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# EFFECTS OF ACADEMIC AND ACTIVITY CLASS PARTICIPATION ON COGNITION IN YOUNG ADULTS

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# EFFECTS OF ACADEMIC AND ACTIVITY CLASS PARTICIPATION ON COGNITION IN YOUNG ADULTS

By

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# CHAPTER ONE

## Introduction to the Study

Current research links physical exercise and nutritional status with cognitive and brain health. Much of the literature focuses on elderly adults or young children, but a gap in knowledge exists for the adult (18-60 years) population.

## Purpose of the Study

The purpose of this study is to evaluate the effects of physical activity on measures of cognition in collegiate activity class students, adjusted for baseline physical fitness and dietary fat intake.

## Statement of Problem

Cognitive impairment toward the end of the human lifecycle generates emotional, physical, and financial hardship for approximately 35.6 million adults globally (Dannhauser et al., 2014). Results of this study will add to the expanding body of knowledge that exercise is medicine, and that nutritional choices may influence the effect of exercise on cognition. The specific aim of this study is to examine the effects of 14 weeks of exercise on five areas of mental performance, including speed, memory, attention, flexibility, and problem solving adjusted for baseline fitness and dietary fat intake.

## Research Questions

1. How does self-reported baseline physical fitness in young adults affect cognitive function across activity levels as categorized by the International Physical Activity Questionnaire (IPAQ)?
2. How does self-reported baseline nutritional status, specifically quantity and variety of fat consumption, in young adults affect cognitive function and changes in cognitive function across activity levels as categorized by the IPAQ?

## Delimitations

The following criteria delimit the study:

1. The study will be delimited to students who are enrolled in an Activity (ACT) class or one of four introductory academic courses (chemistry, psychology, anthropology, or kinesiology) at the University of Montana.
2. Data will be collected online, and supplemented with hard-copy questionnaires.
3. Data will be restricted to self-reported responses from the questionnaires.
4. Additionally, the study will be limited by voluntary participation and a convenience sample.

## Limitations

The following criteria limit the study:

1. Information collected for the study via the internet and hard-copy questionnaires will be limited to the voluntary action of participants completing the questionnaire.

2. Responses gathered for this study will be limited to the honesty and accuracy of the participants during the completion of the questionnaires.
3. Responses gathered for this study will be limited to individuals enrolled in ACT classes and non-activity courses, including psychology, chemistry, anthropology, and kinesiology at the University of Montana during the spring semester of 2015.

## Definition of Terms

1. Block dietary fat screener: This questionnaire is a brief screening tool that includes 17 questions, and takes 5 minutes to complete. The self-administered paper-and-pencil version is useful for clinical applications and was designed to rank individuals with regard to their usual fat intake. Data collected using this form also may be analyzed using prediction equations to generate point estimates of total fat (grams), saturated fat (grams), percent calories from fat, and cholesterol (mg). Portion sizes are not asked.
2. International physical activity questionnaire (IPAQ): The IPAQ is a well-developed instrument that can be used internationally to obtain comparable estimates of physical activity. There are two versions of the questionnaire. The short version is suitable for use in national and regional surveillance systems and the long version provides more detailed information often required in research work or for evaluation purposes. Results are expressed as MET-min per week: MET level x minutes of activity x events per week.
3. Metabolic equivalent (MET): A MET is the amount of oxygen consumed while sitting at rest and is equal to 3.5 ml $O_2$ x kg body weight$^{-1}$ x min$^{-1}$; The usage of the MET concept represents a simple, practical, and easily understood procedure for expressing

the energy cost of physical activities as a multiple of the resting metabolic rate (Jette et al., 1990).

4. Monounsaturated fatty acid (MUFA): MUFA's are fats found in avocados, canola oil, nuts, olives and olive oil, and seeds and are characterized by fatty acids that have one double bond in the fatty acid chain with all of the remainder carbon atoms being single-bonded. (NIH - National Institute of Diabetes and Digestive and Kidney Diseases).
5. Polyunsaturated fatty acid (PUFA): PUFA's are fatty acids with more than one double carbon bond in the fatty acid chain. This type of fat is liquid at room temperature. There are two types of PUFAs: omega-6(ω-6) and omega-3(ω-3) differentiated by the double bonded carbons. Omega-6 fatty acids are found in liquid vegetable oils, such as corn oil, safflower oil, and soybean oil. Omega-3 fatty acids come from plant sources including canola oil, flaxseed oil, soybean oil, and walnuts, and from fish and shellfish (NIH - National Institute of Diabetes and Digestive and Kidney Disease).
6. Physical activity (PA): Physical activity is any bodily movement produced by skeletal muscles that requires energy expenditure (WHO).
7. Physical activity readiness questionnaire (PARQ): A questionnaire which assesses readiness to begin a physical exercise program.
8. University of Montana *ACTivity* (ACT) Classes: These are 1-2 credit classes that meet 2-3 times a week with a requirement that students cannot miss more than 6 hours to pass. For a list of physical activity classes given the abbreviation of ACT at the University of Montana (See Appendix 1).

9. Neurotrophins: Endogenous proteins, such as Brain-Derived Neurotrophic Factor (BDNF), that sustain brain plasticity and potentially mediate the beneficial effects of exercise on the brain (Ploughman, 2008).

# CHAPTER TWO

## Introduction of Literature Review

In recent decades research investigating the interplay between cognition, physical exercise, and nutrition has flourished in a variety of scientific disciplines. This holistic approach benefits from the global emphasis on improving all aspects of health (Bailey et al., 2013). A holistic approach is advantageous since health is multifaceted and omnipotent throughout the lifecycle. Traditionally, research linking physical exercise and nutrition with cognitive health are investigated independently and within specific sectors of the population. Much research has been conducted in youth and elderly, but a paucity exists in the young adult population (Blondell et al., 2014). This review primarily highlights research in the areas of physical exercise relating to cognitive functioning. Secondly, this review independently presents the current relationship of dietary fatty acid (FA) intake to cognitive health. In the literature, both physical exercise and nutrition correlate with cognitive health across the human lifespan, but little is known about the interaction of the two. This review of literature, while evaluating exercise and nutrition separately, will present ideas on the potential direction of future research to understand the supportive roles of both nutrition and exercise, as well as their interaction, on cognition.

## Physical Activity Overview

Physical activity (PA) plays a key role in healthy cognitive functioning, especially in the later stages of life- to reduce risk of cognitive decline and dementia (Scarmeas et al., 2009). The relationship between cognition and exercise has been examined extensively in the elderly and youth populations (Kramer et al., 2006; Khan & Hillman, 2014). Regular PA has been shown to be protective against developing chronic diseases including obesity, Type II diabetes, cardiovascular disease, cancers and others. Independently of PA, these diseases have been linked to reduced cognitive functioning and brain health, thus PA both directly and indirectly attenuates the decline of cognitive health (Khan & Hillman, 2014).

Meta-analyses conducted since 2010 have shown mixed reviews, but overall the data support that PA, defined as the movement of skeletal muscles resulting in energy expenditure exceeding the resting state, does indeed play a role in lowering the risk of cognitive decline (Blondell et al., 2014; Aarsland et al., 2010). Contradictory data was noted by Aarsland and colleagues who found that of five studies looking into PA and cognitive decline, two reported a significant relationship for both sexes, two reported a significant relationship for females only, and one showed no association (Blondell et al., 2014).

Arguably too great an importance has been placed on disease prevention through PA and a lack of emphasis placed on PA for overall health, including cognitive health (Bailey et al., 2013). Less than 50% of the world's population gets the recommended amount of PA to obtain health benefits. Globally, if individuals were sufficiently physically active, about 35% of deaths attributed to coronary heart disease, 25% to stroke and osteoporosis, 20% to colon cancer, hypertension, and type 2 diabetes, and 14% to breast cancer could be prevented. A reduction in chronic disease would concomitantly reduce healthcare costs (Bailey et al., 2013).

## Health Burden of Insufficient PA

Despite the growing evidence for the benefits of PA on health, society and individuals under-appreciate the importance (Bailey et al., 2013). CVD is the leading cause of death globally (Bailey et al., 2013) and it is estimated that individuals who meet PA guidelines reduce their CVD risk and chronic disease health care costs by up to 80% (U.S. CDC-2013).

Given that dementia affects 35 million people globally and is incurable with large negative repercussions on local, national and international economy and societies, treatments must be explored to prevent or attenuate the debilitating effects on individual families, institutions and society as a whole. Dementia, in many instances, may be preventable. Previous studies have shown that regular participation in physical, mental and social leisure activities during middle age is associated with up to a 47% dementia risk reduction over the lifespan. Dannhauser and colleagues designed a program to address possible methods to prevent dementia. Their program, ThinkingFit, aims to engage adults with mild cognitive impairment (MCI) in three activity components: 1) Physical activity, 2) Group-based cognitive stimulation (GCST), and 3) Individual cognitive stimulation (ICST) (Dannhauser et al., 2014). The physical health outcomes include decreased BMI, systolic blood pressure, resting and recovery heart rates, and increased cognition (working memory). Neural recruitment, retention, and engagement rate, were coupled with significant treatment effects in elderly MCI patients. Dannhauser and colleagues conclude that randomized controlled trials using ThinkingFit or similar cognitive, PA interventions could augment current evidence-based recommendations for PA and cognitive health.

## Effects of Physical Activity on the Brain

Many studies have shown that PA influences cognitive performance systemically in the areas of attention, learning, and memory (Ratey and Loehr, 2011; Lin & Kuo, 2013). These executive functions stem primarily from the frontal lobes of the brain and include planning, scheduling, working memory, inhibiting habitual behaviors, reasoning, strategic thinking, and multitasking (Bellebaum & Daum, 2007). Along with systemic affectations, exercise alters the brain at the molecular and cellular levels. At the molecular level, exercise influences neurotrophins (like BDNF) and growth factors (like IGF-1, FGF-2, VEGF, etc.). Cellular adaptations from PA include increases synaptic plasticity, neurogenesis, and angiogenesis (Ratey and Loehr, 2011).

Brain structure has been shown to be altered by PA through increased neural connection density, neurogenesis, and widening of sulci (Lamont et al., 2014). Higher levels of PA are linked to increased cerebral volume, lower rates of atrophy, better cognitive function, and lower risk of cognitive decline and dementia (Lamont et al., 2014).

### *Depression*

Physical exercise is currently a treatment strategy for many patients suffering from depression (Ratey, 2008). The underlying mechanisms responsible for the attenuation of depression via exercise were studied using a murine model. Researchers found that exercised mice could achieve greater resistance to stress-induced changes in brain due to activation of PGC-1α1 in skeletal muscle (Agudelo et al., 2014).

### *Cognitive Decline*

Cognitive decline affects individuals differently, but lifestyle modifications such as increased exercise, cognitive training, and nutritional intervention have been shown to lessen cognitive decline, perhaps even reverse some age-related changes in brain functioning (Vital et al., 2014, Verstynen et al., 2012).

### *Brain-Derived Neurotrophic Factor*

Mechanisms which enable PA to bolster cognition have been in the limelight the past decade. Of the studied concepts, physical exercise is known to robustly enhance brain-derived neurotrophic factor (BDNF) signaling, an essential brain neurotrophin. Neruotrophins are responsible for neural cell proliferation, neurogenesis, and synaptic plasticity. BDNF increases long-term potentiation, learning, retention, and performance in cognitive tasks (Cotman & Berchtold, 2002, Huang et al., 2014, Kramer et al., 2006; Meeusen, 2004, Ploughman, 2008, Ratey & Loehr, 2011).

## Physical Activity and Cognitive Health across the Lifespan

Longitudinal, observational studies show an association between higher PA levels and reduced risk of cognitive decline and dementia (Bherer et al., 2013; Carvalho et al., 2014; Blondell et al., 2014). Regardless of any effect on cognition, PA and reduced sitting should be encouraged, as it has been shown to be beneficial on numerous health levels.

## *Physical Activity and Cognition in Specific Age Groups*

### *Youth*

In several studies, fitness and increased physical exercise is associated with better cognition, attentional control, and achievement in school-age children (Davis & Cooper, 2011; Ortega et al., 2007; Ploughman, 2008).

### *Young Adults*

Moderate-intensity aerobic exercise has been shown to improve cognitive functioning in the young-adult population (Chang et al., 2013; Rattray & Smee, 2013). Chang and colleagues explored potential evidence-based recommendations for the prescription of a single session of exercise to improve cognitive performance. In particular, they evaluated the dose-dependent response relationship between exercise duration and cognitive performance for a moderate intensity session of aerobic exercise. Twenty-six healthy, young men performed 10, 20, or 45 minutes of moderate intensity cycling at ~65% of heart rate reserve. It was found that exercise at moderate intensity for 20 minutes resulted in significantly better cognitive performance (shorter response time and higher accuracy on the administered Stroop Test). This result was found regardless of the type of cognitive function assessed. Additionally, a curvilinear dose-response relationship was observed between exercise duration and cognitive performance. In conclusion an exercise session consisting of a 5-min warm-up, 20 minutes of moderate intensity exercise, and a 5-min cool-down improves cognition; whereas shorter or longer durations of moderate exercise have negligible benefits. This study provides the foundation for the prescription of a single session of moderate exercise to facilitate cognitive function in healthy, younger adults (Chang et al., 2013).

### *Elderly*

Cognitive decline is associated with the aging process, especially at ages ≥50 years. This loss in cognitive function is considered normal and results from a reduction in brain size and plasticity (Blondell et al., 2014). This reduction is associated with molecular, structural, and functional changes in the brain (Leckie et al., 2012). Not all cognitive deterioration is considered normal, however, and the severity is categorized into three sub-types including Cognitive Impairment No Dementia (CIND), Mild Cognitive Impairment (MCI), and Dementia. In a meta-analysis published by Blondell and colleagues in 2014, longitudinal, observational studies were compiled to determine if PA has been shown to prevent cognitive decline and dementia. A total of 47 studies were examined, 21 of which looked at PA and cognitive decline and 26 that examined PA and dementia. The analysis concluded there is an association between higher levels of PA and a reduced risk of cognitive decline and dementia. In regards to future research, the authors highlighted that future studies should employ objective measures of PA, adjust for the full range of confounders, and have adequate follow-up length. Ideally, randomized controlled trials will be carried out. Nonetheless, PA should be encouraged as it has been shown to be beneficial on numerous health benefit levels beyond just cognition (Blondell et al., 2014; Leckie et al., 2012).

### *Physical Activity Summary*

In summary, PA has been shown to attenuate the age-related cognitive decline, reduce depression and anxiety, and benefit executive functioning. Most work has been completed on youth or elderly, and while there is evidence of positive effects of PA in young adults, there is a scarcity of large scale studies to support this. Some dose-response research has been conducted, but much work remains. Furthermore, acute versus chronic effects of exercise has not been studied in depth.

## Nutrition

The examination of nutrition and cognitive health is characteristically broken into broad categories of evaluation which include single and multi-nutrient observations investigated on macro- and micro-nutrient scales.

Current evidence on dietary pattern and cognitive function was recently reviewed by Cheung and colleagues. Their findings indicate the most prevalent nutrition and cognition investigations are retrospective studies with follow-up ranging from three to greater than 30 years. Methods of data analysis vary, but two common approaches, a *priori* and *a posteriori methods,* offer unique advantages and tell a different story. A posteriori methods evaluate just the population under study, so generalizability is challenging (Cheung et al., 2013; Kiefte-de Jong et al., 2014).

Commonly, single-nutrient observations are studied in relation to cognitive function in elderly populations. Numerous studies support improved cognition with dietary habits that consist of fewer processed foods and greater intake of fish, fruits, vegetables, and low-fat dairy. Diets high in polyunsaturated fatty acids (PUFAs), vitamin D, B vitamins, and antioxidants may be linked with improved cognition. Features of these diets parallel one another and include lower overall energy intake, decreased consumption of saturated fatty acids (SFAs), cholesterol, simple sugars, and sodium. The synergism of these features appears to contribute to higher cognitive function in the elderly. Although many studies report positive correlations between single-nutrient intake and cognitive functioning, a major limitation is that these studies lack the complexity of realistic dietary intakes (Cheung et al., 2013).

### *Elderly*

Age-related mental decline is typified by the loss of the short-term memory as a result of a progressive degradation in brain cell processes. Brain damage results from a myriad of etiologies, some of which may likely be affected by diet. The possibility of nutritional intervention as a means to delay onset of cognitive decline may be a practical solution to attenuating the impairment. The most abundant FA in the brain is docsahexaenoic acid (DHA), a derivative of ω-3 PUFA, and the western diet is typically low these FAs. Insufficient DHA has been linked with altered brain processes, memory deficiency, and emotional disturbances in rat models. Human studies with DHA supplementation have shown promising cognitive effects. FAs have been shown to slow age-related cognitive decline and protect against senile dementia. The mechanisms by which ω-3 PUFAs provide optimal effects have recently been under investigation and are linked with specific functions that optimize endogenous brain repair mechanisms. Denis and colleagues hypothesized that adequate DHA intake may influence neuronal functions and protect synaptic transmission. Specifically, that it would influence glutamatergic neurotransmission in the hippocampus, which is the memory forming region of the brain. DHA also plays a vital role in neurogenesis, crucial to maintain cognitive function, stemming from the hippocampus. The researchers found that ω-3 PUFA intake may be a promising intervention for preventing age-related brain deterioration (Denis et al., 2013).

### *Fish Intake*

A higher intake of ω-3 PUFAs and fish may aid in the maintenance of cognitive function in old age. Danthiir and colleagues aimed to tease apart the previous incongruous, inconclusive research by examining the association between multiple areas of cognition and erythrocyte membrane ω-3 PUFA proportions in 390 normal older adults by analyzing baseline data from the Older People, Omega-3, and Cognitive Health trials. Past and present fish intake values were assessed via food-frequency questionnaires, and ω-3 PUFAs in erythrocyte membranes were measured. Cognitive performances were assessed on reasoning, working memory, short-term memory, retrieval fluency, perceptual speed, simple-choice reaction time, speed of memory-scanning, reasoning speed, inhibition, and psychomotor speed. Confounding factors were addressed in the regression analysis, including age, education, sex, apolipoprotein E-ε 4 allele, PA, smoking, alcohol intake, socioeconomic status, and other health-related variables. Higher erythrocyte membrane EPA proportions lent to slower perceptual and reasoning speed in females, which was weakened once current fish intake was controlled. No other positive associations were present between ω-3 PUFA proportions and cognitive performance. Further, contrary to previous studies, Danthiir and colleagues found that higher current fish consumption resulted in slower cognitive speed performance. Higher intake of fish in childhood was shown to decrease perceptual speed and simple-choice reaction time. This study found no evidence to support that higher fish or long-chain ω-3 PUFA intake leads to cognitive benefits (Danthiir et al., 2014).

***Omega-3 Fatty Acids***

DHA performs structural functions and influences numerous neuronal and glial cell processes, accumulates in areas of the brain involved in memory and attention, such as the cerebral cortex and hippocampus. Despite DHA's critical role in brain function, the capacity to synthesize DHA de novo is limited in mammals (Stonehouse et al., 2013). Research on the efficacy of DHA, in terms of its effects on cognitive function in humans, via randomized controlled trials, has focused on end of life cycle or children supplementation on cognitive performance in younger, healthy adults, with only 5 trials, all with considerable design limitations, prior to 2013. Stonehouse and colleagues found that DHA supplementation improved both memory and reaction time in a study with 176 healthy, young adults ages 18-45 years.

Over the past 20 years, the potential role for ω-3 FAs such as docsahexaenoic acid (DHA) and eicosapentaenoic acid (EPA) in the prevention of cognitive decline and Alzheimer's disease (AD) has attracted much interest (Cederholm et al., 2013). The human brain is a lipid-rich organ where DHA is enriched and EPA may have anti-inflammatory effects. Cederholm and colleagues compiled a review of recent observational, interventional, and experimental studies. The review provides insight into whether ω-3 FA intake can moderate cognitive function during aging. The researchers found that in longitudinal, observation studies there are mainly inverse relations between fish intake or serum concentrations of DHA and cognitive impairment. Intervention studies of EPA and DHA supplementation in healthy, older adults have, thus far, been negative (i.e., after up to two years of treatment, no differences in cognitive between treated and non-treated individuals have been seen). In studies that provided EPA and DHA supplements to adults with MCI or age-related cognitive impairment the data appear to be positive, but in those with AD, no benefits were achieved. For studies on healthy adults, a major shortcoming may be the brevity of the trial length. There is also potential for subgroup effects due to risk factor burden or the carriage of certain alleles. Experimental trials have been consistently promising.

Cederholm and colleagues believe the scientific community is nearing evidence-based recommendations on fish and fish oil intake to facilitate memory function during old age. In the meantime, the CDC has maintained their guidelines of consuming 2-3 fish meals per week or equivalent diets containing long-chain ω-3 FAs, particularly DHA.

Morris and colleagues at Rush University in Chicago examined a cohort of 2,560 participants in the Chicago Health and Aging Project (≥ 65 years). Cognitive function was measured three times: at baseline, 3-year, and 6-year follow-ups. Four tests were administered, the East Boston Test of Immediate and Delayed Recall, the Mini-Mental State Examination, and the Symbol Digit Modalities Test. Analysis of the separate mixed models illustrated that higher intakes of SFAs and trans-unsaturated fats were linearly associated with greater decline in cognitive scores over the 6-year period. Additionally, inverse associations with cognitive decline were observed in higher MUFA and PUFA to SFA ratios. Conclusively, a diet high in SFAs and trans-unsaturated FAs could contribute to cognitive decline in elder populations (Morris et al., 2004).

At Brigham and Women's Hospital in Boston, researchers conducted a sub-study of 6,183 older women (≥ 65 years) who participated in the Women's Health Study (WHS) examining cognitive function and dietary fat intake.  The WHS was a randomized, double-blind, placebo-controlled 2 x 2 trial of aspirin and vitamin E supplements for primary prevention of heart disease and cancer. Between 1992 and 1995, 39,876 US female health professionals, aged ≥45 years, were randomized to 1 of 4 factorial groups. In 1998, cognitive exams were conducted via telephone by hypotheses-blind interviewers and consisted of 5 parts: 1) Telephone Interview for Cognitive Status (TCIS); 2) immediate and; 3) delayed recall of the East Boston Memory Test (EBMT); 4) delayed recall trial of the TCIS 10-word list; and 5) category fluency. The EBMT is a verbal memory task of paragraph recall and involves immediate and 15-minute delayed recalls. Scientists categorized FAs into four groups, saturated (SFA), monounsaturated (MUFA), polyunsaturated (PUFA), and trans-unsaturated. The cognitive function took place over 4 years, 5 years after the completion of the WHS.

Researchers found that higher SFA intake was associated with lower global cognitive and verbal memory trajectories. In contrast, higher MUFA intake correlated with better trajectories. These results illustrate that consumption of major specific fat types, rather than total fat intake, appear to influence cognitive aging (Okereke et al., 2012).

***Dairy Intake and Cognitive Health***

Crichton et al., 2010 examined dairy consumption and cognitive performance in adults. The researchers examined three cross-sectional and 5 prospective studies which focused on dairy intake and cognition. Poorer cognitive function and an increased risk for vascular dementia were associated with lower consumption of milk or dairy products. The consumption of whole-fat dairy products, however, may be associated with cognitive decline in the elderly. Due to methodological variability and study limitations, conclusions concerning optimal dairy intake and cognitive performance cannot be drawn. Randomized controlled trials are needed to explore the relationship between dairy intake and cognition (Crichton et al., 2010).

***Nut Intake and Cognition***

A sub-study of the Nurse's Health Study (NHS) was conducted using 16,010 women (≥70 years, mean 74 years) from 1995-2001, to examine the relationship of long-term nut intake to cognitive function. The final sample included 15,467 women who completed the initial cognitive interview and complete information on nut-intake was available. All subjects had no history of stroke. Nuts contain both MUFAs and PUFAs, and are low in SFAs. Researchers found that higher nut intake was related to better overall cognition at older ages, and could be an easily modifiable public health intervention (O'Brien et al., 2014).

### *Nutrition, Physical Activity and Cognition Interplay*

Recent literature has examined the combined effects of dietary intake and physical exercise. A growing body of knowledge explores the interplay between two distinct, dynamic, intertwined entities (Gomez-Pinilla, 2011). Noble and colleagues examined the effects of exercise on hippocampal-dependent memory using rats. The researchers designed the experiment based on previously established research that a western diet hinders, whereas physical exercise augments hippocampus-dependent learning and memory. Diet and exercise both impact expression of hippocampal brain-derived neurotrophic factor (BDNF), which is associated with improved cognition. Researchers used the Sprague-Dawely cognitive test and employed a two-way active avoidance test (TWAA), which exposed rats to a short shock in a specific area of the chamber in which they were housed. Memory was measured by an escape or latency to reenter the chamber where they received the initial shock. The first experiment randomly assigned rats to an exercise or control group. During a second experiment, two groups of rats were fed either a high-fat diet or control diet for 16 weeks, then randomly assigned to running wheel access or sedentary condition. The TWAA memory test was completed once a week for 7 weeks of exercise intervention. Both groups of exercised animals had improved memory as indicated by reduced latency to avoid and escape shocks. Exposure to a high-fat diet led to inferior performance during both the acquisition and retrieval phases of the memory test as compared to controls. Exercise reversed high-fat diet-induced memory impairment, and amplified BDNF in neurons of the hippocampal CA3 region.

Several retrospective, observational studies have been conducted in the past decade that examine dietary fat intake in relation to cognitive health. Studies show a relationship between better cognitive performance and lower SFA and trans-unsaturated fatty acid (TFA) intakes. Associations between higher PA and lower SFA and TFA intakes with better cognitive health have been independently associated. Omega-3 FAs and PA have been independently associated with better cognitive performance (Leckie et al., 2014). Leckie and colleagues aimed to tease apart the potentially modifying effects of FA intake of PA on neurocognitive function. In rat models, DHA supplementation combined with PA had additive effects on synaptic plasticity and membrane structure biomarkers in the hippocampus. Leckie and colleagues examined whether the concomitant effects emerged similarly in middle-aged adults (30- 54 years of age). Subjects were recruited through the University of Pittsburgh Adult Health and Behavior Project. Participants were given a smattering of cognitive tests including Trails A and B, spatial and letter n-back tasks, and Logical Memory from the Wechsler Memory Scale, 3rd edition (WMS-III). Separately, both DHA and PA have been sensitive to this battery of tests.

Researchers recruited 344 participants (mean age 44.42 years, ±6.72 years) and aimed to tease apart the relationship between ω-3 FAs and PA. Both factors have been shown to independently affect neurocognitive function. The ratio of ω-3 to ω-6 FAs was determined by blood samples. Participants were also given the Paffenbarger Physical Activity Questionnaire (PPAQ) to determine level of PA. There was a significant interaction between PA and the ratio of ω-6 to ω-3 FA serum levels on cognitive performance. Higher amount of ω-3 FAs offset the negative effects of lower levels of PA. These results remained significant when compared to the control group (n=299). In conclusion, higher dietary intake of ω-3 FAs attenuated the effect of lower PA levels on cognitive performance. This study reveals the importance of simultaneously examining dietary and PA factors in relation to cognitive health (Leckie et al., 2014).

## Conclusion

There is limited research on the interaction of PA and dietary intake on brain health. The present study will add to the growing body literature that examines the interplay of dietary intake and PA on cognitive health, specifically in the young adult population.

# CHAPTER THREE

## Methodology

### *Participants:*

Approximately 600 experimental subjects, aged 18-40, were recruited from ACT courses through the department of Health and Human Performance. ACT classes met between two and three hours per week during the spring semester (Jan. 27$^{th}$-May 14$^{th}$, 2015). Exclusionary criteria for experimental subjects included: 1) answering yes to any question on the PARQ health screening questionnaire, 2) under age 18 or over age 40, or 3) are a member of a University of Montana varsity athletic team.

Approximately 300 control subjects, aged 18-40, were enrolled in lower division psychology,chemistry, anthropology, and kinesiology classes where the instructor agreed to allow recruitment. Exclusionary criteria for control subjects included: 1) answering yes to any question on the PARQ health screening questionnaire, 2) under age 18 or over age 40, 3) was a current member of a University of Montana varsity team or 4) participated in an activity class.

### *Pilot Testing*

Pilot testing was conducted in the fall semester, 2014. Approximately five activity classes were used to pilot methods and procedures.

***Baseline Information and Data***

During the first week of the 2015 spring semester, all participating leaders of ACT classes and control group classes announced the research and distributed introductory packets to interested students. The introductory packet included a cover letter, informed consent, a brief demographic survey, the IPAQ and the Block 17-item Dietary Fat Screener.

*Cover Letter*

The cover letter asked potential participants to read the informed consent, and if they still wanted to participate, to sign the signature page or call the researchers with any additional questions. If they selected to participate they were instructed to complete the demographic survey, IPAQ and the Block 17-item dietary fat screener. Students who were eligible and chose to participate were asked to complete these forms and return them at the next meeting of the class.

*Brief Demographics Survey:*

The brief demographics questionnaire asked participants to self-report age, gender, class in which they were recruited, height and weight. Subjects were also asked to list all activity classes that they were registered for during the term and sport teams of which they were members.

*International Physical Fitness Questionnaire (IPAQ):*

The IPAQ is a well validated and frequently used screening tool to evaluate habitual physical activity levels. The short form requires about 5 minutes to complete and is coded using set rules. The output reports physcial activity in MET-minutes per week as a total physcial activity load.

From the MET-minutes score, participants were categorized into one of three groups, health enhanching physical activity (HEPA), minimally active (MINIM), and inactive (INA).

*Block 17-item dietary fat screener:*

The Block 17-item dietary screener is a brief screening tool that includes 17 questions and takes 5 minutes to complete. The self-administered paper-and-pencil version is useful for clinical applications and was designed to rank individuals with regard to their usual fat intake. Data collected using this form was analyzed using prediction equations to generate point estimates of total fat (grams), saturated fat (grams), percent calories from fat, and cholesterol (mg). Portion sizes are not asked.

**Cognitive Testing**

*Lumosity ® cognitive tests*

Subjects completed 5 short, computer based brain training games (cognitive testing) on Lumosity.com, within the first week of agreeing to participate in this study. Subjects were provided specific directions for signing-up, using their specific identification number and completing the tests. The cognitive testing battery included a specially designed set of proprietary tests provided by Lumosity Labs®, including the validated Trails A and Trails B tests. The Lumosity.com test battery assessed memory, flexibility, problem solving, speed, and attention, with testing requiring between 15-25 minutes.

*Trails Making Tests A and B*

The Trail Making Tests are a commonly used as a diagnostic tool in clinical settings. Poor performance is known to be associated with many types of brain impairment; in particular frontal lobe lesion. The task requires a subject to 'connect-the-dots' of 25 consecutive targets on a sheet of paper or computer screen. There are two parts to the test: A, in which the targets are all numbers (1, 2, 3, etc.) and the test taker needs to connect them in sequential order, and B, in which the subject alternates between numbers and letters (1, A, 2, B, etc.).

The goal of the test is for the subject is to finish the part A and part B as quickly as possible. The time taken to complete the test is used as the primary performance metric. Error rate is not recorded, however, it is assumed that if errors are made it will be reflected in the completion time. Test B, in which the subject alternates between numbers and letters, is used to examine executive functioning. Part A is used primarily to examine cognitive processing speed.

***Recruitment***

*Activity Class Participants*

The Department of Health and Human Performance at the University of Montana offers over 70 one-credit Activity (ACT) courses which serve more than 1,200 students each semester. These classes range across a broad spectrum of activities from very light (billiards) to intense (mountain biking, strength training, conditioning, etc.). Over the course of a 16-week semester, students were required to attend class two to three times each week totaling 150 minutes, with no more than 6 hours of absence. ACT students were targeted for recruitment to examine potential differences in physical activity compared with students not enrolled in an ACT course.

*Academic Class Participants*

In addition to ACT class recruitment, subjects were recruited from introductory chemistry, psychology, anthropology, and kinesiology courses. Students in all groups were evaluated for habitual PA and additional physical activities that they participated in during the study period using the IPAQ.

## Protection of Human Subjects

The human subject application materials and consent forms were submitted to the University of Montana Institutional Review Board (IRB) for approval (Appendix A). Subjects were identified by an ID number linked to a master name and course (recruited from) list. Confidentiality was maintained.

## Research Design

The study followed a cross-sectional design, with quantitative data. Data collection was conducted during the spring semester (January 27- May 14, 2015). Students willing to participate were given a brief explanation, an informed consent and the opportunity to ask for clarification prior to the completing the informed consent. Baseline screening and testing and post-testing was done as previously noted.

Variables Descriptive variables collected for each participant included, self-reported age, gender, height and weight. These data were used to compare gender, age and BMI group, as well as to describe the population.

Baseline physical activity as determined by the IPAQ and nutritional fat consumptions as determined from the Block 17-item dietary fat screener were used as additional variables.

## Data Analysis

Descriptive statistics were reported as number, mean, and standard error of the mean. Each of the five Lumosity scores, the Trails Making A and B scores, and the baseline dietary fat scores were calculated and used in a Student's t-Test to compare the HEPA group to the MINIM group. Data analysis was conducted using Microsoft Excel.

# CHAPTER FOUR

## Results

### *Subject Descriptive Data*

Initially, 116 students out of approximately 300 recruited, returned the pre-testing packet. Of the 116 returned packets only 31 were complete and provided usable data for this project. Post-testing packets were given to all of the pre-testing participants in an effort to collect complete data for at least a portion of the variables. Of the 31 subjects with complete pre-testing packets, four returned a post-testing packet. The decision was thus made to evaluate the data from the 31 original complete subject data sets in a cross sectional manner and drop the analysis of pre- to post-activity class compared to a control group. See **Table 1** for subject descriptive data.

**TABLE 1:** ***Demographic Data***

| | **Males** | **Females** |
|---|---|---|
| AGE | 22.7 ± 2.5 | 20.8 ± 1.0 |
| HEIGHT (in) | 70.9 ± 0.8 | 65.8 ± 0.8 |
| WEIGHT (lb) | 173.7 ± 6.1 | 141.3 ± 7.1 |
| BMI ($Kg/M^2$) | 24.3 ± 0.7 | 23.0 ± 1.1 |
| MET-min/week | 6263.9 ± 1457.0 | 4183.0 ± 593.3 |

Table 1: Mean age, height, weight, BMI, and MET-minutes of activity per week are reported Mean ± SEM (n=31, 11 males, 20 females).

### *IPAQ Scores*

Self-reported physical activity was collected using the IPAQ. Physical activity values were reported in hours per week and converted to MET-minutes per week. Vigorous-intensity (VIG) and moderate-intensity (MOD) activity were converted by the following formulas: (minutes/week **x** days/week **x** 8.0) and (minutes/week **x** days/week **x** 4.0), respectively. Walking values were converted by (minutes/week **x** days/week **x** 3.3) (IPAQ Scoring, 2004). Subjects were then classified by the number of MET-minutes of physical activity performed each week and grouped into one of three categories- health enhancing physical activity (HEPA) (n=22, 14 females, 8 males), minimally active (MINIM) (n=9, 6 females, 3 males), or inactive. None of the 31 subjects reported physical activity levels low enough for the inactive category. To classify as HEPA, individuals were required to perform VIG activity at least 3 days/week, accumulating 1500 MET-minutes or achieve 7 days of any combination of walking, MOD, or VIG activity achieving a minimum of 3,000 MET-minutes per week. MINIM participants needed to accumulate 3 or more days of VIG activity of at least 20 minutes per day or ≥5 days of any combination of MOD activity or walking of at least 30 minutes per day. Additional criteria for MINIM included achieving ≥5 days of walking, MOD, or VIG activities achieving a minimum of at least 600 MET-minutes per week. To qualify as inactive, participants must have reported no activity or some activity, but not enough to meet HEPA or MINIM requirements. Table 2 illustrates the average MET-minutes for the HEPA and MINIM group for all levels (vigorous- and moderate-intensity and walking).

**TABLE 2:** ***Activity Level by MET- minutes for HEPA and MINIM Groups***

| | **HEPA (n=22)** | **MINIM (n=9)** |
|---|---|---|
| *VIG MET-MINS* | 2575.2 ± 271.9 | 973.3 ± 127.2 |
| *MOD MET-MINS* | 1696.3 ± 325.8 | 377.3 ± 146.5 |
| *WALK MET-MINS* | 1797.7 ± 438.8 | 764.5 ± 176.9 |
| *Total MET Minutes* | 6437.8 ± 838.5 | 2115.2 ± 267.5 |

Table 2: Values are shown from each category of physical activity for HEPA and MINIM groups. The values are reported as mean ± SEM.  HEPA=Health Enhancing Physical Activity Group. MINIM = Minimally Active Group

***Lumosity*® *Test Scores***

A battery of tests from Lumosity Labs® evaluating 5 areas of cognition (memory, flexibility, problem solving, speed, and attention) were completed by all 31 subjects. Tests included Digit-Symbol Coding (speed, memory), Go/no-go (speed, attention), Grammatical Reasoning (flexibility, logical reasoning), Memory Span (memory), Progressive Matrices (flexibility, problem solving), Reverse Memory Span (memory, attention), and Wordy Equations (flexibility, problem solving), plus Trails Making A (speed) and B (speed, flexibility). For each test category scores were evaluated between the HEPA and MINIM groups with a Student's t-Test. No significant difference was found between overall raw score between HEPA and MINIM groups. There were no significant differences at the $\alpha=0.05$ level between HEPA and MINIM for Digital Symbol Coding, Go/no-go, Memory Span, Wordy Equations, Grammatical Reasoning, or Trails Making A and B. For Progressive Matrices and Reverse Memory Span HEPA subjects scored significantly higher than MINIM participants at the $\alpha=0.05$ level ($P<0.05$), see Appendix III for statistics. Table 5 shows the t-test data for the overall Lumosity® score. The Lumosity test score data is shown in Tables 3 and 4.

**TABLE 3*: Categorized Lumosity Scores for the HEPA and MINIM Groups***

| Name of Test | Test Area | HEPA (n=22) | MINIM (n=9) |
|---|---|---|---|
| Digit-Symbol Coding | *speed, memory* | 51.4 ± 1.6 | 47.6 ± 4.0 |
| Go/No-Go | *speed, attention* | 441.4 ±15.1 | 441.9 ± 24.6 |
| Grammatical Reasoning | *flexibility, logical reasoning* | 20.3 ± 2.0 | 24.0 ± 3.0 |
| Memory Span | *memory* | 10.4 ± 0.5 | 9.4 ± 1.0 |
| Progressive Matrices | *flexibility, problem solving* | 9.5 ± 0.7* | 7.0 ± 1.1 |
| Reverse Memory Span | *memory, attention* | 10.0 ± 0.6* | 7.6 ± 0.7 |
| Trails Making A | *speed* | 19921.7 ± 759.9 | 19858.0 ± 1566.9 |
| Trails Making B | *speed, flexibility* | 32801.5 ± 2127.5 | 30411.7 ± 3032.5 |
| Wordy Equations | *flexibility, problem solving* | 16.6 ± 0.9 | 13.6 ± 1.2 |
| **Overall Score** | | **857.7 ± 10.4** | **849.4± 16.6** |

** Significant difference from MINIM (P<0.05)*

**TABLE *4: HEPA compared to MINIM Overall Raw Lumosity Scores***

| | HEPA | MINIM |
|---|---|---|
| Mean ± SEM | 857.6 ± 10.4 | 849.4 ± 16.6 |
| Variance | 2392.227 | 2480.277 |
| Observations | 22 | 9 |
| df | 15 | |
| t Stat | 0.420 | |
| P(T<=t) one-tail | 0.340 | |
| t Critical one-tail | 1.753 | |
| P(T<=t) two-tail | 0.680 | |
| t Critical two-tail | 2.131 | |

Student's t-test illustrating no difference between overall raw score on the Lumosity battery of tests between the HEPA (n=22) and MINIM (n=9) groups.

### ***Block Dietary Fat Screener***

There was no difference in total fatty acid intake or saturated fatty acid intake between the HEPA and MINIM groups at $\alpha=0.05$ level ($P>0.05$) as shown in **Table 5**.

**TABLE *5: Block Dietary Fatty Acid Intake between HEPA and MINIM Groups***

| | TOTAL FAT (grams) | | SAT FAT (grams) | |
|---|---|---|---|---|
| | *HEPA* | *MINIM* | *HEPA* | *MINIM* |
| Mean ± SEM | 81.7 ± 4.2 | 87.4 ± 7.2 | 22.5 ± 1.5 | 24.3 ± 2.5 |
| Variance | 391.752 | 462.400 | 54.970 | 57.666 |
| Observations | 22 | 9 | 22 | 9 |
| df | 29 | | 29 | |
| t Stat | -0.704 | | -0.623 | |
| P(T<=t) one-tail | 0.244 | | 0.269 | |
| t Critical one-tail | 1.699 | | 1.699 | |
| P(T<=t) two-tail | 0.487 | | 0.538 | |
| t Critical two-tail | 2.045 | | 2.045 | |

**TABLE 6:** ***Correlation Matrix of All Variables***

A correlation matrix with all variables was calculated to evaluate the cross sectional bivariate relationship between all variables related to cognitive scores. That matrix is shown in Figure xxx.

| | *Lumos_Test_ALL* | *Digit-symbol coding 45 raw score* | *Go/no-go 32 raw score* | *Grammatical reasoning 46 raw score* | *Memory span 43 raw score* | *Progressive matrices 50 raw score* | *Reverse memory span 44 raw score* | *Trail making a 39 raw score* | *Trail making b 40 raw score* | *Wordy equations 29 raw score* |
|---|---|---|---|---|---|---|---|---|---|---|
| IPAQ SCORE | *0.252* | *0.111* | *-0.055* | *0.057* | *-0.039* | *0.145* | *0.316* | *-0.243* | *-0.230* | *0.323* |
| Vig-MET-Min | 0.315 | 0.206 | -0.170 | 0.023 | 0.095 | 0.238 | 0.510 | -0.214 | -0.200 | 0.303 |
| Mod_MET_Min | 0.196 | -0.010 | -0.059 | -0.234 | -0.030 | -0.029 | 0.143 | -0.317 | -0.188 | 0.445 |
| Light_MET_Min | 0.233 | 0.112 | -0.156 | 0.198 | 0.046 | 0.027 | 0.341 | -0.172 | -0.230 | 0.112 |
| TOTAL UFA (servings/week) | *0.084* | 0.031 | -0.039 | 0.135 | -0.009 | -0.059 | -0.077 | 0.045 | -0.090 | -0.004 |
| UFA_SCORE | *0.089* | 0.036 | -0.009 | 0.182 | -0.025 | -0.063 | -0.069 | 0.000 | -0.093 | -0.014 |
| Total Fat (gm) | *0.142* | 0.197 | -0.111 | 0.155 | 0.271 | 0.187 | -0.034 | 0.167 | -0.071 | -0.121 |
| Saturated Fat (gm) | *0.152* | 0.162 | -0.147 | 0.190 | 0.326 | 0.172 | 0.011 | 0.147 | -0.097 | -0.089 |
| Fat (%) | *0.144* | 0.196 | -0.116 | 0.160 | 0.279 | 0.188 | -0.030 | 0.167 | -0.074 | -0.119 |
| Cholesterol (mg) | *0.175* | 0.152 | -0.181 | 0.204 | 0.324 | 0.173 | 0.030 | 0.130 | -0.107 | -0.042 |
| Percent_Cal_SFA | *0.161* | 0.136 | -0.154 | 0.195 | 0.318 | 0.159 | 0.037 | 0.111 | -0.109 | -0.050 |
| Walnuts | *-0.029* | -0.279 | 0.170 | -0.058 | -0.411 | -0.135 | -0.133 | -0.107 | -0.104 | 0.071 |
| Fatty Fish | *0.238* | 0.148 | -0.340 | -0.003 | 0.275 | 0.007 | 0.149 | 0.049 | -0.115 | 0.169 |
| Avocados | *0.132* | -0.020 | 0.099 | 0.166 | 0.244 | 0.068 | 0.118 | -0.120 | -0.067 | -0.109 |
| Almonds, pecans, cashews | *-0.078* | 0.292 | -0.138 | 0.036 | -0.144 | -0.317 | -0.103 | 0.084 | 0.023 | -0.059 |
| Peanuts | *0.093* | 0.183 | -0.037 | 0.253 | 0.123 | 0.043 | 0.042 | 0.141 | -0.100 | 0.011 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Omega-3 Sup, fish oil | *0.011* | -0.069 | 0.056 | 0.173 | -0.024 | -0.036 | -0.134 | 0.076 | -0.004 | -0.109 |
| ground flaxseed | *0.050* | -0.156 | -0.038 | -0.033 | -0.108 | 0.119 | -0.241 | 0.053 | -0.066 | 0.093 |

| |
|---|
| Significant r>0.362 p<0.05: |
| Significant r>0.467 p<0.01: |
| df=30 |

In a second analysis of the data, each variable was divided into two groups such that group 1 was the half of the group with the lowest values for that variable and group 2 was the half with the highest values for that variable. A between groups ANOVA was then calculated for each pair of variables with one variable being a cognitive score and a second variable being either a nutritional or physical activity score. Each pair of variables was evaluated both with the cognitive score as the factor to see if there was a difference in the non-cognitive variable means and then factoring the non-cognitive score to see if there was a difference in the means of the cognitive score. Significant differences are shown in the list below.

**Physical Activity Groups (Low activity vs. High activity)**

High activity group had significantly higher *Reverse Memory Span 44 test scores*

P =.036 F=4.83 Low activity=8.25±2.3 High activity=10.4±3.1

High activity group had significantly higher *Wordy Equation test scores*

P =.028 F=5.38 Low activity=14.2±4.1 High activity=17.4±3.5

There were no significant differences between the high and low physical activity groups for the overall Lumosity Score or other cognitive scores

**Vigorous Physical Activity Groups (Low vigorous activity minutes vs. High vigorous activity minutes)**

High activity group had significantly higher *Reverse Memory Span 44 test scores*

P =.036 F=4.83 Low activity=8.25±2.3 High activity=9.29±2.9

There were no significant differences between the high and low physical activity groups for the overall Lumosity Score or other cognitive scores

**Lumosity Overall Score (Low score vs. High score)**

High Lumosity Score group has a significantly higher *Vigorous MET Minutes Score*

P =0.039 F=4.69 Low Lumos Score=1643±788 High Lumos Score=2608±1586

There was no significant difference between the high and low Lumosity score for the overall IPAQ score.

**Progressive Matrices 50 Score (Low score vs. High score)**

There were no significant differences between the high and low Progressive Matrices 50 score groups for the overall IPAQ score or for Vigorous MET minutes.

**Reverse Memory Span 44 Score (Low score vs. High score)**

High Reverse Memory 44 score group has a significantly higher *Vigorous MET Minutes Score*

P =0.030 F=5.17 Low Rev Mem Score=1624±808 High Rev mem Score=2629±1561

There were no significant differences between the high and low Reverse memory Span 44 score groups for the overall IPAQ score.

**Wordy Equations 29 Score (Low score vs. High score)**

High Wordy Equations 29 score group has a nearly significant higher *IPAQ Score*

P =0.054 F=4.044 Low Wordy Eq Score=3708±2423 High Wordy Eq 29 Score=6216±4319

There were no significant differences between the high and low Wordy Equations 29 score groups for the Vigorous MET minute score.

**Unsaturated Fatty Acids Servings (Low score vs. High score)**

High Unsaturated Fatty Acids Serving group has a significantly higher overall Lumosity Score

P =0.023 F=5.75 Low Unsat. Fat= 837±40 High Unsat. Fat 29 Score=875±50

There were no significant differences between the Unsaturated Fat serving groups for the physical activity or sub tests of cognition.

**Total Fat (Low score vs. High score)**

There were no significant differences between Total Fat groups for any physical activity or cognition variables.

**Saturated Fat (Low score vs. High score)**

Low Saturated Fat group has a significantly higher overall IPAQ Score

P =0.003 F=10.2 Low Sat. Fat=6691±4278 High Sat. Fat 29 Score=3033±1190

There were no significant differences between Sat Fat groups for Vigorous MET minutes or any cognition variables.

**Percent Fat in diet (Low score vs. High score)**

Low Percent Fat in Diet group has a significantly higher overall IPAQ Score

P =0.024 F=5.64 Low Sat. Fat=6321±4390 High Sat. Fat 29 Score=3428±1773

There were no significant differences between % Fat in Diet groups for Vigorous MET minutes or any cognition variables.

**Total Cholesterol (Low score vs. High score)**

There were no significant differences between Total Cholesterol groups for any physical activity or cognition variables.

**Saturated Fat Percent in Diet (Low score vs. High score)**

There were no significant differences between Saturated Fat groups for any physical activity or cognition variables.

# CHAPTER FIVE

## Discussion

The purpose of this study was to evaluate the effects of habitual physical activity on measures of cognition in college students. At the onset of the study a quasi-experimental design was in place with the intention of evaluating differences in cognitive test scores before and after 12-14 weeks of an exercise intervention (experimental group) or no exercise intervention (control group). As described in the results, only 31 participants completed all portions of the initial surveys; only 4 of the original completed the post-testing survey. Due to the low response rate, a cross-sectional examination of the study was undertaken using the pre-testing data comparing activity level to cognition and dietary fat.

Low response rate from the study may be a result of little incentive for recruits and/or delimitations on subject requirements. Participation in the study required activity (ACT) class participation or enrollment in one of four academic (ACA) courses. Between ACT and ACA subjects, 85 of 116 returned incomplete pre-testing packets. This suggests students either did not understand the directions (regardless of the opportunity for clarification) or did not place importance on completing the entire packet. Students in ACA classes whom were offered extra credit from their respective professors may have returned completed packets in at a higher rate; but records of incentives by specific professors were not documented.

The majority of the students who fully completed the initial survey met the HEPA criteria suggesting that more active students self-selected to this project possibly due to their interest in physical activity. Prior research has shown that those with low physical fitness are most likely to see cognitive benefits from physical activity. While the goal had been to recruit a reasonably representative sample from the student population it is likely that students in activity classes are more interested in physical fitness than non-participants. If this project were to be repeated a different model might have to be employed to recruit lower fit individuals to the experimental (physical activity) group.

The failure of 85 students, out of 116 who returned the survey, to complete all parts of the preliminary testing could have been the result of several aspects of the project. Most likely is that there were too many parts to the initial testing requiring both paper tests and registering online for the Lumosity® testing. It may also be that the directions to complete all parts of the initial testing were confusing. The project was piloted with a number of individuals and all seemed able to easily follow the instructions. An additional problem appeared to be with the login procedures for the Lumosity® testing which required using usernames and passwords that we supplied, but which did not always seem to work. Although an incentive- one iPad mini- was offered at the end of the study, the prize failed to present immediate gratification.

If allowable, recruitment could be bolstered by requiring students to complete the testing as part of the course grade in both ACA and ACT courses. If the study were repeated, it would be beneficial to recruit and retain a greater number of both HEPA and MINIM active participants. To diversify the participant pool, recruiting efforts should be spread across a greater number of academic departments. Additionally, the time requirement and ease of completion could be helped by dropping the nutritional fat survey and providing computers at the time of recruitment. Creating Lumosity accounts prior to distributing the materials would streamline participant time, as well. Adequate funding to have a large enough research group to simultaneously manage the recruitment and logistics for a large number of participants who all start classes at the same time might also be helpful.

Due to low recruitment and completion rates we did not achieve a critical n (power) to measure the small differences that were expected, especially in a cross sectional study. The research group at Lumosity had suggested that a sample size of about 75 was the minimum necessary to power cognition studies with the Lumosity tests. This failure to both complete an interventional study and to have adequate power due to low numbers suggests that the lessons learned in this project would benefit future researchers and help improve methodology. The low sample size may be the reason that few differences between the two (HEPA and MINIM) groups were found. Potentially, with a larger sample, subjects would have been separated into three physical activity groups and the original research questions could have been better examined, especially between inactive and HEPA groups.

Of the tests in the Lumosity test battery, the Reverse Memory Span and Progressive Matrices mean scores were lower in the MINIM compared with HEPA groups. This suggests that, even in a small sample, individuals who are higher fit (HEPA group) perform better in cognitive tasks requiring memory (Reverse Memory Span test) and also in flexibility and problem solving (Progressive Matrices test). Memory, attention, flexibility, and problem solving fall under the executive functioning umbrella of cognitive functions (Salthouse et al., 2003). Executive functioning declines with age and in less physically active individuals (Gajewski & Falkenstein, 2015). This study examined areas of executive functioning and supports that physical activity may benefit executive functioning. Limitations, however, include the small sample size and a cross-sectional design. Although the current findings support the previous studies, no definitive claims should be made based on the results.

The nutritional analysis revealed one significant finding which showed a correlation between the consumption of walnuts and the Wordy Equations Lumosity score. The participants with a higher walnut consumption performed significantly better on the Wordy Equations Lumosity test. Although the correlation was significant, just as the physical activity scores in relation to the two Lumosity tests mentioned previously, the nutritional correlations should not be used to make claims in the literature. This result, however, suggests that a higher intake of walnuts (a high source of ω-3 fatty acids), may positively impact flexibility and problem solving functions of cognition. This finding supports the findings of O'Brien and colleagues in 2014, but does not prove causation. Additionally, since no other category of fatty acid consumptions significantly correlated to physical activity or cognitive score in the analyses, these findings must be interpreted cautiously.

## Conclusion

The current study provides a glimpse of the similarities and differences in cognitive function between HEPA and MINIM active groups of college students. The protocol and methods differed from the intended study in that participants did not complete both pre- and post- testing. Retention may be more successful in future endeavors with a monetary allowance for completion of both parts and/or a reduction in the completion requirements. Although no overall cognitive differences were observed between MINIM and HEPA groups, this may be due to small sample size (n=31) and lack of an experimental intervention. With additional subjects and a group of inactive subjects, differences may be seen. While the overall Lumosity score was not different between the two groups, two Lumosity tests differentiated the HEPA from the MINIM group. Progressive Matrices and Reverse Memory Span scores were higher among HEPA participants than MINIM participants. Both tests assess executive functioning supporting current literature showing greater physical activity is associated with higher cognitive functioning. Finally, our small population of both HEPA active and MINIM active young adults scored similar to the average overall scores as other registered users of Lumosity.com.

# Appendix I: IRB-Approval

## Appendix II: IPAQ

ID_______________

***INTERNATIONAL PHYSICAL ACTIVITY QUESTIONNAIRE***

We are interested in finding out about the kinds of physical activities that people do as part of their everyday lives. The questions will ask you about the time you spent being physically active in the **last 7 days**. Please answer each question even if you do not consider yourself to be an active person. Please think about the activities you do at work, as part of your house and yard work, to get from place to place, and in your spare time for recreation, exercise or sport.

Think about all the **vigorous** activities that you did in the **last 7 days**. **Vigorous** physical activities refer to activities that take hard physical effort and make you breathe much harder than normal. Think *only* about those physical activities that you did for at least 10 minutes at a time.

**1.** During the **last 7 days**, on how many days did you do **vigorous** physical activities like heavy lifting, digging, aerobics, or fast bicycling?

_____ **days per week**

☐ No vigorous physical activities → ***Skip to question 3***

**2.** How much time did you usually spend doing **vigorous** physical activities on one of those days?

________:_________ **hours:minutes per day**

☐ Don't know/Not sure

Think about all the **moderate** activities that you did in the **last 7 days**. **Moderate** activities refer to activities that take moderate physical effort and make you breathe somewhat harder than normal. Think only about those physical activities that you did for at least 10 minutes at a time.

**3.** During the **last 7 days**, on how many days did you do **moderate** physical activities like carrying light loads, bicycling at a regular pace, or doubles tennis? Do not include walking.

_____ **days per week**

☐ No moderate physical activities → ***Skip to question 5***

**4.** How much time did you usually spend doing **moderate** physical activities on one of those days?

________:_________ **hours:minutes per day**

☐ Don't know/Not sure

Think about the time you spent **walking** in the **last 7 days**. This includes at work and at home, walking to travel from place to place, and any other walking that you might do solely for recreation, sport, exercise, or leisure.

**5.** During the **last 7 days**, on how many days did you **walk** for at least 10 minutes at a time?

_____ **days per week**

☐ No walking → ***Skip to question 7***

**6.** How much time did you usually spend **walking** on one of those days?

________:_________ **hours:minutes per day**

☐ Don't know/Not sure

The last question is about the time you spent **sitting** on weekdays during the **last 7 days**. Include time spent at work, at home, 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.

**7.** During the **last 7 days**, how much time did you spend **sitting** on a **week day**?

________:_________ **hours:minutes per day**

☐ Don't know/Not sure

**This is the end of the questionnaire, thank you for participating.**

## Appendix III: Statistics

**TABLE 6:** Reverse Memory Span (RMS) T-test

| | *RMS HEPA raw score* | *RMS MINIM raw score* |
|---|---|---|
| Mean | 10 | 7.556 |
| Variance | 8.476 | 4.278 |
| Observations | 22 | 9 |
| df | 21 | |
| t Stat | 2.635 | |
| P(T<=t) one-tail | 0.008 | |
| t Critical one-tail | 1.721 | |
| P(T<=t) two-tail | 0.015 | |
| t Critical two-tail | 2.080 | |

**TABLE 7:** Digital-Symbol Coding (DSC) T-test

| | *DSC HEPA raw score* | *DSC MINIM raw score* |
|---|---|---|
| Mean | 51.409 | 47.556 |
| Variance | 58.920 | 144.528 |
| Observations | 22 | 9 |
| df | 11 | |
| t Stat | 0.890 | |
| P(T<=t) one-tail | 0.196 | |
| t Critical one-tail | 1.796 | |
| P(T<=t) two-tail | 0.392 | |
| t Critical two-tail | 2.201 | |

**TABLE 8:** Progressive Matrices (PM) T-test

| | *PM HEPA raw score* | *PM MINM raw score* |
|---|---|---|
| Mean | 9.5 | 7 |
| Variance | 12.071 | 11 |
| Observations | 22 | 9 |
| df | 16 | |
| t Stat | 1.879 | |
| P(T<=t) one-tail | 0.039 | |
| t Critical one-tail | 1.746 | |
| P(T<=t) two-tail | 0.079 | |
| t Critical two-tail | 2.120 | |

**TABLE 9** Go/No-Go (GNG) T-test

| | *GNG HEPA score* | *GNG MINIM score* |
|---|---|---|
| Mean | 441.364 | 441.889 |

| | | |
|---|---|---|
| Variance | 4990.338 | 5433.361 |
| Observations | 22 | 9 |
| df | 14.000 | |
| t Stat | -0.018 | |
| P(T<=t) one-tail | 0.493 | |
| t Critical one-tail | 1.761 | |
| P(T<=t) two-tail | 0.986 | |
| t Critical two-tail | 2.145 | |

**TABLE 10:** Grammatical Reasoning (GR) T-test

| | *GR HEPA raw score* | *GR MINIM raw score* |
|---|---|---|
| Mean | 20.318 | 24 |
| Variance | 92.132 | 82 |
| Observations | 22 | 9 |
| df | 16.000 | |
| t Stat | -1.010 | |
| P(T<=t) one-tail | 0.164 | |
| t Critical one-tail | 1.746 | |
| P(T<=t) two-tail | 0.328 | |
| t Critical two-tail | 2.120 | |

**TABLE 11:** Trail Making A (TMA) T-test

| | *TMA HEPA raw score* | *TMA MINIM raw score* |
|---|---|---|
| Mean | 19921.682 | 19858 |
| Variance | 12703683.084 | 22095843 |
| Observations | 22 | 9 |
| df | 12 | |
| t Stat | 0.037 | |
| P(T<=t) one-tail | 0.486 | |
| t Critical one-tail | 1.782 | |
| P(T<=t) two-tail | 0.971 | |
| t Critical two-tail | 2.179 | |

**TABLE 12:** Trail Making B (TMB) T-test

| | *TMB HEPA raw score* | *TMB MINIM raw score* |
|---|---|---|
| Mean | 32801.545 | 30411.667 |
| Variance | 99579394.26 | 82765116.25 |
| Observations | 22 | 9 |
| df | 16 | |

| | |
|---|---|
| t Stat | 0.645 |
| P(T<=t) one-tail | 0.264 |
| t Critical one-tail | 1.746 |
| P(T<=t) two-tail | 0.528 |
| t Critical two-tail | 2.120 |

# Appendix IV: Block 17-item Dietary Fat Screener

## Dietary Fat Screener©

Name : 

Age: 

Sex: O Male O Female

**Think about your eating habits over the past year or so. About how often do you eat each of the following foods? Remember breakfast, lunch, dinner, snacks and eating out. Mark one bubble for each food.**

| Meals and Snacks | (0) 1/ MONTH or less | (1) 2-3 times a MONTH | (2) 1-2 times a WEEK | (3) 3-4 times a WEEK | (4) 5+ times a WEEK | Score |
|---|---|---|---|---|---|---|
| Hamburgers, ground beef, meat burritos, tacos | O | O | O | O | O | ______ |
| Beef or pork, such as steaks, roasts, ribs, or in sandwiches | O | O | O | O | O | ______ |
| Fried chicken | O | O | O | O | O | ______ |
| Hot dogs, or Polish or Italian sausage | O | O | O | O | O | ______ |
| Cold cuts, lunch meats, ham (not low-fat) | O | O | O | O | O | ______ |
| Bacon or breakfast sausage | O | O | O | O | O | ______ |
| Salad dressings (not low-fat) | O | O | O | O | O | ______ |
| Margarine, butter or mayo on bread or potatoes | O | O | O | O | O | ______ |
| Margarine, butter or oil in cooking | O | O | O | O | O | ______ |
| Eggs (not Egg Beaters or just egg whites) | O | O | O | O | O | ______ |
| Pizza | O | O | O | O | O | ______ |
| Cheese, cheese spread (not low-fat) | O | O | O | O | O | ______ |
| Whole milk | O | O | O | O | O | ______ |
| French fries, fried potatoes | O | O | O | O | O | ______ |
| Corn chips, potato chips, popcorn, crackers | O | O | O | O | O | ______ |
| Doughnuts, pastries, cake, cookies (not low-fat) | O | O | O | O | O | ______ |
| Ice cream (not sherbet or non-fat) | O | O | O | O | O | ______ |
| | | | | | **Fat Score =** | ________ |

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# Dietary Fat Screener©

## How well are you doing?

### How to score your answers

- Mark one bubble for each food.
- At the top of each column is a number. At the right side of the page, beside each food, write the number that appears at the top of the column you marked (see the example below).

**EXAMPLE**

| Meals and Snacks | (0) 1/ MONTH or less | (1) 2-3 times a MONTH | (2) 1-2 times a WEEK | (3) 3-4 times a WEEK | (4) 5+ times a WEEK | Score |
|---|---|---|---|---|---|---|
| Hamburgers, ground beef, meat burritos, tacos | ○ | ○ | ⊙ | ○ | ○ | 2 |
| Beef or pork, such as steaks, roasts, ribs, or in sandwiches | ○ | ⊙ | ○ | ○ | ○ | 1 |

Add up these numbers for all of your answers and refer to the scoring key below.

### Scoring key:

**If your score is:**

**0-7:** Your fat intake is very low, probably less than 25% of calories. Congratulations!

**8-14:** Your fat intake is about like most Americans, probably between 30% and 35% of calories. Experts recommend that it be less than 30%. Try eating some of your high-scoring foods less often, and eat more fruits and vegetables.

**15-22:** Your diet is quite high in fat, probably higher than the U.S. average of 35% of calories. Look at the foods you scored highest on. You don't have to give up your favorites, just eat them less often or in smaller portions. Try lower-fat milk, low-fat salad dressing. And fill up on grains, fruits and vegetables!

**23+:** Your diet is very high in fat, probably 40-50% of calories! Look at the foods you scored highest on, and eat them less often. Switch to 2% milk, and low-fat lunch meats and salad dressing. Most of the food you eat should come from bread, rice, cereals, fruits and vegetables.

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