Abstract

The Relationship Between Executive Functions and Physical Activity in University Students

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Obesity is a major health concern in the United States. Regular participation in physical activity is associated with lower rates of obesity and co-morbid health concerns. While a number of studies have demonstrated a link between participation in physical activity and executive functions (e.g., working memory, inhibition, problem-solving, initiation skills), the majority of these studies have used performance-based measures of executive functioning. Performance-based measures are highly structured and may not capture an individual's capacity to use these skills in daily functioning. The purpose of the present study was to assess the association between a behavioral rating scale of inhibition and initiation and physical activity in a sample of university students. It was hypothesized that better initiation skills would be associated with higher rates of physical activity. The multiple linear regression analysis revealed that initiation was a significant predictor of physical activity behaviors. These results demonstrate the importance of analyzing individual executive functions for their unique role in predicting physical activity behaviors.

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THE RELATIONSHIP BETWEEN EXECUTIVE FUNCTIONS AND PHYSICAL ACTIVITY IN UNIVERSITY STUDENTS

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CHAPTER ONE

Background and Introduction

Obesity is a problem in the United States (U.S.). In 2011-2012, 16.9% of U.S. children ages 2 to 19 were obese and 34.9% of adults age 20 years and older were obese (Ogden CL, Carroll MD, Kit BK, & Flegal KM, 2014). Obesity is associated with adverse health outcomes, such as increased risk for diabetes, hypertension, and heart disease (Flegal, 2005). The onset of obesity is related, in part, to behavioral factors such as a sedentary lifestyle (Gable, Chang, & Krull, 2007; World Health Organization, 2015). The World Health Organization (WHO) recommends that adults age 18-64 should get 150 minutes of moderate-intensity physical activity per week or 75 minutes of high-intensity physical activity per week ("WHO | Physical Activity and Adults"). Less than 10% of U.S. adults meet these recommended weekly physical activity guidelines (Tucker, Welk, & Beyler, 2011).

Executive functions are the higher order mental processes linked to the frontal lobe that play an important role in goal-directed behaviors (Etnier & Chang, 2009). Executive functions include inhibition (e.g., the ability to resist impulses and stop behaviors), set shift ability (e.g., the ability to transition and tolerate change), emotional control (e.g., the ability to moderate emotions), initiation (e.g., the ability to start a task), self-monitoring (e.g., the ability to be socially and interpersonally aware of the effects of ones behavior), and working memory (e.g., the ability to hold information in the mind while completing a task) (Roth, Isquith, & Gioia, 2005).

A number of studies have investigated the associations between executive functions and exercise behaviors. Huh et al. (2011) assessed set shifting, working memory, cognitive flexibility, and physical performance in an elderly Korean adult population. They found that cognitive flexibility was significantly positively related to physical performance and muscle strength, but that set shifting and working memory were not significantly related. Among 4th grade students in California, a significant negative correlation was reported between executive cognitive function and sedentary behavior (Riggs, Spruijt-Metz, Chou, & Pentz, 2012). Further, the data demonstrated that self-reported executive cognitive function was positively correlated with levels of physical activity (Riggs et al., 2012).

Other researchers have theorized that executive functions act as a moderator of intention and health behaviors. Hall, Fong, Epp, and Elias (2008) completed two studies looking into this. In study one, a sample of 64 Canadian undergraduates completed a Go/NoGo Task, which was used to assess response inhibition and initiation. The scores on the Go and the NoGo phases were combined into a single reaction time and used as an overall measure of executive functioning. In other words, the measure of executive functioning was a combination of inhibition and initiation. Hall et al. had participants disclose the number of hours they engaged in physical activity over the past week. They also asked how much physical activity they intended to get over the next week. The results of this study revealed that behavioral intention significantly predicted behavior for those who were high in executive functioning. It was also a predictor for those with lower executive functioning, but the relationship was not quite as strong. In their second study, Hall et al. repeated the study design, but examined fruit and vegetable consumption. The results again revealed that behavioral intention significantly predicted behavior for those with strong executive functioning, and that it predicted behavior for those with weak executive functioning, but not as strongly. From these results, Hall et al. concluded that executive functions act as a moderator for the link between behavior intention and physical activity and dietary behaviors.

Studies have also demonstrated the beneficial effect of physical activity on cognitive processes, including executive functions. Forty-two college students from the National Taiwan Sport University were randomly assigned to either the exercise or control conditions and then completed the Tower of London task both before and after their given condition (Chang et al., 2011). In the exercise condition, heart rate was monitored to establish and maintain a level of exercise intensity. The results of this study indicated that acute aerobic physical activity facilitated planning and problem solving (Chang et al., 2011). In another study, researchers looked into the effects of acute aerobic physical activity on inhibition, working memory, and shifting in a pre-adolescent population in Beijing (Chen, Yan, Yin, Pan, & Chang, 2014). In this study, participants were randomly assigned into one of two groups: the exercise group or the control group. The study was conducted over the course of two days using four different classrooms of students. The authors found that the exercise group significantly outperformed the control group on the cognitive tasks that measured inhibition, working memory, and set shifting. These results led the investigators to the conclusion that acute aerobic physical activity facilitates multiple aspects of executive functioning in pre-adolescent children.

While these studies demonstrate the important relationship between physical activity and executive functions, they have methodological limitations that need to be addressed. First,

the majority of existing studies have been conducted with older adult and youth populations outside the U.S. There is a need for studies that focus on young adults in the U.S. to determine if the findings generalize to this population. Many of the existing studies also only evaluated executive functioning as a broad construct as opposed to analyzing individual domains of executive functions. Looking into specific areas of executive functioning could help elucidate the relationship between executive functions and physical activity. Finally, the previously reported studies used performance-based measures of executive functioning. Performance-based measures of executive functioning are highly structured and often administered in a one-on-one testing setting. It has been argued that performance-based measures may not adequately assess executive functions that influence daily functioning which has been evidenced by low correlations between performance-based measures and behavioral rating scales (Limbers, Young, Jernigan, Bryant, & Stephen).

The purpose of the present study was to assess the associations between the executive functions inhibition and initiation and physical activity in a sample of U.S. university students. These executive functions were selected based on temporal self-regulation theory (Hall & Fong, 2015). In temporal self-regulation theory, it is theorized that when the costs and benefits are temporally close, the best predictor of completion of that behavior is the intention to complete the behavior. On the other hand, if the costs and benefits of a behavior are temporally distant, then prepotencies and executive functioning will play a larger role in determining the completion of that behavior. Prepotencies involve concepts such as habits and natural inclinations. A major executive function in this theory is inhibition, which is defined as the ability to suspend a prepotency. For physical activity, the costs (effort and time) are distant from the benefits (being physically fit and healthy). Based on temporal self-regulation, prepotencies and executive functions will play a larger role in determining the completion of physical activity. The executive functions will be measured using a self-reported behavioral rating scale of executive functioning. From this theory, one can argue that initiation, which is the executive function that is related to the ability to start a task/behavior with relative ease, is likely important in the completion of physical activity. Based on temporal self-regulation theory and other literature, I hypothesize that initiation will be associated with exercise frequency and inhibition will not (Hall, Fong, Epp, & Elias, 2008; Hall, Zehr, Paulitzki, & Rhodes, 2014; Riggs et al., 2012). I also hypothesize that there will be a significant difference in frequency of physical activity for those who score high in initiation compared to those who do not. Furthermore, there should not be a significant difference for those who score high on inhibition than those who do not.

CHAPTER TWO

Methods

Participants

Data for the present study came from a pre-existing dataset. Participants consisted of 240 undergraduate students from a private university in the southern United States. The average age of the participants was 19.03 years (SD= 0.90), and ranged from 17-23 years. The majority of the participants were female (82.50%). The participants were also largely Caucasian (59.60%). The fact that the majority of participants were Caucasian females is consistent with the general population of students taking psychology at this particular university. With regard to Body Mass Index (BMI), approximately 2.1% of the people in the sample were underweight, 64.6% were normal weight, 25.4% were overweight, and 7.9% were obese.

Measures

Executive functioning was measured using the self-report version of the Behavior Rating Inventory of Executive Function—Adult Version (BRIEF-A). The BRIEF-A is a standardized rating scale measuring everyday behaviors associated with executive functions in adults (Roth et al., 2005). This measure has demonstrated internal consistency, reliability, convergent validity, and construct validity in adult populations (Ciszewski, Francis, Mendella, Bissada, & Tasca, 2014; Hauser, Lukomski, & Samar, 2013; Roth et al., 2005). The BREIF-A is composed of 75 items which yield 9 nonoverlapping clinical scales (Inhibit, Shift, Emotional Control, Self-Monitor, Initiate, Working Memory, Plan/Organize, Task Monitor, Organization of Materials) and two summary index scales (Behavioral Regulation Index and Metacognition index). The T scores have a mean of 50 and a standard deviation of 10; a T score of 65 or greater is indicative of a clinically significant score. This current study examines two of the clinical scales: Inhibition and Initiate. As previously noted, these two clinical scales were chosen based on temporal self-regulation theory (Hall & Fong, 2015).

Exercise behaviors were measured using two self-report questions from the Summary of Diabetes Self-Care Activities (SDSCA) Questionnaire (Toobert & Glasgow, 1994). The participants answered the following questions: (1) On how many of the last SEVEN DAYS did you participate in at least 30 minutes of physical activity? (Total minutes of continuous activity, including walking) (2) On how many of the last SEVEN DAYS did you participate in a specific exercise session (such as swimming, walking, biking) other than what you do around the house or as part of your work? The responses were made on an 8-point scale ranging from 0 to 7. These items have demonstrated adequate psychometric properties across multiple studies (Toobert, Hampson, & Glasgow, 2000).

Finally, Body Mass Index (BMI) was measured objectively. It was calculated as weight in kilograms divided by height in meters squared (Choices, 2014). Based on guidelines from the Centers for Disease Control and Prevention (2014), classifications were as follows: a BMI below 18.5 was classified as underweight, a BMI from 18.5 to 24.9 was classified as normal weight, a BMI from 25.0 to 29.9 was classified as overweight, and a BMI of 30 or greater was classified as obese.

Procedures

Participants were recruited for the Psychology subject pool at a private university using SONA, the online Psychology subject pool system. An advertisement for the study was placed on the system explaining the general objective and procedures of the study. Students who completed the study were informed that they would receive one unit of research credit for participating in the study. The study was conducted in a lecture hall in groups of 10-15 students at each data collection session. Each participant gave written informed consent to be included in the study. The participants then completed a demographic questionnaire asking for gender, age, race/ethnicity, and parental highest educational attainment, followed by the BRIEF-A and the exercise items on the Diabetes Self-Care Activities (SDSCA). After each participant completed the questionnaires, a trained research assistant took each participant into a separate room to take their height and weight. These procedures took about 30 minutes to complete.

Statistical Analysis

Descriptive statistics were computed for the two scales of the BRIEF-A and the individual items of the SDSCA assessing participation in physical activity. Four independent samples *t* tests were conducted using mean score on initiate or inhibit as the independent variables and the mean score on each of the two questions from the SDSCA asking about physical activity as the dependent variables: (1) On how many of the last SEVEN DAYS did you participate in at least 30 minutes of physical activity? (Total minutes of continuous activity, including walking) and (2) On how many of the last SEVEN DAYS did you participate in a specific exercise session (such as swimming, walking, biking) other than what you do around the house or as part of your work? Initiate and inhibit were split into high and normative level groups with placement in the high group requiring a t-score of 65 or higher (which is considered clinically significant). Any scores lower than 65 were included in the normative group. Cohen's d was also calculated as a measure of effect size. Multiple linear regression analysis was conducted using frequency of physical activity as the outcome. Hierarchical entry was used in the analysis with the demographics entered in the first block and BMI entered in the second block as control variables; the two BRIEF-A clinical scales were entered in the third block. The level of statistical significance was set at ($p<0.05$) for testing the amount of variance accounted for by the two executive functions.

CHAPTER THREE

Results

Table 1 presents descriptive statistics for the 2 scales of the BRIEF-A and the individual items of the SDSCA assessing participation in physical activity. On average, the participants reported participating in at least 30 minutes of physical activity on 4.39 of the last seven days. They also reported participating in a specific exercise session on an average of 3.18 of the last seven days.

None of the independent sample *t*–tests were significant. There was not a statistically significant difference between those who were high in inhibition and those who were not for number of days with 30 minutes or more physical activity (d = .47, t (29) = 1.5, $p < .144$). This represents a medium effect. There was also not a statistically significant difference between those who were high in inhibition and those who were not for a measure of number of days attending a specific exercise class (d = .10, t (76) = .41, $p < .681$). This represents a small effect. There was not a significant difference between those who were high in initiation and those who were not for number of days with 30 minutes or more physical activity (d = .04, t (29) = .134, $p < .894$). This represents a small effect. Finally, there was not a significant difference between those who were high in initiation and those who were not for a measure of number of days attending a specific exercise class (d = .29, t (76) = 1.135, $p < .260$). This represents a medium effect.

Table 2 presents the standardized beta coefficients for the two models for which the primary outcomes were frequency of physical activity and number of specific exercise sessions. After controlling for demographic variables and BMI, initiation skills were a significant predictor of amount of physical activity per week (standardized beta= -0.214; $p < .003$). After controlling for demographic variables and BMI, Initiation Skills were a significant predictor of amount of physical activity sessions attended per week (standardized beta= -0.234; $p < .001$). Inhibition was not a significant predictor of either frequency of physical activity and number of specific exercise sessions.

CHAPTER FOUR

Discussion

The objective of the present study was to assess the associations between inhibition/ initiation and physical activity in a sample of U.S. university students. While previous studies have demonstrated an association between physical activity and executive functioning using performance-based measures, the present project represents one of the first studies to examine this research question using a behavior rating scale of executive functioning. The results supported my hypothesis that initiation (and not inhibition) would be associated with exercise frequency. In the multiple linear regression analysis, initiation was a significant predictor of physical activity after controlling for demographic variables and BMI. The results of this study are consistent with other studies that have examined executive functions and physical activity. Higher initiatory control has been linked to greater number of hours of exercise and more hours spend studying (de Ridder, de Boer, Lugtig, Bakker, & van Hooft, 2011).

The Theory of Planned Behaviors, which is a cognitive-behavioral approach to predicting behavior that claims that intention to perform a behavior is the best predictor of performing a behavior, uses a construct similar to initiatory control to predict intention to perform a behavior: perceived behavioral control (Gulley & Boggs, 2014). Gulley and Boggs (2014) claim that perceived behavioral control is essentially the same construct as self-efficacy. Self-efficacy is similar to initiation in that they both deal with actually doing a task or behavior. The two are different in that initiation is the ability to start up a task while self-efficacy is the belief in one's ability to complete a task. The Theory of Planned Behavior has been found to be a predictor of physical activity (Gulley & Boggs, 2014; Rhoades, Al-Oballi Kridli, & Penprase, 2011).

The results of this study are consistent with the results of studies that have examined executive functions and other health behaviors, such as diet. Higher initiatory control has been linked to healthy eating behaviors, such as eating more fruits and vegetables (Limbers & Young, 2015). Higher initiation, using the framework of the Theory of Planned Behaviors, has also been linked to eating breakfast (Wong & Mullan, 2009). Beyond relating to other health behaviors, this study may have important clinical implications as well. It may be possible to identify individuals who may be at risk for lower physical activity by knowing that they are lower on initiation. Determining this relationship could help create more effective lifestyle interventions, perhaps interventions that focus on strengthening initiation skills.

My results suggest that initiation skills regardless if measured via performance based measures or behavioral rating scales are associated with physical activity. While the cross-sectional nature of my study precludes me from concluding that initiation skills are a predictor of physical activity, it should be noted that previous research has shown greater physical activity enhances cognitive processes. For example, one study looked at the effect of physical activity on cognitive processes, including the executive function planning in an elementary aged population in Canada (Pirrie & Lodewyk, 2012). One group of participants completed baseline testing after sitting in a classroom for one hour and then completing the same cognitive tests the following week after a one-hour PE lesson. The other group did the exact opposite and had the PE session first and the sitting in the classroom for an hour condition second. They found a main effect for the treatment on the planning test. This main effect demonstrated that planning was increased after physical activity compared to the group with no physical activity. Thus, in the present study it is possible that university students who engaged in greater physical activity reported better initiation skills due to the positive physiological effects of physical activity on cognitive processes.

The Independent samples t-tests did not support the hypothesis that there would be a difference in frequency of physical activity for those with higher initiation than those with lower initiation, but it did support the hypothesis that there would be no significant difference between groups for inhibition. None of the effect sizes for these tests were large. The lack of statistical significant results could have been due to the small number of participants that fell into the elevated category for initiation (N=11) or inhibition (N=26). It will be important for future studies to replicate these findings using larger samples of university students with clinically elevated deficits in inhibition and initiation skills.

In order to test the theory that these results are due to a lack of a substantive population, I decided to run the same independent samples *t* tests using a median split instead of grouping based on clinically significant results. The results for both of the tests on inhibition were still not significant. Interestingly, when splitting the high and low groups based on a median split, initiation became significant. There was a significant difference between those who were high in initiation and those who were not for number of days with 30 minutes or more physical activity (d =0.30, $t\,(231) = 2.527$, $p < .012$). This represents a small effect. Finally, there was not a significant difference between those who were high in initiation and those who were not for a measure of number of days attending a specific exercise class (d = 0.36, t (232) = 2.819, $p < .005$). This represents a small effect. It does seem that there are group differences in physical activity between those who fall above the mean and those who fall below the mean for initiation skills.

Understanding the role of particular executive functions may be important in creating weight loss treatment plans. As mentioned above, initiation is a similar construct to self-efficacy and may be related to self-efficacy. Evidence shows that other executive functions seem to be related to self-efficacy. One study found that older individuals who have a better ability to inhibit habitual responses had higher self-efficacy, or belief in their ability to adhere to a physical activity routine even in the face of barriers, and were more likely to adhere to an exercise routine (McAuley et al., 2011). While there is a general lack of research specifically analyzing the ability of inhibitory and initiatory self-control to predict exercise behaviors, there is much research that analyzes the relationship between self-efficacy and both diet and exercise. Working to increase self-efficacy, or individuals' beliefs in their own ability, has been found to help increase weight loss (J. Annesi, 2013; Byrne, Barry, & Petry, 2012). Further, improving self-efficacy has been shown to predict increased fruit and vegetable consumption as well as exercise behavior changes (J. J. Annesi, 2011; Kreausukon, Gellert, Lippke, & Schwarzer, 2012; Parschau et al., 2013). The study by Annesi (2011) showed that improving self-regulatory skills strengthened self-efficacy, which in turn, led to improved eating and exercise in the severely obese. If improving self-efficacy leads to improved eating and exercise behaviors, and if improving self-regulatory skills leads to improved self-efficacy, then analyzing the relationship between self-regulatory skills and diet and exercise might be interesting. Connecting self-efficacy to the temporal self-regulation theory, it is possible that self-efficacy may play a role in strengthening or moderating the connection between the executive functions and completing the behavior. A future study may use self-efficacy as a possible confound to analyze if the individual executive function remains a predictor of physical activity frequency after controlling for self-efficacy. Furthermore, self-efficacy may act as a moderator explaining the condition in which initiation may best predict completion of physical activity.

Based on the results of the current study and on the current literature, I would consider testing an obesity intervention strategy that involves strengthening initiation and self-efficacy. It seems that strengthening initiation would help an individual both increase frequency of physical activity as well as improve dietary behaviors. Finally, strengthening self-efficacy seems likely to either strengthen or moderate the role of executive functioning.

One limitation of this study was that the sample was predominantly composed of normal weight, Caucasian females from a private university. The results may not be generalizable to other university or young adult populations. Another major limitation of this study was that the measure of physical activity was a self-report measure based on recalling physical activity behaviors over the past seven days. These past seven days may not be representative of a normal week. A future study may ask its participants to keep an exercise log for at least a month to get a more representative sample of normal physical activity behaviors. The cross-sectional nature of the study does not make it possible to infer causation.

Based on the results of this study and information from other research, I would design a future study with the same basic design as the current study. The major differences would be that I would have the participants keep a log of both their sedentary and active behaviors for a month. I would look into their sedentary behaviors to see if the theory that initiatory self-control predicts doing good behaviors while inhibitory self-control predicts not doing bad behaviors (de Ridder et al., 2011). I would then still complete independent samples *t* tests, but I would test initiation and inhibition for both physical activity and sedentary behaviors. Furthermore, I would use self-efficacy as a possible confound in the multiple linear regression models. I would also complete multiple linear regression models for both physical activity and sedentary behaviors.

In conclusion, though no group differences were found for those high or low in either initiation or inhibition based on grouping using clinically significant scores, initiation was found to be a significant predictor of both frequency of physical activity and amount of specific exercise sessions per week. Furthermore, after taking a median split, group differences did exist for those higher in initiation. These results highlight the importance of analyzing executive functions individually in relation to physical activity. Furthermore, such studies could be useful in creating future weight-loss treatment programs, especially once factoring in the role of self-efficacy and its relationship to physical activity, executive functioning, and self-regulation.

APPENDIX

Table 1

Descriptive Statistics for Frequency of Physical Activity, Physical Activity Sessions, and BRIEF-A Clinical Scales

Item/Scale	Mean	SD	Range
How many of the last seven days did you participate in at least 30 minutes of physical activity?	4.39	2.23	0-7
How many of the last seven days did you participate in a specific exercise session (such as swimming, walking, biking) other than what you do around the house or as part of your work?	3.18	2.49	0-7
BRIEF-Inhibit	54.86	9.84	6-82
BRIEF-Initiate	52.64	10.17	36-91

Table 2

Multiple Linear Regression Analysis

Variables	Physical Activity Frequency	Specific Exercise Sessions
Block 1		
R^2	0.02	0.02
Gender	0.03	0.06
Age	0.14*	0.09
Race/Ethnicity	-0.03	-0.05
Parental Education	-0.03	-0.08
Block 2		
R^2 change	0.00	0.00
BMI	-0.01	0.01
Block 3		
R^2 change	0.04**	0.05**
Initiate	-0.21**	-0.23**
Inhibition	0.13	0.06

Note: Beta presented are standardized betas for the full model. *p<.05, **p<.01, ***p<.001

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