THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF KINESIOLOGY

DAILY ACTIVITY AND INACTIVITY ARE ASSOCIATED WITH DAILY EXECUTIVE FUNCTION

PATRICK FITZSIMMONS

SPRING 2013

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree
in Kinesiology
with honors in Kinesiology

Reviewed and approved* by the following:

David Conroy
Professor of Kinesiology and Human Development & Family Studies
Thesis Supervisor

Steriani Elavsky
Assistant Professor of Kinesiology
Honors Adviser

* Signatures are on file in the Schreyer Honors College.

ABSTRACT

Objective: Physical activity is known to play a significant role in prevention of serious health concerns like obesity, diabetes, cancer, and cardiovascular disease. In addition to the physical health benefits, physical activity enhances mental health, including executive function. Recent research has shown the benefits of physical activity on executive functioning in children and older adults, but it remains unclear if physical activity is linked to executive functioning in college students (ages 18 to 25 years). Also, very little is known about how sedentary behavior affects executive function**. Methods**: A 14-day daily diary study was designed to determine the association between perceived executive function and physical activity and inactivity at the between- and within-person level, using self-reported activity. **Results:** Daily physical activity and sedentary behavior are associated with daily perceived executive function at the within-person level. Contrary to previous research, this study did not show support for a between-person association between activity levels and executive function. **Conclusions:** Although knowledge of these benefits (i.e., outcome expectations) will not be sufficient to influence behavior directly, increasing awareness of these benefits may be another route for facilitating intention formation and motivating physical activity. Additionally, these findings reinforce the benefits of increasing daily physical activity and limiting sedentary time for college students who require strong executive functions to succeed academically.

Keywords: executive functioning, physical activity, sedentary behavior, within-person

TABLE OF CONTENTS

LIST OF TABLES

ACKNOWLEDGEMENTS

I'd like my Mom for being supportive throughout the entire process, on days I would call and be frustrated; you would always keep things in perspective and for being my motivation throughout this entire process. I'd also like to thank Dr. Conroy, Amanda Hyde, and Jackie Maher for their continued support, dedication and commitment to me not only as a student but as a person. It was a long process and I was always greeted with a positive attitude and welcoming support at every step of the way. Though this was an overwhelming project at times, I find myself better for it and I have you three to thank for that. You have all given me a better appreciation and understanding for research, and have inspired me to stay involved in research.

<u>Daily Activity and Inactivity Are Associated with Daily Executive Function</u>

Physical activity plays a significant role in the prevention of several chronic diseases like cardiovascular disease, diabetes, cancer and obesity (Warburton, Nicol, & Bredin, 2006; Physical Activity Guidelines Advisory Committee, 2008). In addition to the physical health benefits, physical activity also enhances mental health, including executive functioning (Aha & Fedewa, 2011; Colcombe & Kramer, 2003). The benefits of physical activity on executive functioning have been shown in children (Ahn & Fedewa, 2011) and older adults (Colcombe & Kramer, 2003), but it remains unclear if physical activity is linked to executive functioning, in between those extremes of the lifespan. Additionally, little is known about how sedentary behavior affects executive function. Given that sedentary behavior has distinct physical health consequences from insufficient levels of physical activity (Owen, Healy, Matthews, & Dunstan, 2010) it may have distinct consequences for executive functioning as well. To fill these gaps in the literature the present study tested the association between daily activity and sedentary behavior and executive functioning in a sample of college students.

Executive Functioning

Executive functioning is an overarching construct reflecting the cognitive abilities of inhibition, working memory, and cognitive flexibility (Eslinger, 1996; Lezak, Howieson, Loring, Julia, & Fischer, 2004). *Inhibition* is the ability to stay focused and make decisions; it is a form of self-control over external stimuli, emotions or predisposed behavioral tendencies. *Working memory* is the ability to retain information and store it for later use. The ability to hold information makes it possible for us to remember our plans and others instructions (e.g., class lectures, social conversations). It creates the ability to make abstract connections between unrelated information to produce a higher processed thought. *Cognitive flexibility* is the ability to switch focus and to think about multiple concepts simultaneously (Diamond, 2006). These abilities are important for the cognitive and social tasks that people confront across the lifespan.

For example, in college students, executive function is particularly relevant for academic strivings and self-regulation in the face of increasing autonomy and independence. Executive function has correlated significantly (and positively) with academic achievement across childhood and adolescence (Best, Miller, & Naglieri, 2011).

Physical Activity and Inactivity

Physical activity is defined as any bodily movement produced by skeletal muscles that require energy expenditure (Caspersen, Powell, & Christenson, 1985). Light physical activity, which is often grouped with sedentary behavior, is in fact a distinct construct; it involves energy expenditure between 1.6 and 2.9 METs. Activity in that range includes slow walking, cooking food, and washing dishes, all of which are forms of physical activity (Pate, O'Neill, & Lobelo, 2008). In contrast, sedentary behavior refers to activities that do not increase energy expenditure substantially above the resting level, including activities like sleeping, sitting, lying down and watching television. Overall, sedentary behavior is any activity that involves energy expenditure at the level of 1.0-1.5 metabolic equivalent units (METs) (Pate, O'Neill, & Lobelo, 2008).

Connections between (In)activity and Executive Function

Individual differences in fitness have been repeatedly linked with direct and indirect indicators of executive function. Duration, intensity, and type of exercise have all shown associations with executive function (Castelli et al., 2007; McNaughten & Gabbard, 1993; Ruscheweyh et al., 2011). Multiple studies have found an association between physical activity and academic achievement in elementary school students. Higher fit children performed better on tests than their less active classmates (Carlson et al., 2008; Coe, Pivarnik, Womack, Reeves, & Malina, 2006; Castelli, Hillman, Buck, & Erwin, 2007; Wu et al., 2011). Physical activity also buffers the decline of executive functioning that can occur in later adulthood (Kimura, Yasunaga, & Wang, 2013; Langlois et al., 2012). In a longitudinal study, participants asked to retrospectively record their physical activity when they were children. For those that recorded higher fitness when they were children, higher executive functioning was reported as an adult (Dik, Deeg, Visser, & Jonker, 2003). Increases in cognition, mental functioning, mood and memory storage are also all positively associated with increased physical activity (Hillman et al., 2006; Lichtman & Poser, 1983; Pesce, Crova, Cereatti, Casella, & Bellucci, 2009). There is a gap in literature in reference to college students' physical activity and executive functioning and this study seeks to fill that gap in this study. The available literature suggests the hypothesis that college students who engage in more physical activity overall will report greater perceived executive function.

Sedentary behavior can displace physical activity and confound interpretations of associations between physical activity and executive function because those associations may reflect either insufficient activity or excessive inactivity. Examining these behaviors simultaneously will increase the validity of conclusions about each of their associations with executive function. One study has mixed results when discussing executive function and sedentary behaviors. There was a positive association between directed sedentary behavior (computer usage) and executive function. However, there was a negative association between executive function and sedentary behavior if the sedentary behavior was television watching (Kesse-Guyot et al., 2012). These results were surprising, as sedentary behavior in general was expected to stunt executive function. Due to these mixed results, sedentary behavior and executive function require further investigation. Based on the limited available literature, we hypothesized that sedentary behavior would be associated with lower perceived executive function.

Most of the past research studying the relationship between executive functioning and physical activity or sedentary behavior has focused on differences in executive function between more and less active people (i.e., between-person associations; Aha & Fedewa, 2011; Colcombe & Kramer, 2003). Such between-person associations are important because they inform our understanding of the effects of chronic behavioral differences (Mroczek, Avron Spiro, & Almeida 2003). Associations between daily fluctuations in behavior and executive function are equally important for revealing the effects of acute behavioral differences. College students' schedules are characterized by a variable schedule of academic, extracurricular, and interpersonal demands. Consequently, physical activity and inactivity varies at the daily level. Previous research focused on between-person associations has not been sensitive to that daily variation in behavior so we will examine both between- and within-person associations between physical activity, sedentary behavior, and executive function in this study. In the absence of literature on within-person associations between behavior and executive function, our hypotheses were identical at the between- and within-person levels of analysis.

Methods

Participants

Participants were college students enrolled in undergraduate courses that participated in a daily diary study as part of a class project. All but one participant indicated that they were capable of performing normal physical activity. Another participant did not give permission to use his data for research purposes. Those two participants were excluded from analyses, resulting in a sample of 75 women and 53 men. The sample consisted of predominately White (87%), non-Hispanic (96%) women (58%) in their third (16%) or fourth (78%) year or schooling.

Procedures

Participants provided informed consent and permission to use their data for research purposes, and then completed a questionnaire to provide demographic information. Research assistants instructed participants on how to access a secure website at the end of every day (7pm-4am) over the course of the 14-day study. They were instructed to complete a brief questionnaire about their daily physical activity, sedentary behaviors, and perceived executive function as close to bedtime as possible. The local institutional review board approved all study protocols.

Measures

Executive functioning. Executive functioning was assessed using an abbreviated four-item subscale from the Patient Reported Outcomes Measurement Information System (PROMIS) adapted for daily subjective use. PROMIS is an initiative of the National Institutes of Health (NIH), and is designed to validate self-reported participant outcomes by using a computerized adaptive test for quantitative analysis (Cella et al., 2007). Participants reported how much they agreed with statements such as "Today I have been able to keep track of what I am doing, even if I was interrupted" on a slider scale ranging from 1 (not at all) to 100 (very much). Along with this question, content from the other three items focused on cognitive flexibility, working memory and inhibition, which are all components of executive functioning evaluated by the PROMIS measure.

Physical activity. The International Physical Activity Questionnaire (IPAQ; Booth, 2000) was used to self-report daily physical activity. Items were adapted to focus on physical activity that day instead of over the previous week; Craig et al. (2003) validated IPAQ as an appropriate measure for adult physical activity. An example from the questionnaire would be "Think about all the vigorous activities which take hard physical effort that you did today. Vigorous activities make you breathe much harder than normal and may include heavy lifting, digging, aerobics, or fast bicycling. Think only about those physical activities that you did for at least 10 minutes at a time. How much time did you spend doing vigorous physical activity today? " (IPAQ; Booth, 2000). The other questions focused on the moderate physical activity efforts, walking efforts, and time spent sitting. Physical activity was measured by using a standard data processing procedure of the IPAQ to convert duration of activities into metabolic equivalents. Activity times were weighted by standard MET estimates (vigorous PA=8, moderate PA=4, walking=3.3) and summed to create a daily physical activity MET*minutes/day score (Sjöström et al., 2002, 2005).

Sedentary behavior. Sedentary behavior was measured using the sitting item from the IPAQ (Booth, 2000). The IPAQ-based weekly measure of sedentary behavior was found a reliable measure by Rosenberg et al. (2008). That item from Booth (2000) was adapted for daily administration in this study by modifying it to read. "Think about the time you spent sitting today. Include time spent at work, while doing course work, and during leisure time. This may include time spent sitting at a desk, visiting friends, reading or sitting or lying down to watch television. How much time did you spend sitting today?". Participants recorded the amount of sitting based on total amount of time for that day in hours and minutes; responses were transformed into the total number of minutes.

Data Analyses

Study hypotheses were tested with a hierarchical linear regression model implemented in SAS 9.2 PROC MIXED (Littell, Milliken, Stroup, & Wolfinger, 1996) to account for the nested data structure (days nested within people). Maximum likelihood was used to handle the small amount of missing data. Data was missing for 67 (4%) of the total possible 1,664 person days; 94% of participants provided data for at least 10 days. To estimate both the overall (between-person) and daily (within-person) effects, physical activity and sedentary behaviors variability was separated into between- and within-person components (Snijders & Bosker, 1999). Scores for overall physical activity and sedentary behavior were calculated as the within-person mean score across the 14 days between lab visits. Scores for daily physical activity and sedentary behavior were calculated as the daily deviations from the within-person means. For example, a positive daily physical activity score means that the person was more physically active on that day than their average physical activity levels across the study, and a negative daily physical activity score means that the person was less physically active than usual on that day. In the model, daily ratings of perceived executive functioning were regressed on overall and daily physical activity and sedentary behaviors, and interaction terms between physical activity and sedentary behaviors at the overall and daily levels. The model is presented in equations 1-5.

Level-1 Model:

$$\text{Executive Functioning}_{di} = \beta_{0i} + \beta_{1i}(\text{Daily Physical Activity}_{di}) + \beta_{2i}(\text{Daily Sedentary Behavior}_{di}) + \beta_{3i}(\text{Daily Physical Activity}_{i} \times \text{Daily Sedentary Behavior}_{i}) + e_{di} \quad (1)$$

Level-2 Model:

$$\beta_{0i} = \gamma_{00} + \gamma_{01}(\text{Overall Physical Activity}) + \gamma_{02}(\text{Overall Sedentary Behavior}) + \gamma_{03}(\text{Overall Physical Activity} \times \text{Sedentary Behavior}) + u_{0i} \quad (2)$$

$$\beta_{1i} = \gamma_{10} + u_{1i} \quad (3)$$

$$\beta_{2i} = \gamma_{20} + u_{2i} \quad (4)$$

$$\beta_{3i} = \gamma_{30} + u_{3i} \quad (5)$$

Equation 1 represents the within-person model of daily perceived executive function and it is constrained by the between-person models expressed in equations 2-5. Equation 2 tests if people's typical level of perceived executive functioning is related to their usual levels of physical activity or sedentary behavior ($\gamma_{01,}\ \gamma_{02}$) or the interaction between the usual level of those behaviors. Equation 3 tests if daily deviations in perceived executive functioning are associated with daily deviations in physical activity. Equation 4 tests if daily deviations in perceived executive functioning are associated with daily deviations in sedentary behavior. Equation 5 tests if within-person associations between daily executive functioning and daily deviations in physical activity vary as a function of daily deviations in sedentary behavior. The residual within- and between-person variance terms are represented with the *e* and *u* terms.

Results

Table 1 presents descriptive statistics, intraclass correlations, and bivariate correlations between perceived executive functioning, physical activity and sedentary behavior scores. Correlations were estimated using overall scores which disregard daily fluctuations in scores within people (above the diagonal) as well as daily scores which disregard the nesting of scores across occasions (below the diagonal). Because of the limitations of each correlation coefficient, these estimates are interpreted descriptively rather than inferentially. Physical activity and sedentary behaviors exhibited weak correlations in the expected direction with executive functioning at the within-person but not at the between-person level of analysis. Intraclass correlations suggested that variance in perceived executive functioning, physical activity and sedentary behaviors was distributed both between- and within-people in similar proportions; this finding reinforced the need to test for both between- and within-person associations between these variables.

Table 2 shows the results of the hierarchical linear model testing the study hypotheses. On days when participants were more active than usual (γ_{10}), they reported greater perceived executive function. Additionally, on days when participants were more sedentary than their average (γ_{20}), they reported worse executive function. Random effects show significant residual variability in daily perceived executive function as well as in the associations that physical activity and sedentary behavior exhibited with perceived executive function.

Discussion

This study investigated the association between daily physical (in)activity and perceived executive function. Consistent with study hypotheses, people reported greater executive function on days when they were more active and less inactive than usual. Contrary to study hypotheses, neither activity nor inactivity was associated with differences between people who reported greater and worse executive function.

Between-Person Associations between (In)Activity and Executive Function

Previous research has shown that people who engage in more physical activity exhibit greater executive function (Aha & Fedewa, 2011; Colcombe & Kramer, 2003), but this effect was not replicated in this study. A past study found a positive association between physical activity (self-reported) and faster reaction time and response accuracy on a flanker task as a means of evaluating executive function (Hillman et al., 2006). The decreased reaction time and increased response accuracy on a flanker task indicates an increase in attention. The present study did not observe a similar between-person association. Both studies used self-reports to evaluate physical activity, but differed in the measures used to assess executive function. The objective measures may have found a between-person association because of task specificity. While the present study certainly evaluated the same form of executive functioning (attention) it did so using a self-reported PROMIS measure, which also assessed participants' perceived functional abilities including cognitive flexibility and memory. The objective test used in previous research was a narrower measure of a specific executive function so it will be important to evaluate whether the between-person differences are specific to particular executive functions.

Another study found that an acute bout of moderate to intense exercise might facilitate memory storage in students aged 11-12 years old (Pesce, Crova, Cereatti, Casella, & Bellucci, 2009). The study administered a 20-item word list that was given to the students on three separate occasions. Memory was assessed via free-recall of a 20-item word list that participants reviewed for 1 minute and 40 seconds. Memory was tested in three conditions: 12 minutes of inactivity, 20 minutes of team sport physical activity, and 20 minutes of aerobic physical activity. Participants' recalled more words following the two physical activity conditions than in the baseline test. The unexpected result from the present study may also reflect the use of repeated assessments of executive function over a 2-week period whereas previous research has typically focused on cross-sectional differences in executive function during a single day. Executive function may only provide evidence of a between-person association when dealing with acute bouts of physical activity. Assessing and modeling daily variation in perceived executive function in the present study clarified that a robust within-person association existed between (in)activity and perceived executive function.

Within-Person Association between (In)Activity and Executive Function

To the best of our knowledge, the present results are the first evidence of a within-person association between (in)activity and perceived executive function. One study found that following a 20-minute bout of physical activity, children exhibited greater response accuracy and stimulus related processing on an adapted flanker task (Pontifex, Saliba, Raine, Picchietti, & Hillman, 2013). In addition to an increase in response accuracy, greater performance in reading and arithmetic were observed following physical activity, showing improved comprehension (working memory) and concentration (inhibition). It concluded that single bouts of moderately intense aerobic exercise might have positive implications for executive function in children. The present study extends those findings by demonstrating that daily fluctuations in physical activity volume are associated with perceived executive function and that those acute benefits of physical activity exist over the course of a 14-day period, instead of just at different times of day. These findings also provide the first evidence that sedentary behavior is linked with daily perceived executive function. It would be beneficial to extend this within-person finding by using objective measures of (in)activity and executive function, and by manipulating physical activity and inactivity to test whether the association with executive function is causal in nature. Another interesting extension of this finding would involve applying this study to similar sample populations like working and older adults who engage in limited activity or excessive inactivity on selected days due to the constraints of their roles (e.g. employment). In addition to the adult population, the findings could be examined in the elementary school student population, to see if there are greater gains in acute executive function in the youth or adult populations.

Possible Mechanisms for the Within-Person Association

Overall, there is very limited research that exists about biological mechanisms that can explain why physical activity is influential for executive function. Perhaps the most studied relation would be with measurement of P3 amplitudes and latency periods. Higher-fit individuals compared to lower-fit individuals exhibited increases in P3 amplitude and shorter P3 latency periods, which indicates more flexibility of cognitive control and processing to meet task demands (O'Leary, Pontifex, Scudder, Brown, & Hillman, 2011; Pontifex et al., 2011). There was also a positive association with increases in local gray matter volume in prefrontal and cingulated cortex, and BDNF levels with an increase in total physical activity (Ruscheweyh et al., 2011). These biological results may provide some reasoning for increased daily-perceived executive function in association with increased daily physical activity and inactivity.

Based on the observed variation in executive function and coefficients from this model, a large change in executive function can be realized by modifying one's usual physical activity to include either (a) an additional 20 minutes of vigorous activity, (b) an additional 40 minutes of moderate physical activity, or perhaps most realistically, (c) an additional 50 minutes of walking. A medium-sized change in executive function and physical activity would require adding either (a) 10 minutes of vigorous activity, (b) 20 minutes of moderate physical activity, or (c) 25 minutes of more walking. In contrast, changes in sedentary behavior must be considerably larger to have similar impacts on executive function (5 hrs 20 min less than usual for a large effect, 2 hrs 40 min less than usual for a medium effect). Increasing physical activity seems to be the simpler solution to improve executive function.

Limitations and Future Directions

The present study was conducted with a sample that was largely White, young adults enrolled in college. Studies with more diversity in terms of race, ethnicity and educational attainment are necessary before these conclusions can be generalized to a broader population. Additionally, the research design was non-experimental and did not manipulate physical activity or inactivity so it is not possible to draw causal conclusions from these data. We measured executive function, physical activity and inactivity using self-reported subjective data. In the future, objective measures may prove beneficial for ruling out concerns that participants may have limited awareness of their behavior or executive function (or both). Future research on associations between perceived and actual executive function is necessary to improve our understanding of executive functioning and activity levels.

In summary, this study revealed that physical activity has a positive within-person association with executive functioning and inactivity has a negative within-person association with executive functioning. Although knowledge of these benefits (i.e., outcome expectations) will not be sufficient to influence behavior directly, increasing awareness of these benefits may be another route for facilitating intention formation. Additionally, these findings reinforce the benefits of increasing daily physical activity and limiting sedentary time for college students who require strong executive functions to succeed academically.

REFERENCES

Ahn, S., & Fedewa, A. L. (2011). A meta-analysis of the relationship between children's physical activity and mental health. *Journal of Pediatric Psychology*, *36*(4), 385–397. doi:10.1093/jpepsy/jsq107

Best, J. R., Miller, P. H., & Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. *Learning and Individual Differences*, *21*(4), 327–336. doi:10.1016/j.lindif.2011.01.007

Booth, M. L. (2000). Assessment of physical activity: An international perspective. *Research Quarterly for Exercise and Sport, 71(2 Suppl),* S114–120.

Carlson, S. A., Fulton, J. E., Lee, S. M., Maynard, M. L., Brown, D. R., Kohl, H. W., & Dietz, W. H. (2008). Physical education and academic achievement in elementary school: Data from the early childhood longitudinal study. *American Journal of Public Health*, *98*(4), 721–727. doi:10.2105/AJPH.2007.117176

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports*, *100*(2), 126-131.

Castelli, D. M., Hillman, C. H., Buck, S. M., & Erwin, H. E. (2007). Physical fitness and academic achievement in third- and fifth-grade students. *Journal of Sport & Exercise Psychology*, *29*(2), 239–252.

Cella, D., Yount, S., Rothrock, N., Gershon, R., Cook, K., Reeve, B., … Rose, M. (2007). The patient-reported outcomes measurement information system (PROMIS). *Medical Care*, *45*(5 Suppl 1), S3–S11. doi:10.1097/01.mlr.0000258615.42478.55

Chaddock, L., Hillman, C. H., Pontifex, M. B., Johnson, C. R., Raine, L. B., & Kramer, A. F. (2012). Childhood aerobic fitness predicts cognitive performance one year later. *Journal of Sports Sciences*, 30(5), 421–430. doi:10.1080/02640414.2011.647706

Coe, D. P., Pivarnik, J. M., Womack, C. J., Reeves, M. J., & Malina, R. M. (2006). Effect of physical education and activity levels on academic achievement in children. *Medicine and Science in Sports and Exercise*, *38*(8), 1515–1519. doi:10.1249/01.mss.0000227537.13175.1b

Colcombe, S., & Kramer, A. F. (2003). Fitness effects on the cognitive function of older adults: A meta-analytic study. *Psychological Science*, *14*(2), 125–130. doi:10.1111/1467-9280.t01-1-01430

Craig, C. L., Marshall A. L., Sjöström M., Bauman A. E., Booth M. L., Ainsworth B. E., et al (2003) International physical activity questionnaire: 12-country reliability and validity. *Medicine and Science in Sports and Exercise*, 35 (8), 1381–1395.

Diamond, A. (1996). The early development of executive functions. In E. Bialystok & F.I.M. Craik (Eds.), *Lifespan cognition: Mechanisms of change* (pp. 70-95). NY: Oxford University Press.

Dik, M. G., Deeg, D. J. H., Visser, M., & Jonker, C. (2003). Early life physical activity and cognition at old age. *Journal of Clinical and Experimental Neuropsychology*, *25*(5), 643–653. doi:10.1076/jcen.25.5.643.14583

Eslinger, P. J., & Grattan, L. M. (1993). Frontal lobe and frontal-striatal substrates for different forms of human cognitive flexibility. *Neuropsychologia*, *31*, 17–28.

Hillman, C. H., Motl, R. W., Pontifex, M. B., Posthuma, D., Stubbe, J. H., Boomsma, D. I., & deGeus, E. J. (2006). Physical activity and cognitive function in a cross-section of younger and older community-dwelling individuals. *Health Psychology*, *25*(6), 678–687. doi:10.1037/0278-6133.25.6.678

Kamijo, K., O'Leary, K. C., Pontifex, M. B., Themanson, J. R., & Hillman, C. H. (2010). The relation of aerobic fitness to neuroelectric indices of cognitive and motor task preparation. *Psychophysiology*, *47*(5), 814–821. doi:10.1111/j.1469-8986.2010.00992.x

Kesse-Guyot, E., Charreire, H., Andreeva, V. A., Touvier, M., Hercberg, S., Galan, P., & Oppert, J.-M. (2012). Cross-sectional and longitudinal associations of different sedentary behaviors with cognitive performance in older adults. *PloS One*, 7(10), e47831. doi:10.1371/journal.pone.0047831

Kimura, K., Yasunaga, A., & Wang, L.-Q. (2013). Correlation between moderate daily physical activity and neurocognitive variability in healthy elderly people. *Archives of Gerontology and Geriatrics*, *56*(1), 109–117. doi:10.1016/j.archger.2012.10.004

Kozey-Keadle, S., Libertine, A., Staudenmayer, J., & Freedson, P. (2012). The feasibility of reducing and measuring sedentary time among overweight, non-exercising office workers. *Journal of Obesity*, 1–10. doi:10.1155/2012/282303

Langlois, F., Vu, T. T. M., Chassé, K., Dupuis, G., Kergoat, M.-J., & Bherer, L. (2012). Benefits of physical exercise training on cognition and quality of life in frail older adults. *The Journals of Gerontology*. *Series B, Psychological Sciences and Social Science.* doi:10.1093/geronb/gbs069

Lezak, M. D. (1995). *Neuropsychological assessment* (3rd ed.). New York: Oxford University Press.

Lichtman, S., & Poser, E. G. (1983). The effects of exercise on mood and cognitive functioning. *Journal of Psychosomatic Research*, 27(1), 43–52.

Littell, R. C., Milliken, G. A., Stroup, W. W., & Wolfinger, R. D. (1996). *SAS system for mixed models*. Cary, NC: SAS Institute.

McNaughten D. & Gabbard, C. (1993). Physical exertion and immediate mental performance of sixth-grade children. *Perceptual and Motor Skills*, *77*(3f), 1155–1159. doi:10.2466/pms.1993.77.3f.1155

Mroczek, D., Avron, S., & Almeida, D. M. (2003). Between- and within-person variation in affect and personality over days and years: How basic and applied approaches can inform one another. *Ageing International*, *28*(3), 260–278. doi:10.1007/s12126-002-1007-

O'Leary, K. C., Pontifex, M. B., Scudder, M. R., Brown, M. L., & Hillman, C. H. (2011). The effects of single bouts of aerobic exercise, exergaming, and videogame play on cognitive control. *Clinical Neurophysiology: Official Journal of the*

International Federation of Clinical Neurophysiology, *122*(8), 1518–1525. doi:10.1016/j.clinph.2011.01.049

Owen, N., Healy, G. N., Matthews, C. E., & Dunstan, D. W. (2010). Too much sitting: The population-health science of sedentary behavior. *Exercise and Sport Sciences Reviews*, *38*(3), 105–113. doi:10.1097/JES.0b013e3181e373a2

Pate, R. R., O'Neill, J. R., & Lobelo, F. (2008). The evolving definition of "sedentary". *Exercise and Sport Sciences Reviews*, *36*(4), 173–178. doi:10.1097/JES.0b013e3181877d1.

Pesce, C., Crova, C., Cereatti, L., Casella, R., & Bellucci, M. (2009). Physical activity and mental performance in preadolescents: Effects of acute exercise on free-recall memory. *Mental Health and Physical Activity*, *2*(1), 16–22. doi:10.1016/j.mhpa.2009.02.001

Pontifex, M. B., Saliba, B. J., Raine, L. B., Picchietti, D. L., & Hillman, C. H. (2013). Exercise improves behavioral, neurocognitive, and scholastic performance in children with attention-deficit/hyperactivity disorder. *The Journal of Pediatrics*, *162*(3), 543–551. doi:10.1016/j.jpeds.2012.08.036

Rosenberg, D. E., Bull, F. C., Marshall, A. L., Sallis, J. F., & Bauman, A. E. (2008). Assessment of sedentary behavior with the international physical activity questionnaire. *Journal of Physical Activity & Health*, *5*(Suppl 1), S30–44.

Ruscheweyh, R., Willemer, C., Krüger, K., Duning, T., Warnecke, T., Sommer, J., … Flöel, A. (2011). Physical activity and memory functions: An interventional study. *Neurobiology of Aging*, *32*(7), 1304–1319. doi:10.1016/j.neurobiolaging.2009.08.001

Snijders, T. A. B., & Bosker, R. J. (1999). *Multilevel analysis: An introduction to basic and advanced multilevel modeling*. Sage Publications Ltd.

Stamatakis, E., Hamer, M., Tilling, K., & Lawlor, D. A. (2012). Sedentary time in relation to cardio-metabolic risk factors: Differential associations for self-report vs accelerometry in working age adults. *International Journal of Epidemiology*, *41*(5), 1328–1337. doi:10.1093/ije/dys077

U.S. Department of Health and Human Services. *Physical activity guidelines advisory committee report.* Washington, DC: USDHHS; 2008.

Warburton, D. E. R., Nicol, C. W., & Bredin, S. S. D. (2006). Health benefits of physical activity: The evidence. *Canadian Medical Association Journal*, *174*(6), 801–809. doi:10.1503/cmaj.051351

Watkinson, C., Sluijs, E. M. van, Sutton, S., Hardeman, W., Corder, K., & Griffin, S. J. (2010). Overestimation of physical activity level is associated with lower BMI: A cross-sectional analysis. *International Journal of Behavioral Nutrition and Physical Activity*, *7*(1), 68. doi:10.1186/1479-5868-7-68

Wu, C.-T., Pontifex, M. B., Raine, L. B., Chaddock, L., Voss, M. W., Kramer, A. F., & Hillman, C. H. (2011). Aerobic fitness and response variability in preadolescent children performing a cognitive control task. *Neuropsychology*, *25*(3), 333–341. doi:10.1037/a0022167

APPENDIX

Table 1

Descriptive Statistics and Correlations of Executive Functioning, Physical Activity and Sedentary Behavior

	M	SD	ICC	1	2	3
1. Executive function	71.07	20.74	.51	--	.05	-.06
2. Physical activity (MET•min/day)	648.13	504.70	.47	.05	--	-.29
3. Sedentary time (min/day)	365.21	154.64	.48	-.06	-.29	--

Note. Between-person correlations are on the top half of the matrix. Between-person correlations were calculated between the within-person mean of daily intentions and daily physical activity

Table 2

Coefficients of Hierarchical Linear Model Testing the Moderating Influence of Physical Activity and Sedentary Behavior have on Executive Functioning

Variables	*Fixed Effects*		*Random Effects*	
	Estimate	*SE*	*Estimate*	*SE*
Intercept, γ_{00}	0.02*	0.07	0.52*	0.07
Overall Physical Activity, γ_{01}	0.06	0.08	--	--
Overall Sedentary Behavior, γ_{02}	0.004	0.07	--	--
Overall Physical Activity × Sedentary Behavior, γ_{03}	0.08	0.06	--	--
Daily Physical Activity, γ_{10}	0.10*	0.02	0.02*	0.007
Daily Sedentary Behavior, γ_{20}	-0.05*	0.02	0.02*	0.007
Daily Physical Activity × Sedentary Behavior, γ_{30}	0.03	0.02	--	--
Residual Variance	0.44*	0.02	--	--

Note. Unstandardized estimates based on 100 posterior simulations, * $p < .05$

ACADEMIC VITA

Patrick Fitzsimmons

825 Bellaire Avenue, State College PA, 16801

ptf5013@gmail.com

Education

B.S., Kinesiology 2013, Pennsylvania State University, University Park, Pennsylvania

Research Interests

I have broad interests in sport psychology, particularly motivation in sports and physical activity. Specifically, I am interested in why people exercise, and what mental health benefits, and habitual benefits exercise has on the individual.