huizenga, H, 2014) that consists of behavioral inhibition and selective attention (Miyake & Friedman, 2012). As a Knock and Tap test that is widely used for assessing behavioral inhibitory control in many populations including typically developing children (Molfese et al., 2010), adults with autism and comorbid learning disability (Barnard, Muldoon, Hasan, O'Brien, & Stewart 2008), adolescents and young adults with DS (Chen, Spanò, & Edgin, 2013), as well as children with ID (Tremblay, Richer, Lachance, & Côté, 2010).

As for the WM, extensive research has established over the past years that the WM is not a single store but a system comprised of separable interacting components (Shah & Miyake, 1996). Baddeley and Logie (1999) proposed the storage of information is mediated by two domain-specific systems: the phonological loop (i.e., verbal WM), which provides temporary storage of verbal-analytic information, and the visuospatial sketchpad (i.e., visuospatial WM), specialized for the maintenance and manipulation of visual and spatial representations.

EF on Motor Learning

To date, researchers have proposed different models to describe changes in motor performance during learning processes and identify the learner based on which learning stages they reside in. Among them, the three-stage theory of motor learning has been predominantly adopted in the area of motor learning, and the early motor learning stages has been referred to as a cognitive stage due to its heavy reliance on cognitive resource during the novel motor skill learning (Fitts & Posner 1967). During the early stage of motor learning, individuals have not selected an appropriate movement pattern to achieve a particular task goal. Therefore, novice performers in the cognitive stage need to figure out *"what"* needs to be done and "*how*" something can be done to achieve an assigned task goal. That is, individuals during the early motor learning process were believed to utilize a considerable amount of cognitive resources until an appropriate or optimal movement pattern is determined; thus, the early stage of motor learning is referred to as the "cognitive stage." People in this stage typically produce a large magnitude of errors that result from inconsistent movement patterns. Researchers in the respective area have been questioning on which types of cognitive function is involved in the cognitive stage of motor learning, and many researchers have focused on the involvement of WM (Brocken et al. 2016; Maxwell et al. 2003; Zhu et al. 2015), and inhibition (Bexkens et al., 2014; Nigg, 2000). The previous research documented that the inhibitory control function is associated with sports skills (Liao, Meng, & Chen, 2017; Martin et al., 2016; Wang et al., 2013). Researchers proposed that the inhibitory function was thought to be utilized in detecting and correcting errors during motor skill acquisition, especially the early motor learning stage (Chan et al. 2011).

The WM has been considered as one of the building blocks for cognitive planning and problem-solving in simple motor tasks (Bo & Seidler, 2009; Seidler, Bo, & Anguera, 2012). Traditionally, such cognition has been thought to be related to verbal-analytic information (Beilock et al. 2004). However, to date, a study indicated that the verbal WM hinders fluent movement production, thereby compromising motor skill learning (Zhu et al. 2015), and other studies demonstrated an association between visuospatial WM capacity and a novel motor skill acquisition (Anguera, Reuter-Lorenz, Willingham, & Seidler, 2010; Anguera et al. 2012; Bo & Seidler, 2009). These studies are all supporting that the visuospatial WM, but not verbal-analytic WM, promotes motor skill acquisition and learning. Indeed, previous research successfully verified the detrimental impact of verbal WM on a complex motor skill learning using golf putting task (Zhu et al. 2015). The study suppressed a verbal-analytic WM processing using a cathodal transcranial direct current stimulation (tDCS) technique over the left dorsolateral prefrontal cortex (DLPFC) that is known to be responsible for the verbal-analytic WM function (Buszard, Farrow, Zhu, & Masters, 2016; Wolf et al. 2015). The neural stimulation over the left DLPFC indicated a positive effect on motor learning, which is suggested that the involvement of the verbal-analytic WM could be detrimental in motor learning. In contrast, a positive association has been reported between visuospatial WM and motor skill learning during early, but not late, stage of sensorimotor adaptation (Anguera et al., 2010). The study used forward and backward Corsi Block task to assess visuospatial WM and adopted a forward and backward digit span task from WAIS-R (Wechsler 1997) to assess verbal WM. Also, a joystick aiming task with rotated vision was employed to measure simple visuomotor adaptation skill learning. The result indicated that visuospatial WM appears to be involved in visuomotor adaptation task (i.e., joystick aiming adaptation with rotated vision) during the early, but not late, stage of adaptation. The researchers further examined that WM depletion intervention adversely affected the rate of early visuomotor adaptation task following the intervention (Anguera et al., 2012). Moreover, another evidence confirmed that the visuospatial WM capacity predicted the rate of explicit motor sequence learning (Bo et al., 2011). This series of literature suggested that the visuospatial

WM may play an important role in facilitating the early stage of motor skill learning that includes both visuomotor adaptation and motor sequence learning.

Inhibition is known to be involved in the cognitive stage of motor learning as well. Anguera et al. (2009) expanded the involvement of inhibition on behavioral adjustment to the area of visuomotor adaptation. The visuomotor adaptation is one of the two forms of motor learning, accompanied by sequential learning, and can be defined as an online adaptation or adjustment of the motor output based on the online visual input information. Therefore, the detection and correction of an error are the essential components of the visuomotor adaptation. According to the findings from Anguera et al. (2009), the greater magnitude of discrepancy between intended and actual performance outcomes was reflected by the amount of brain activity observed over the anterior cingulate cortex (ACC). Behavioral evidence was also documented that the inhibitory control function had a strong association with specific sports skills. For example, Liao et al. (2017) compared action inhibition using a stop-signal task between professional badminton players and non-athlete controls. The result indicated not only a greater action inhibition performance among the athletes compared with their non-athlete counterparts but also a strong correlation between the level of competition and action inhibition capacity. Martin et al. (2016) reported a similar finding that professional road cyclists performed an inhibitory control task captured by the color-word Stroop test better than recreational cyclists.

The two core EFs (i.e., WM and inhibition) are known to have an interrelationship with each other. That is, we need to activate our WM function to maintain the goal to determine which stimulus to focus on and which one needs to be inhibited. Oppositely, we cannot hold multiple information in a brief amount of time since we have limited WM capacity. In this situation, we need to narrow down our focus and focus exclusively on what we need to focus, and inhibitory control helps to screen the stimuli whether it is necessary to hold or not before activating WM (Diamond, 2013). A “problem-solving model” proposed by Zelazo, Carter, Reznick, and Frye (1997) can provide a well-developed framework to incorporate the two core EF constructs in the cognitive stage of motor skill acquisition within four problem-solving phases. The first phase is to represent a problem that involves an error-detection via an inhibitory control mechanism. A second phase is planning for reducing or eliminating the detected error by selecting strategies, and the phase activates executive attention (Kane & Engle, 2002) and central executive (Repovš & Baddeley, 2006). Those “supervisory attention” components are highly synonymous to the cognitive control mechanism (Miyake & Friedman, 2012). Therefore, the inhibitory control might be extensively utilized during the first two phases. A third phase is the execution of the movement and maintains the goal and strategies. Working memory resource seems to be used to hold necessary information such as action goal, plan, and strategies. Especially when learning a sensorimotor skill such as a golf putting, visuomotor adaptation is likely to occur (Anguera et al. 2010; 2012). The visuomotor adaptation requires spatial working memory capacity as it needs to store visual information regarding the discrepancy between an intended outcome (i.e., target) and an actual outcome in the visuospatial sketch pad (Repovš & Baddeley, 2006), and adjusting subsequent movements based on the errors. The last one is an evaluation phase after utilizing error detection and correction through manipulating the attentional resources, detect and store necessary information regarding the error, adjust the movement to correct an error, and evaluate the adjusted movement by doing subsequent error detection and correction procedure (i.e., problem-solving process). Throughout those four phases, WM and inhibitory control function appear to be necessary. For these reasons, the two core EF constructs are being connected to the cognitive stage of motor learning.

Executive function in intellectual disabilities. It has been widely known that individuals with ID exhibit poorer EF performance compared to their typically developing peers as well as the compromised motor function (Chen, Ringenbach et al. 2014; Hartman et al., 2010). As for the WM performance in individuals with ID, research indicated that the visuospatial component of EF exhibited a developmental lag whereby the visuospatial WM in individuals with ID was obviously lower than that of the chronological age-matched peers, but similar to mental age-matched peers without ID; however, verbal-analytic EF in individuals with ID showed abnormal developmental pattern whereby verbal WM capacity was even poorer than their mental age-matched peers without ID (Henry, & MacLean 2002; Rosenquist et al. 2003; Schuchardt et al. 2010). Another research also supported the superiority of visuospatial over verbal-analytic processing in individuals with ID in that cognitive function tests involving a visuospatial memory (i.e., picture recognition) resulted in significantly higher performance outcome compared with the cognitive tests requiring a verbal memory (i.e., story recall), measured by the Rivermead Behavioural Memory Test, among adults with mild ID (Martin, West, Cull, & Adams, 2000). Therefore, it appears that, typically, the visuospatial WM might not be compromised as much as the verbal WM in individuals with ID.

The deficits in inhibitory control among the people with ID were also documented from several previous studies. For example, previous research compared each EF construct between children with ID and their mental age (MA) and chronological age (CA) matched counterparts. As a result, all five EF constructs, including WM, switching, fluency, planning, and inhibition, were poorer than their CA-matched counterparts as expected. As for the inhibition, children with an ID indicated even lower inhibitory control performance than their MA-matched comparisons. Bexkens et al. (2014) documented meta-analysis research, and the findings indicated that the type of inhibition moderated inhibitory control performance. Specifically, the size of the inhibition deficit tends to be greater in behavioral inhibition and interference control, but not for cognitive and motivational inhibition. Given that the cognitive and motivational inhibition is more "automatic" type of inhibition whereas the behavioral inhibition and interference control are known to be more "deliberate" type of the inhibition (Logan, 1995; Nigg, 2000), the findings could be interpreted that individuals with ID tend to exhibit greater deficits in the behavioral or deliberate type of inhibition. Importantly, the inhibitory deficit was proven to be negatively associated with IQ level; that is, among the individuals with mild ID and borderline intellectual functioning, inhibition deficit tends to be greater as the IQ score decreases.

AE on EF

There are a series of meta-analysis review papers examining the positive effect of an acute AE on cognition with healthy populations in diverse age groups (Chang et al., 2012; Lambourne & Tomporowski 2010). According to the literature, cognitive test following an acute AE was beneficial in general. When testing a cognitive function immediately after the acute AE, executive function measures were improved following the moderate-intensity exercise. Also, between 1- and 15-minutes delayed measures indicated a significant improvement in cognition, especially inhibitory control and visual short-term storage, following exercise. Therefore, the meta-analysis suggested that moderate intensity, administering the cognitive test between 1 and 15 minutes following the completion of the exercise, will improve inhibitory and visual component but not the verbal-analytic component of EF. Recently, Roig et al. (2013) focused on human memory exclusively and published a meta-analysis paper. The study found that, first, an acute AE did moderate the WM function as well as long-term memory. Secondly, the study indicated that the walking protocol has proven to be the best to improve WM. Third, acute AE tends to improve visuospatial more than verbal-auditory WM. Further, the effect of an acute AE appears to be greater when an exercise duration was shorter than 20 minutes. Lastly, the initial fitness level was not a significant moderator.

In terms of the exercise intensity to be effective to the EF benefit, recent meta-analysis evidence was in favor of the moderate-intensity of AE toward core EF constructs (Ludyga, Gerber, Brand, Holsboer-Trachsler, & Pühse 2016; Verburgh, Königs, Scherder, & Oosterlaan 2014). The studies indicated that moderate AE improve inhibition and WM, and 20 minutes duration was suggested for maximizing the EF benefit (Kamijo, Nishihira, Higashiura, & Kuroiwa 2007). All in harmony, 20 min of moderate-intensity appears to be the most reasonable duration and intensity of a single bout of AE to improve EF. Also, it seems to be beneficial in inhibition and spatial component, but not a verbal-analytic component of WM. There are several empirical studies that followed the suggestions from the meta-analytic studies. Nanda, Balde, and Manjunatha (2013) applied 30-min cycle exercise at moderate intensity (60 – 70 % heart rate reserve (HRR) in healthy adult males, and there was a significant improvement in spatial-related memory and reasoning. The 60–70% of the maximal exercise intensity was classified based on the American Heart Association. Previous research also applied moderate-intensity acute AE, and the intensity was manipulated between 60 – 70 % of maximal heart rate during 30 minutes of group jogging among preadolescent children (Chen, Yan, et al., 2014). They found that inhibitory control and WM have improved following the acute AE.

Three underlying mechanisms can explain the introduced improvement in diverse constructs of EF immediately after the acute aerobic exercise. The first possible explanation is exercise-induced arousal (Lambourne & Tomporowski, 2010; McMorris et al. 2008), and the exercise-induced temporary arousal is associated with an inverted-U theory, which supports the moderate-intensity of exercise. Secondly, an up-regulation of catecholamine (i.e., dopamine and norepinephrine) may result in the facilitation of attentional arousal, which, in turn, improves the target cognitive capacity. The third mechanism is an immediate increase in peripheral BDNF concentration in blood (Piepmeier & Etnier, 2015). The researchers found that the increased peripheral BDNF concentration favorably affected the spatial learning and memory function. Considering that BDNF is known as proteins to be responsible for the growth of the nervous system related to memory and learning, the findings provided a possible explanation with biological mechanisms on how acute aerobic exercise improved EF.

Several studies provided behavioral evidence suggesting a positive impact of a single bout of AE on EF in people with ID (Chen, Ryuh et al., 2019; Pastula, Stopka, Delisle, & Hass, 2012; Protic & Válková, 2018; Vogt et al., 2012; 2013). Pastula et al. (2012) recruited young adults with ID, and they participated in an 8-week exercise intervention containing circuit training, aerobic dancing, and sports activities. Each session lasted 45 minutes, and the exercise intensity was monitored within 60 – 70% of HRmax, which is moderate intensity. After completion of the intervention program, the participants with ID improved their cognitive function, including visual matching task and processing speed. Also, Protic and Válková (2018) compared the result of the Behavior Rating Inventory of Executive Function (BRIEF) scale in children with ID after a light, moderate, vigorous, and moderate-to-vigorous intensity physical activity. As a result, physical activity under the moderate-intensity and moderate-to-vigorous intensity improved EF constructs, including WM, planning, and metacognition. Most recently, Chen, Ryuh et al. (2019) administered an inclusive soccer intervention with young adults with ID and their typically developing counterparts. The result indicated improvement in EF performance in both populations with and without ID; that is, typically developing individuals improved visuospatial

WM measured by the Corsi block test, while individuals with ID improved inhibitory control after the completion of the 15-week inclusive soccer intervention program. While other studies mentioned above did chronic exercise interventions, Vogt et al. (2012; 2013) administered an acute AE intervention in individuals with ID. Most importantly, individuals with an ID indicated a similar brain cortical response to AE as their counterparts without ID, and showed the transient hypofrontality (i.e., decreased frontotemporal area brain areas) immediately following a 30-min running (Vogt et al. 2012) and cycle exercise (Vogt et al. 2013). Especially, Vogt et al. (2012; 2013) indicated a heightened cortical current density over the medial frontal gyrus, whereby responsible for the inhibitory control component of EF. Although Vogt et al. (2012) did not exhibit improved cognitive function following an AE bout, Vogt et al. (2013) did indicate an improved cognitive function mirrored by faster reaction time during the basic computerized decision-making task which could be resulted from the hypofrontality following the exercise bout.

Neural correlates of motor learning

Numerous evidence revealed that the temporal cortex area involves in motor performance and learning as well as related information processing (Janelle & Hatfield, 2008; Woods et al. 2015; Zhu et al., 2010); thus, the present study assessed temporal activity using EEG. Typically, left temporal cortex is associated with verbal-analytic information processing whereas the right temporal cortex is known to be responsible for visuospatial information processing (Kerick, Douglass, & Hatfield 2004), and the alpha band power is a well-known indicator negatively associated with the cortical arousal (Zhu et al. 2010). Thus, it is widely established that the expert sensorimotor skill performers tend to indicate higher alpha power on the left temporal cortex, whereas relatively lower alpha power output on the right side (Kerick et al., 2004; Wolf et al., 2015). With the notion, that elite sensorimotor skill performers tend to activate right temporal area relatively more than the left side, in mind, temporal alpha asymmetry (TAA; T4/T3) has been proposed as a means of differentiating brain activity during the movement execution between skilled and non-skilled performers (Janelle & Hatfield, 2008; Wolf et al. 2015). Specifically, Wolf et al. (2015) compared neural activity between elite and amateur table tennis players when they watched a video that an opponent player serving toward the participant. This study employed TAA by subtracting left temporal alpha power from the right temporal alpha power, and the result indicated that the amateurs exhibited a significantly low left temporal area activation compared with elite performers while the right temporal area remained constant. Zhu et al. (2010), similarly, noted that the novice performers in a sequential finger-tapping task indicated increased temporal activation as they learned the motor skill. Also, beta power coherence at the T4-Fz area, the connection between right temporal area and premotor area whereby planning movement execution, was stronger as the participants learned the movement. The findings suggested that the utilization of the right temporal area was becoming more pronounced as the motor skill is becoming better. As such, the temporal area is involved in both novice and skilled performers during motor skill execution, and the involvement in the left temporal area is getting decreased as the performers became skillful in a particular motor skill.

CHAPTER III

METHODS

Participant

A total of 23 adults with ID initially participated in the present study. However, four participants had to be removed from further analysis as their exercise intensity during the treadmill exercise was even lower than 40 % of HRR, which is the criteria to be moderate-intensity (American College of Sports Medicine, 2017). Also, a participant dropped out from further analysis due to pregnancy, and another participant could not complete the data collection procedure. As a result, a total of 17 adults with ID (aged 31.41 ± 9.7, mental age as 7.69 ± 3.06, and 11 males and 6 females) participated in the present study.

The inclusion criteria for the present study were 1) adults above 18 years old, 2) individuals who have no golfing experience, and 3) diagnosed as having ID. Also, individuals who have 1) any type of physical limitation, 2) mental age lower than 3 years old, and 3) individuals with DS have been excluded from this study due to their distinctive features among the types of ID such as physical distinction (American Academy of Pediatrics, 2001; Pitetti, Climstein, Mays, & Barrett, 1992), deficits in the cerebellum (Pinter, Eliez, Schmitt, Capone, & Reiss, 2001), and different EF profiles and learning styles from other types of ID (Vicari, Carlesimo, & Caltagirone, 1995). The participants with ID were recruited from a Southeastern University in the United States and its surrounding community. The participants were recruited either from a university post-secondary transition program or a community organization serving individuals with ID. The Peabody Picture Vocabulary Test: 4th edition (PPVT-4: Dunn & Dunn 2007) was employed to assess the MA of the participants. If their MA was lower than 3 years old, they were excluded from the study as they may have compromised capability to rate their perceived exertion during exercise (Groslambert & Mahon, 2006). All the participants signed an assent form to agree on partaking in the study, and their parents also agreed to participate in the present study via consent form. All protocols were approved by the Human Subjects Institutional Review Board of the University (IRB-19-152).

Intervention

A 20-min acute intervention was administered in between the pre- and post-test. Participants in the AE condition were asked to perform treadmill walking at vigorous intensity while participants in the CON condition were asked to sit on a chair and watch a video during the intervention period.

Experimental condition

Before stepping on to the treadmill, each participant wore the HR monitor on the dominant upper arm to monitor the HR during the intervention. The Polar OH1 Optical Heart Rate Sensor was applied to each participant's non-dominant upper arm to continuously monitor their HR. The AE bout started with the warm-up phase up to 10 minutes until the HR reached to a target range, followed by the 20-min AE and 5-min cool-down. The participants' $HR_{exercise}$ during the 20-min AE was maintained within a vigorous-intensity range, which is between 60 and 89 % HRR (American College of Sports Medicine, 2017). The HRR stands for HR_{max} minus HR_{rest}, and the HR_{max} was computed through the prediction equation, developed by Fernhall et al. (2001; $HR_{max} = 210 – 0.56 \text{ (age)} – 15.5$). The HR_{rest} was measured at the end of the 6 min seated rest. Then, the target HR was computed with the equation: $HR_{exercise}$ = % exercise intensity x (HR_{max} -HR_{rest}) + HR_{rest}. Researchers manipulated the speed of the treadmill to keep participants' heart rate within the target zone, and the slope of the treadmill increased by 5 degrees every 5 minutes.

Children’s OMNI-walk/run Scale of Perceived Exertion (hereafter: RPE), developed by Utter, Robertson, Nieman, and Kang (2002), was adopted to assess subjective exercise intensity of each participant. Stanish and Aucoin (2007) adopted this RPE scale for monitoring exercise intensity in adults with ID, and there was a significant positive relationship among RPE, heart rate, and workload. The RPE and $HR_{exercise}$ were assessed every minute during the 20 min AE.

Control Condition

The researchers also recorded the RPE and HR every minute for the control group while they were sitting on a chair and watching a pre-selected video, one of the National Geographic videos: National Geographic: NatGeo Wild Turf War Lions and Hippos (Documentaire, 2017). While most studies with typically developing people used seated resting activity only as their CON condition, the present study adopted the video to keep the participants with ID being attentive while seated rest. A similar study with individuals with DS also used a video to keep their participants with DS attentive during the seated resting activity (Chen, & Ringenbach, 2016; 2019). The participants in the control group were asked to pay attention to the video for 20 min, and the researchers will intermittently observe the participants ensure whether they are focusing on the film.

Measurement

Golf Putting

The putt task utilized in this study took place on artificial turf in the laboratory. Most studies employed golf putt performance recruited healthy population without a cognitive limitation, so task difficulty may be too challenging for the participants with ID in this study. Thus, the putt task instruction and assessment was made based on a Special Olympics Golf Coaching Guide. Also, to prevent floor effect, golf putt performance was conducted with both conditions: one was with a white dotted guideline drawn by erasable chalk from 30 cm behind of the initial ball location toward a targeted hole, and the other was without a guideline.

Each participant performed the putt tasks on a designated line two meters away from the target hole, and each test phase consisted of 10 shots. Each participant had a brief break after five putt trials. The putt distance (i.e., two meters) and the number of trials (i.e., five shots) were retrieved from the Special Olympics Minnesota Golf Handbook. The participants practiced 10 shots during the familiarization day, which is a day before the actual test day. During the pre-test session, each participant putted two practice shots followed by 10 shots of the pre-test block. The participant will stroke 10 shots after the intervention during the post-test phase. From the post-test up to the 7-day retention test, each participant performed two blocks of 10 putts: 10 shots of standard putt condition which is the same as pre-test condition with a guideline, and 10 shots of transfer putt condition without a guideline.

Accuracy and consistency were computed and recorded using an absolute error and variable error (review Hancock, Butler, & Fischman, 1995). In order to compute x and y coordinates of each landed ball, x and y-axis with the cm-based tape measure attached were places at 1-meter behind and 1-meter right side from the target hall; thus, each of x and y axis ranges were from -100 cm to 100 cm. For put balls exceeded the scoring range were recorded as either 101 or -101. Stroked balls hit the target were given (0, 0). After computing the (x, y) coordinates of each putt, the mean absolute error and variable error were recorded for the data analysis in the present study. Therefore, the putt performance outcomes under both standard condition and transfer conditions across the testing phases (T_{PRE} ~ T_{7d}) were represented as accuracy and consistency.

Lastly, the attentional focus was directed to the external focus. This is because many researchers found that the focus of attention significantly moderates the performance outcome, and external focus is beneficial for novice learners to acquire novel motor skills (Kal et al. 2013; Wulf, McNevin, & Shea, 2001), including golf putt task (Kearney, 2015). In this study, the participants were asked to focus on the guideline when they swing and hit a golf ball.

EF

Inhibition. The present study adopted the Knock and Tap task for assessing inhibitory control function. The Knock and Tap task is known as tapping both inhibitory control and WM introduced in the NEPSY, which stands for a developmental neuropsychological assessment (Korkman, Kirk, & Kemp, 1998), and it is widely utilized for assessing EF in individuals with ID (Molfese et al., 2010; Tremblay et al., 2010). The task had 2 phases. In the first phase with 15 trials, each participant was asked to tap on the table when an examiner knocked and vice versa. In the second phase with another 15 trials, the participant was requested to bang on the table using side fist when the examiner knocked, knocked when the examiner banged the table with side fist, and not moving when the examiner tapped the table. The number of trials with a correct response was recorded for the data analysis.

Table 1

An Example of the Digit Span and Corsi Block Test Assessment Sheet

	Span	Presented	Digit Span			Corsi block		
			Response	#	Outcome	Response	#	Outcome
FORWARD	2	8, 5						
	2	3, 1						
	3	8, 4, 5						
	3	7, 9, 6						
	4	8, 2, 7, 9						
	4	4, 2, 5, 3						
	5	1, 7, 3, 9, 2						
	5	4, 5, 4, 7, 1						
	6	3, 8, 2, 9, 9, 2						
	6	1, 7, 3, 6, 3, 9						
	7	4, 8, 1, 5, 6, 8, 9						
	7	7, 2, 5, 6, 4, 2, 7						
BACKWARD	2	8, 1						
	2	3, 6						
	3	5, 9, 4						
	3	9, 6, 7						
	4	5, 2, 8, 3						
	4	2, 3, 1, 7						
	5	9, 4, 6, 5, 8						
	5	4, 1, 5, 7, 8						
	6	6, 9, 2, 3, 8, 5						
	6	4, 9, 6, 2, 3, 1						
	7	8, 5, 3, 1, 8, 4, 5						
	7	7, 9, 6, 8, 2, 7, 9						

#: number of correct response / Outcome: either 1 or 0 was awarded for an accurate or inaccurate answer, respectively. The present study used "#" for data analysis.

WM. The verbal and visuospatial WM were assessed separately using the Digit span task and Corsi block test, respectively**.** First, the Digit span task is a widely-used tool for measuring verbal-analytic WM. The visual forward and backward digit span tests were administered with a computer screen with the pre-determined number sequence developed by California Cognitive Assessment Battery (CCAB; Woods et al. 2011). It started from two up to seven number span, and each span has two consecutive trials (e.g., table 1). Therefore, the span length was increased by one in every two trials. The participants in the present study continued the task until the two consecutive failures, and the total number of correct responses was recorded for the data analysis. For example, each participant earned three points if the participant successfully responded to trial with three digit span, and earned five points if he/she responded five numbers accurately out of seven digit span task. The forward and backward Digit span task were administered following the same protocol.

The Corsi block test was employed to measure the visuospatial WM function in the present study. The forward Corsi block test assessed visual cache, responsible for the short-term storage of visual input as a form of visual code, and the backward Corsi block test assessed visual scribe function that is responsible for holding and manipulating the visual code stored in the visuospatial sketch pad as the visual code (Corsi, 1972; Logie & Logie, 1995). The present study followed standardized administration and scoring procedure of the Corsi block test suggested by Kessels, Van Zandvoort, Postma, Kappelle, and De Haan (2000). The test consisted of nine red cubes (30 x 30 x 30 mm) attached on a sandy-colored board (225 x 205 mm) as suggested by Kessels et al. (2000), and figure 1 provides a visual description of the Corsi block task equipment used in the present study. As shown in figure 1, each of 9 blocks on the board has a number from 1 to 9, and the numbers were only visible from the researchers' sight. The order of block tapping sequence was pre-determined using CCAB, which was the same as the Digit span task so that the difficulty of both verbal-analytic and visuospatial WM was matched. Each participant started testing with a sequence of 2 blocks, and each span length has 2 consecutive trials (e.g., table 1). The participants were allowed to continue testing until the 2 consecutive trials. The scores were computed for each participant using the total number of correct responses throughout the trials, which is more rigorous than just counting the number of correct trials alone (Kessels et al. 2000).

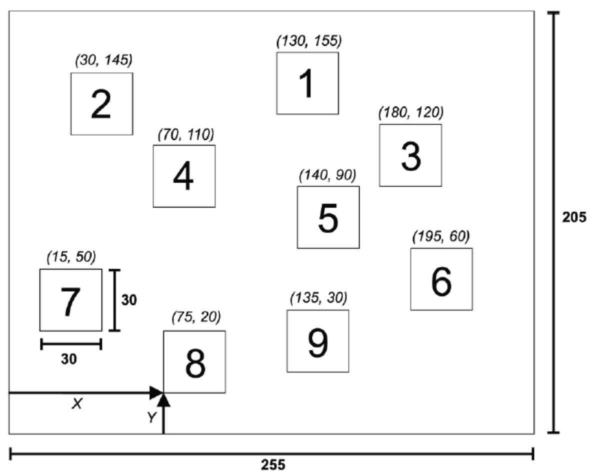

Figure 1. Visual description of the standardized Corsi block test. Retrieved from Kessels et al. (2000).

Resting EEG

The resting EEG measure was carried out with a wireless Emotiv EEG headset (Emotiv Technology Inc., USA). The EEG has 14 channels over the scalp areas, and the channel locations follow the international 10-20 system of EEG electrode placement, including Fp1/2, F3/4, F7/8, FC5/6, T3/4, P7/8, and O1/2, with 2 reference points on mastoids (behind ears) (Jasper, 1958). To ensure a nice contact quality, a saline solution was applied to each of the electrodes, and the good contact quality was confirmed by showing the “green light” in the Emotiv Test Bench software program. After wearing the EEG headset with a good contact quality, each participant closed eyes, then a researcher spoke out “start” and start recording the EEG power for approximately 75 seconds, a little more than 60 seconds that we need, to spare a room as a researcher visually examined the EEG recordings and removed artifacts that are suspected of being caused by eye blinks, muscle activation, movement, or other biological confounders. A researcher manually removed artifacts and store them as an offline file. The EEG sampling frequency was 128 Hz, a digital notch bandpass filter was set at 0 – 45 Hz, and the acquired data was transmitted via Bluetooth connection to a computer. Also, the Bandpass filter separated EEG signals into 4 frequency bands: Delta (0 – 4 Hz), Theta (4 – 8 Hz), Alpha (8 – 12 Hz), and Beta (12 – 24 Hz). One-min of the average power spectrum for each power band was converted into log-transformed data for securing the normality of the acquired EEG power (Delorme & Makeig 2004).

Procedure

After the consent/assent, the recruited participants participated in both an intervention and a control condition, and the order of participating conditions was counterbalanced with about a 1-month gap between conditions to remedy a learning effect. The AE condition was a 20-min steady-state treadmill walking exercise with 5-min warm-up and cool down while the CON condition seated on a chair and watched a pre-selected video for 20 min. Each participant visited a laboratory 4 times: a familiarization, intervention and pre- and post-test, 24-hour retention test, and 7-day retention test days. From the first (familiarization) to the third (24-hour retention) visits were scheduled on 3 consecutive days.

As the present study was a within-group counterbalanced design, each participant firstly went through from day 1 to day 4 with either AE or CON condition, and at least after a month of wash-out period, the participant did the 4-day cycle again with the other condition. Half of the participants started with the AE condition first, and vice versa to counterbalance the order effect. The following paragraphs described a cycle, including 4 visits.

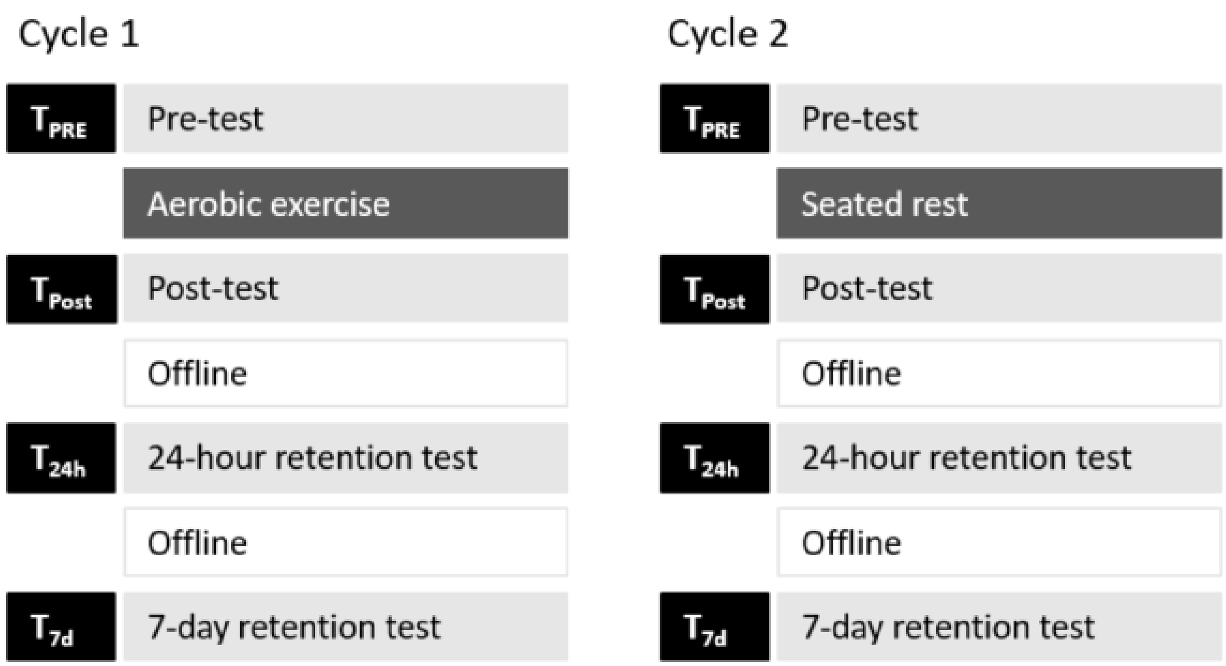

Figure 2. *Figure 1* Research procedure. A month of wash-out period was placed between cycle 1 and 2.

Day 1: Familiarization

The purpose of the first-day session was to mitigate any possible confounding factors due to the unfamiliarity of the tasks. During the first visit, each participant answered a demographic questionnaire, including golf experience, age, height, weight, and then the PPVT-4 was administered for assessing MA. Following the questionnaires, each participant was briefly introduced each activity that would be conducted during the second visit, such as wearing HR monitor, putting EEG headset, answering feeling scale, maintaining 5 min sitting still, practicing

EF tasks, watching golf putt instruction with photos and short demonstration videos, practicing 10 golf putts, and walking on a treadmill for more than 5 minutes up to 10 minutes until the HR reached to the target zone.

Day 2: Intervention (T_{PRE} & T_{post})

The day after the familiarization session, each participant visited our laboratory and went through a pre-test block (T_{PRE}), intervention, and post-test block (T_{post}) in order. Participants were asked to sit quietly for 5 minutes with an HR monitor. The Resting HR was recorded at the end of the 5-min quiet sitting. Next, participants answered a 5-point feeling scale with a visual description of a face of each mood (1: great, 2: good, 3: fine, 4: unhappy, 5: angry) to assess their daily mood, and recorded a 1-min resting EEG. Participants sat on a chair in the quiet laboratory wearing the headset with closed eyes, and the researchers recorded the participant's neural activities for a minute. After that, the modified feeling scale was conducted to measure their mood status. The scale was developed by Hardy and Rejeski (1989) and recommended as an effective affect measurement within the exercise context by Ekkekakis and Petruzzello (2000); however, the 11-point scale was hard to be applied for the individuals with ID, so the present study used a modified 5-point feeling scale with facial images (great, good, fine, unhappy, and angry). EF tasks, including the Knock and Tap task, and forward and backward Digit span task and Corsi block task, were tested to measure WM and inhibitory control. Lastly, participants watched a golf putt instruction that contains a putting demonstration and visual information regarding stance, grip, tips for adjusting speed and direction. Thereafter, participants practiced 2 putts and performed the 10 pre-test putt task in standard putt condition.

After the pre-test, each participant was randomly assigned to either an AE or CON condition. After completion, each participant took the same testing procedure as a pre-test. Their scores were recorded as the performance in the post-test block (T_{post}), including HR, EEG recording, feeling scale, EF tasks, and golf putting. While the pre-test only performed 10 putts with a guideline, but from the post-test to the 7-day retention test, there will be another 10 putts without a guideline to assess the participants' performance change under the transfer condition.

Day 3: 24-hour Retention Test (T_{24h})

Twenty-four hours after intervention day, each participant visited the laboratory and went through the same testing procedure as the pre- and post-tests. His/her scores were recorded as the performance in 24-hour retention test block (T_{24h}). The test procedure was the same as T_{post}.

Day 4: 7-day Retention Test (T_{7d})

The 7-day retention test procedure was identical from the T_{post} and T_{24h}. The visual flowchart of the process, as shown in figure 1.

Data Analysis

Descriptive statistics were applied to report mean (M) and standard deviation (SD) of anthropometric variables such as height, weight, body mass index, and chronological and mental age. A series of independent samples t-tests were computed to analyze any significant difference in anthropometric variables and exercise data, including HR_{rest} for each visit, exercise HR after the intervention, RPE, and feeling scale, between the AE and CON conditions.

Golf Putt Skill

For both of the putting accuracy and consistency, a condition (AE vs. CON) x cycle (1 vs. 2) factorial analysis of variance (ANOVA) was computed to assess any initial difference between AE and CON conditions as well as between cycle 1 and 2. For the main analysis, a 4 (time: T_{pre} vs. T_{post} vs. T_{24h} vs. T_{7d}) x 2 (condition: AE vs. CON) repeated measures ANOVA was carried out and, subsequently, a planned contrast in ANOVA, that broke down the primary ANOVA analysis into several motor learning phases, were computed. The ANOVA analysis was broken down into exercise-induced motor skill acquisition, motor learning, and offline motor memory consolidation phases, because each of the phases are conceptually distinctive based on the motor behavior-memory framework (Kantak & Winstein, 2012; Robertson, 2009). In short, the framework proposed that the acquisition phase encodes, offline delayed period consolidates, and the retention/transfer test phase retrieves the motor memory. Thus, in accordance with the framework, similar analysis methods have been used in the previous studies (Snow et al., 2016; Statton et al., 2015; Thomas et al., 2016). First, exercise-induced acquisition was computed with the 2 (time: T_{pre} vs. T_{post}) x 2 (condition) repeated measures ANOVA. The 24-hour and 7-day motor learning were calculated via the repeated measures ANOVA as well with time (T_{pre} vs. T_{24h}, and T_{pre} vs. T_{7d}, respectively) and condition. Lastly, 24-hour and 7-day offline motor memory consolidation were computed from the golf putt accuracy score, and assessed using the 2 (time: T_{post} vs. T_{24h}, and T_{24h} vs. T_{7d}, respectively) x 2 (condition) repeated measures ANOVA. Figure 3 depicts the break-down of the planned contrast in ANOVA analysis. In the appearance of a significant time x condition interaction effect, paired samples t-tests separated into conditions were computed as a post hoc analysis.

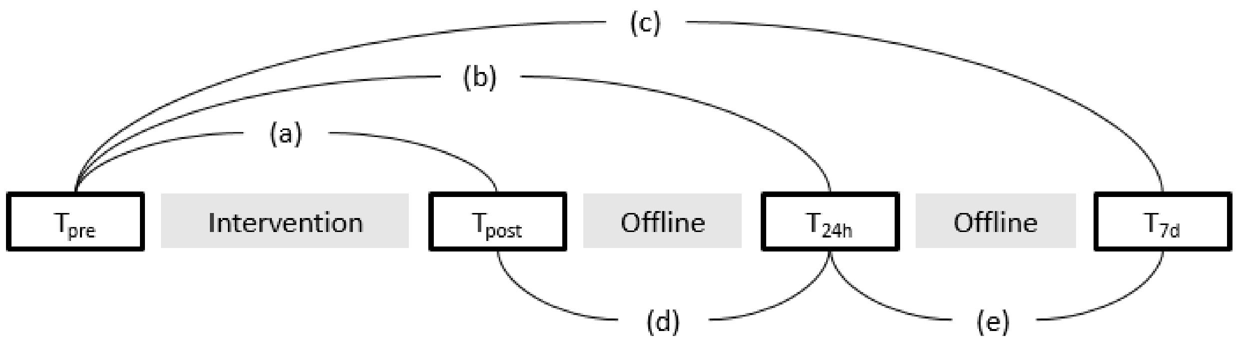

Figure 3. *Figure 2* Break down of the planned contrasts of the golf putt analysis. (a) Motor skill acquisition, (b) 24-hour motor learning, (c) 7-day motor learning, (d) 24-hour offline motor memory consolidation, (e) 7-day offline motor memory consolidation

EF

A condition (AE vs. CON) x cycle (1 vs. 2) factorial ANOVA was computed to assess any initial difference between AE and CON conditions as well as between cycle 1 and 2. Thereafter, 4 (time: T_{pre} vs. T_{post} vs. T_{24h} vs. T_{7d}) x 2 (condition: AE vs. CON) were carried out. In the appearance of a significant time x group interaction, paired samples t-tests with the data split up into condition were computed for the post hoc analysis.

Resting EEG

After the artifact removal process, 6 participants were eliminated from the EEG analysis due to high impedance during the EEG recording process; thus, 11 participants remained in EEG analysis. To supplement the aspects of motor learning and memory consolidation, the EEG temporal alpha asymmetry (TAA: log T4 / log T3) was carried out, and a condition (AE vs. CON) x cycle (1 vs. 2) factorial ANOVA was computed to confirm that there was no significant initial difference between condition, as well as between cycles, in EF task performances at the pre-test phase. Thereafter, 4 (time: T_{pre} vs. T_{post} vs. T_{24h} vs. T_{7d}) x 2 (condition: AE vs. CON) mixed-design ANOVAs were carried out. In the appearance of a significant time x group interaction, paired samples t-tests with the data split up into condition were computed for the post hoc analysis. The relatively lower TAA score indicates in favor of motor learning (Janelle & Hatfield, 2008).

Statistical analysis was carried out with IBM SPSS Statistics 26, and the significant alpha level was set at 0.5 throughout the statistical analysis in the present study except for the motor memory consolidation analysis. Partial eta squared (η_p^2) was used in ANOVAs to evaluate an effect size as follows: .01 to < .06 as small; .06 to < .14 as medium; and > .14 as a large effect size. For the t-tests, Cohen's *d* (Cohen, 1992) was applied to evaluate the effect size: 0.2 represents small differences, 0.5 as moderate, and 0.8+ indicates large differences. Lastly, the Greenhouse-Geisser correction was applied when Sphericity was violated for the ANOVAs.

CHAPTER IV

RESULTS

In this chapter, the results of the data analysis for the present study were introduced. First, demographic information including anthropometric information, such as age, BMI, resting HR, and feeling scale, and exercise data, such as $HR_{exercise}$, RPE, and intensity, were reported. Thereafter, the main analysis with the dependent variables were described one at a time, including golf putting, EF, and EEG data.

Demographic Information

A total of 17 participants were included in the data analysis (aged 31.41 ± 9.7, mental age as 7.69 ± 3.06, 11 males and 6 females). A detailed description of the demographic information can be seen in table 2.

Table 2

Demographic Information of the Participants

Variables	*Male (n=11)*	*Female (n=6)*	*Total (n=17)*
Age (years)	33.00 ± 9.64	28.50 ± 9.98	31.41 ± 9.70
Mental age (years)	8.10 ± 3.58	6.93 ± 1.77	7.69 ± 3.06
Height (cm)	1.72 ± .06	1.61 ± .06	168.41 ± 8.03
Weight (kg)	96.07 ± 26.72	79.22 ± 31.96	90.12 ± 28.89
Body Mass Index (kg/m^2)	32.58 ± 10.21	30.71 ± 13.78	31.92 ± 11.20
% Exercise HRR	60.01 ± 12.17	67.15 ± 13.16	62.53 ± 12.61

Exercise Data

Resting HR. The results indicated that the resting heart rate following 5-min seated resting between AE and CON condition had no significant differences as shown in table 3. Specifically, although close to the significant alpha level, the first visit (T_{ire}) had no significant difference in HR_{rest} between AE (71.88 ± 8.86) and CON condition (79.00 ± 11.92; p = .06). Also, there was no significant mean difference in HR_{rest} between AE and CON condition in second (76.35 ± 12.06 vs. 77.29 ±12.03, p = .82) and third visits (76.18 ± 11.66 vs. 79.24 ± 12.56, p = .47) as well.

Table 3

Resting Heart Rate Between Conditions

	AE (N = 17)	*CON (N = 17)*	*p value*
T_{pre}	71.88 ± 8.86	79.00 ± 11.92	.06
T_{24h}	76.35 ± 12.06	77.29 ±12.03	.82
T_{7d}	76.18 ± 11.66	79.24 ± 12.56	.47

Table 4

Feeling Scale Results Between Conditions

	Condition		*p*-value
	Aerobic exercise (N = 17)	Control (N = 17)	
T_{pre}	1.59 ± .51	1.76 ± 1.03	.53
T_{post}	1.76 ± .75	1.59 ± .62	.46
T_{24h}	2.00 ± .94	1.59 ± .71	.16
T_{7d}	1.76 ± .56	1.65 ± .70	.59

Feeling scale. Paired samples t-tests revealed that there was no significant differences in feeling scale between groups across the experiment period as shown in table 4. No significant mean differences between the AE and CON conditions was indicated in the pre-test (1.59 ± .51 vs. 1.76 ± 1.03, $p = .53$), post-test (1.76 ± .75 vs. 1.59 ± .62, $p = .46$), 24-hour retention test (2.00 ± .94 vs. 1.59 ± .71, $p = .16$), and 7-day retention test phase (1.76 ± .56 vs. 1.65 ± .70, $p = .59$).

Exercise intensity. $HR_{exercise}$ and RPE were compared between AE and CON conditions to assess exercise intensity after the intervention. Independent t-test confirmed that a significant difference in mean $HR_{exercise}$ was shown between AE condition (137.10 bpm ± 15.29) and CON condition (79.48 bpm ± 12.88; $p < .001$). A significant difference in % HRR indicated more specifically that the exercise intensity in AE condition (62.53 % ± 12.61) was higher than CON condition (0 % ± .05; $p < .001$). Also, a significant difference in self-reported RPE was also indicated between AE condition (6.78 ± 1.24) and CON condition (1.05 ± 1.46; $p < .001$). Thus, the results confirmed that the participants performed and perceived higher physical efforts in AE condition than CON condition.

Table 5

Exercise Intensity

	Condition		*p*-value
	Aerobic exercise (N = 17)	Control (N = 17)	
$HR_{exercise}$ (bpm)	137.10 ± 15.29	79.48 ± 12.88	< .001
%HRR	62.53 ± 12.61	0 ± .05	< .001
RPE	6.78 ± 1.24	1.05 ± 1.46	< .001

Dependent Variable

Golf Putting Skill

Golf putting measures include putt accuracy, putt consistency, and offline motor memory consolidation. Each of the 3 comparisons had original and transfer putt tasks, and the performance results of both original and transfer putt tasks have been described separately into motor skill acquisition and learning phases.

Golf putt accuracy. A factorial ANOVA was conducted to assess the impact of condition (AE vs. CON) and cycle (1 vs. 2) on the initial golf putt accuracy. The ANOVA analysis indicated that there was no significant effect in condition: $F(1, 30) = 1.11$, $p = .30$, $\eta_p^2 = .04$, cycle: $F(1, 30) = 2.47$, $p = .13$, $\eta_p^2 = .08$, as well as a condition x cycle interaction: $F(1, 30) = .94$, $p = .34$, $\eta_p^2 = .03$. Thus, there was no significant initial difference in putt accuracy induced by the condition and cycle.

Original putt task. For the putt accuracy, a repeated measures ANOVA with time (T_{pre} vs. T_{post} vs. T_{24h} vs. T_{7d}) and condition (AE vs. CON) was computed. There was no significant main effect in time: $F(3, 96) = 1.02$, $p = .39$, $\eta_p^2 = .03$, condition: $F(1, 32) = .05$, $p = .83$, $\eta_p^2 = .001$, and interaction: $F(3, 96) = 1.96$, $p = .13$, $\eta_p^2 = .06$.

Planned contrasts. Based on the motor memory-behavioral framework (Kantak & Winstein, 2012), motor skill acquisition, learning, and offline motor memory consolidation phases were analyzed separately. Motor skill acquisition was analyzed with 2-way ANOVA on time (T_{pre} vs. T_{post}) and condition (AE vs. CON). Descriptive statistics indicated that the putt error magnitude was reduced in the AE condition from T_{pre} (58.62 ± 24.00) to T_{post} (56.87 ± 20.93) whereas increased in the CON condition from T_{pre} (51.84 ± 17.37) to T_{post} (57.78 ±

15.69). The ANOVA result indicated that there was no interaction effect: $F(1, 32) = 1.68$, $p = .20$, $\eta_p^2 = .05$, main effect in time: $F(1, 32) = .50$, $p = .48$, $\eta_p^2 = .02$, and condition: $F(1, 32) = .23$, $p = .63$, $\eta_p^2 = .01$.

Motor learning for 24-hour retention were assessed using 2-way ANOVA on time (T_{pre} vs. T_{24h}) and condition (AE vs. CON). The descriptive statistics indicated that the putt error magnitude in the AE condition was decreased from T_{pre} (58.62 ± 24.00) to T_{24h} (50.45 ± 16.82) whereas the CON condition showed an increased error magnitude from T_{pre} (51.84 ± 17.37) to T_{24h} (59.44 ± 16.93). The ANOVA result indicated that there was a close to significant interaction effect between time and group: $F(1, 32) = 4.07$, $p = .052$, $\eta_p^2 = .113$. However, there was no significant main effect in time: $F(1, 32) = .01$, $p = .942$, $\eta_p^2 < .001$, and in condition: $F(1, 32) = .05$, $p = .83$, $\eta_p^2 = .001$. Due to the significant interaction effect, a paired samples t-test comparing T_{pre} and T_{24h} was computed separately between conditions. As a result, there were no significant mean difference in the AE condition: $t(16) = -1.426$, $p = .17$; $d = .40$, and in the CON condition: $t(16) = 1.430$, $p = .172$; $d = .44$.

Motor learning for 7-day retention were assessed using 2-way ANOVA on time (T_{pre} vs. T_{7d}) and condition (AE vs. CON). The descriptive statistics indicated that the putt error magnitude was reduced in the AE condition from T_{pre} (58.61 ± 24.00) to T_{7d} (51.13 ± 17.24) whereas similar in the CON condition between T_{pre} (51.84 ± 17.37) and T_{7d} (52.28 ± 19.15). The ANOVA revealed that no interaction effect was evident in 7 day retention test: $F(1, 32) = 1.43$, $p = .24$, $\eta_p^2 = .04$. Also, there was no main effect in time: $F(1, 32) = 1.13$, $p = .30$, $\eta_p^2 = .03$, in condition: $F(1, 32) = .23$, $p = .64$, $\eta_p^2 = .01$. A figure 3-A showed the golf putt accuracy across time for the AE and CON conditions.

Transfer putt task. For the putt accuracy, a repeated measures ANOVA with time (T_{pre} vs. T_{post} vs. T_{24h} vs. T_{7d}) and condition (AE vs. CON) was computed. There was no significant main effect in time: $F(3, 96) = .52$, $p = .67$, $\eta_p^2 = .02$, condition: $F(1, 32) = .001$, $p = .97$, $\eta_p^2 < .001$, and interaction: $F(3, 96) = 2.07$, $p = .11$, $\eta_p^2 = .06$.

Planned contrasts. Motor skill acquisition was analyzed with 2-way ANOVA on time (T_{pre} vs. T_{post}) and condition (AE vs. CON). The descriptive statistics indicated that the putt error magnitude was decreased in the AE condition from T_{pre} (58.62 ± 24.00) to T_{post} (56.02 ± 17.60) whereas increased in the CON condition from T_{pre} (51.84 ± 17.37) to T_{post} (57.35 ± 14.12). The ANOVA analysis did not indicate an interaction effect: $F(1, 32) = 1.15$, $p = .30$, $\eta_p^2 = .04$, main effect in time: $F(1, 32) = .15$, $p = .70$, $\eta_p^2 = .01$, and condition: $F(1, 32) = .28$, $p = .60$, $\eta_p^2 = .28$.

Motor learning for 24-hour retention were assessed using 2-way ANOVA on time (T_{pre} vs. T_{24h}) and condition (AE vs. CON). The descriptive statistics indicated that the putt error magnitude in the AE condition was decreased from T_{pre} (58.62 ± 24.00) to T_{24h} (47.98 ± 17.78) whereas increased in the CON condition from T_{pre} (51.84 ± 17.37) to T_{24h} (57.05 ± 17.67). The ANOVA analysis revealed an interaction effect: $F(1, 32) = 5.26$, $p = .03$, $\eta_p^2 = .14$, but neither main effect in time: $F(1, 32) = .62$, $p = .44$, $\eta_p^2 = .02$, nor condition: $F(1, 32) = 04$, $p = .84$, $\eta_p^2 = .001$. Due to the significant interaction, a paired samples t-test was carried out with data split up into conditions. Similar to the original putt task result, the t-test result approached to a conventional level of significance in the AE condition, $t(16) = -1.93$, $p = .07$; $d = .51$, but no significance was indicated in the CON condition, $t(16) = 1.253$, $p = .23$; $d = .30$.

Motor learning for 7-day retention were assessed using 2-way ANOVA on time (T_{pre} vs. T_{7d}) and condition (AE vs. CON). The descriptive statistics indicated that the putt error magnitude in the AE condition was reduced from T_{pre} (58.62 ± 24.00) to T_{7d} (56.31 ± 17.21) whereas similar in the CON condition between T_{pre} (51.84 ± 17.37) and T_{7d} (52.10 ± 17.68). The ANOVA analysis revealed that the putting accuracy did not indicate any significant interaction effect: $F(1, 32) = .14$, $p = .71$, $\eta_p^2 = .004$, main effect in time: $F(1, 32) = .09$, $p = .77$, $\eta_p^2 = .003$, and main effect in condition: $F(1, 32) = .95$, $p = .34$, $\eta_p^2 = .03$. Figure 3-B illustrates the putt accuracy under the transfer condition across the time between conditions.

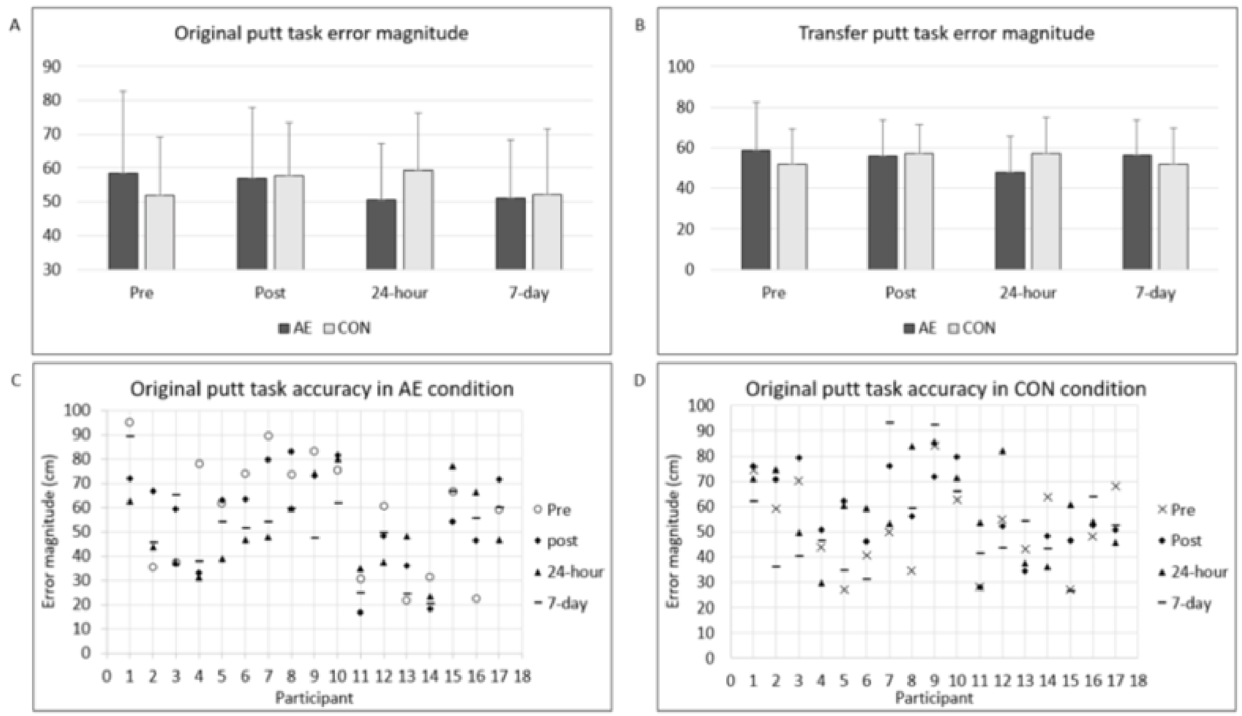

Figure 4. Changes in error magnitude over time between conditions. A & B: Mean and standard deviation values of the error magnitude in the original and transfer putt task over time, respectively / C & D: Individual golf putt accuracy data under the original putt task over time in the AE and CON condition, respectively / E & F: Individual golf putt accuracy data under the transfer putt task over time in the AE and CON condition, respectively.

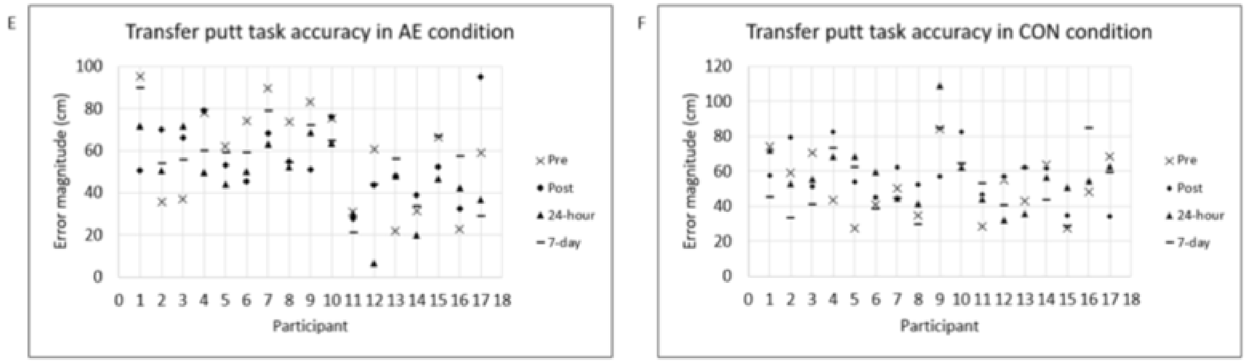

Figure 4 (continued). A & B: Mean and standard deviation values of the error magnitude in the original and transfer putt task over time, respectively / C & D: Individual golf putt accuracy data under the original putt task over time in the AE and CON condition, respectively / E & F: Individual golf putt accuracy data under the transfer putt task over time in the AE and CON condition, respectively.

Golf putt consistency. A factorial ANOVA was conducted to assess the impact of condition (AE vs. CON) and cycle (1 vs. 2) on the initial golf putt consistency. The ANOVA analysis indicated that there was no significant difference in condition: $F(1, 30) = .19$, $p = .67$, $\eta_p^2 = .01$, cycle: $F(1, 30) = 1.38$, $p = .25$, $\eta_p^2 = .04$, as well as a condition x cycle interaction: $F(1, 30) = 1.19$, $p = .28$, $\eta_p^2 = .04$. Thus, there was no significant initial difference in putt consistency induced by the condition and cycle.

Original putt task. For the putt consistency, a repeated measures ANOVA with time (T_{pre} vs. T_{post} vs. T_{24h} vs. T_{7d}) and condition (AE vs. CON) was computed. There was no significant main effect in time: $F(3, 96) = .23$, $p = .88$, $\eta_p^2 = .01$, condition: $F(1, 32) = .52$, $p = .48$, $\eta_p^2 = .02$, and interaction: $F(3, 96) = .64$, $p = .59$, $\eta_p^2 = .02$.

Planned contrasts. Motor skill acquisition was analyzed with 2-way ANOVA on time (T_{pre} vs. T_{post}) and condition (AE vs. CON). The descriptive statistics indicated that the putt consistency range in the AE condition was similar between T_{pre} (43.00 ± 16.54) and T_{post} (42.99

± 10.98), and increased in the CON condition from T_{pre} (45.35 ± 10.35) to T_{post} (47.08 ± 9.32). The ANOVA analysis revealed that there was no interaction effect: $F(1, 32) = .12$, $p = .74$, $\eta_p^2 = .004$, main effect in time: $F(1, 32) = .12$, $p = .74$, $\eta_p^2 = .004$, and main effect in condition: $F(1, 32) = .95$, $p = .34$, $\eta_p^2 = .03$.

Motor learning for 24-hour retention were assessed using repeated measures ANOVA on time (T_{pre} vs. T_{24h}) and condition (AE vs. CON). The descriptive statistics indicated that the putt consistency range in the AE condition was increased from T_{pre} (43.00 ± 16.54) to T_{24h} (44.62 ± 10.11) and also increased in the CON condition from T_{pre} (45.35 ± 10.35) to T_{24h} (47.31 ± 5.82). The ANOVA analysis revealed that there was no significant interaction effect: $F(1, 32) = .004$, $p = .95$, $\eta_p^2 < .001$, main effect in time: $F(1, 32) = .40$, $p = .53$, $\eta_p^2 = .01$, and main effect in condition: $F(1, 32) = .88$, $p = .36$, $\eta_p^2 = .03$.

Motor learning for 7-day retention were assessed using repeated measures ANOVA on time (T_{pre} vs. T_{7d}) and condition (AE vs. CON). The descriptive statistics indicated that the putt consistency range in the AE condition was increased from T_{pre} (43.00 ± 16.54) to T_{7d} (45.59 ± 12.15) whereas decreased in the CON condition from T_{pre} (45.35 ± 10.35) to T_{7d} (43.46 ± 9.81). The ANOVA analysis revealed that there was no significant interaction effect: $F(1, 32) = .74$, $p = .40$, $\eta_p^2 = .02$, main effect in time: $F(1, 32) = .01$, $p = .91$, $\eta_p^2 < .001$, and main effect in condition: $F(1, 32) = .002$, $p = .96$, $\eta_p^2 < .001$.

Transfer putt task. For the putt consistency, a repeated measures ANOVA with time (T_{pre} vs. T_{post} vs. T_{24h} vs. T_{7d}) and condition (AE vs. CON) was computed. There was no significant main effect in time: $F(3, 96) = .21$, $p = .89$, $\eta_p^2 = .01$, condition: $F(1, 32) = .57$, $p = .46$, $\eta_p^2 = .02$, and interaction: $F(3, 96) = 1.00$, $p = .40$, $\eta_p^2 = .03$.

Planned contrasts. Motor skill acquisition was analyzed with repeated measures ANOVA on time (T_{pre} vs. T_{post}) and condition (AE vs. CON). The descriptive statistics indicated that the putt consistency range in the AE condition was increased from T_{pre} (43.00 ± 16.54) to T_{post} (44.35 ± 8.69) and also increased in the CON condition from T_{pre} (45.35 ± 10.35) to T_{post} (47.37 ± 9.80). The ANOVA analysis did not indicated an interaction effect: $F(1, 32) = .02$, $p = .90$, $\eta_p^2 = .001$, main effect in time: $F(1, 32) = .42$, $p = .52$, $\eta_p^2 = .01$, and main effect in condition: $F(1, 32) = .76$, $p = .39$, $\eta_p^2 = .02$.

Motor learning for 24-hour transfer were assessed using repeated measures ANOVA on time (T_{pre} vs. T_{24h}) and condition (AE vs. CON). The descriptive statistics indicated that the putt consistency range in the AE condition was similar between T_{pre} (43.00 ± 16.54) and T_{24h} (42.44 ± 11.22) whereas increased in the CON condition from T_{pre} (45.35 ± 10.35) to T_{24h} (47.72 ± 8.34). The ANOVA analysis indicated no significance in the interaction effect: $F(1, 32) = .32$, $p = .57$, $\eta_p^2 = .01$, main effect in time: $F(1, 32) = .12$, $p = .73$, $\eta_p^2 = .004$, and main effect in condition: $F(1, 32) = 1.14$, $p = .24$, $\eta_p^2 = .04$.

Motor learning for 7-day transfer were assessed using repeated measures ANOVA on time (T_{pre} vs. T_{7d}) and condition (AE vs. CON). The descriptive statistics indicated that the putt consistency range in the AE condition was increased from T_{pre} (43.00 ± 16.54) to T_{7d} (47.67 ± 14.71) whereas decreased in the CON condition from T_{pre} (45.35 ± 10.35) to T_{7d} (44.36 ± 11.02) The ANOVA analysis did not indicate an interaction effect: $F(1, 32) = .77$, $p = .39$, $\eta_p^2 = .02$, main effect in time: $F(1, 32) = .32$, $p = .57$, $\eta_p^2 = .01$, and main effect in condition: $F(1, 32) = .02$, $p = .88$, $\eta_p^2 = .001$.

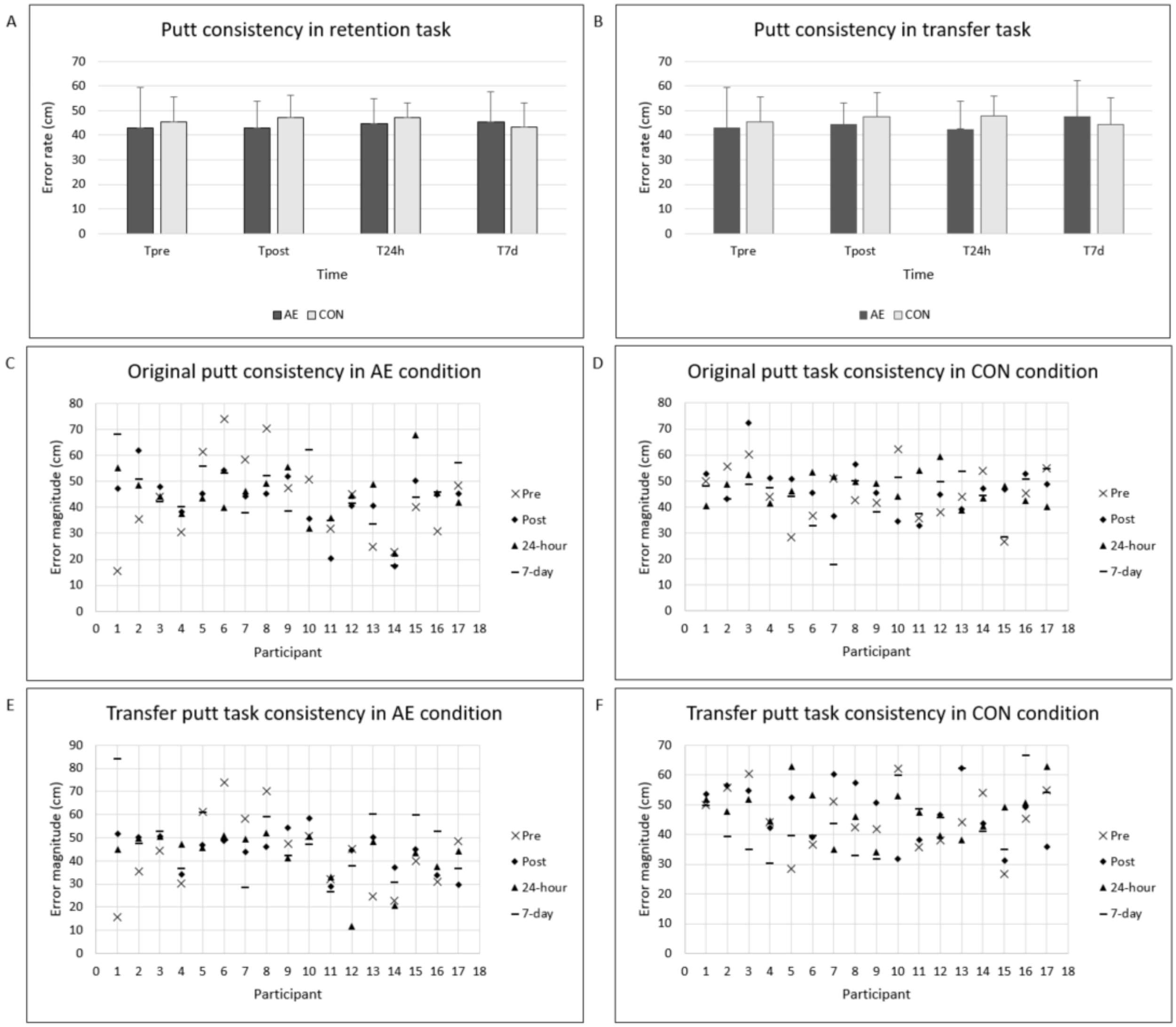

Figure 5. Changes in putt consistency over time between conditions. A & B: Mean and standard deviation values of consistency in the original and transfer putt task over time, respectively / C & D: Individual golf putt consistency data under the original putt task over time in the AE and CON condition, respectively / E & F: Individual golf putt consistency data under the transfer putt task over time in the AE and CON condition, respectively.

Offline motor memory consolidation. Motor memory was assessed via comparison of the putt accuracy between before and after the offline non-practice period (Kantak & Winstein, 2012; Snow et al., 2016; Statton et al., 2015). That is, the 24-hour and 7-day offline motor memory consolidation was inferred from a change in golf putt performance from T_{post} to T_{24h}, and T_{24h} from T_{7d}, respectively.

Original putt task. Descriptively, the putt error magnitude in the AE condition was decreased from T_{post} (56.87 ± 20.93) to T_{24h} (50.45 ± 16.82) whereas increased in the CON condition from (57.78 ± 15.69) to T_{24h} (59.44 ± 16.93). The descriptive statistics indicated a greater motor memory consolidation in the AE condition over the CON condition. However, the ANOVA analysis revealed that there was neither a significant main effect in time: $F(1, 32) = .62$, $p = .44$, $\eta_p^2 = .02$, main effect in time: $F(1, 32) = .88$, $p = .35$, $\eta_p^2 = .03$, main effect in condition: $F(1, 32) = 1.02$, $p = .32$, $\eta_p^2 = .03$, nor interaction effect: $F(1, 32) = .62$, $p = .44$, $\eta_p^2 = .02$

Descriptive statistics regarding the 7-day offline motor memory consolidation indicated that the putt error magnitude in the AE condition was increased from T_{24h} (50.45 ± 16.82) to T_{7d} (51.13 ± 17.24) whereas decreased in the CON condition from T_{24h} (59.44 ± 16.93) to T_{7d} (52.28 ± 19.15). The ANOVA analysis yielded no significant main effect in time: $F(1, 32) = .94$, $p = .34$, $\eta_p^2 = .03$, in condition: $F(1, 32) = .62$, $p = .44$, $\eta_p^2 = .02$, and interaction effect: $F(1, 32) = 1.38$, $p = .25$, $\eta_p^2 = .04$.

Transfer putt task. Similar to the original putt task, descriptive statistics regarding the 24-hour offline motor memory consolidation also indicated a decline in putt error magnitude in the AE condition from T_{post} (56.02 ± 17.60) to T_{24h} (47.98 ± 17.78) whereas similar in the CON condition between T_{post} (57.35 ± 14.12) and T_{24h} (57.05 ± 17.67). The descriptive statistics indicated a greater motor memory consolidation in the AE condition over the CON condition. However, the ANOVA analysis revealed that there was no significant main effect in time: $F(1, 32) = 1.35$, $p = .25$, $\eta_p^2 = .04$, condition: $F(1, 32) = 1.31$, $p = .26$, $\eta_p^2 = .04$, and interaction effect: $F(1, 32) = 1.16$, $p = .29$, $\eta_p^2 = .04$.

As for the 7-day offline motor memory consolidation, descriptive statistics indicated that the error magnitude was increased in the AE condition from T_{24h} (47.98 ± 17.78) to T_{7d} (56.31 ± 17.21) and decreased in the CON condition from T_{24h} (57.05 ± 17.67) to T_{7d} (52.10 ± 17.68). The ANOVA analysis yielded no significant main effect in time: $F(1, 32) = .44$, $p = .51$, $\eta_p^2 = .01$, condition: $F(1, 32) = .20$, $p = .66$, $\eta_p^2 = .01$, but there as a significant interaction effect: $F(1, 32) = 6.75$, $p = .01$, $\eta_p^2 = .17$. Paired samples t-test with the data split up into 2 conditions indicated that the AE condition yielded a significant mean difference between T_{24h} and T_{7d}: $t(16) = -2.73$, $p = .02$; $d = .48$, but not in the CON condition: $t(16) = 1.21$, $p = .25$; $d = .28$. However, this t-test result suggested that the AE condition exhibited a significantly decreased motor memory consolidation while the CON condition maintained their performance during the 7-day offline period.

EF

Inhibition. A factorial ANOVA was conducted to assess the impact of condition (AE vs. CON) and cycle (1 vs. 2) on the Knock and Tap test performance. The ANOVA analysis did not indicate a significant effect in condition: $F(1, 30) = .10$, $p = .76$, $\eta_p^2 = .003$, cycle: $F(1, 30) = .13$, $p = .72$, $\eta_p^2 = .004$, as well as a condition x cycle interaction: $F(1, 30) = .09$, $p = .76$, $\eta_p^2 = .003$. Thus, there was no significant initial difference in the Knock and Tap test scores induced by the condition and cycle.

The Knock and Tap test results was descriptively increased across the testing phases in the AE condition including T_{pre} (23.41 ± 7.41), T_{post} (25.41 ± 4.95), T_{24h} (24.06 ± 6.17), and T_{7d} (27.29 ± 2.82) phases, as well as in the CON condition at T_{pre} (24.06 ± 5.12), T_{post} (24.24 ± 6.40), T_{24h} (25.35 ± 6.12), and T_{7d} (25.35 ± 5.23). The 4 (time) by 2 (condition) repeated measures

ANOVA indicated that there was a significant main effect in time: $F(3, 96) = 3.60$, $p = .02$, $\eta_p^2 = .10$, but no significant main effect in condition: $F(1, 32) = .03$, $p = .86$, $\eta_p^2 = .001$, and interaction effect: $F(3, 96) = 1.81$, $p = .15$, $\eta_p^2 = .05$.

Verbal WM. A factorial ANOVA was conducted to assess the impact of condition (AE vs. CON) and cycle (1 vs. 2) on both forward and backward Digit span test. As for the forward span test, the ANOVA analysis did not indicate a significant difference in condition: $F(1, 30) = .10$, $p = .76$, $\eta_p^2 = .003$, cycle: $F(1, 30) = .13$, $p = .72$, $\eta_p^2 = .004$, as well as a condition x cycle interaction: $F(1, 30) = .09$, $p = .76$, $\eta_p^2 = .003$. Similarly, the backward span test also exhibited no significant difference in condition: $F(1, 30) = .05$ $p = .83$, $\eta_p^2 = .002$, cycle: $F(1, 30) = .05$ $p = .83$, $\eta_p^2 = .002$, and condition x cycle interaction: $F(1, 30) = .16$ $p = .69$, $\eta_p^2 = .01$. Thus, there was no significant initial difference in both forward and backward Digit span test scores induced by the condition and cycle.

For the forward Digit span test, the descriptive result in the AE condition remained similar across the testing phases including T_{pre} (4.59 ± 2.37), T_{post} (4.76 ± 2.71), T_{24h} (4.53 ± 2.50), and T_{7d} (4.29 ± 2.78), as well as in the CON condition including T_{pre} (4.53 ± 2.13), T_{post} (4.47 ± 2.15), T_{24h} (4.59 ± 2.15), and T_{7d} (4.71 ± 3.00). The repeated measures ANOVA indicated that the forward span test exhibited no significant main effect in time: $F(3, 96) = .06$, $p = .98$, $\eta_p^2 = .002$, condition: $F(1, 32) = .001$, $p = .97$, $\eta_p^2 < .001$, and interaction: $F(3, 96) = .60$, $p = .62$, $\eta_p^2 = .02$.

For the backward Digit span test, the descriptive result in the AE condition was increased across the testing phases including T_{pre} (2.00 ± 2.37), T_{post} (2.76 ± 2.71), T_{24h} (2.88 ± 2.50), and T_{7d} (2.94 ± 2.05), as well as in the CON condition including T_{pre} (1.82 ± 1.88), T_{post} (2.35 ± 2.45), T_{24h} (2.65 ± 3.02), and T_{7d} (2.88 ± 3.00). The repeated measures ANOVA yielded a significant main effect in time: $F(3, 96) = 4.35$, $p = .01$, $\eta_p^2 = .12$, but neither a significant main effect in condition: $F(1, 32) = .08$, $p = .78$, $\eta_p^2 = .002$, nor an interaction effect: $F(3, 96) = .12$, $p = .95$, $\eta_p^2 = .004$.

Visuospatial WM. A factorial ANOVA was conducted to assess the impact of condition (AE vs. CON) and cycle (1 vs. 2) on both forward and backward Corsi block test. As for the forward span test, the ANOVA analysis did not indicate a significant difference in condition: $F(1, 30) = .10$, $p = .76$, $\eta_p^2 = .003$, cycle: $F(1, 30) = .02$, $p = .89$, $\eta_p^2 = .001$, and a condition x cycle interaction: $F(1, 30) = 2.42$, $p = .14$, $\eta_p^2 = .08$. Similarly, the backward span test also exhibited no significant difference in condition: $F(1, 30) = .75$ $p = .39$, $\eta_p^2 = .02$, cycle: $F(1, 30) = .08$ $p = .77$, $\eta_p^2 = .003$, and condition x cycle interaction: $F(1, 30) = .01$ $p = .91$, $\eta_p^2 < .001$. Thus, there was no significant initial difference in both forward and backward Corsi block test scores induced by the condition and cycle.

For the forward Corsi block test, the descriptive result in the AE condition increased until T_{24h} and decreased, T_{pre} (4.29 ± 2.26), T_{post} (4.35 ± 2.23), T_{24h} (4.76 ± 1.72), and T_{7d} (4.53 ± 2.18), and the CON condition exhibited the similar pattern of change, T_{pre} (4.53 ± 2.00), T_{post} (4.71 ± 2.44), T_{24h} (5.18 ± 2.16), and T_{7d} (4.35 ± 1.94). The repeated measures ANOVA indicated that the forward span test exhibited a significant main effect in time: $F(3, 96) = 1.51$, $p = .22$, $\eta_p^2 = .05$, condition: $F(1, 32) = .11$, $p = .75$, $\eta_p^2 = .003$, and interaction: $F(3, 96) = .39$, $p = .76$, $\eta_p^2 = .01$.

For the backward Digit span test, the descriptive statistics in the AE condition was increased across the testing phases including T_{pre} (2.71 ± 2.69), T_{post} (2.82 ± 2.46), T_{24h} (2.41 ± 1.97), and T_{7d} (2.88 ± 2.37), as well as in the CON condition including T_{pre} (1.94 ± 2.16), T_{24h} (2.59 ± 2.62), T_{24h} (2.59 ± 2.62), and T_{7d} (2.94 ± 2.79). The repeated measures ANOVA did not indicate a significant main effect in time: $F(3, 96) = 1.55$, $p = .21$, $\eta_p^2 = .05$, condition: $F(1, 32) = .06$, $p = .81$, $\eta_p^2 = .002$, and an interaction effect: $F(3, 96) = 1.06$, $p = .37$, $\eta_p^2 = .03$.

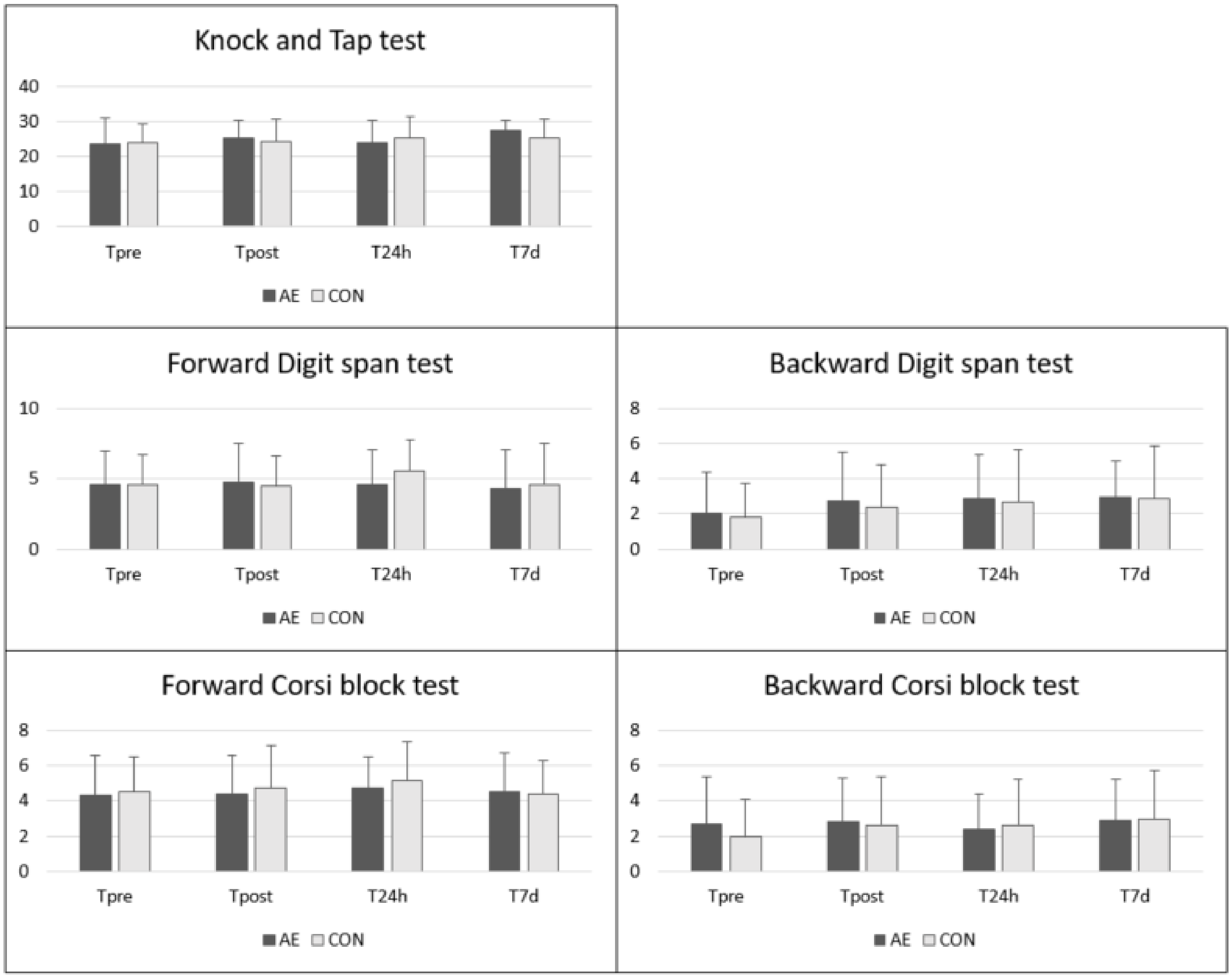

Figure 6. Change in EF scores over time between conditions.

Resting EEG: Temporal Alpha Asymmetry

A factorial ANOVA was conducted to assess the impact of condition (AE vs. CON) and cycle (1 vs. 2) on the TAA. The ANOVA analysis did not indicate a significant effect in condition: $F(1, 18) = 3.50$, $p = .08$, $\eta_p^2 = .16$, cycle: $F(1, 18) = .45$, $p = .51$, $\eta_p^2 = .02$, as well as a condition x cycle interaction: $F(1, 18) = 2.09$, $p = .17$, $\eta_p^2 = .10$. Thus, there was no significant initial difference in the KAA scores induced by the condition and cycle.

The descriptive statistics in the AE condition was similar across the testing phases including T_{pre} (.34 ± .60), T_{post} (.22 ± .54), T_{24h} (.56 ± .52), and T_{7d} (.54 ± .45). The CON condition indicated a similar descriptive pattern: T_{pre} (.69 ± .19), T_{post} (.46 ± .35), T_{24h} (.56 ± .52), and T_{7d} (.64 ± .32). The repeated measures ANOVA analysis revealed that there was no significant main effect in time: $F(3, 60) = 1.30$, $p = .28$, $\eta_p^2 = .06$, condition, $F(1, 20) = 3.22$, $p = .09$, $\eta_p^2 = .14$, and an interaction effect: $F(3, 60) = .72$, $p = .54$, $\eta_p^2 = .04$.

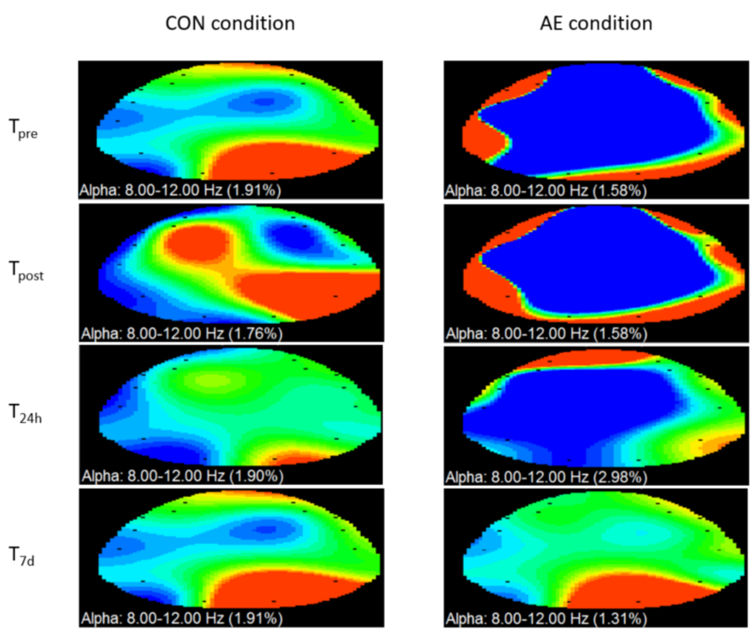

Figure 7. EEG alpha band power map over time.

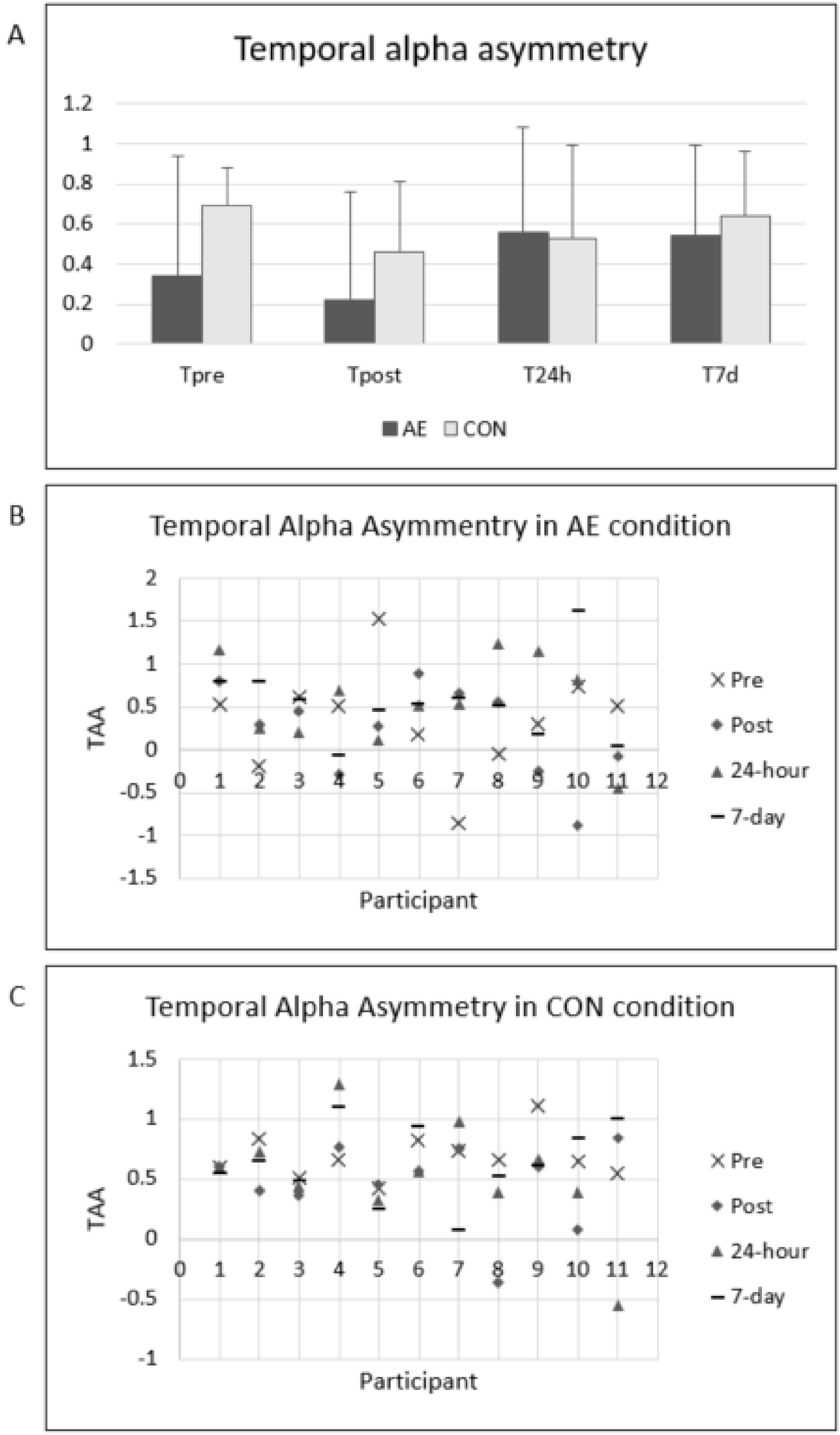

Figure 8. Resting EEG log-transformed temporal alpha asymmetry. A: Mean and standard deviation values of TAA / B & C: Individual TAA scores in the AE and CON condition, respectively.

CHAPTER V

DISCUSSION

The present study was to examine the impact of an acute bout of AE on motor skill learning in individuals with ID. Golf putting was adopted to represent a complex motor skill in this study. Motor learning was comprehensively assessed by employing the motor behavior-memory framework (Kantak & Winstein, 2012), including skill acquisition, retention, and offline motor memory consolidation. In addition, the EF and resting EEG measures were employed to elucidate possible underlying mechanisms of changes in putt skill performance induced by the AE in individuals with ID. The first hypothesis in the present study was that that the adults with ID under the AE condition would improve the putting skill after the offline period, but not immediately after the intervention. The result was partially consistent with the hypothesis in that, although no evident effect in the primary analysis, there was a trend of improvement in golf putting in the AE, compared with CON, condition at the 24-hour retention test phase. The second, hypothesis was that the offline motor memory consolidation after 24-hour and 7-day of the non-practice delayed period would be greater under the AE condition relative to the rest condition. Similar to the first hypothesis, 24-hour offline motor memory consolidation indicated a trend that the AE condition was greater than that of the CON condition. Third and fourth hypothesis was about the underlying mechanisms of motor learning, which was the expected improvement in EF and EEG in the AE condition but not the CON condition; however, the result did not indicate any notable change throughout the experiment. All in harmony, the present study indicated that an acute AE might have a potential to be an effective method to assist individuals with ID in learning a golf putt skill. However, the underlying mechanisms of the positive impact of the AE on golf putt skill learning need to be further investigated.

AE on Golf Putting

Consistent with the first hypothesis, the post-test administered immediately after the intervention did not indicate any notable change in golf putt skill performance. The findings suggest that the AE might not intervene in motor memory encoding. Extensive behavioral evidence regarding the association between the vigorous AE and motor learning supports the notion that an AE does not have a substantial impact on motor memory encoding or immediate motor skill acquisition (Roig et al., 2012, 2013; Skriver et al., 2014). Instead, the literature aforementioned indicated that the AE positively affected the 24-hour and 7-day delayed motor learning and, thus, it suggested that an acute bout of vigorous AE is beneficial for motor memory consolidation and retrieval but not encoding. Theoretically, participants were thought to encode their practiced movement during the pre-test phase. After the motor memory encoding phase, it is essential for each learner to go through a motor memory consolidation process to "learn" the practiced putt skill, and the consolidation process typically takes at least 4 to 6 hours following practice (Kantak & Winstein, 2012; Fischer et al., 2005). The required consolidation period might explain that the immediate post-test could not indicate a putt accuracy improvement.

Our first hypothesis also expected to be greater putt skill improvement and motor memory consolidation in the AE over CON condition at retention test phases, including both 24-hour and 7-day retention phases. This hypothesis was made upon the recently emerging evidence that has been supportive to a higher intensity exercise for the long-term motor learning and memory consolidation (Dal Maso et al., 2018; Roig et al., 2012; Skriver et al., 2014). Partially consistent with the hypothesis, although not statistically significant, the 24-hour retention putt accuracy and offline motor memory consolidation indicated an improvement in the AE, but not CON, condition with a moderate effect size; however, there was no evident improvement at the 7-day retention test phase including both accuracy and motor memory consolidation. Given that t no study by far implement an experiment to verified the impact of AE on motor learning in individuals with ID, the findings from the present study, that the vigorous AE indicated a favorable effect toward motor learning, can be promising as the learning trend in individuals with ID might be similar to that of typically developing population. Nevertheless, there are several possible speculations that kept the AE protocol in the present study from inducing as much motor skill improvement as the previous studies with typically developing individuals.

First, a possible explanation can be made that the exercise intensity in the present study (i.e., 63%HRR, range from 43% to 81%) was not high enough to sustain the learned motor memory until the 7-day retention phase. Indeed, our descriptive statistics indicated that the golf putt skill was improved in the AE condition but it was not last until the 7-day retention test phase. Several studies previously employed moderate intensity to assist motor learning (Snow et al., 2016; Statton et al., 2015) discovered that the moderate AE outperformed the resting condition in motor acquisition phase, but the improvement was not evident in the 24-hour retention phase, which is in contrast to the vigorous intensity (Dal Maso et al., 2018; Roig et al., 2012; Skriver et al., 2014; Thomas et al., 2016). It can be another supportive evidence that the AE might need to reach to vigorous-intensity to discover the motor learning effect in a longer-term. Compared with these findings supporting the high intensity in long-term motor learning and memory consolidation (e.g., 90% VO_2peak), the AE intensity range in the present study was somewhat wider and lower as some participants either failed to maintain the vigorous exercise intensity throughout the AE intervention period or kept the intensity within the moderate-intensity range most of the AE intervention period. Therefore, it can be plausible to speculate that the wide range of exercise intensity seems to be sufficient to yield a learning effect at 24-hour retention period, but not vigorous enough until the 7-day retention period.

However, it can be also plausible that the vigorous exercise intensity on a treadmill that worked for typically developing individuals might not be applicable for the population with ID. That is, even if we had a familiarization session, including the treadmill walking activity, several participants still had difficulties in performing the treadmill activity. For example, 2 participants could not walk alone, so a research had to constantly push their back to prevent fall. Also, several participants hold a side bar too hard during the walking activity which might affect their RPE reporting as well as their actual HR. Further, the researchers sometimes placed their hands in front of the participants' feet to assist them in stepping forward. Many times, participants with these difficulties reported higher RPE score than their objective exercise intensity measured by %HRR; indeed the average RPE (67.8%) was higher than the average %HRR (62.5%). Therefore, although the researchers pushed the participants toward to vigorous intensity, some participants could not sustain the vigorous intensity due to already high RPE and/or unfamiliarity. This argument suggests that subsequent studies sought to achieve the vigorous exercise intensity using the treadmill activity with participants with ID need to remedy to alleviate the unfamiliarity or difficulty of the assigned task, such as administering multiple familiarization sessions and switch the activity from treadmill to over-ground walking.

In addition to the relatively low exercise intensity, another possibility of no improvement at the 7-day retention test phase might be related to task complexity. Most evidence previously reported in the respective area was conducted with a simple motor skill (Dal Maso et al., 2018; Roig et al., 2012; 2013; Skriver et al., 2014; Statton et al., 2015; Thomas et al., 2016)). Recently, Loras et al. (2020) adopted a golf putt task, and the result demonstrated that there was no notable improvement in golf putting on both the 24-hour retention and transfer tests in healthy young adults. Therefore, Loras et al. (2020) speculated that the higher complexity that the golf putt task possesses, compared with other relatively simple motor tasks adopted in the previous research, could result in involvement of many confounding variables other than the exercise-induced effect, thereby limiting the influence of exercise on motor skill learning. Given that the mentioned studies were conducted with individuals without ID, the complexity of the golf putt task might be relatively higher in individuals with ID participated in the present study since the population experiences compromised intellectual functioning (Schalock et al., 2010), lower EF profile (Henry, & MacLean, 2002; Rosenquist et al., 2003; Schuchardt et al., 2010). Thus, it could be speculated that the more effective intervention with controlling more confounding variables would be needed in order for individuals with ID to elicit a motor learning benefit similar to that of the typically developing counterparts. However, this speculation is not yet able to be further verified due to limited existing literature compared to the AE-dependent motor learning benefit between individuals with and without ID. Therefore, follow-up studies are recommended to further investigate this area of interest.

All in harmony, individuals with ID participated in this study followed a similar motor learning trajectory as their typically developing counterparts. Consistent with our hypothesis, the putting accuracy was not positively influenced by the AE in motor skill acquisition, but accuracy was altered by AE, compared with the seated rest, in the 24-hour retention test phase. Although there was no evident effect of the AE on the 7-day retention golf putt task; however, a greater 7-

day offline motor memory consolidation occurred under the AE condition, compared to the seated rest condition, opens up the possibility that the AE might be effective in a long-term motor learning in individuals with ID. Lastly, the findings that the transfer putt task yielded a significant 7-day offline motor memory consolidation where the original putt task did not shed light on a new study line in which the rate of AE-dependent motor learning based on the degree of the task challenge. The findings are promising in that the AE appears to be effective in the long-term motor learning in individuals with ID. Given that the participants with ID did not have a sufficient amount of practice trials, a follow-up study with a larger sample size and more practice trials would be expected to elicit a more evident effect of the acute AE on motor learning.

AE on EF

The WM and inhibitory control functions were assessed to elucidate a possible underlying mechanism for the change in golf putt performance over time. We hypothesized that the improvement would be observed immediately after the AE, but not after the rest condition (Chang et al., 2012; Lambourne & Tomporowski, 2010). Also, the transient increase in EF capacity would not last a day, as the previous study documented that the increase in prefrontal function did not last 2 hours (Basso, Shang, Elman, Karmouta, & Suzuki, 2015). The present study, therefore, hypothesized that the AE would improve EF immediately after the intervention, but it would not last until 24 hours. However, the findings from this study were not supportive of our hypothesis as the EF measures indicated notable improvement neither after the AE intervention nor the seated rest.

A possibility can be made from the wide range of exercise intensity administered in the present study as a cognitive benefit is known to be sensitive to the exercise intensity (Chang et al., 2012; Ekkekakis, 2009). First, review articles reported that a moderate-intensity is most likely to elicit a cognitive benefit (Lambourne & Tomporowski, 2010; Ludyga et al., 2016; Verburgh et al., 2014). However, our exercise protocol was a vigorous intensity to maximize the motor learning benefit (Roig et al., 2012; Thomas et al., 2016), thereby hindered the optimal cognitive benefit following the AE bout. Also, the present study employed a wide range of exercise intensity as several participants failed to maintain vigorous intensity during the AE intervention, and the wide intensity range might result in individually varied neural activation, which could lead to the statistical insignificance, thereby failed to elicit the improvement in EF.

Another plausible explanation can be made related to exercise preference. According to a recent line of research, the EF benefit following the AE bout might be affected by an exercise preference (Brümmer, Schneider, Abel, Vogt, & Strueder, 2011; Schneider, Brümmer, Abel, Askew, & Strüder, 2009). Yet extensive evidence already corroborated that an endurance-oriented, or steady-state, AE protocols are likely to induce subsequent EF benefit (Lambourne & Tomporowski, 2010), emerging evidence revealed that the improvement in EF appears to be observed only after a preferred type of AE (Brümmer et al., 2011). As many participants with ID in the present study were unfamiliar with the treadmill walking activity, and the researchers often observed that the participants were afraid of standing on a treadmill especially when a treadmill belt is moving, the treadmill walking protocol adopted in this study might not be the most preferred mode of AE for our participants, thereby failed to achieve an increased EF following the AE intervention. Additionally, exercise modality might also play a part. Although the walking protocol is the most frequently reported exercise modality (Rafferty, Reeves, McGee, &

Pivarnik, 2002), several studies focused on the impact of acute AE on cognition in individuals with ID stated that a cycling exercise modality might enhance cognition more than the walking protocol (Lambourne & Tomporowski, 2010; Vogt et al., 2012; 2013). First, Lambourne and Tomporowski (2010) reported that, in their meta-analysis review paper, cycling was associated with improved cognitive function after exercise, whereas treadmill exercise protocol only led to a small improvement after the following exercise. Also, Vogt et al. (2012) applied a 30-min moderate-intensity treadmill running exercise (i.e., average HR of 154.50 bpm among young adults), and the participants did not improve their cognitive function, including continuous visual recognition and a reaction time task, following the exercise bout. However, they conducted a similar study 1 year later with a moderate-intensity cycling exercise (i.e., average HR of 143.09 among young adults), and the exercise protocol yielded an improved reaction time task. Therefore, although the cognitive function test the Vogt et al. (2012; 2012) employed, as well as participant characteristics (e.g., age range, gender, and disability), were different from the present study, there is a possibility that the treadmill walking exercise protocol employed in the present study might not as effective as a cycling exercise modality.

AE on Resting EEG

The purpose of the present study adopting the TAA analysis at the temporal cortex area was to assess neural activities reflecting the golf putt skill learning over time in individuals with ID. Although the TAA in the present study indicated a reduction in the TAA immediately following the AE, which is favorable to the motor learning status, but the alteration was not statistically significant. Nevertheless, it is worthwhile to be replicated with a larger sample size as the observed trend was in accordance with the hypothesis.

Existing evidence indicated that the alpha power at the hippocampal area in the temporal cortex is known to be negatively associated with motor memory retention (Brokaw et al., 2016). For this reason, the increased alpha power ratio on the left temporal area over the right temporal area is positively associated with motor skill competence and, therefore, several researchers have started utilizing TAA (log T4 / log T3) during the movement execution (Janelle & Hatfield, 2008; Wolf et al., 2015). As a result, our analysis did not indicate any notable change in neural activity before and after the exercise bout. Although insignificant, however, the TAA score was decreased after the intervention and increased again at the 24-hour retention phase. This descriptively lower TAA score suggested that the activation of the left temporal area has been reduced compared with the right side, and it has been seen in the skilled performers' brain (Wolf et al., 2015). Similarly, Zhu et al. (2010) also found the stronger right temporal activity compared with the left side as their performers becoming skilled. Therefore, despite no significant statistics, the trend seems to be in line with the hypothesis, so a follow-up study with a larger sample size is recommended.

However, there are 2 major limitations in the EEG analysis in the present study related to our technical limitation. Importantly, converging evidence documented that a medial frontal cortex area houses the anterior cingulate cortex, a crucial area responsible for error detection and correction process during sensorimotor skill learning (Kerns et al., 2004); therefore, the medial frontal cortical area appears to be the important location of interest regarding the functional neural plasticity reflecting the motor learning status. However, the present study could not access to the medial frontal cortex area due to the technical limitation. The Emotiv 14-channel EEG system that we utilized could access to the bilateral temporal area, but it does not possess an electrode projecting the medial frontal area. Thus, the limited technology was one of the major limitations of the present study that prevented the researchers from assessing the neural activity more rigorously. In addition, we could only assess the EEG during the rest; however, most studies applied the TAA score measured the brain activity during the movement execution. This timing issue is also one major technical limitation in the present study. Nevertheless, the present study is the first one connecting EEG measurement with acute AE and motor learning in adults with ID. Thus, the area of study is promising, and subsequent studies to more rigorously capture the relationship among EEG, motor learning, and AE are necessary to enrich the body of knowledge.

Implication and Limitation

The present study was a pioneering research as no existing literature conducted a research regarding the association between an acute bout of AE and motor learning in the population with ID. Therefore, the findings and suggestions from the present study would be valuable in that the present study can be a stepping stone for subsequent research activities in this area. The present study expanded the existing evidence in 2 ways. First, this study expanded the body of knowledge of the effect of an acute bout of AE on from simple to complex motor skill. Second, most previous studies in the respective area were conducted predominantly with a healthy population without a disability. Therefore, the findings in the present study are worthwhile to continue investigating. As a result, the results of the present study illuminated the possibility that an acute bout of vigorous AE might positively influence the golf putt skill learning in the long-term in individuals with ID. Therefore, the findings from the present study can support the utility of the AE training program for motor rehabilitation as well as assisting people with ID in learning a novel motor skill. However, there are issues to be resolved or refined for the subsequent research in the future as well. First remedy would be adding practice blocks to comprehensively investigate motor learning induced by the AE is recommended. Most studies in the area of motor learning had practice blocks; however, the present study sought to limit the scope of interest within the “exercise-induced” change in golf putt skill, thereby extracted the practice blocks from the design. Nevertheless, the present study did indicate a tendency of the putt skill improvement at the 24-hour retention test phase with a moderate effect size. Therefore, a subsequent study with the practice blocks, as well as larger sample size, would be recommended to more rigorously verify the impact of an acute vigorous AE on the long-term motor learning. Also, following research is recommended to administer more familiarization sessions to remedy the participants’ unfamiliarity with the assigned exercise and motor tasks. Through the addition of practice blocks and multiple familiarization sessions will be favorable to remedy a wide range of variability that this population with ID typically possess. Lastly, since the intensity range we administered was wide from the moderate to vigorous intensity, narrow down the intensity to reveal a possible dose-response relationship will be worthwhile as well.

As for the underlying mechanisms, although the EF did not indicate any significant change following the AE intervention, thereby failed to verify the connection between the EF and motor learning in individuals with ID, the result also shed lights on the respective area in that the association between the EF and motor learning might be the difference between people with and without ID. This is also worthwhile to investigate further.

Despite the several promising findings and implications, there are several limitations in the present study that need to be discussed. First, the activity timing of the AE and CON intervention and sleep were not controlled in the present study. As the circadian rhythm has a high probability of affecting one’s cognitive and motor performance (Blatter & Cajochen, 2007), and the sleep time and quality also influences the performance (Diekelmann, Biggel, Rasch, & Born, 2012), a consideration of experiment timing within a day as well as sleep would elicit more scientifically rigorous knowledge. Secondly, as mentioned several times, the present study had a wide range of participant characteristics such as chronological and mental age, and exercise intensities in the AE condition due to operational difficulties. As an initial fitness level within the participants were widely varied, a treadmill walking protocol was not vigorous enough to several individuals and, at the same time, it was highly strenuous for several participants. Thus, this operational difficulty resulted in a wide range of exercise intensity across the participants during the AE intervention activity. In addition, some of the participants with ID never experienced a treadmill walking activity before, which result in a low preference for the intervention activity even though we had a familiarization session. That is, even if walking protocol exerted a favorable outcome in cognitive tests following the exercise (Lambourne & Tomporowski, 2010), the familiarity of the treadmill walking needs to be taken into consideration for individuals with ID. Therefore, future research wanting to direct individuals with ID to engage in an AE protocol up to vigorous-intensity is recommended to have a sufficient amount of familiarization session for treadmill walking, or adopt the more familiar yet safe format of the AE, such as using cycle, arm ergometer, and over-ground walking.

Conclusion

The present study was to examine the effect of an acute bout of moderate-to-vigorous AE of golf putt skill learning in adults with ID. To achieve this purpose, motor learning was captured comprehensively, including motor skill acquisition, 24-hour and 7-day retention, and offline motor memory consolidation. As a result, the results indicated that the AE, compared with the

CON condition, positively influenced motor learning at the 24-hour retention period. The EF and EEG alpha power were assessed to elucidate the underlying mechanisms of the change in golf putt skill performance over time within the individuals with ID. Although EF and EEG did not indicate any change throughout the procedure, we could observe the reduction in temporal alpha power ratio following after the exercise that might result in greater motor learning effect subsequently. In conclusion, the present study provided promising results that the AE could be an effective avenue to assist individuals with ID in learning a complex motor skill, and the finding would be worthwhile for practitioners to apply the AE program in the adapted physical activity field and motor rehabilitation for the people with ID.

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APPENDIX A

VISUAL DESCRIPTION OF GOLF PUTT INSTRUCTION

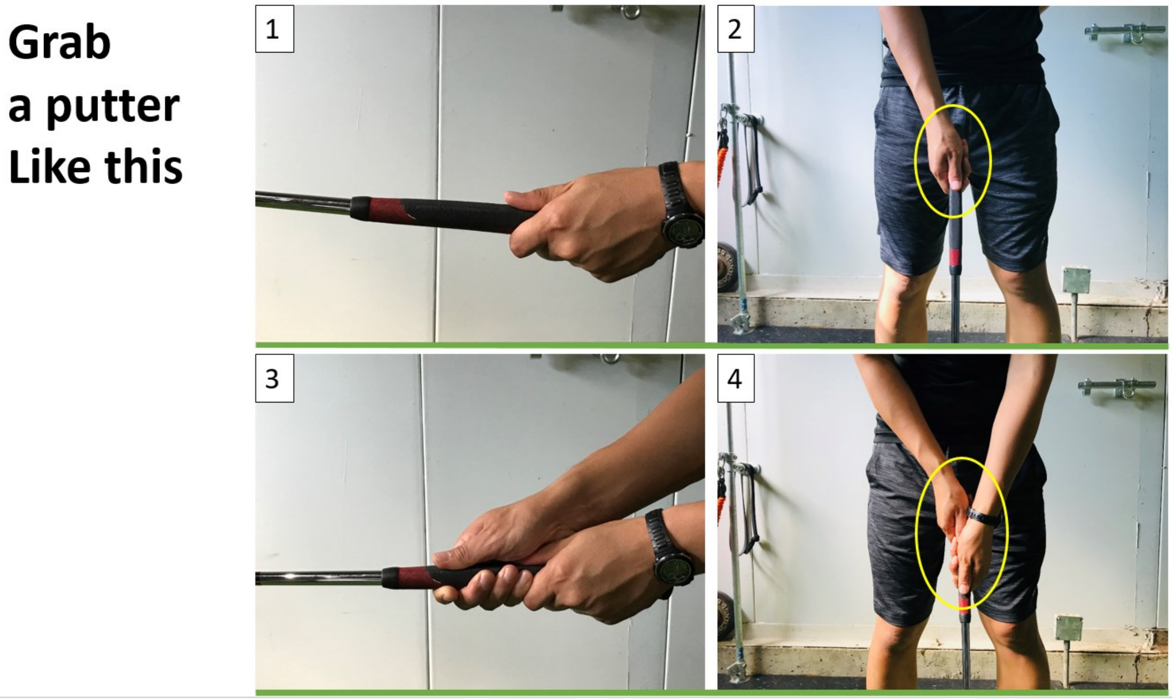

Figure A1. *Visual description of golf putt instruction*

Figure A1 (continued)

Figure A1 (continued)

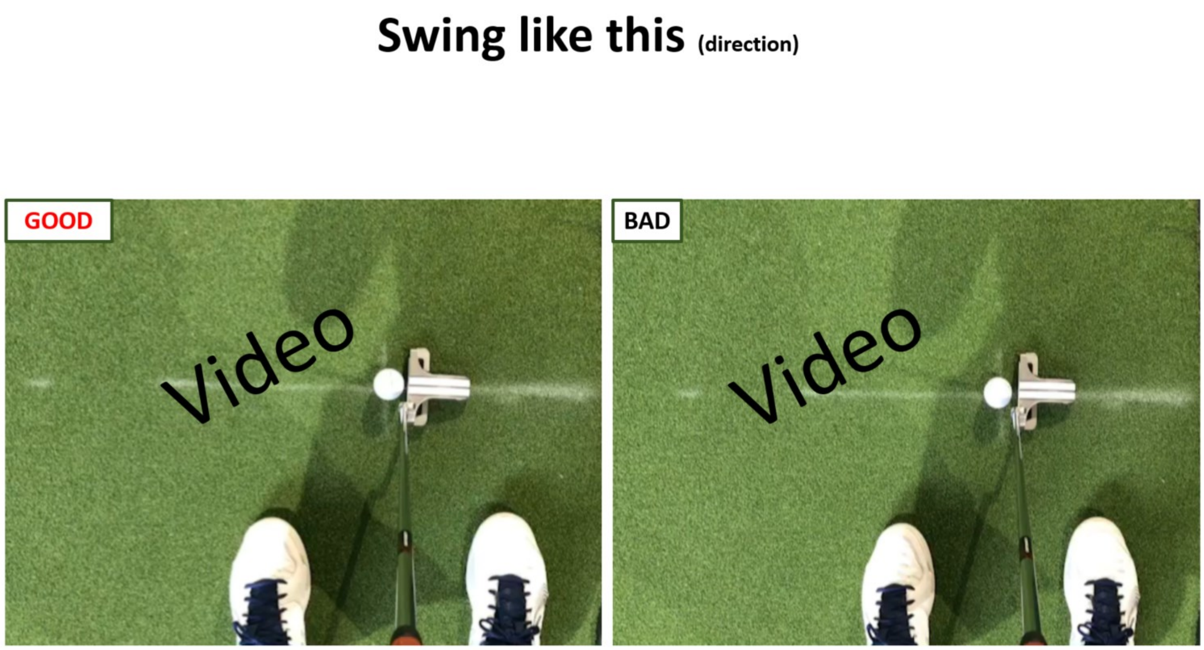

Figure A1 (continued)

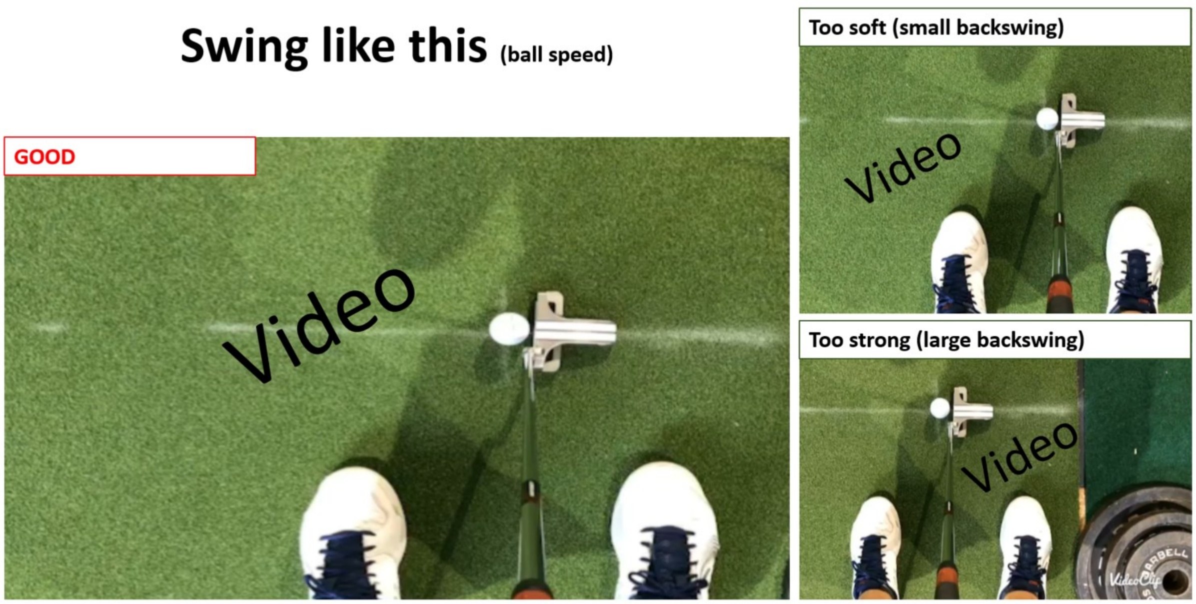

Figure A1 (continued)

APPENDIX B

DATA COLLECTION SHEET

Assessment Sheet for (ID:___________________)

1st day: Familiarization *(Date: ___/___/___)*

1. Signing consent form

2. Wear heart rate monitor in the upper arm

3. 5 min quiet break with nature video (resting HR: _____________)

4. Wear EEG headset for a minute

5. Demographic information

Birthday	MM/DD/YYYY:			Age	
Height (m)				Gender	
Weight (kg)		BMI (kg/m^2)		Handedness	
				Golf experience	

6. Peabody Mental Age assessment

- Ceiling item: _____ / Total errors: _____.
- Raw score:
- Age equivalent score:

7. Executive function tests

1) *Knock & Tap test*

2) *Digit span test (span 4)*
   Forward & backward.

3) *Corsi block task (span 4)*
   Forward & backward.

8. Golf putt

- Watch a video instruction.
- Practice 2 blocks of 5 shots.

9. Treadmill walking practice

Time (min)	MPH	%incline	HR	RPE
Start	1	0		
1	1.5			
2	2			
3	2.5			
4	3	2.5		
5	3~3.5			
6				
7				
8		5		
9				
10				
End				

2nd day: Intervention & tests (Date: ___/___/___)

1. Wear heart rate monitor

2. 5 min quiet break with nature video (resting HR: ______________)

3. Feeling scale: _____

4. 1 min resting EEG

5. Baseline EF tests

1) *Knock and Tap:* total score: ______________/30
2) *Span tasks (Span 1)*

	Span	Presented	Digit Span			Corsi block		
			Response	#	Outcome	Response	#	Outcome
FORWARD	2	8, 5						
	2	3, 1						
	3	8, 4, 5						
	3	7, 9, 6						
	4	8, 2, 7, 9						
	4	4, 2, 5, 3						
	5	1, 7, 3, 9, 2						
	5	4, 5, 4, 7, 1						
	6	3, 8, 2, 9, 9, 2						
	6	1, 7, 3, 6, 3, 9						
	7	4, 8, 1, 5, 6, 8, 9						
	7	7, 2, 5, 6, 4, 2, 7						
BACKWARD	2	8, 1						
	2	3, 6						
	3	5, 9, 4						
	3	9, 6, 7						
	4	5, 2, 8, 3						

	4	2, 3, 1, 7						
	5	9, 4, 6, 5, 8						
	5	4, 1, 5, 7, 8						
	6	6, 9, 2, 3, 8, 5						
	6	4, 9, 6, 2, 3, 1						
	7	8, 5, 3, 1, 8, 4, 5						
	7	7, 9, 6, 8, 2, 7, 9						

6. Golf putt

- Assess verbal-analytic memory checklist during 2 shots of practice before actual testing.

Criteria	Question	0	1	2
Grip	Place non-dominant hand above the dominant hand.			
	Both thumbs are in the middle of the grip.			
Positioning	Ball position and feet position form an isosceles triangle			
	The putter face and feet direction are aligned toward the same direction.			
Aiming	Align the putter face toward the target hole.			
	Swing along the anticipated trajectory line.			
Swing speed	Maintain consistent swing speed from backswing to follow swing.			
	Maintain consistent pendulum size from backswing to follow swing.			

Total point:

- Baseline test

1st block				2nd block			
Trial	X axis	Y axis	Distance: $(X^2 + y^2)^{1/2}$	Trial	X axis	Y axis	Distance: $(X^2 + y^2)^{1/2}$
1				1			
2				2			
3				3			
4				4			
5				5			

	Accuracy	Bias	Consistency
Baseline			

7. Intervention

1) Video watching (20 min)

- Write HR and RPE every minute in the table below.
- Video: YouTube → NetGeo Wild (42:30)

2) Acute aerobic exercise (70 % ≤ HRR ≤ 80 %)

- HR_{max} = 210 – 0.56 (age)-15.5 = _________ / HR_{rest} = __________ / HRR = __________.
- %HR = % intensity x HRR + HR_{rest}
- Target heart rate: 70%HRR: _________ ≤ HR ≤ 80%HRR _________.

Phase	Time (min)	MPH	%incline	HR	RPE
Warm up	Start	1	0		
(up to 10 min)	1	1.5			
(up to 3.5 mph)	2	2			
	3	2.5			
	4	3			
	5				
	6				
	7				
	8				
	9				
Exercise	Start		0		
(MPH ≤ 3.5)	1				
	2				
	3				
	4		2.5		
	5				
	6				
	7				
	8		5		
	9				
	10				
	11				
	12		7.5		
	13				
	14				

	15		
	16	10	
	17		
	18		
	19		
	20 (finish)		
$HR_{average}$ during exercise:		**/ %intensity = ($HR_{average}$ – HR_{rest}) / HRR =**	
Cool-down (5 min)	1	1	0
	2	1	0
	3	1	0
	4	1	0
	5 (End)	1	0
Rest	Until HR dropped to 10% of pre-exercise HR (***Resting time:*** ***min***)		

9. Feeling scale: ________

10. 1 min Exercise EEG

11. Post EF tests

1) *Knock and Tap:* total score: ______________/30
2) *Span tasks (span2)*

	Span	Presented	Digit Span			Corsi block		
			Response	#	1/0	Response	#	1/0
FORWARD	2	8 2						
	2	7 9						
	3	4 2 5						
	3	3 1 7						
	4	3 9 2 4						
	4	5 4 7 1						
	5	3 8 2 9 9						
	5	2 1 7 3 6						
	6	3 9 4 8 1 5						
	6	6 8 9 7 2 5						

	7	6 4 2 7 8 1 3						
	7	6 5 9 4 9 6 7						
BACKWARD	2	5 2						
	2	8 3						
	3	2 3 1						
	3	7 9 4						
	4	6 5 8 4						
	4	1 5 7 8						
	5	6 9 2 3 8						
	5	5 4 9 6 2						
	6	3 1 8 5 3 1						
	6	8 4 5 7 9 6						
	7	8 2 7 9 4 2 5						
	7	3 1 7 3 9 2 4						

12. 2 min break

13. Golf putt post-test

- Assess verbal-analytic memory checklist during 2 shots of practice before actual testing.

Criteria	Question	0	1	2
Grip	Place non-dominant hand above the dominant hand.			
	Both thumbs are in the middle of the grip.			
Position ing	Ball position and feet position form an isosceles triangle			
	The putter face and feet direction are aligned toward the same direction.			
Aiming	Align the putter face toward the target hole.			
	Swing along the anticipated trajectory line.			
Swing speed	Maintain consistent swing speed from backswing to follow swing.			
	Maintain consistent pendulum size from backswing to follow swing.			

Total point: ______

- Post-test:

Transfer test (no line)				Retention test (line)			
Trial	X axis	Y axis	Distance: $(X^2 + y^2)^{1/2}$	Trial	X axis	Y axis	Distance: $(X^2 + y^2)^{1/2}$
1				1			
2				2			
3				3			
4				4			
5				5			
6				6			
7				7			
8				8			
9				9			
10				10			

	Accuracy	Bias	Consistency
Transfer			
Retention			

3rd day: 24-hour Retention test *(Date: ___/___/___)*

1. Wear heart rate monitor

2. 5 min quiet break with nature video (resting HR: ________________)

3. Feeling scale: _____

4. 1 min resting EEG

5. EF tests

1) *Knock and Tap:* total score: ____________/30
2) *Span tasks (span 3)*

	Span	Presented	Digit Span			Corsi block		
			Response	#	1/0	Response	#	1/0
FORWARD	2	3 9						
	2	2 4						
	3	5 4 7						
	3	1 3 8						
	4	2 9 9 2						
	4	1 7 3 6						
	5	3 9 4 8 1						
	5	5 6 8 9 7						
	6	2 5 6 4 2 7						
	6	8 1 3 6 5 9						
	7	4 9 6 7 5 2 8						
	7	3 2 3 1 7 9 4						
BACKWARD	2	6 5						
	2	8 4						
	3	1 5 7						
	3	8 6 9						
	4	2 3 8 5						

	4	4 9 6 2						
	5	3 1 8 5 3						
	5	1 8 4 5 7						
	6	9 6 8 2 7 9						
	6	8 5 3 1 8 4						
	7	5 7 9 6 8 2 7						
	7	9 4 2 5 3 1 7						

6. 2 min break

7. Golf putt test

- Assess verbal-analytic memory checklist during 2 shots of practice before actual testing.

Criteria	Question	0	1	2
Grip	Place non-dominant hand above the dominant hand.			
	Both thumbs are in the middle of the grip.			
Positioning	Ball position and feet position form an isosceles triangle			
	The putter face and feet direction are aligned toward the same direction.			
Aiming	Align the putter face toward the target hole.			
	Swing along the anticipated trajectory line.			
Swing speed	Maintain consistent swing speed from backswing to follow swing.			
	Maintain consistent pendulum size from backswing to follow swing.			

Total point: ____

- Putting task:

Transfer test (no line)				Retention test (line)			
Trial	X axis	Y axis	Distance: $(X^2 + y^2)^{1/2}$	Trial	X axis	Y axis	Distance: $(X^2 + y^2)^{1/2}$
1				1			
2				2			
3				3			
4				4			
5				5			
6				6			
7				7			
8				8			
9				9			
10				10			

	Accuracy	Bias	Consistency
Transfer			
Retention			

4th day: 7-day Retention test *(Date: _____/_____/_____)*

1. Wear heart rate monitor

2. 5 min quiet break with nature video (resting HR: ________________)

3. Feeling scale: _____

4. 1 min resting EEG

5. EF tests

1) *Knock and Tap:* total score: _____________/30
2) *Span tasks (span 4)*

2	Span	Presented	Digit Span			Corsi block		
			Response	#	1/0	Response	#	1/0
FORWARD	2	2 9						
	2	9 2						
	3	1 7 3						
	3	6 3 9						
	4	4 8 1 5						
	4	6 8 9 7						
	5	2 5 6 4 2						
	5	7 8 1 3 6						
	6	5 9 4 9 6 7						
	6	5 2 8 3 2 3						
	7	1 7 9 4 6 5 8						
	7	4 1 5 7 8 6 9						
BACKWARD	2	2 3						
	2	8 5						
	3	4 9 6						
	3	2 3 1						
	4	8 5 3 1						

	4	8 4 5 7						
	5	9 6 8 2 7						
	5	9 4 2 5 3						
	6	1 7 3 9 2 4						
	6	9 4 7 1 3 8						
	7	2 9 9 2 1 7 3						
	7	6 3 9 4 8 1 5						

6. 2 min break

7. Golf putt test

- Assess verbal-analytic memory checklist during 2 shots of practice before actual testing.

Criteria	Question	0	1	2
Grip	Place non-dominant hand above the dominant hand.			
	Both thumbs are in the middle of the grip.			
Positioning	Ball position and feet position form an isosceles triangle			
	The putter face and feet direction are aligned toward the same direction.			
Aiming	Align the putter face toward the target hole.			
	Swing along the anticipated trajectory line.			
Swing speed	Maintain consistent swing speed from backswing to follow swing.			
	Maintain consistent pendulum size from backswing to follow swing.			

Total point: ____________

- Putting task:

Transfer test (no line)				Retention test (line)			
Trial	X axis	Y axis	Distance: $(X^2 + y^2)^{1/2}$	Trial	X axis	Y axis	Distance: $(X^2 + y^2)^{1/2}$
1				1			
2				2			
3				3			
4				4			
5				5			
6				6			
7				7			
8				8			
9				9			
10				10			

	Accuracy	Bias	Consistency
Transfer			
Retention			

APPENDIX C

CONSENT FORMS

Informed consent form for college students with intellectual disabilities

MSU HRPP Approved: 08/12/19 Expires: 05/27/24 IRB # 19-152

Mississippi State University
Informed Consent Form for Participation in Research

Title of Research Study: Effect of aerobic exercise on executive function and motor skill acquisition in adults with intellectual disabilities.
Study Site: McCarthy gym, Cognitive and Motor Performance Lab.

Researchers:
Mr. Yonjoong Ryuh, Department of Kinesiology, Mississippi State University
Dr. Chih-Chia Chen, Department of Kinesiology, Mississippi State University
Dr. John Lamberth, Department of Kinesiology, Mississippi State University
Dr. Stamatis Agiovlasitis, Department of Kinesiology, Mississippi State University
Dr. Zhujun Pan, Department of Kinesiology, Mississippi State University

Purpose
The purpose of this research is to know how walking exercise can help improve memory, attention, and golf putting skill.

Procedures
You will be invited to a laboratory 7 times, and each visit will be a week after the previous visit.

1st day: You will answer some questions about how much you exercise, your previous golf experience, how you think, and which hand you throw a ball and write with. Also, you will practice activities that we will do later including golf putting, wearing a headset to measure your brain activity, wearing a chest strap to measure your heart beat, practice quizzes, and walk on a treadmill for 20 min.

2nd day: You will play some game related to memory and attention. Also, you will learn and practice how to putt a golf ball. Thereafter, you will either walk on a treadmill for 30 minutes, or sit and watch a video for 30 minutes. Then, you will play some board games and practice golf putting again.

3rd day: 24 hours after the 2nd day, you will visit our room again and play with board games and practice golf putting.

4th day: 7 days after the second day, you will do the same thing as the third day.

5th day: You will do the same thing as the second day. However, if you walked on the second day, then you will watch a video. Oppositely, if you watched the video on the second day, you will walk on a treadmill for 30 min. After, we will do some games and golf putt practice.

6th day: 24 hours after the 5th day, you will do the same thing as the third and fourth day.

7th day: 7 days after the 5th day, you will do the same thing as the third and fourth day.

If you read and understand what you are going to do in this research, please check the appropriate below:

_____ I DO give permission for the researchers to look at my medical record and/or health information through ACCESS program, which will be used to understand my cognitive and motor performance.

I understand that my name and any other personally identifiable information will not appear on any of the submitted materials.

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Version: 05.29.2018

Figure C1. *Informed consent form for college students with intellectual disabilities*

_____ I DO NOT give permission for the researchers to look at my medical record and/or health information through ACCESS program, which will be used to understand my cognitive and motor performance.

Risks or Discomforts

You may feel fatigue after the walking exercise. However, the risk in this study is not greater than you would experience in a daily living. Likewise, any physical discomfort will not be greater than that experienced with typical physical activity. All information about you will be collected and maintained confidentially. Only trained people will interact with you during the activity. Data will be stored on a password-protected computer and paper documents will be stored in a locked filing cabinet. Only study personnel will have access to the data.

Benefits

You may learn how to putt a golf ball. Also, you may learn how to practice golf putting efficiently, and that knowledge can be applied to your own sports learning situation.

Incentive to participate

You will be given $30 for the completion of participation. $15 will be award after finishing half of the procedure, and another $15 will be award after the completion of the participation.

Confidentiality

The data will only be identified by a code number. The research team will have access to the names of you as we will be directly interacting with you during data collection. Upon completion, the data files will be stored on a password protected computer. In addition, all data including the signed consent forms will be stored in a locked cabinet. Names, age, sex, and racial information will be collected but will only be accessible by the research personnel. Likewise, the indirect identifies will be used in data collection.

Please note that these records will be held by a state entity and therefore are subject to disclosure if required by law. Research information may be shared with the MSU Institutional Review Board (IRB) and the Office for Human Research Protections (OHRP) and others who are responsible for ensuring compliance with laws and regulations related to research. The information from the research may be published for scientific purposes; however, your identity will not be given out.

Questions

If you have any questions about this research project or want to provide input, please feel free to contact Mr. Yonjoong (YJ) Ryuh at (662) 694-2194.
For questions regarding your rights as a research participant or to request information, please feel free to contact the MSU Human Research Protection Program (HRPP) by e-mail at irb@research.msstate.edu, or visit our participant page on the website at http://orc.msstate.edu/humansubjects/participant/.

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Figure C1 (continued)

MSU HRPP | Approved: 08/12/19 | Expires: 05/27/24 | IRB # 19-152

To report problems, concerns, or complaints pertaining to your involvement in this research study, you may do so anonymously by contacting the MSU Ethics Line at http://www.msstate.ethicspoint.com/.

In addition to reporting an injury to Mr. Yonjoong (YJ) Ryuh at (662) 694-2194 and to the Research Compliance Office at 662-325-3994, you may be able to obtain limited compensation from the State of Mississippi if the injury was caused by the negligent act of a state employee where the damage is a result of an act for which payment may be made under §11-46-1, et seq. Mississippi Code Annotated 1972. To obtain a claim form, contact the University Police Department at *MSU UNIVERSITY POLICE DEPARTMENT, Williams Building, Mississippi State, MS 39762, (662) 325-2121.*

Voluntary Participation

Please understand that your **participation is voluntary.** Your **refusal to participate will involve no penalty or loss** of benefits to which you are otherwise entitled. You **may discontinue your participation** at any time without penalty or loss of benefits.

Please take all the time you need to read through this document and decide whether you would like to participate in this research study.

If you agree to participate in this research study, please sign below. You will be given a copy of this form for your records.

______________________________ __________

Participant Signature Date

______________________________ __________

Investigator Signature Date

Research Participant Satisfaction Survey

In an effort to ensure ongoing protections of human subjects participating in research, the MSU HRPP would like for research participants to complete this anonymous survey to let us know about your experience. Your opinion is important, and your responses will help us evaluate the process for participation in research studies.
https://www.surveymonkey.com/r/M5M95YF

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Figure C1 (continued)

Informed consent form for community residents with intellectual disabilities

MSU HRPP | Approved: 08/12/19 | Expires: 05/27/24 | IRB # 19-152

Mississippi State University
Informed Consent Form for Participation in Research

Title of Research Study: Effect of aerobic exercise on executive function and motor skill acquisition in adults with intellectual disabilities.
Study Site: McCarthy gym, Cognitive and Motor Performance Lab.

Researchers:
Mr. Yonjoong Ryuh, Department of Kinesiology, Mississippi State University
Dr. Chih-Chia Chen, Department of Kinesiology, Mississippi State University
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Dr. Stamatis Agiovlasitis, Department of Kinesiology, Mississippi State University
Dr. Zhujun Pan, Department of Kinesiology, Mississippi State University

Purpose
The purpose of this research is to know how walking exercise can help improve memory, attention, and golf putting skill.

Procedures
You will be invited to a laboratory 7 times, and each visit will be a week after the previous visit.

1st day: You will answer some questions about how much you exercise, your previous golf experience, how you think, and which hand you throw a ball and write with. Also, you will practice activities that we will do later including golf putting, wearing a headset to measure your brain activity, wearing a chest strap to measure your heart beat, practice quizzes, and walk on a treadmill for 20 min.

2nd day: You will play some game related to memory and attention. Also, you will learn and practice how to putt a golf ball. Thereafter, you will either walk on a treadmill for 30 minutes, or sit and watch a video for 30 minutes. Then, you will play some board games and practice golf putting again.

3rd day: 24 hours after the 2nd day, you will visit our room again and play with board games and practice golf putting.

4th day: 7 days after the second day, you will do the same thing as the third day.

5th day: You will do the same thing as the second day. However, if you walked on the second day, then you will watch a video. Oppositely, if you watched the video on the second day, you will walk on a treadmill for 30 min. After, we will do some games and golf putt practice.

6th day: 24 hours after the 5th day, you will do the same thing as the third and fourth day.

7th day: 7 days after the 5th day, you will do the same thing as the third and fourth day.

Risks or Discomforts

You may feel fatigue after the walking exercise. However, the risk in this study is not greater than you would experience in a daily living. Likewise, any physical discomfort will not be greater than that experienced with typical physical activity. All information about you will be collected and maintained confidentially. Only trained people will interact with you during the activity. Data will be stored on a password-protected computer and paper documents will be stored in a locked filing cabinet. Only study personnel will have access to the data.

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Figure C2. *Informed consent form for community residents with intellectual disabilities*

MSU HRPP | Approved: 08/12/19 | Expires: 05/27/24 | IRB # 19-152

Benefits

You may learn how to putt a golf ball. Also, you may learn how to practice golf putting efficiently, and that knowledge can be applied to your own sports learning situation.

Incentive to participate

You will be given $30 for the completion of participation. However, even if you stopped participating during the procedure, we will still give you $3 per each visit.

Confidentiality

The data will only be identified by a code number. The research team will have access to the names of you as we will be directly interacting with you during data collection. Upon completion, the data files will be stored on a password protected computer. In addition, all data including the signed consent forms will be stored in a locked cabinet. Names, age, sex, and racial information will be collected but will only be accessible by the research personnel. Likewise, the indirect identifies will be used in data collection.

Please note that these records will be held by a state entity and therefore are subject to disclosure if required by law. Research information may be shared with the MSU Institutional Review Board (IRB) and the Office for Human Research Protections (OHRP) and others who are responsible for ensuring compliance with laws and regulations related to research. The information from the research may be published for scientific purposes; however, your identity will not be given out.

Questions

If you have any questions about this research project or want to provide input, please feel free to contact Mr. Yonjoong (YJ) Ryuh at (662) 694-2194.
For questions regarding your rights as a research participant or to request information, please feel free to contact the MSU Human Research Protection Program (HRPP) by e-mail at irb@research.msstate.edu, or visit our participant page on the website at http://orc.msstate.edu/humansubjects/participant/.

To report problems, concerns, or complaints pertaining to your involvement in this research study, you may do so anonymously by contacting the MSU Ethics Line at http://www.msstate.ethicspoint.com/.

In addition to reporting an injury to Mr. Yonjoong (YJ) Ryuh at (662) 694-2194 and to the Research Compliance Office at 662-325-3994, you may be able to obtain limited compensation from the State of Mississippi if the injury was caused by the negligent act of a state employee where the damage is a result of an act for which payment may be made under §11-46-1, et seq. Mississippi Code Annotated 1972. To obtain a claim form, contact the University Police Department at *MSU UNIVERSITY POLICE DEPARTMENT, Williams Building, Mississippi State, MS 39762, (662) 325-2121.*

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Figure C2 (continued)

Voluntary Participation

Please understand that your **participation is voluntary.** Your **refusal to participate will involve no penalty or loss** of benefits to which you are otherwise entitled. You **may discontinue your participation** at any time without penalty or loss of benefits.

Please take all the time you need to read through this document and decide whether you would like to participate in this research study.

If you agree to participate in this research study, please sign below. You will be given a copy of this form for your records.

______________________________ __________
Participant Signature Date

______________________________ __________
Investigator Signature Date

Research Participant Satisfaction Survey

In an effort to ensure ongoing protections of human subjects participating in research, the MSU HRPP would like for research participants to complete this anonymous survey to let us know about your experience. Your opinion is important, and your responses will help us evaluate the process for participation in research studies.
https://www.surveymonkey.com/r/M5M95YF

Figure C2 (continued)

Parental permission form for college students with intellectual disabilities

MSU HRPP | Approved: 08/12/19 | Expires: 05/27/24 | IRB # 19-152

Mississippi State University
Parental or Legally Authorized Representative Permission Form
for Participation in Research

You are being asked to allow the participant to participate in a research project. This form provides you with information about the project. Please read the information below and ask any questions you might have before deciding whether or not to allow the participant to participate.

Title of Research Study: Effect of aerobic exercise on executive function and motor skill acquisition in adults with intellectual disabilities.

Study Site: McCarthy gym, Cognitive and Motor Performance Lab.

Researchers:
Mr. Yonjoong (YJ) Ryuh, Department of Kinesiology, Mississippi State University
Dr. Chih-Chia Chen, Department of Kinesiology, Mississippi State University
Dr. John Lamberth, Department of Kinesiology, Mississippi State University
Dr. Stamatis Agiovlasitis, Department of Kinesiology, Mississippi State University
Dr. Zhujun Pan, Department of Kinesiology, Mississippi State University

Purpose
The purpose of this research is to
1) examine the relationship among aerobic exercise, cognitive function, and golf putt learning capacity.
2) compare which type of cognitive function is helpful in learning a golf putt skill.

Procedures
If you agree to allow the participant to participate in this research project, we will ask the participant to do the following things:

The participant will be invited to a laboratory 7 times, and each visit will be a week after the previous visit.

1st day: The participant will answer some questions about how much the participant exercise, The participant's previous golf experience, how his/her think, and which hand the participant throw a ball and write with. Also, the participant will practice activities that we will do later including golf putting, wearing a headset to measure the brain activity, wearing a chest strap to measure heart beat, practice some board games, and walk on a treadmill for 20 min.

2nd day: The participant will play some game related to memory and attention. Also, the participant will learn and practice how to putt a golf ball. Thereafter, the participant will either walk on a treadmill for 30 minutes, or sit and watch a video for 30 minutes. Then, the participant will play some board games and practice golf putting again.

3rd day: 24 hours after the 2nd day, the participant will visit our room again and play with board games and practice golf putting.

4th day: 7 days after the second day, the participant will do the same thing as the third day.

5th day: The participant will do the same thing as the second day. However, if the participant walked on the second day, then the participant will watch a video. Oppositely, if the participant watched the video on the second day, the participant will walk on a treadmill for 30 min. After, we will do some games and golf putt practice.

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Figure C3. *Parental permission form for college students with intellectual disabilities*

6th day: 24 hours after the 5th day, the participant will do the same thing as the third and fourth day.

7th day: 7 days after the 5th day, the participant will do the same thing as the third and fourth day.

The total estimated time to participate in this research project:

- 1st day: familiarization – 1 hour.
- 2nd day: pre-test, intervention, and post-test – 1.5 hour.
- 3rd day: 24-hour retention test – 1hour.
- 4th day: 1-week retention test – 1 hour.
- 5th day: pre-test, second intervention, and post-test – 1.5 hour.
- 6th day: 24-hour retention test – 1 hour.
- 7th day: 7-day retention test – 1hour.

Incentive to participate

- The participant will be given $30 for the completion of participation. $15 will be award after finishing half of the procedure, and another $15 will be award after the completion of the participation.

The risks of participation:

- The participant may feel fatigue, muscle tension or soreness after performing golf putt performance and, if applicable, aerobic exercise. However, the risk associated with participation in this study is not greater than the participant would experience in a typical daily living. Likewise, any physical discomfort will not be greater than that experienced with typical physical activity. All data will be collected and maintained confidentially. Only trained personnel will interact with the participant during data collection. Data will be encrypted and stored on a password-protected computer and paper documents will be stored in a locked filing cabinet. Only study personnel will have access to the data.

If the participant is injured as a result of participating in this research project, you should know the following:

- In addition to reporting an injury to Mr. Yonjoong (YJ) Ryuh (662-694-2194) and to the MSU Research Compliance Office (662-325-3994), the participant may be able to obtain limited compensation from the State of Mississippi if the injury was caused by the negligent act of a state employee where the damage is a result of an act for which payment may be made under §11-46-1, et seq. Mississippi Code Annotated 1972. To obtain a claim form, contact the MSU Police Department at (662) 325-2121.

The benefits of participation:

- The participant can learn how to putt a golf ball.
- The participant may learn how to practice golf putt effectively, and that knowledge can be applied to the other sports learning situations.

Compensation:

- The researchers recognize that participation may pose some inconvenience.
- In order to compensate for the time, the participant will be paid a total of $15, $5 for each visit.

Figure C3 (continued)

Approved: 08/12/19 Expires: 05/27/24
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Confidentiality and privacy protections:

- All information obtained and recorded in this study is strictly confidential. The identity of participant will not be revealed in publications that may result from this study, nor will names be used in other research communication, such as lectures to scientific meetings. Only summary statistics such as the participant's age and gender will be included in published experimental results.
- After the experiment is completed, all data can be assessed only by the Investigators and authorized personnel (i.e., graduate research assistants, postdoctoral associates, and research associates) and will be stored indefinitely.
- It is important to understand that these records will be held by a state entity and therefore are subject to disclosure if required by law.

Contacts and questions:

- If you have any questions, please ask now. If you should have any questions later or want additional information, please contact Mr. Yonjoong (YJ) Ryuh at 662- 694-2194. For information regarding your rights as a research subject, please contact the MSU Research Compliance Office at 662-325-3994.

If you read and understand the project description offered in this form, please check the appropriate below:

- _____ I DO give permission to researchers to review my child's medical record and/or health information through ACCESS program, to be used for the purpose of the assessment of motor performance and sleep behavior.

I understand that my child's name and any other personally identifiable information will not appear on any of the submitted materials.

- _____ I DO NOT give permission to researchers to review my child's medical record and/or health information through ACCESS program, to be used for the purpose of the assessment of motor performance and sleep behavior.

If you do not want the participant to participate:
Please understand that the participation is voluntary. Your refusal to allow the participant to participate will involve no penalty or loss of benefits to which you or the participant is otherwise entitled. You may discontinue the participation at any time without penalty or loss of benefits. The participant may skip any items that he or she chooses not to answer. Your refusal will not impact current or future relationships with Mississippi State University. To do so, simply tell the researcher that you wish to stop.

If after reading the information above, you agree to allow your child to participate, please sign below. If you decide later that you wish to withdraw your permission, simply tell the researcher. You may discontinue your child's participation at any time. You will be given a copy of this form for your records.

Figure C3 (continued)

MSU HRPP Approved: 08/12/19 Expires: 05/27/24 IRB # 19-152

____
Participant's name (please print)

______________________________ __________
Parent or *Legally Authorized Representative's Signature Date

______________________________ __________
Parent or *Legally Authorized Representative's Signature Date
(if applicable)

______________________________ __________
Investigator's Signature Date

If a Legally Authorized Representative (rather than a parent), must have documentation to show LAR status.

Research Participant Satisfaction Survey

In an effort to ensure ongoing protections of human subjects participating in research, the MSU HRPP would like for research participants to complete this anonymous survey to let us know about your experience. Your opinion is important, and your responses will help us evaluate the process for participation in research studies.
https://www.surveymonkey.com/r/M5M95YF

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Figure C3 (continued)

Parental permission form for community residents with intellectual disabilities

Approved: 08/12/19 Expires: 05/27/24
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Mississippi State University
Parental or Legally Authorized Representative Permission Form
for Participation in Research

You are being asked to allow the participant to participate in a research project. This form provides you with information about the project. Please read the information below and ask any questions you might have before deciding whether or not to allow the participant to participate.

Title of Research Study: Effect of aerobic exercise on executive function and motor skill acquisition in adults with intellectual disabilities.

Study Site: McCarthy gym, Cognitive and Motor Performance Lab.

Researchers:
Mr. Yonjoong (YJ) Ryuh, Department of Kinesiology, Mississippi State University
Dr. Chih-Chia Chen, Department of Kinesiology, Mississippi State University
Dr. John Lamberth, Department of Kinesiology, Mississippi State University
Dr. Stamatis Agiovlasitis, Department of Kinesiology, Mississippi State University
Dr. Zhujun Pan, Department of Kinesiology, Mississippi State University

Purpose
The purpose of this research is to
1) examine the relationship among aerobic exercise, cognitive function, and golf putt learning capacity.
2) compare which type of cognitive function is helpful in learning a golf putt skill.

Procedures

If you agree to allow the participant to participate in this research project, we will ask the participant to do the following things:

The participant will be invited to a laboratory 7 times, and each visit will be a week after the previous visit.

1st day: The participant will answer some questions about how much the participant exercise, The participant's previous golf experience, how his/her think, and which hand the participant throw a ball and write with. Also, the participant will practice activities that we will do later including golf putting, wearing a headset to measure the brain activity, wearing a chest strap to measure heart beat, practice some board games, and walk on a treadmill for 20 min.

2nd day: The participant will play some game related to memory and attention. Also, the participant will learn and practice how to putt a golf ball. Thereafter, the participant will either walk on a treadmill for 30 minutes, or sit and watch a video for 30 minutes. Then, the participant will play some board games and practice golf putting again.

3rd day: 24 hours after the 2nd day, the participant will visit our room again and play with board games and practice golf putting.

4th day: 7 days after the second day, the participant will do the same thing as the third day.

5th day: The participant will do the same thing as the second day. However, if the participant walked on the second day, then the participant will watch a video. Oppositely,

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Figure C4. *Parental permission form for community residents with intellectual disabilities* if the participant watched the video on the second day, the participant will walk on a treadmill for 30 min. After, we will do some games and golf putt practice.

6th day: 24 hours after the 5th day, the participant will do the same thing as the third and fourth day.

7th day: 7 days after the 5th day, the participant will do the same thing as the third and fourth day.

The total estimated time to participate in this research project:

- 1st day: familiarization – 1 hour.
- 2nd day: pre-test, intervention, and post-test – 1.5 hour.
- 3rd day: 24-hour retention test – 1hour.
- 4th day: 1-week retention test – 1 hour.
- 5th day: pre-test, second intervention, and post-test – 1.5 hour.
- 6th day: 24-hour retention test – 1 hour.
- 7th day: 7-day retention test – 1hour.

Incentive to participate

- The participant will be given $20 for the completion of participation. However, even if you stopped participating during the procedure, we will still give you $3 per each visit.

The risks of participation:

- The participant may feel fatigue, muscle tension or soreness after performing golf putt performance and, if applicable, aerobic exercise. However, the risk associated with participation in this study is not greater than the participant would experience in a typical daily living. Likewise, any physical discomfort will not be greater than that experienced with typical physical activity. All data will be collected and maintained confidentially. Only trained personnel will interact with the participant during data collection. Data will be encrypted and stored on a password-protected computer and paper documents will be stored in a locked filing cabinet. Only study personnel will have access to the data.

If the participant is injured as a result of participating in this research project, you should know the following:

- In addition to reporting an injury to Mr. Yonjoong (YJ) Ryuh (662-694-2194) and to the MSU Research Compliance Office (662-325-3994), the participant may be able to obtain limited compensation from the State of Mississippi if the injury was caused by the negligent act of a state employee where the damage is a result of an act for which payment may be made under §11-46-1, et seq. Mississippi Code Annotated 1972. To obtain a claim form, contact the MSU Police Department at (662) 325-2121.

The benefits of participation:

- The participant can learn how to putt a golf ball.
- The participant may learn how to practice golf putt effectively, and that knowledge can be applied to the other sports learning situations.

Compensation:

- The researchers recognize that participation may pose some inconvenience.

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Figure C4 (continued)

- In order to compensate for the time, the participant will be paid a total of $15, $5 for each visit.

Confidentiality and privacy protections:

- All information obtained and recorded in this study is strictly confidential. The identity of participant will not be revealed in publications that may result from this study, nor will names be used in other research communication, such as lectures to scientific meetings. Only summary statistics such as the participant's age and gender will be included in published experimental results.
- After the experiment is completed, all data can be assessed only by the Investigators and authorized personnel (i.e., graduate research assistants, postdoctoral associates, and research associates) and will be stored indefinitely.
- It is important to understand that these records will be held by a state entity and therefore are subject to disclosure if required by law.

Contacts and questions:

- If you have any questions, please ask now. If you should have any questions later or want additional information, please contact Mr. Yonjoong (YJ) Ryuh at 662- 694-2194. For information regarding your rights as a research subject, please contact the MSU Research Compliance Office at 662-325-3994.

If you do not want the participant to participate:
Please understand that the participation is voluntary. Your refusal to allow the participant to participate will involve no penalty or loss of benefits to which you or the participant is otherwise entitled. You may discontinue the participation at any time without penalty or loss of benefits. The participant may skip any items that he or she chooses not to answer. Your refusal will not impact current or future relationships with Mississippi State University. To do so, simply tell the researcher that you wish to stop.

If after reading the information above, you agree to allow your child to participate, please sign below. If you decide later that you wish to withdraw your permission, simply tell the researcher. You may discontinue your child's participation at any time. You will be given a copy of this form for your records.

Figure C4 (continued)

Approved: 08/12/19 Expires: 05/27/24
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____
Participant's name (please print)

______________________________ __________
Parent or *Legally Authorized Representative's Signature Date

______________________________ __________
Parent or *Legally Authorized Representative's Signature Date
(if applicable)

______________________________ __________
Investigator's Signature Date

If a Legally Authorized Representative (rather than a parent), must have documentation to show LAR status.

Research Participant Satisfaction Survey

In an effort to ensure ongoing protections of human subjects participating in research, the MSU HRPP would like for research participants to complete this anonymous survey to let us know about your experience. Your opinion is important, and your responses will help us evaluate the process for participation in research studies.
https://www.surveymonkey.com/r/M5M95YF

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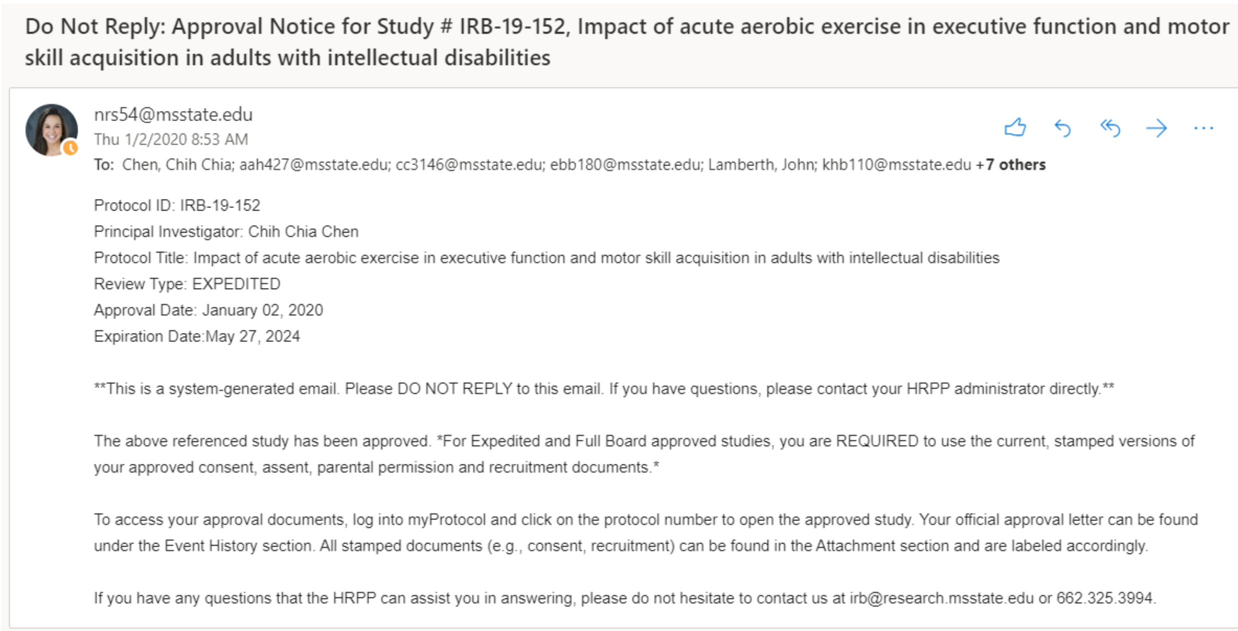
Figure C4 (continued)

APPENDIX D

IRB APPROVAL E-MAIL



Do Not Reply: Approval Notice for Study # IRB-19-152, Impact of acute aerobic exercise in executive function and motor skill acquisition in adults with intellectual disabilities

nrs54@msstate.edu
Thu 1/2/2020 8:53 AM
To: Chen, Chih Chia; aah427@msstate.edu; cc3146@msstate.edu; ebb180@msstate.edu; Lamberth, John; khb110@msstate.edu **+7 others**

Protocol ID: IRB-19-152
Principal Investigator: Chih Chia Chen
Protocol Title: Impact of acute aerobic exercise in executive function and motor skill acquisition in adults with intellectual disabilities
Review Type: EXPEDITED
Approval Date: January 02, 2020
Expiration Date:May 27, 2024

This is a system-generated email. Please DO NOT REPLY to this email. If you have questions, please contact your HRPP administrator directly.

The above referenced study has been approved. *For Expedited and Full Board approved studies, you are REQUIRED to use the current, stamped versions of your approved consent, assent, parental permission and recruitment documents.*

To access your approval documents, log into myProtocol and click on the protocol number to open the approved study. Your official approval letter can be found under the Event History section. All stamped documents (e.g., consent, recruitment) can be found in the Attachment section and are labeled accordingly.

If you have any questions that the HRPP can assist you in answering, please do not hesitate to contact us at irb@research.msstate.edu or 662.325.3994.

Figure D1. *Figure* **D**. *Captured e-mail of IRB approval notice*