COORDINATIVE AEROBIC EXERCISE DOES NOT ENHANCE ATTENTION AND CONCENTRATION IN COLLEGE STUDENTS

By

Meryl Heather Epstein

Bachelor of Science, Rutgers University, New Brunswick, New Jersey, 2002

Thesis

presented in partial fulfillment of the requirements
for the degree of

Masters of Science
in Health and Human Performance, Exercise Science

The University of Montana
Missoula, MT

Spring 2011

Approved by:

Stephen Sprang, Associate Provost for Graduate Education
Graduate School

Dr. Steven E Gaskill, Chair
Department

Dr. Charles Palmer
Health and Human Performance

Charles Wellenstein, M.S.W
School of Social Work

Epstein, Meryl, Master of Science, Spring 2011 Health and Human Performance
Exercise Science

Coordinative Aerobic Exercise Does Not Enhance Attention and Concentration in College Students

Chairperson: Dr. Steven E. Gaskill

There is a historic and recently growing body of research that shows physical activity and fitness both have a positive effect on cognitive function, improved memory, and learning. The purpose of this study was to determine whether acute moderate to vigorous coordinative-aerobic activity carried out prior to taking the d2 Test of Attention positively affected attention and concentration measures in a sample of college students at the University of Montana. The results of this investigation found no acute physical activity effect on the test scores. The results did demonstrate that there was a significant learning effect to the d2 Test of Attention when repeated after a short time span and that even after a week, participants maintained the improved ability to complete the d2 test. Thus all d2 test improvements were the result of the order they completed the d2 Test of Attention and could not be attributed to the intervention. Before future experimental studies are carried out in a similar manner, there is a need to determine an appropriate wash-out period for the d2 Test of Attention.

Acknowledgements

I would like to thank my chairperson and mentor Steven Gaskill for his support throughout the thesis process. His quick thinking and continual guidance enabled me to complete my research in a timely fashion. I am forever grateful for his help. I would also like to thank my committee members Charlie Palmer and Charlie Wellenstein for their assistance in writing and support. Thank you Joe Domitrovich and Stephanie Domitrovich for your help with statistics and innovative ideas these past two years. I would like to thank my family, particularly Starr, Alan and Cara for always believing in me. Lastly, I would like to thank my best friend and soon to be husband Joseph Pellegrino for his knowledge, direction, and love.

TABLE OF CONTENTS

Chapter One: Statement of the Problem

Research Problem

Physical activity can be added to the school curriculum without being a detriment to student academic achievement positively influencing concentration, memory and classroom behavior (69).   Determining not only if physical activity will spawn academic success, but what form of exercise, how to implement it and how to advantageously integrate it into the school curriculum for the younger student into the college years is not as well known. There is also a paucity of research on cognitive and behavioral responses to physical activity during the school day for middle and high school students (68) and less on college students. Therefore we intend to determine if acute aerobic exercise requiring coordinative complex movements acutely increases concentration and attention scores in college students as measured by the d2 test of attention.

Introduction

The educational system is continually seeking to enhance the learning experience of their students through programs targeted towards improving the teacher's ability to impart and the students' to retain classroom material. Recently, exercise scientists have begun to focus on the benefits of physical activity on learning. Early research is beginning to help us understand the role that physical activity has in the world of academia. Myriad studies have identified the positive benefits of physical education (13, 65), recess (5, 33, 51), and extra-curricular activities (25, 26, 29, 57, 58, 73) on student performance regarding both grades and behavior. A summary report from the Robert Wood Johnson Foundation reported that students who participated in school based physical activity maintained or improved their scores on standardized achievement tests when compared with controls (67). In 2010, the Center for Disease Control (CDC) reviewed the literature and reported the evidence that physical activity is capable of improving academic achievement and effecting cognitive skills, attitudes and academic behavior (16). In the school environment exercise and movement can occur in a number of different venues: physical education, recess, extra-curricular activities and classroom-based physical activity. However, many schools are still resistant to the idea of adding physical activity into their day: only 3.8% of all high schools, 10% of all middle schools and 15.5% of all elementary school districts require that students be provided with regular physical activity breaks (39). College student exercise patterns appear to mimic time spent in physical activity during their primary and secondary schooling with only 40 to 50% of college students physically active (35). If fitness and health are not developed as an integral aspect of learning in a student's younger years, the current situation will remain the reality despite numerous studies showing physical activity is beneficial to cognitive learning.

Relating physical activity and particularly coordinative aerobic exercise, to potential cognitive benefits is straightforward. Aerobic exercise increases cerebral blood flow (30, 34, 37, 63), capillarization (7), and important neurotransmitter and hormone release (8, 46, 72). These physiological changes may help to boost learning in students. The coordinative component of the movement increases synapses in important brain areas such as the cerebellum (4). From an application stand point not only are student's cognitive skills' improving (15, 41, 47) but their ability to concentrate on the lesson presented is increased as well. Coordinative aerobic exercise such as Zumba could serve as a potential new intervention employed to increase cognitive skills in all levels of academia.

Purpose of Research

The purpose of this study is to determine whether moderate to vigorous acute coordinative-aerobic activity carried out prior to taking the d2 test of attention positively affects attention and concentration measures in a sample of college students at the University of Montana. Data from the exercise trial will be used to relate intensity via heart rate (HR) and rating of perceived exertion (RPE) as well as complexity of the activity to its actual effectiveness. The end result will be to provide feedback to determine a prescribed intensity for type of coordinative aerobic exercise and duration for maximal benefits in learning outcomes in the classroom. The main focus of this study will be attention.

Research Hypothesis

H: Engagement in moderate to vigorous acute coordinative aerobic activity will lead to an improvement in concentration and attention scores as measured by the d2 test of attention.

Significance of Study

This study will provide data on cognition, particularly attention and concentration, to acute coordinative aerobic activity in college students, an area of research lacking in the literature. The information collected will help to determine if moderate to vigorous acute coordinative aerobic exercise enhances attention and concentration, two very important factors in the ability to learn. Data will help researchers understand which aspects of exercise guidelines best maximize the student's ability to concentrate. The data can then be used by educational administrators (elementary, middle, high school and college) to be incorporated into the school curriculum to increase student proficiency and classroom efficiency.

Limitations

Limitations for this study will largely come from the actual homogeneity of the sample used. First, the expected sample age will be near 20-24 years. Thus additional research will be necessary to speak on the relevance of these findings of non-college-aged students, especially those in primary and secondary school systems. Results may be related to other sample characteristics such as socio-economic status, present life stressors, etc. which will not be screened, controlled, or monitored. In this way the researchers caution against universal generalizability of the findings. Additionally, findings will be limited to those determinable from the d2 test of attention (visual perceptual speed and concentrative capacities), but not for cognition in general or other attributes of learning or intelligence. Despite controlling for time of day and day of week between trials, the academic calendar will dictate inter-subject differences for the extraneous variable of underlying academic stress/load between those recruited earlier and later during the project. Finally, personal influence by the Zumba instructor herself (atmosphere, energy level) may affect results, but the same instructor, music and dance routine will be used for all participants.

Delimitations

An understanding of learning requires many functional psychological traits; however, testing all of them would necessitate the use of numerous tests and questionnaires. The time and resources demanded both of the subjects and the testers make this impractical. Therefore, only attentiveness will be addressed, as this is considered to be one of the major factors affecting the learning process. Moreover, the location and nature of the d2 test itself is similar to that of an exam (quiet room with all participants taking the test simultaneously). While learning itself is useful in a classroom situation, it was not possible to administer a test in a class setting or similar environment. Lastly, heart rate data will be gathered for average heart rate during the exercise session as well as max value attained, but time spent in heart rate zones, and individual determination of heart rate maximum and resting heart rate could be estimated, but not directly measured. Particular effects of intensity, while interesting, will not be addressed here, and heart rate will be used simply to ensure moderate to vigorous intensity achieved during the Zumba class.

Definition of Terms

Borg Scale: In sports and exercise testing the Borg RPE Scale measures perceived exertion. In medicine this is used to document the patient's exertion during an exercise test, and sports coaches use the scale to assess the intensity of training and competition reported by athletes. The original scale introduced by Gunnar Borg rated exertion on a scale of 6 (very, very light) -20(extremely hard).

Zumba: A fitness program that combines Latin and international music with dance.

Chapter 2: Review of Literature

The decline of physical activity in today's adolescents is of growing concern. It is recommended that school-age youth participate in 60 minutes of moderate to vigorous physical activity a day (59). However, even with a growing awareness of the health needs of today's children, nearly 1/3 of youth and teenagers are overweight with physical inactivity as one of the leading causes (68). Incorporating physical activity into the school day has become more important as several studies have shown that physical activity is beneficial, not only for health and weight, but also to cognitive learning in a school setting. In 2010, the Center for Disease Control (CDC) reported evidence that physical activity is capable of improving academic achievement and effecting cognitive skills, attitudes and academic behavior (16). Similar data are well supported in the literature. Tomporowski et al., found that physical exercise aids children's executive function, adding that physical movement may be effective at enhancing their cognitive development (64). Sibley et al. conducted a review dividing cognitive assessment into eight categories: perceptual skills, intelligence quotient, achievement, verbal tests, math tests, memory, and developmental level/academic readiness and concluded that a significant positive relationship is present between all types of physical activity, both acute and chronic, and cognitive functioning in children (56). A similar trend was found in first year college students. Trockel et al. established a positive relationship with grade point average and amount of time spent strength training (66).

Several studies support the addition of physical activity into the school curriculum, replacing academic time, without being a detriment to student academic achievement (1, 67, 68) and having a positive influence on concentration, memory and classroom behavior (70). However, a recent review conducted in 2005, found that while physical activity, particularly of vigorous intensity, may provide some short-term improvements on concentration, benefits of physical activity on long-term academic gains are inconclusive (62).

Even with the documented benefits of physical activity most schools, particularly high schools, do not provide the opportunity for any physical activity during the school day. A recent study conducted by Lee et al., found that only 3.8% of all districts and 8.6% of all high schools provide regular physical activity breaks for their students (39).

Additionally, according to the Robert Wood Johnson Foundation (RWJF) research brief, the literature on "cognitive and behavior responses to physical activity during the school day have not been systematically investigated among middle or high school students" (p.5, 68), and to the researcher's knowledge very little research exists for college students. With more than 12 million students continuing on to college (48) the decline in physical activity prevalent in the primary and secondary school system may be leading to a decrease in healthy lifestyle choices. This is evident by the findings of Suminski et al., in an ethnically diverse college student population (aged 18-25 years) 46.7% did not engage in vigorous physical activity and 16.7% were not active at all (61). It appears that many students continuing their education beyond high school may not see the connection between the importance of keeping both the mind and the body healthy.

The limited research to date on the role physical activity should have in a school setting, especially high school and college, and what a chronic versus an acute exercise program may be able to provide, has produced mixed results. Complicating matters is innovative research exploring the benefits aerobic exercise, in the form of coordinative complex movements, may have upon cognitive functioning. This new field of research is in its infancy and many questions still remain on the positive role it may play for students in a learning environment.

Physical Fitness and Academics

Several studies have attempted to define the relationship between physical fitness and scholastic achievement. Most have focused their attention on comparing fitness to an academic achievement score or rating. It has been demonstrated that physically active children tend to perform better academically (68).

The Fitness-gram is a well documented fitness test widely used by school systems to determine several aspects of fitness such as aerobic capacity, flexibility, and strength in school-aged children. Several studies have used the Fitness-gram score as a measure of fitness to compare with academic achievement. Castelli et al. used this test for comparison in 259 public schools in third and fifth graders and found a positive relationship between physical fitness and academic achievement as measured by standardized testing. Aerobic fitness, but not strength and flexibility, scores from the Fitness-gram were related to achievement in reading and mathematics (14). Another study of 884,715 California public school children enrolled in fifth, seventh and ninth grade compared their Fitness-gram scores to their reading and mathematics scores on the Stanford Achievement Test. The correlation between physical fitness test and reading and math scores was 0.186 and 0.217 respectively. A constant positive relationship was found: as their overall fitness improved so did their mean achievement scores (28). Other researchers have utilized the Fitness-gram but compared it to the Stroop color-word task testing for interference control, one measure of executive function. Results indicated higher aerobic fitness was linked with better performance on all three Stroop conditions. The authors concluded fitness may serve a beneficial role to cognitive development, particularly aspects of executive function, during preadolescent development (9). While most of these studies are limited by their cross-sectional design they support the theory that higher fitness or scores on the Fitness-gram are related to increased academic achievement. What these studies fail to demonstrate is if improved fitness will improve academic achievement.

Several studies have evaluated general physical fitness tests that are an existing part of the physical education curriculum, and compared them to standardized achievement tests. All reviewed studies reported a positive relationship between performance on a physical fitness test and scholastic achievement. The California Department of Education took data from the 2004 Physical Fitness Test and compared it to the California Standards Tests in fifth, seventh and ninth graders. A strong positive relationship was found, even more so amongst females and those of higher socioeconomic status (SES) (12). McGowan et al. designed a study to determine the relationship between fitness achievement, defined as the number of physical fitness tests passed, and academic achievement scores in mathematics and English in a minority group of public school children. Factors such as weight, sex, grade, and SES were controlled. A statistically significant relationship was found between fitness and academic achievement (17). An Australian study used a nationally representative sample of 7,961 students aged 7-15 years and compared scholastic performance with physical fitness. The fitness test used the following exercises: long jump, sit-and-reach, 50 meter dash, 1.6 km run, sit-ups and push-ups. Academic performance was determined by a five point rating scale, on a continuum of excellent to poor. The findings indicated that physical activity and fitness enhanced academic performance (21).

In contrast to studies showing a positive relationship between fitness and cognition was a study conducted by Martin et al. His sample of 5,847 Seattle school district students in third, fifth, sixth and eighth grade completed the Iowa Test of Basic Skills and the President's Challenge physical fitness test. The correlation between mean physical and academic percentile scores was 0.19. This weak relationship led the authors to the conclusion that the relationship between academic performance and physical fitness is of low importance (44). Another study focused on Chinese primary school children and the relationship between physical fitness and education, behavior and academic performance. The researchers tested 464 children using an eight item fitness test including: bilateral handgrip, shuttle run, standing long jump, vertical jump, and one minute sit-up. Academic performance and conduct were based upon each subject's year-end grades. The authors concluded that no relationship exists between academic performance and behavior in relation to their composite fitness score (38). While the results are mixed, most researchers have found a positive relationship between aerobic fitness and student academic success. Most studies which have found no relationship between fitness and cognition have focused on fitness scores with an emphasis on strength and anaerobic rather than aerobic fitness.

Context of School Based Physical Activity

In 2009 the CDC published a review discussing the effects of physical activity on academic performance. They organized the available literature based upon the school setting and context which it occurred. The following four physical activity contexts were used: school- based physical education, recess, extra-curricular physical activity, and classroom-based physical activity. Each setting provides a different environment for physical activity to occur while impacting cognitive outcomes in school.

School-based Physical Education

Data show that physical education (PE) has dramatically declined over the past two decades. In the United States over 50% of states have either no requirement for PE in high school or require only one semester or year to graduate. In fact, daily PE is missing from many schools: Colorado, Mississippi and South Dakota have no PE mandates at all (43). More recently financial concerns and an increased emphasis on academic achievement scores are accelerating the decrease in physical education. This is especially true at the middle and high school levels.

Recently, several studies have confirmed that sacrificing PE for classroom time does not show an improvement in academic performance (67). In addition, increasing the amount of time spent in PE does not adversely affect academic performance (68). Of the fourteen articles that the CDC included in their review, eleven of the fourteen studies found one or more positive associations between school-based physical education and indicators of academic performance (16).

A number of studies have demonstrated PE and giving academic time to PE, does not hinder academic performance and may even play a beneficial role. Tremarche et al. published a study comparing two Massachusetts schools with differing amounts of PE time in a comparable curriculum. The 311 fourth grade students either attended School 1 with 28 hours of PE or School 2 completing 56 hours of PE per year. All students were required to take the Massachusetts Comprehensive Assessment System (MCAS) and the scores were compared between the two schools. It was found that students receiving more quality PE per school year scored significantly higher in the English and Language Arts portion of the exam. No difference was found in math scores between the two schools (65). It is important to note several limitations to this study: the MCAS is a new measure of assessment and the study was cross-sectional in design with a small sample size using schools from the same area. Another study comparing amount of PE time to standardized test scores took data from the Early Childhood Longitudinal Study. Girls enrolled in more hours of PE scored higher in reading and mathematics. No association between PE hours and academic scores was found for boys (13).

A two year longitudinal randomized study: Sports, Play and Active Recreation for Kids Curriculum (SPARK) evaluated fitness compared to academic achievement based on standardized test scores. Seven schools, grade level k-5, were assigned to one of three conditions: (1) specialist would implement the SPARK program; (2) trained teachers would implement the SPARK program or (3) usual PE program. After two years it was concluded that more time in PE did not have harmful effects on standardized academic achievement test scores in elementary school children (54).

An innovative study was used to manipulate the amount of time spent in PE compared to mental performance on a math computation test. Six treatments were given to four second grade classrooms during PE class. The study design consisted of: pre- and post-math testing with no physical exertion during class compared to twenty, thirty, forty and fifty minutes of physical exertion in the form of five different ball relays. Five minutes after each condition subjects were given a two minute math computation test. Significant differences were only found at the fifty minute treatment suggesting the necessity for a critical duration of physical exertion to occur in order to demonstrate a positive influence on mental performance (27).

In addition to academics, aerobic exercise has been compared to PE for possible effects on creativity. Tuckman et al. evaluated physical and psychological effects of running compared to a normal PE class in fourth, fifth and sixth graders. Students were randomly assigned to a running program or PE. The running program consisted of three 30 minute sessions a week for 12 weeks. Gradual increases in distance and workouts occurred throughout the study. Creativity was measured using the Alternate Uses Test which provides a novel object to the student and they have to name as many appropriate uses for it as they can. Running as opposed to PE appeared to be more effective in enhancing creativity in school aged youth (70). As noted at the beginning of this review, there may be a possible mechanism linking aerobic exercise to improvement in cognitive innovation.

Recess

Another avenue, besides PE, for children to participate in physical activity during the school day is recess. Similar to PE, hours of recess at all school levels has been decreasing over the past two decades: only 3.8% of all high schools, 10% of all middle schools and 15.5% of all elementary school districts required that students are provided with regular physical activity breaks (39). The 2009 CDC review concluded that recess appears to have either a positive or no relationship, depending on the study, on children's attention, concentration and/or on-task behavior. Of the eight studies reviewed, all found one or more positive associations between recess and development of cognitive skills, attitudes and academic behavior. None of the studies found a negative relationship (16). Barros et al. used data from the Early Childhood Longitudinal Study Kindergarten Class of 98-99 and compared the amount of recess children eight to nine years old receive in relation to teacher's ratings of classroom behavior (TRCB). Researchers found that TRCB scores were significantly better for children participating in higher amounts of recess time (time varied between studies) compared to children given minimal recess time or no break at all (5). This study may have the potential for teacher bias and the results are only representative of eight to nine year olds.

Several studies have manipulated timing or location of recess to evaluate the impact those variables have on classroom behaviors. One such study conducted three separate experiments. In the first two the timing of recess was manipulated, the third experiment changed the location of recess. The subjects were in kindergarten, second and fourth grade. The researchers found that pre-recess inattention increased as classroom duration without recess increased. Inattention rates were always higher before recess compared to after recess. The effect of the indoor versus outdoor study suggested that colder temperatures resulted in more physically active play within students (51). Another study, conducted by Stephens et al., controlled recess break and measured classroom behavior in terms of working, fidgeting, and listlessness. A school system with a policy of "uninterrupted instructional time" was chosen and two fourth grade classes participated. Each class was randomly assigned recess once a week 15 to 20 minutes in length on one of the two days when they did not have PE class. When recess was not provided to the students they were on task 85% of the time and fidgeted 16% of the time. With recess they were on task 90% of the time and fidgeted 7%. There was no difference in listless behaviors between the two interventions. The findings suggested children were less efficient with their time during instructional lessons when not provided with a recess break (33).

The findings on recess are incomplete. More research is necessary to determine what age groups, sex, grade, environment and time of day is best for recess to benefit school-aged youth.

Extra-curricular Physical Activity

As adolescents continue in their education, extra-curricular activities become an option providing physical activity within the school setting but outside of the normal school day. Several researchers have explored the relationship that extracurricular physical activity may have on academic grades, behavior and psychological development. At the present time, extra-curricular activities have been found to have a positive relationship with all aspects of education. In fact, in the CDC summary, all nineteen studies reviewed found at least one or more positive associations with participation in extra-curricular activities and academic performance (16).

Extra-curricular activities have been found to have a positive relationship with grade point average. Stephens et al. studied 73 athletes and 63 non-athletes in an urban middle school in Omaha, NE. A student was considered an athlete if they competed in one or more interscholastic sport seasons. The data show that as interscholastic sport participation increased, grade point averages improved (58). A survey sent out to a random sample of high schools in Alberta found that participation in school sports resulted in above average academic achievement (57). Fredricks et al. examined 1,074 youth and found similar findings supporting involvement in athletics is related to a higher than expected grade (25). A limitation to studies in the area of extra-curricular activities is the responsibility of the student to maintain a certain grade point average to be able to participate in after-school sports as well as the higher socio-economic status of students participating in sports. Unfortunately, most research studies do not control for grade point requirements and higher socio-economic status in athletes. These confounding variables may affect the results.

In addition to extra-curricular activities benefiting academics, these activities also appear to have a positive psychological and behavioral component. In a diverse sample of African American and European American youth, organized activity was found to be associated with several developmental benefits in areas such as self-esteem, resiliency and school value for the future (25). Through the use of a survey, Spence et al. cited that high school sport participation is associated with positive lifestyle behaviors (57). In another study using a secondary analysis of the National Educational Longitudinal Study of 1988, 1,883 student scores support prior findings that interscholastic sport participation plays a positive role in adolescents' self-concept and cognitive test scores (73). Another study using data from the National Educational Longitudinal Study of 1988 took a public school sample of 1,105 African American males and 1,112 African American females' participating in either interscholastic or intramural sports. They also found evidence for athletic participation to have a positive impact on aspects such as student motivation and engagement (29).

Fredricks et al., in addition to analyzing academic, behavioral and psychological outcomes from extra-curricular activities, also addressed the effects of extra-curricular participation on future success. Starting with a sample of 1,500 families the sample number changed depending upon the year of data collection. Data was collected via interviews and questionnaires from the participants in eighth grade (n=1,060), again in eleventh grade (n=1,075) and one year after high school (n=912). Findings found that extra-curricular participation was associated with positive academic, psychological and behavioral outcomes including adjustment beyond high school (26).

Data appears to support the positive effect that extra-curricular activities may have on decisions a student makes during and even after their time in school.

Classroom-based Physical Activity

In the Robert Wood Johnson Foundation summary students who participated in school based physical activity maintained or improved their scores on standardized achievement tests when compared with controls (67). Eight out of the nine studies that the CDC reviewed found positive associations between classroom-based physical activity and markers of cognitive ability, attitude, conduct and achievement. None of the studies found negative associations (16). From these results the CDC stated that teachers who integrate movement activities and physical activity breaks into a classroom may possibly improve the academic progress and performance of their students.

It remains unclear what type, timing and duration of physical activity is most beneficial for positive academic and behavioral outcomes. Four different types of physical activity have emerged from the literature. Study designs are using physical activity learning, relaxation, age appropriate activities or aerobic exercise as a method of intervention during the school day. All four activities have shown benefits to students in the school setting.

Physical activity learning is when students are presented with a task and incorporate movement patterns into the lesson. Della Valle et al. presented a word pair task using two conditions to junior high school students. In the first condition the students were presented with 15 word pairs shown at four second intervals while sitting in their seats. The active condition involved the same 15 word pairs, however the students moved around the perimeter of the classroom looking at each card for four seconds and then moving onto the next one. The findings from this study demonstrated that students learned best when they were in the environment they normally preferred. Active students performed better in the active setting and the passive condition better suited the students who favored an inactive learning atmosphere (20).

Another study incorporated a relaxation program during the school day to determine the effects on the classroom setting and academic experience of students. 88 students in five classrooms (mean age = 11.31 years) were introduced to a four week relaxation program. The relaxation program consisted mostly of upper body stretches. Students participated twice daily, each session lasting five to ten minutes. Monitors measured the noise level in each classroom before and after the four weeks. The researchers found a significant reduction in noise after the relaxation program. There was not a significant reduction in student stress levels but teachers reported an increase in student concentration (50). The researchers summarized that relaxation programs may be a beneficial addition to a classroom enabling students to be able to refocus their attention on the task at hand.

Age appropriate activities have an increased appeal due to their grade specific movements. Fredericks et al. studied age appropriate activities in 53 first graders. They randomly assigned the students into one of four groups: (1) experimental, (2) control, (3) educational toys group, and (4) free-play for twenty minutes a day for ten weeks. The experimental condition engaged in progressively more difficult stations containing activities such as flip flops, back rolls or hops. An aptitude test was given to all groups at the beginning and end of the study. Results demonstrated that the experimental group showed significantly greater improvement in their reading and mathematics scores in comparison to the other groups (24). Similarly, 287 boys and girls in fourth and fifth grades participated in an intervention known as Action Schools! BC. This model adds 15 more minutes a day of physical activity in addition to PE. Activities offered were grade appropriate and ranged from skipping to resistance exercises. They found that even with the additional 75 minutes of physical activity a week the students maintained their same level of academics compared to controls (1). In another study the investigators reported not only an improvement in academics but also saw a positive change in the environment and student's behavior after an exercise intervention. Sixty at-risk teenagers in grades ninth through twelfth took part in a six month study. For 20-30 minutes a day 30 students lead each other in exercises such as push-ups, sit-ups and jumping jacks, the other 30 students served as the control. Before and after the study the students took the test of adult basic education. After the six month period the researchers found an improvement in standardized test scores and classroom environment and a decrease in negative social behaviors in the study group when compared to the controls (11). Similarly, Mahar et al. found an improvement in the behavior of students after a classroom based exercise program was introduced. 243 students received "Energizers" (n=135) or served as the control (n=108). "Energizers" are ten minute grade appropriate activities that change depending upon the subject. Examples of the many exercises include: squats, spinning in circles or pretend swimming. After the "Energizers" were executed student's on-task behavior improved (42). These studies suggest that age appropriate activities may be advantageous in a wide range of benefits including improving the classroom environment, behavior and academic functioning of the student.

The final activity intervention generally employed by researchers is the use of acute and chronic aerobic exercise to improve the cognitive skills of students. While most investigators have had students engage in aerobic activity during the school day, two studies reported on an exercise protocol at the end of school day. One study reported an after school program to test the effects of aerobic exercise on the executive function of overweight children. Executive function was determined by a score received on a standardized academic test taken pre- and post-study intervention. 94 elementary school children were randomly assigned to either a control group, low dose (20 minutes of aerobic exercise), or a high dose exercise treatment (40 minutes of aerobic exercise). The intensity of both conditions was the same based on similar heart rates. The intervention lasted 12 weeks. The findings suggest a "threshold effect" may occur in terms of duration of exercise and cognitive gains. There was only a significant difference found between the high dose exercise condition and the control group's executive function suggesting the need for at least 40 minutes of aerobic exercise at the end of the school day to improve executive function in elementary children (19). Stroth et al. also found that an acute aerobic exercise intervention may benefit some cognitive functions. In a six week study, 28 individuals aged 17 to 19 years were equally and randomly assigned to experimental or control conditions. The experimental condition consisted of increasing intensity aerobic walking or running for 30 minutes (weeks 1-2= 70-90% aerobic threshold (AT); weeks 3 - 4 = 90-100% AT and weeks 5 - 6 = 70-100% AT). Subjects took a Visual and Verbal Memory Test before and after completion of the study. The results indicated mood state was elevated and visuospatial but not verbal memory improved in the experimental group compared to the control group (60). The results from all reviewed studies suggest that aerobic activity appears to be a positive end of school day component to improve some cognitive skills.

Studies have also been completed that utilize an aerobic exercise intervention in the classroom. Caterino et al. evaluated 177 second, third and fourth graders. The students were randomly assigned to either staying in the classroom 15 minutes for a continuation of the teacher's lesson plan or given 15 minutes of aerobic walking and stretching. Following the walking or classroom studying students took the Woodcock-Johnson Test of Concentration. Physical activity had no effect on concentration for the second and third graders but the fourth graders who participated in physical activity before the test performed significantly better than those who did not (15). McNaugten et al. conducted a study examining the effects of time and duration of aerobic activity on concentration. In this five week study 120 sixth grade students were either assigned to one of two control groups or one of two experimental groups. The experimental groups participated in 20, 30, and 40 minutes of walking (heart rate around 120-145 beats per minute) at three different time points in the school day: 8:30 a.m., 11:50 a.m., and 2:20 p.m. Pre- and post-testing consisted of a math performance test directly relating to concentration. Math performance was not significantly different for any morning walking duration. However, student's math scores were significantly higher at the 11:50 and 2:20 session for the 30 and 40 minute physical activity sessions compared to the 20 minute session (45). Further research in this area is needed.

Also relevant to our present study is the investigation of acute aerobic exercise and its impact on math performance in the classroom. One study took 32 children and had them participate in three different conditions: no exercise, five minutes of exercise and ten minutes of exercise. All aerobic activity was done at a constant cadence. One minute after each session participants took an achievement test measuring arithmetic performance. Only the five minute exercise bout resulted in a positive effect on arithmetic performance (47). Maeda et al. also used five minutes of aerobic activity to determine its effects on math fluency. One second grade classroom consisting of 19 students incorporated a walking program into their school day four times a week for a total of 61 days. The teacher divided the class into two groups based on their math ability (grade level and below grade level). The study was essentially broken down into two phases that were repeated. Phase one required students to complete as many math problems as they could correctly in one minute. Phase two was five minutes of walking followed by one minute of math problems. A small positive effect from physical activity for math performance was found. The improvement was more apparent in the group below grade level in math ability. The teacher also noted positive changes in student behavior and their ability to concentrate after exercise (41). It appears students, particularly lower performing ones, benefit from an aerobic exercise bout before partaking in a math lesson. More research needs to be conducted to determine the best type, time, and duration of aerobic exercise needed to best assist student's cognitive learning in school.

Cognitive Theories

While it is not the main focus of this review to detail the mechanisms responsible for the influence of exercise on cognitive functioning it is important to note that research on exercise and the mechanisms of its effects on the brain is a growing field. Etnier et al. in 1997 conducted a meta-analytic review on the influence physical fitness and exercise has upon cognitive functioning. They found the overall effect size to be 0.25 suggesting that exercise may have a small but positive effect on cognition (22). This possible effect can best be described by three theories developed within the literature, their findings help support why aerobic exercise that requires coordination may provide the greatest cognitive benefits compared to an aerobic program alone.

Increase in Cerebral Blood Flow

During and after aerobic exercise there is an increase in cerebral blood flow (CBF) (30, 34, 37, 63). Thomas et al. found increases in CBF during dynamic exercise in humans (63). Another study found similar results when subjects were exercising at a high intensity and reported that during recovery after high intensity exercise there were large increases in brain glucose, oxygen and lactate (37). The findings suggest that an acute bout of moderate to high intensity exercise results in a significant increase in CBF. This may benefit cognitive functioning due to the increased delivery of important nutrients to the brain. The increased circulation may further benefit observed structural changes that occur in the brain as a result of exercise.

Structural Changes in the Brain

In exercising animals several physiological changes in the brain have been found to occur. Black et al. found animals who engage in exercise have a greater density of blood vessels compared to animals that are inactive or perform simple acrobatics (7). The aerobic exercise stimulated new blood vessel growth in the prefrontal cortex (36) and cerebellum (7). The cerebellum-prefrontal connection is becoming a focus of research because it is the job of these centers to coordinate thoughts, attention, and emotions, certainly an area important in the process of learning. Black and his colleagues did find that acrobatic animals had a greater number of synapses per Purkinje cell in the cerebellum compared to the animals from the control and exercise group. They proposed motor learning involved with acrobatics, unlike aerobics which requires the repetitive use of synapses during aerobic exercise, is what caused new synapses in the cerebellum to develop (7). Perhaps to reap the greatest benefits of exercise a combination of aerobics (greater density of blood vessels) and complex movement (increased synapses) should be incorporated into a program to increase learning.

Influence of Exercise on Brain Hormones

Several studies have cited that brain neurotransmitters and hormones increase after an acute bout of exercise (4, 8, 46). Currently, brain derived neurotrophic factor (BDNF) has received the most attention. BDNF is present in the hippocampus and has several roles in the brain: it improves the exchange and retention of information by neurons, cell growth, turns on genes to produce neurotransmitters and neurotrophins, stops self-destructive cellular activity, releases antioxidants, and provides proteins used as building materials for axons and dendrites. These activities of BDNF may result in several aspects of learning and understanding to occur at a faster rate. BDNF has consistently shown to be up-regulated with exercise treatments (18) in brain areas including the cerebellum, hippocampus, and cortex (49). Winter et al. evaluated what influence different exercise intensity protocols have on cognition. They took a sample of 27 males, age 19-27, and using a cross-over design assigned them to one condition each week for three weeks. The three conditions were as follows: 15 minutes sedentary, 40 minutes low impact or two three minute sprints at increasing speeds. Following exercise, subjects gave a blood sample and participated in a learning lesson where they were provided with novel words from an artificial language. They were then given a retention test immediately after, a week later and eight months later. Blood samples were also drawn after the retention tests. Results from the study indicated vocabulary learning occurred 20% faster after the intense exercise condition, and brought about the greatest increase in BDNF (72). Ferris et al. also demonstrated the concentration of BDNF in human serum is dependent on exercise intensity. His group measured the largest increase when subjects rode on a stationary bicycle at 10% above ventilatory threshold compared to 20% below (23). In another innovative study, the compound neurotrophic tyrosine kinase receptor type 2 [TrkB], a high affinity receptor for BDNF, was used to bind to BDNF molecules and block BDNF in the hippocampus from binding to specific receptors to determine the role BDNF plays in learning and recall abilities. For one week rats were provided with a running wheel or served as the sedentary control, the group that received voluntary exercise was better able to learn and recall the location of a platform in the Morris water maze (MWM). After five days the exercised animals received the BDNF blocker reducing their ability to find the platform to that measured in the sedentary controls (71).

Schaaf et al. found a dose-dependent relationship between increasing corticosterone concentrations and decreased BDNF mRNA in the hippocampus (55). This may be relevant in a school setting where an acute stressor such as an exam may provide an increase in cortisol, thus decreasing BDNF availability in the hippocampus. However, exercise has been found to suppress the BDNF blockade. Rats given one week of voluntary wheel running before a forced swimming activity (serving as the stressor) did not see a decrease in mRNA BDNF in the hippocampus (53). BDNF may be a link in determining how physical exercise may help to improve learning and its release may be dependent upon the intensity and type of exercise completed. It appears acute, aerobic exercise may result in the greatest retention rate.

Contracting muscles (exercise), as well as the brain, release several important growth factors that travel through the blood brain barrier to aid BDNF during exercise. Vascular endothelial growth factor (VEGF), insulin-like growth factor (IGF-1), and basic fibroblast growth factor (FGF-2) all play key roles in aiding in the learning process as well as having a complex relationship with one another in determining their effects. IGF-1 increases the production of serotonin and glutamate which results in greater number of BDNF receptors. High glucose levels reduce the production of BDNF. In the body, IGF-1 helps deliver glucose to the cells and helps to keep blood glucose levels reduced and allows for maintenance of BDNF production. VEGF allows for the building of more capillaries in the body and brain, it also changes the permeability of the blood-brain barrier allowing other factors into the brain during exercise. FGF-2 aids in tissue growth in the body and the process of long-term potentiation in the brain (strength of brain cell's potential to send a signal across the synaptic gap). It is now apparent that interactions occurring between BDNF, IGF-1, VEGF, and FGF-2 are an intricate network of relationships. For example, Lopez-Lopez et al. used systemic injections of IGF-1 in the brain and found new vessel formation through the regulation of VEGF (40). All the possible mechanisms by which they interact are beyond the scope of this review.

These three theories offer possible explanations for a scientific understanding of how acute aerobic exercise requiring coordination and skill may improve academic achievement in youth and adults. As research continues in this area greater understanding will allow for specific recommendations for activity requirements and the cognitive benefits. Meanwhile, a few notable studies have begun exploring coordinative exercise as an intervention to increase cognition.

Coordination Exercise Studies

Most appropriate and significant to the proposed study is research investigating the relationship between coordinative exercise and cognitive functioning. Complex movement patterns engage the cerebellum which affects areas such as memory and attention, functions the cerebellum is now known to influence. One study found that the circuitry involved in episodic memory had a cortical and cerebellar component much greater than seen from earlier lesion studies (2).

Until recently, no known research had been conducted exploring the influence of an acute bout of coordinative exercise on cognition. In 2008 Budde et al. conducted a study using adolescents in an elite school. Half of the students participated in 10 minutes of a normal sport lesson (control) and the other group completed a coordinative exercise: soccer skills. Both groups completed the d2 test of attention one week before the study and after activity. Even though both groups improved on attention and concentration, a significantly higher progression was found in the coordinative exercise group. The authors suggest that the coordinative exercise was responsible for the significant improvement because the heart rates were comparable between the two groups (10). In contrast, another study compared acute aerobic and coordinative exercise to see if an improvement in attention could be found in graduate students in a classroom setting. Each student took part in all three conditions: fifteen minutes of waking, coordinative exercise, or rest, seven days apart. Each time they took the d2 test of attention. They found that acute aerobic and coordinative exercise did not affect the attention of grad students in a classroom setting (3). More research needs to be conducted to determine the benefits of acute coordinative exercise compared to or in addition to aerobic exercise to benefit cognitive functioning.

Chapter 3: Methodology

Subjects

132 students (male n=40, female n=92), between the ages of 18 and 56 years old (21.4 ± 4.3 years) from the University of Montana took part in this study. All subjects gave written informed consent and completed a PAR-Q identifying them as healthy. Subjects were explained the purpose of the study and risks associated with participating. This study was approved by the Institutional Review Board of the University of Montana.

d2 Test of Attention

The d2 Test of Attention is a cancellation test where visually similar stimuli are simultaneously presented. The test consists of 14 rows of 47 randomly mixed letters: p or d. Subjects were given 20 seconds per line to identify the letter d when it is presented with two dashes above or below it or both above and below. On any given line a subject found several competing stimuli: the letter d with more or less than two dashes and p with any number of dashes. After 20 seconds the participants moved onto the next line. The d2 test of attention took 4.67 minutes to complete.

This test has been found by several investigators to have very high validity and test-retest reliability (6, 52). Bates & Lemay found a significant correlation with the d2 Test of Attention total number correct (TNC) and the Symbol Digit Modalities Test (an assessment of visual scanning, tracking, and sustained attention) and the Stroop Color Word Test (a measure of concentration, distractibility, and response inhibition). Their results support the validity of the d2 Test of Attention's measures as indicator of attention. The internal test–retest reliability of the d2 Test of Attention has been recognized to be extremely high (0.95–0.98), test values have been shown to be stable over an extended period of up to 23 months after initial testing (52).

Physical Activity Intervention

The activity chosen was Zumba which allows participants to self select an intensity level from moderate to vigorous, dependent upon the subject's effort. Additionally Zumba has both aerobic and coordinative components. All classes included a variation of appropriate Zumba music (approximately 6 songs) and dances, including a warm-up and cool down. Each session lasted approximately 25 minutes. The instructor was Zumba certified. During the session each subject wore a coded heart rate monitor (Polar FT1, Finland) from which average heart rate was recorded. Coded heart rate monitors allow close proximity to other subjects wearing heart rate monitors without signal interference.

Research Design

All testing occurred in McGill Hall at the University of Montana in Missoula, Montana. All trials occurred during the months of January through March. Our study utilized a randomized cross-over design. All subjects completed a control and experimental condition in group settings of 10-30 other subjects in their session. The order (control or experimental) was determined using a computer sorter. Trials were separated by 7 days and the time of day was repeated for both trials. Times were determined based on the availability of the subjects, classroom space, and availability of the Zumba instructor.

Experimental Trial

Subjects were instructed to refrain from vigorous or sustained moderate physical activity during the day before attending the testing. Subjects entered a classroom and were given a heart rate transmitter strap with electrode gel applied to the strap to allow for better conductance and heart watch to put on. Participants were instructed to sit for 5 minutes. During this time they were given instruction on how to complete the paper and pencil version of the d2 Test of Attention per the d2 Test of Attention manual. Following the instructions subjects were given the d2 Test of Attention.

After completion of the d2 Test of Attention subjects entered a large carpeted room to participate in 25 minutes of physical activity. All participants removed their shoes and the activity was completed in socks. Before beginning the activity subjects were introduced to the 6-20 Borg Scale of Perceived Exertion and explained how to determine a perceived rating using a correct corresponding number. Subjects were then instructed on how to start their heart rate watches. After starting the heart rate monitors the subjects participated in 25 minutes of directed Zumba activity. At the completion of the session, subjects were instructed to stop their watches which were turned in and later downloaded to obtain heart rate profiles.

Subjects then returned to the classroom (one minute walk down a flight of stairs) where all subjects in every session were offered to hear the d2 Test of Attention instructions again. All sessions declined. They then repeated the d2 Test of Attention. Finally, subjects completed a questionnaire to provide the researchers with information on physical activity habits including vigorous and/or moderate exercise, previous Zumba experience, an overall difficulty rating of the Zumba activity, hours of sleep the night prior, recent food consumed, age, gender, and previous diagnosis of a learning disability.

Control Trial

Subjects entered the classroom and were instructed to sit for 5 minutes. During this time they were given instruction on how to complete the d2 Test of Attention per the d2 Test of Attention manual. The subjects were given the d2 Test of Attention.

After completion of the test subjects remained in the classroom and were instructed to simply sit and study or read quietly for 25 minutes. It was explained to the participants to follow similar rules they would have if they were in a study hall (no cell phones, sleeping, or any activity that is not school related). After 25 minutes subjects then completed the d2 Test of Attention again as done in the experimental trial. Finally, subjects completed a questionnaire to provide the researchers information on hours of sleep the night prior, recent food consumed, age and gender.

Data Analysis

Means and standard deviations were calculated for descriptive characteristics overall and by gender. Differences in total number answers processed (TN), error rate (E) and total number correct (TNC) between the two trials were evaluated overall and within gender using a 2 way (trial by time) repeated measures design covaried for order of treatment. All analysis was completed using SPSS (IBM Corporation, Somers, NY) software. Significance was set at an alpha level of 0.05.

References

1. Ahamed, Y., MacDonald, H., Reed, K., Naylor, P. J., & Liu-Ambrose, T. (2007). School-based physical activity does not compromise children's academic performance. *Medicine & Science in Sports & Exercise, 39*(2), 367-371.

2. Andreasen, N. C., O'Leary, D. S., Arndt, S., Cizadlo, T., Hurtig, R., Rezai, K., et al. (1994). Short-term and long-term verbal memory: A positron emission tomography study. *Behavioral Neuroscience, 108*(5), 848-865.

3. Bailey, E. K., Douglas, T. J., Wolff, D. L., & Bailey, S. (2010). Impact of coordinative and aerobic exercise on attention in graduate students. *Medicine & Science in Sports & Exercise, 42*(5), 432.

4. Barchas, J. D., & Freedman, D. X. (1963). Brain amines: Response to physiological stress. *Biochemistry and Pharmacology, 12*, 1232-1235.

5. Barros, R. M., Silver, E. J., & Stein, R. E. K. (2009). School recess and group classroom behavior. *Pediatrics, 123*(2), 431-436.

6. Bates, M. E., & Lemay, E. P. (2004). The d2 test of attention: Construct validity and extensions in scoring techniques. *Journal of the International Neuropsychological Society, 10*, 392-400.

7. Black, J. E., Isaacs, K. R., Anderson, B. J., Alcantara, A. A., & Greenough, W. T. (1990). Learning causes synaptogenesis, whereas motor activity causes angiogenesis, in cerebellar cortex of adult rats. *Proceedings of the National Academy of Sciences, 87*(5568-5572)

8. Bortz, W. M., Angwin, P., Mefford, I. N., Boarder, M. R., Noyce, N., & Barchas, J. D. (1981). Catecholamines, dopamine, and endorphin levels during extreme exercise. *New England Journal of Medicine, 305*, 466-467.

9. Buck, S. M., Hillman, C. H., & Castelli, D. M. (2007). The relation of aerobic fitness to stroop task performance in preadolescent children. *Medicine and Science in Sports and Exercise, 40*(1), 166-172.

10. Budde, H., Voelcker-Rehage, C., Pietraßyk-Kendziorra, S., Ribeiro, P., & Tidow, G. (2008). Acute coordinative exercise improves attentional performance in adolescents. *Neuroscience Letters, 441*, 219-223.

11. Butler, G. (2009). Exercise and academic achievment in the classroom.

12. California Department of Education. (2005). California physical fitness test: A study of the relationship between physical fitness and academic achievment in California using 2004 test results Sacramento, CA: California Department of Education.

13. Carlson, S. A., Fulton, J. E., & Lee, S. M. (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.

14. 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.

15. Caterino, M. C., & Polak, E. D. (1999). Effects of two types of activity on the performance of second-, third- and fourth-grade students on a test of concentration. *Perceptual and Motor Skills, 89*, 245-248.

16. Center for Disease Control and Prevention. (2010). The association between school-based physical activity, including physical education, and academic performance. Atlanta, GA: U.S. department of health and human services.

17. Chomitz, V. R., Slining, M. M., McGowan, R. J., Mitchell, S. E., Dawson, G. F., & Hacker, K. A. (2009). Is there a relationship between physical fitness and academic achievement? positive results from the public school children in the northeastern United States. *Journal of School Health, 79*(1), 30-37.

18. Cotman, C. W., & Berchtold, N. C. (2002). Exercise: A behavioral intervention to enhance brain health and plasticity. *TRENDS in Neurosciences, 25*(6), 295-301.

19. Davis, C. L., Tomporowski, P. D., Boyle, C. A., Waller, J. L., Miller, P. H., & Naglieri, J. A. (2007). Effects of aerobic exercise on overweight children's cognitive functioning: A randomized controlled trial. *Research Quarterly for Exercise and Sport, 78*(5), 510-519.

20. Della Valle, J., Dunn, R., Geisert, G., Sinatra, R., & Zenhausern, R. (1986). The effects of matching and mismatching students' mobility preferences on recognition and memory tasks. *Journal of Educational Research, 79*(5), 267-272.

21. Dwyer, T., Sallis, J. F., Blizzard, L., Lazarus, R., & Dean, K. (2001). Relation of academic performance to physical activity and fitness in children. *Pediatric Exercise Science, 13*(3), 225-237.

22. Etnier, J. L., Salazar, W., Landers, D. M., Petruzzello, S. J., Han, M., & Nowell, P. (1997). The influence of physical fitness and exercise upon cognitive functioning: A meta-analysis. *Journal of Sport & Exercise Psychology, 19*, 249-277.

23. Ferris, L. T., Williams, J. S., & Shen, C. (2007). The effect of acute exercise on serum brain-derived neurotrophic factor levels and cognitive function. *Medicine & Science in Sports & Exercise, 39*(4), 728-734.

24. Fredericks, C. R., Kokot, S. J., & Krog, S. (2006). Using a developmental movement programme to enhance academic skills in grade 1 learners. *South African Journal for Research in Sport, Physical Education and Research, 28*(1), 29-42.

25. Fredricks, J., & Eccles, J. (2008). Participation in extracurricular activities in the middle school years: Are there developmental benefits for African American and European American youth? *Journal of Youth and Adolescence, 37*(9), 1029-1043.

26. Fredricks, J. A., & Eccles, J. S. (2006). Is extracurricular participation associated with beneficial outcomes? Concurrent and longitudinal relations. *Developmental Psychology, 42*(4), 698-713.

27. Gabbard, C. (1978). Physical exertion and immediate classroom mental performance among elementary school children. *U.S. Department of Health Education & Welfare National Institute of Education*.

28. Grissom, J. B. (2005). Physical fitness and academic achievement. *Journal of Exercise Physiology Online,* 11-25.

29. Hawkins, R., & Mulkey, L. M. (2005). Athletic investment and academic resilience in a national sample of African American females and males in the middle grades. *Education and Urban Society, 38*(1), 62-88.

30. Herholz, K., Buskies, W., Rist, M., Pawlik, G., Hollmann, W., & Heiss, W. D. (1987). Regional cerebral blood flow in man at rest and during exercise. *Journal of Neurology, 234*(1), 9-13.

31. Hillman, C. H., Castelli, D. M., & Buck, S. M. (2005). Aerobic fitness and neurocognitive function in healthy preadolescent children. *Medicine and Science in Sports and Exercise, 37*(11), 1967-1974.

32. Isaacs, K. R., Anderson, B. J., Alcantara, A. A., Black, J. E., & Greenough, W. T. (1992). Exercise and the brain: Angiogenesis in the adult rat cerebellum after vigorous physical activity and motor skill learning. *Journal of Cerebral Blood Flow Metabolism, 12*(1), 110-119.

33. Jarrett, O. S., Maxwell, D. M., Dickerson, C., Hoge, P., Davies, G., & Yetley, A. (1998). Impact of recess on classroom behavior: Group effects and individual differences. *The Journal of Educational Research, 92*(2), 121-126.

34. Jorgensen, L. G., Perko, G., & Secher, N. H. (1992). Regional cerebral artery mean flow velocity and blood flow during dynamic exercise in humans. *Journal of Applied Physiology, 73*(5), 1825-1830.

35. Keating, X. D., Guan, J., Pinero, J. C., & Bridges, D. M. (2005). A meta-analysis of college students' physical activity behaviors. *Journal of American College of Health, 54*(2), 116-125.

36. Kleim, J. A., Cooper, N. R., & VandenBerg, M. (2002). Exercise induces angiogenesis but does not alter movement representations within rat motor cortex. *Brain Research, 934*, 1-6.

37. Kojiro, I., & Secher, N. H. (2000). Cerebral blood flow and metabolism during exercise. *Progress in Neurobiology, 61*, 397-414.

38. Lau, P., Yu, C., Lee, A., So, R., & Sung, R. (2004). The relationship among physical fitness, physical education, conduct and academic performance of chinese primary school children. *International Journal of Physical Education, 12*, 17-26.

39. Lee, S. M., Burgenson, C. R., Fulton, J. E., & Spain, C. G. (2007). Physical education and physical activity: Results from the school health policies and programs study 2006. *Journal of School Health, 77*(8), 435-463.

40. Lopez-Lopez, C., LeRoith, D., Torres-Aleman, I., & Gage, F. H. (2004). Insulin-like growth factor I is required for vessel remodeling in the adult brain. *Proceedings of the National Academy of Sciences of the United States of America, 101*(26), 9833-9838.

41. Maeda, J. K., & Randall, L. M. (2003). Can academic success come from five minutes of physical activity. *Brock Education, 13*(1), 14-22.

42. Mahar, M. T., Murphy, S. K., Rowe, D. A., Golden, J., Shields, A. T., & Raedeke, T. D. (2006). Effects of a classroom-based program on physical activity and on-task behavior. *Medicine & Science in Sports & Exercise, 38*(12), 2086-2094.

43. Marshall, J., & Hardman, K. (2000). The state and status of physical education in schools in international context. *European Physical Education Review, 6*(3), 203-229.

44. Martin, L. T., & Chalmers, G. R. (2007). The relationship between academic achievement and physical fitness. *Physical Educator, 64*(4), 214-221.

45. McNaughten, D., & Gabbard, C. (1993). Physical exertion and immediate mental performance of sixth-grade children. *Perceptual and Motor Skills, 77*, 1155-1159.

46. Mitchell, J. B., Flynn, M. G., Goldfarb, A. H., Ben-Ezra, V., & Copman, T. L. (1990). The effects of training on the norepinephrine response at rest and during exercise in 5 degrees and 20 degrees C environments. *The Journal of Sports Medicine, 30*(3), 235-240.

47. Molloy, G. N. (1989). Chemicals, exercise and hyperactivity: A short report. *International Journal of Disability, Development and Education, 36*(1), 57-61.

48. National Center for Education Statistics. (1996). Digest of education statistics. *Washington, DC: US Dept of Education, Office of Educational Research and Improvement,*

49. Neeper, S. A., Gomez-Pinilla, F., Choi, J., & Cotman, C. W. (1996). Physical activity increases mRNA for brain-derived neurotrophic factor and nerve growth factor in rat brain. *Brain Research, 726*, 49-56.

50. Norlander, T., Moas, L., & Archer, T. (2005). Noise and stress in primary and secondary school children: Noise reduction and increased concentration ability through a short but regular exercise and relaxation program. *School Effectiveness and School Improvement, 16*(1), 91-99.

51. Pellegrini, A. D., Huberty, P. D., & Jones, I. (1995). The effects of recess timing on children's playground and classroom behaviors. *American Educational Research Journal, 32*(4), 845-864.

52. R. Brickenkamp, Test d2 Aufmerksamkeits-Belastungs-Test, Manual [The d2 test of attn. (2002). Aufmerksamkeits-belastungs-test, manual [the d2 test of attention]. *Hogrefe, Gottingen-Bern-Toronto-Seattle,*

53. Russo-Neustadt, A., Ha, T., Ramirez, R., & Kesslak, P. J. (2001). Physical activity–antidepressant treatment combination: Impact on brain-derived neurotrophic factor and behavior in an animal model. *Behavioural Brain Research, 120*, 87-95.

54. Sallis, J. F., Mckenzie, T. L., Kolody, B., Lewis, M., Marshall, S., & Rosengard, P. (1999). Effects of health-related physical education on academic achievement: Project SPARK. *Research Quarterly for Exercise and Sport, 70*(2), 127-134.

55. Schaaf, M. J. M., de Jong, J. E., de Kloet, R., & Vreugdenhil, E. (1998). Downregulation of BDNF mRNA and protein in the rat hippocampus by corticosterone. *Brain Research, 813*, 112-120.

56. Sibley, B. A., & Etnier, J. L. (2003). The relationship between physical activity and cognition in children: A meta-analysis. *Pediatric Exercise Science, 15*(3), 243-256.

57. Spence, J. C., & Poon, P. (1997). Results from the Alberta schools' athletic association survey. Alberta, Canada: Alberta Centre for Active Living.

58. Stephens, L. J., & Schaben, L. A. (2002). The effect of interscholastic sports participation on academic achievement of middle level school students. *NASSP Bulletin, 86*(630), 34-41.

59. Strong, W. B., Malina, R. M., & Blimkie, C. J. R. (2005). Evidence based physical activity for school-age youth. *Journal of Pediatrics, 146*(6), 732-737.

60. Stroth, S., Hille, K., Spitzer, M., & Reinhardt, R. (2009). Aerobic endurance exercise benefits memory and affect in young adults. *Neuropsychological Rehabilitation, 19*(2), 223-243.

61. Suminski, R. R., Petosa, R., Utter, A. C., & Zhang, J. J. (2002). Physical activity among ethnically diverse college students. *Journal of American College Health, 51*(2), 75-80.

62. Taras, H. (2005). Physical activity and student performance at school. *Journal of School Health, 75*(6), 214-218.

63. Thomas, S. N., Schroeder, T., Secher, N. H., & Mitchell, J. H. (1989). Cerebral blood flow during submaximal and maximal dynamic exercise in humans. *Journal of Applied Physiology, 67*(2), 744-748.

64. Tomporowski, P. D., Davis, C. L., Miller, P. H., & Naglieri, J. A. (2008). Exercise and children's intelligence, cognition, and academic achievement. *Educational Psychology Review, 20*(2), 111-131.

65. Tremarche, P. V., Robinson, E. M., & Graham, L. B. (2007). Physical education and its effect on elementary testing results. *Physical Educator, 62*(2), 58-64.

66. Trockel, M. T., Barnes, M. D., & Egget, D. L. (2000). Health-related variables and academic performance among first-year college students: Implications for sleep and other behaviors. *Journal of American College Health, 49*, 125-131.

67. Trost, S. (2007). Active education: Physical education, physical activity and academic performance. San Diego, CA: Active living research.

68. Trost, S. (2009). Active education: Physical education, physical activity and academic performance. San Diego, CA: Active living research.

69. Trudeau, F., & Shephard, R. J. (2008). Physical education, school physical activity, school sports and academic performance. *International Journal of Behavioral Nutrition and Physical Activity, 5*, 10.

70. Tuckman, B. W., & Hinkle, J. S. (1986). An experimental study of the physical and psychological effects of aerobic exercise on school children. *Health Psychology, 5*(3), 197-207.

71. Vaynman, S., & Gomez-Pinilla, F. (2006). Revenge of the "sit": How lifestyle impacts neuronal and cognitive health through molecular systems that interface energy metabolism with neuronal plasticity. *Journal of Neuroscience Research, 84*, 699-715.

72. Winter, B., Breitenstein, C., Mooren, F. C., Voelker, K., Fobker, M., Lechtermann, A., et al. (2007). High impact running improves learning. *Neurobiology of Learning and Memory, 87*, 597-609.

73. Yin, Z., & Moore, J. B. (2004). Re-examining the role of interscholastic sport participation in education. *Psychological Reports, 94*, 1447-1454.

Coordinative Aerobic Exercise Does Not Enhance Attention and Concentration in College Students

Meryl Epstein, Steven Gaskill

The University of Montana, Health and Human Performance Department

Abstract

There is a historic and recently growing body of research that shows physical activity and fitness both have a positive effect on cognitive function, improved memory, and learning. The purpose of this study was to determine whether acute moderate to vigorous coordinative-aerobic activity carried out prior to taking the d2 Test of Attention positively affected attention and concentration measures in a sample of college students at the University of Montana. The results of this investigation found no acute physical activity effect on the test scores. The results did demonstrate that there was a significant learning effect to the d2 Test of Attention when repeated after a short time span and that even after a week, participants maintained the improved ability to complete the d2 test. Thus all d2 test improvements were the result of the order they completed the d2 Test of Attention and could not be attributed to the intervention. Before future experimental studies are carried out in a similar manner, there is a need to determine an appropriate wash-out period for the d2 Test of Attention.

1. Introduction

The educational system is continually seeking to enhance the learning experience of their students through programs targeted towards improving the teacher's ability to impart and the students' to retain classroom material. Recently, exercise scientists have begun to focus on the benefits of physical activity on learning. Early research is beginning to help us understand the role that physical activity has in the world of academia. Myriad studies have identified the positive benefits of physical education (Carlson et al., 2008; Tremarche et al., 2007), recess (Barros et al., 2009; Jarrett et al.,1998; Pellegrini et al., 1995), and extra-curricular activities (Fredricks & Eccles, 2008; Fredricks & Eccles, 2006; Hawkins & Mulkey, 2005; Spence & Poon, 1997; Stephens &

Schaben, 2002; Yin & Moore, 2004) on student performance regarding both grades and behavior. A summary report from the Robert Wood Johnson Foundation reported that students who participated in school based physical activity maintained or improved their scores on standardized achievement tests when compared with controls (Trost, 2007). In 2010, the Center for Disease Control (CDC) staff reviewed the literature and reported evidence that physical activity is capable of improving academic achievement and effecting cognitive skills, attitudes and academic behavior (16). However, many schools are still resistant to the idea of adding physical activity into their day. Only 3.8% of all high schools, 10% of all middle schools and 15.5% of all elementary school districts require that students be provided with regular physical activity breaks (Lee et al., 2007). College student exercise patterns appear to mimic time spent in physical activity during their primary and secondary schooling with only 40 to 50% of college students physically active (Keating et al., 2005). If fitness and health are not developed as an integral aspect of learning in a student's younger years, the current sedentary behavior in college students will continue despite numerous studies showing physical activity is beneficial to cognitive learning.

Relating physical activity and particularly coordinative aerobic exercise, to potential cognitive benefits, is straightforward. Aerobic exercise increases cerebral blood flow (Herholz et al., 1987; Jorgensen et al., 1992; Kojiro & Secher, 2000; Thomas et al., 1989), capillarization (Black et al., 1990), and important neurotransmitter and hormone release (Bortz et al., 1981; Mitchell et al., 1990; Winter et al., 2007). These physiological brain changes may help to boost learning in students. The coordinative component of the movement increases synapses in important brain areas such as the cerebellum (Barchas & Freedman, 1963). From an application stand point not only are student's cognitive skills' improving (Caterino & Polak, 1999; Maeda & Randall, 2003; Molloy, 1989) but their ability to concentrate on the lesson presented is increased as well. Coordinative aerobic exercise such as Zumba could serve as a potential type of physical activity intervention to increase cognitive skills at all levels of academia.

Physical activity can be added to the school curriculum without being a detriment to student academic achievement while positively influencing concentration, memory and classroom behavior (Trudeau & Shephard, 2008). The optimal modes, timing, intensity and methods of implementation in K-12 schools of physical activity to spawn academic success are not as well known. There is also a paucity of research on cognitive and behavioral responses to acute physical activity during the school day for middle and high school students (Trost, 2009) and less on college students.

1.1 Objective of the Research

The purpose of this study was to determine whether acute moderate to vigorous coordinative-aerobic activity carried out prior to taking the d2 test of attention positively affected attention and concentration measures in a sample of college students at the University of Montana. This study aimed to provide data on the effect of acute coordinative aerobic activity on cognition, particularly attention and concentration in college students, an area of research lacking in the literature. The information collected was used to determine if acute moderate to vigorous coordinative aerobic exercise enhanced attention and concentration, two very important factors in the ability to learn.

1.1.1 Research Hypothesis

Engagement in acute moderate to vigorous coordinative aerobic activity will lead to an improvement in concentration and attention scores as measured by the d2 test of attention.

2. Materials and Methods

2.1 Subjects

132 students (male n=40, female n=92), between the ages of 18 and 56 years old (21.4 ± 4.3 years) from the University of Montana took part in this study. All subjects gave written informed consent and completed a PAR-Q identifying them as healthy. Subjects were explained the purpose of the study and risks associated with participating. This study was approved by the Institutional Review Board of the University of Montana.

2.2 d2 Test of Attention

The d2 Test of Attention is a cancellation test where visually similar stimuli are simultaneously presented. The test consists of 14 rows of 47 randomly mixed letters: p or d. Subjects were given 20 seconds per line to identify the letter d when it is presented with two dashes above or below it or both above and below. On any given line a subject found several competing stimuli: the letter d with more or less than two dashes and p with any number of dashes. After 20 seconds the participants moved onto the next line. The d2 test of attention took 4.67 minutes to complete.

This test has been found by several investigators to have very high validity and test-retest reliability (Bates & Lemay, 2004; Brickenkamp, 2002). Bates & Lemay (2004) found a significant correlation with the d2 Test of Attention total number correct (TNC) and the Symbol Digit Modalities Test (an assessment of visual scanning, tracking, and sustained attention) and the Stroop Color Word Test (a measure of concentration, distractibility, and response inhibition). Their results support the validity of the d2 Test of Attention's measures as indicator of attention. The internal test–retest reliability of the d2 Test of Attention has been recognized to be extremely high (0.95–0.98), test values have been shown to be stable over an extended period of up to 23 months after initial testing (Brickencamp, 2002).

2.3 Physical Activity Intervention

The activity chosen was Zumba which allow participants to self select an intensity level from moderate to vigorous, dependent upon the subject's effort. Additionally Zumba has both aerobic and coordinative components. All classes included a variation of appropriate Zumba music (approximately 6 songs) and dances, including a warm-up and cool down. Each session lasted approximately 25 minutes. The instructor was Zumba certified. During the session each subject wore a coded heart rate monitor (Polar FT1, Finland) from which average heart rate was recorded. Coded heart rate monitors allow close proximity to other subjects wearing heart rate monitors without signal interference.

2.4 Research Design

All testing occurred in McGill Hall at the University of Montana in Missoula, Montana. All trials occurred during the months of January through March. Our study utilized a randomized cross-over design. All subjects completed a control and experimental condition in group settings of 10-30 other subjects in their session. The order (control or experimental) was determined using a computer sorter. Trials were separated by 7 days and the time of day was repeated for both trials. Times were determined based on the availability of the subjects, classroom space, and availability of the Zumba instructor.

2.4.1 Experimental Trial

Subjects were instructed to refrain from vigorous or sustained moderate physical activity during the day before attending the testing. Subjects entered a classroom and were given a heart rate transmitter strap with electrode gel applied to the strap to allow for better conductance and heart watch to put on. Participants were instructed to sit for 5 minutes. During this time they were given instruction on how to complete the paper and pencil version of the d2 Test of Attention per the d2 Test of Attention manual. Following the instructions subjects were given the d2 Test of Attention.

After completion of the d2 Test of Attention subjects entered a large carpeted room to participate in 25 minutes of physical activity. All participants removed their shoes and the activity was completed in socks. Before beginning the activity subjects were introduced to the 6-20 Borg Scale of Perceived Exertion and explained how to determine a perceived rating using a correct corresponding number. Subjects were then instructed on how to start their heart rate watches. After starting the heart rate monitors the subjects participated in 25 minutes of directed Zumba activity. At the completion of the session, subjects were instructed to stop their watches which were turned in and later downloaded to obtain heart rate profiles.

Subjects then returned to the classroom (one minute walk down a flight of stairs) where all subjects in every session were offered to hear the d2 Test of Attention instructions again. All sessions declined. They then repeated the d2 Test of Attention. Finally, subjects completed a questionnaire to provide the researchers with information on physical activity habits including vigorous and/or moderate exercise, previous Zumba experience, an overall difficulty rating of the Zumba activity, hours of sleep the night prior, recent food consumed, age, gender, and previous diagnosis of a learning disability.

2.4.2 Control Trial

Subjects entered the classroom and were instructed to sit for 5 minutes. During this time they were given instruction on how to complete the d2 Test of Attention per the d2 Test of Attention manual. The subjects were given the d2 Test of Attention.

After completion of the test subjects remained in the classroom and were instructed to simply sit and study or read quietly for 25 minutes. It was explained to the participants to follow similar rules they would have if they were in a study hall (no cell phones, sleeping, or any activity that is not school related). After 25 minutes subjects then completed the d2 Test of Attention again as done in the experimental trial. Finally, subjects completed a questionnaire to provide the researchers information on hours of sleep the night prior, recent food consumed, age and gender.

2.5 Data Analysis

Means and standard deviations were calculated for descriptive characteristics overall and by gender. Differences in total number answers processed (TN), error rate (E) and total number correct (TNC) between the two trials were evaluated overall and within gender using a 2 way (trial by time) repeated measures design covaried for order of treatment. All analysis was completed using SPSS (IBM Corporation, Somers, NY) software. Significance was set at an alpha level of 0.05.

Results

3.1 Order

There was a significant main effect for order ($p<0.0001$) for the two trials with the second trial (either Zumba or Control), higher than the 1st trial results for the total number processed (TN) and total correct (TNC) score. While every attempt was made to randomize and balance the order so that equal numbers did each trial first, logistics resulted in many more subjects completing the control trial first and experimental (Zumba) second. Statistically, the change in pre- to post-intervention d2 score within

Zumba and Control were similar with no between group interactions as shown in Figure 1. (suggest Figure 1 here).

Table 1: Mean score, pre- and post-treatment for the Zumba and control trials. These are the raw scores, uncorrected for order.

Variable	*Pre Treatment Score*		*Post-Treatment Score*		*Pre-Post-significance*	
	Control	*Zumba*	*Control*	*Zumba*	*Control*	*Zumba*
TN	503.7±77.2	521.6±86.6 *	557.3±71.2	579.1±67.6 *	**	**
E	16.3±16.1	14.6±14.0	11.5±12.8	11.7±12.7		
TNC	487.4±80.6	507.0±88.9 *	545.8±73.3	567.4±69.9 *	**	**

Scores are mean ± SD; TN=Total number processed, E=Errors, TNC=Total Number Correct.
** significant difference between pre-intervention values for control and Zumba groups.*
*** significant difference in pre to post scores within each treatment group.*

Mean pre- and post-intervention scores for the d2 Test of Attention variables are shown in Table 1. For TN and TNC there was a main time effect and each group also improved across the pre- to post-test period with the post-treatment scores higher after both Zumba dance and no physical activity. There was no interaction between groups hence the intervention (Zumba or control) had no different effect on the post score as shown in Figure 2 (suggest Figure 2 here).

3.2 Gender

Mean pre- and post-treatment scores for the d2 Test of Attention variables are shown for both males and females in Table 2a and 2b. There was no difference between genders. Again the same pattern as reported in Table 1 is found within each group but there is no difference between the groups and no intervention interactions.

Table 2a: Mean score, pre- and post-treatment for the Zumba and control trials by gender. These are the raw scores, uncorrected for order.

Variable	*Male Pre Treatment Score*		*Male Post-Treatment Score*		*Pre-Post-significance*	
	Control	*Zumba*	*Control*	*Zumba*	*Control*	*Zumba*
TN	508.9±74.6	527.5±86.4 *	566.8±61.9	581.2±68.6 *	**	**

E	19.6±16.1	15.4±14.2	12.5±10.2	12.5±14.7		
TNC	489.3±77.4	512.1±86.2 *	554.3±63.8	568.8±70.0 *	**	**

Scores are mean ± SD; TN=Total number processed, E=Errors, TNC=Total Number Correct.

** significant difference between male pre-intervention values for control and Zumba groups.*

*** significant difference in pre to post scores within each treatment group.*

Table 2b: Mean score, pre- and post-treatment for the Zumba and control trials by gender. These are the raw scores, uncorrected for order.

Variable	*Female Pre Treatment Score*		*Female Post-Treatment Score*		*Pre-Post-significance*	
	Control	*Zumba*	*Control*	*Zumba*	*Control*	*Zumba*
TN	500.8±78.4	519.5±86.7 *	553.1±74.4	641.5±67.9 *	**	**
E	14.9±15.9	14.2±13.9	11.0±13.8	11.2±11.7		
TNC	485.9±82.1	505.3±90.0 *	542.1±76.7	630.3±70.67*	**	**

Scores are mean ± SD; TN=Total number processed, E=Errors, TNC=Total Number Correct.

** significant difference between female pre-intervention values for control and Zumba groups.*

*** significant difference in pre to post scores within each treatment group.*

3.3 Interactions

All subjects improved on TN and TNC scores pre- to post-intervention during visits 1 and 2 regardless of order as shown in Table 1. Repeated measures ANOVA showed no group interaction and no difference in the pre- to post intervention scores between the control group and the intervention group. The ANOVA was covaried to adjust for the order effect, but even after adjustment, there were no group interactions for TN and TNC.

3.4 Summary

In summary, other than the large order effect, the intervention appeared to have no influence on TN, E, or TNC. The second trial, regardless of which intervention was completed first, had significantly higher pre-TN and TNC scores with similar pre-post-intervention improvements as the first trial.

4. Discussion

The decline of physical activity in today's adolescents is of growing concern. It is recommended that school-age youth participate in 60 minutes of moderate to vigorous physical activity a day (Strong et al., 2005). However, even with a growing awareness of the health needs of today's children, nearly 1/3 of youth and teenagers are overweight with physical inactivity as one of the leading causes (Trost, 2009). Incorporating physical activity into the school day is important as several studies have shown that physical activity is beneficial, not only for health and to maintain normal body weight, but also to improve cognitive learning in a school setting. In 2010, the Center for Disease Control (CDC) reported evidence that physical activity is capable of improving academic achievement and effecting cognitive skills, attitudes and academic behavior (CDC, 2010). Similar data are well supported in the literature. Tomporowski et al., (2008) found that physical exercise aids children's executive function, adding that physical movement may be effective at enhancing their cognitive development.

Even with the documented benefits of physical activity most schools, particularly high schools, do not provide the opportunity for any physical activity during the school day. According to the Robert Wood Johnson Foundation (RWJF) research brief, the literature on "cognitive and behavior responses to physical activity during the school day have not been systematically investigated among middle or high school students" (Trost, 2009, p.5), and to the researcher's knowledge very little research exists for college students. With more than 12 million students continuing on to college (National Center for Education Statistics, 1996) the decline in physical activity prevalent in the primary and secondary school system may be leading to a decrease in healthy lifestyle choices. This is evident by the findings of Suminski et al., (2002) in an ethnically diverse college student population (aged 18-25 years) 46.7% did not engage in vigorous physical activity and 16.7% were not active at all. It appears that many students continuing their education beyond high school may not see the connection between the importance of keeping both the mind and the body healthy.

Similar to the findings of this study, Bailey et al., (2010) compared acute aerobic and coordinative exercise to see if an improvement in attention could be found in graduate students in a classroom setting. Each student took part in all three conditions: fifteen minutes of walking, coordinative exercise, or rest, seven days apart. Each time they took the d2 Test of Attention. They found that acute aerobic and coordinative exercise did not affect the attention of graduate students in a classroom setting (Bailey et al., 2010). The Zumba exercise utilized for this study lasted 10 minutes longer compared to the study mentioned above but the sample was from a similar educational background and the results were the same with no acute physical activity affect. In contrast Budde et al., (2008) conducted a study using adolescents in an elite school. Half of the students participated in 10 minutes of a normal sport lesson (control) and the other group completed a coordinative soccer skills exercise. Both groups completed the d2 test of attention one week before the study and after the activity. Even though both groups improved on attention and concentration, a significantly higher progression was found in the coordinative exercise group (Budde et al., 2008).

4.1 Order Effect.

In the two studies mentioned above and in our current investigation a perceived increase in attention determined by the d2 Test of Attention may be the result of a learning effect. The d2 Test of Attention is cited to have very high test-retest reliability (Bates & Lemay, 2004; Brickenkamp, 2002). Studies reporting these results compared a testing period over several months or even years between repeated tests. The physical activity studies mentioned above, including ours, are using it in a very short period of time of 25 minutes to weeks. Therefore the first exposure to the d2 Test of Attention is serving as the learning period and every exposure thereafter results in an improved score. The current study found an order effect with the order they completed the d2 Test of Attention determining their improvement not the intervention. Regardless of condition, subjects always performed their worst on their first exposure to the d2 Test of Attention and improved with each subsequent exposure. Even with a week between the two trials, the TN and TNC pre-scores of the second week testing were as good as the post-scores during the first round of testing.   This short term lack of reliability makes the d2 Test of Attention inappropriate for short test- re-test time periods.

4.2 Other limitations

Limitations for this study largely came from the homogeneity of the sample. All of our subjects were college students with a mean age of 21.4 ± 4.3. Despite controlling for time of day and day of week between trials, the academic calendar dictated inter-subject differences for the extraneous variable of underlying academic stress/load between those recruited earlier and later during the project. Finally, personal influence by the *Zumba* instructor herself (atmosphere, energy level) may have affected results even though the same instructor, music and dance routine was used for all participants.

4.3 Further Research Implications

In the future, researchers should be aware that there is a learning effect to the d2 Test of Attention and take this into consideration when designing their investigation. In addition, there is a need for a wash-out period where subjects still retain the knowledge of how to complete the test but will not have a learning effect. More research is needed to determine an appropriate length of time for a wash-out period. Different tests may prove more appropriate with a college population

4.4 Conclusions

We found no effect of 25 minutes of acute coordinative physical activity on attention when compared to a control group. Our results suggest that short bouts of aerobic exercise with a coordinative component in a college population do not aid in improving attentiveness. However, we are unable to discern the relative contributions to this finding, i.e. the ineffectiveness of the acute exercise intervention versus the observed learning effect for the d2 Test of Attention, both of which may have interfered with our ability to see a change in our measure of attention as a result of exercise.

References

Bailey, E. K., Douglas, T. J., Wolff, D. L., & Bailey, S. (2010). Impact of coordinative and aerobic exercise on attention in graduate students. *Medicine & Science in Sports & Exercise, 42*(5), 432.

Barchas, J. D., & Freedman, D. X. (1963). Brain amines: Response to physiological stress. *Biochemistry and Pharmacology, 12*, 1232-1235.

Barros, R. M., Silver, E. J., & Stein, R. E. K. (2009). School recess and group classroom behavior. *Pediatrics, 123*(2), 431-436.

Bates, M. E., & Lemay, E. P. (2004). The d2 test of attention: Construct validity and extensions in scoring techniques. *Journal of the International Neuropsychological Society, 10*, 392-400.

Black, J. E., Isaacs, K. R., Anderson, B. J., Alcantara, A. A., & Greenough, W. T. (1990). Learning causes synaptogenesis, whereas motor activity causes angiogenesis, in cerebellar cortex of adult rats. *Proceedings of the National Academy of Sciences, 87*(5568-5572)

Bortz, W. M., Angwin, P., Mefford, I. N., Boarder, M. R., Noyce, N., & Barchas, J. D. (1981). Catecholamines, dopamine, and endorphin levels during extreme exercise. *New England Journal of Medicine, 305*, 466-467.

Brickenkamp, R. Test d2 Aufmerksamkeits-Belastungs-Test, Manual [The d2 test of attn. (2002). Aufmerksamkeits-belastungs-test, manual [the d2 test of attention]. *Hogrefe, Gottingen-Bern-Toronto-Seattle.*

Budde, H., Voelcker-Rehage, C., Pietraßyk-Kendziorra, S., Ribeiro, P., & Tidow, G. (2008). Acute coordinative exercise improves attentional performance in adolescents. *Neuroscience Letters, 441*, 219-223.

Carlson, S. A., Fulton, J. E., & Lee, S. M. (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.

Caterino, M. C., & Polak, E. D. (1999). Effects of two types of activity on the performance of second-, third- and fourth-grade students on a test of concentration. *Perceptual and Motor Skills, 89*, 245-248.

Center for Disease Control and Prevention. (2010). The association between school-based physical activity, including physical education, and academic performance. Atlanta, GA: U.S. department of health and human services.

Fredricks, J., & Eccles, J. (2008). Participation in extracurricular activities in the middle school years: Are there developmental benefits for African American and European American youth? *Journal of Youth and Adolescence, 37*(9), 1029-1043.

Fredricks, J. A., & Eccles, J. S. (2006). Is extracurricular participation associated with beneficial outcomes? Concurrent and longitudinal relations. *Developmental Psychology, 42*(4), 698-713.

Hawkins, R., & Mulkey, L. M. (2005). Athletic investment and academic resilience in a national sample of African American females and males in the middle grades. *Education and Urban Society, 38*(1), 62-88.

Herholz, K., Buskies, W., Rist, M., Pawlik, G., Hollmann, W., & Heiss, W. D. (1987). Regional cerebral blood flow in man at rest and during exercise. *Journal of Neurology, 234*(1), 9-13.

Jarrett, O. S., Maxwell, D. M., Dickerson, C., Hoge, P., Davies, G., & Yetley, A. (1998). Impact of recess on classroom behavior: Group effects and individual differences. *The Journal of Educational Research, 92*(2), 121-126.

Jorgensen, L. G., Perko, G., & Secher, N. H. (1992). Regional cerebral artery mean flow velocity and blood flow during dynamic exercise in humans. *Journal of Applied Physiology, 73*(5), 1825-1830.

Keating, X. D., Guan, J., Pinero, J. C., & Bridges, D. M. (2005). A meta-analysis of college students' physical activity behaviors. *Journal of American College of Health, 54*(2), 116-125.

Kojiro, I., & Secher, N. H. (2000). Cerebral blood flow and metabolism during exercise. *Progress in Neurobiology, 61*, 397-414.

Lee, S. M., Burgenson, C. R., Fulton, J. E., & Spain, C. G. (2007). Physical education and physical activity: Results from the school health policies and programs study 2006. *Journal of School Health, 77*(8), 435-463.

Maeda, J. K., & Randall, L. M. (2003). Can academic success come from five minutes of physical activity. *Brock Education, 13*(1), 14-22.

Mitchell, J. B., Flynn, M. G., Goldfarb, A. H., Ben-Ezra, V., & Copman, T. L. (1990). The effects of training on the norepinephrine response at rest and during exercise in 5 degrees and 20 degrees C environments. *The Journal of Sports Medicine, 30*(3), 235-240.

Molloy, G. N. (1989). Chemicals, exercise and hyperactivity: A short report. *International Journal of Disability, Development and Education, 36*(1), 57-61.

National Center for Education Statistics. (1996). Digest of education statistics. *Washington, DC: US Dept of Education, Office of Educational Research and Improvement.*

Pellegrini, A. D., Huberty, P. D., & Jones, I. (1995). The effects of recess timing on children's playground and classroom behaviors. *American Educational Research Journal, 32*(4), 845-864.

Spence, J. C., & Poon, P. (1997). Results from the Alberta schools' athletic association survey. Alberta, Canada: Alberta Centre for Active Living.

Stephens, L. J., & Schaben, L. A. (2002). The effect of interscholastic sports participation on academic achievement of middle level school students. *NASSP Bulletin, 86*(630), 34-41.

Strong, W. B., Malina, R. M., & Blimkie, C. J. R. (2005). Evidence based physical activity for school-age youth. *Journal of Pediatrics, 146*(6), 732-737.

Suminski, R. R., Petosa, R., Utter, A. C., & Zhang, J. J. (2002). Physical activity among ethnically diverse college students. *Journal of American College Health, 51*(2), 75-80.

Thomas, S. N., Schroeder, T., Secher, N. H., & Mitchell, J. H. (1989). Cerebral blood flow during submaximal and maximal dynamic exercise in humans. *Journal of Applied Physiology, 67*(2), 744-748.

Tomporowski, P. D., Davis, C. L., Miller, P. H., & Naglieri, J. A. (2008). Exercise and children's intelligence, cognition, and academic achievement. *Educational Psychology Review, 20*(2), 111-131.

Tremarche, P. V., Robinson, E. M., & Graham, L. B. (2007). Physical education and its effect on elementary testing results. *Physical Educator, 62*(2), 58-64.

Trost, S. (2007). Active education: Physical education, physical activity and academic performance. San Diego, CA: Active living research.

Trost, S. (2009). Active education: Physical education, physical activity and academic performance. San Diego, CA: Active living research.

Trudeau, F., & Shephard, R. J. (2008). Physical education, school physical activity, school sports and academic performance. *International Journal of Behavioral Nutrition and Physical Activity, 5*, 10.

Winter, B., Breitenstein, C., Mooren, F. C., Voelker, K., Fobker, M., Lechtermann, A., et al. (2007). High impact running improves learning. *Neurobiology of Learning and Memory, 87*, 597-609.

Yin, Z., & Moore, J. B. (2004). Re-examining the role of interscholastic sport participation in education. *Psychological Reports, 94*, 1447-1454.

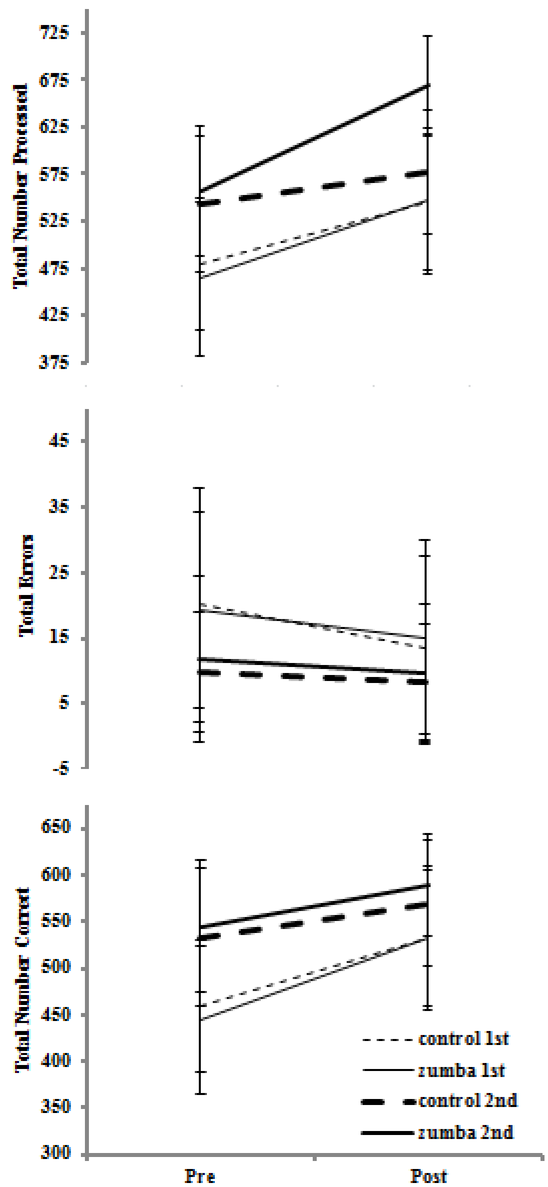

Figure 1- Scores are mean ± SD for Total Number Correct (TNC), Total Errors (E), and Total Number Processed (TN) both pre- and post-testing on the d2 Test of Attention.

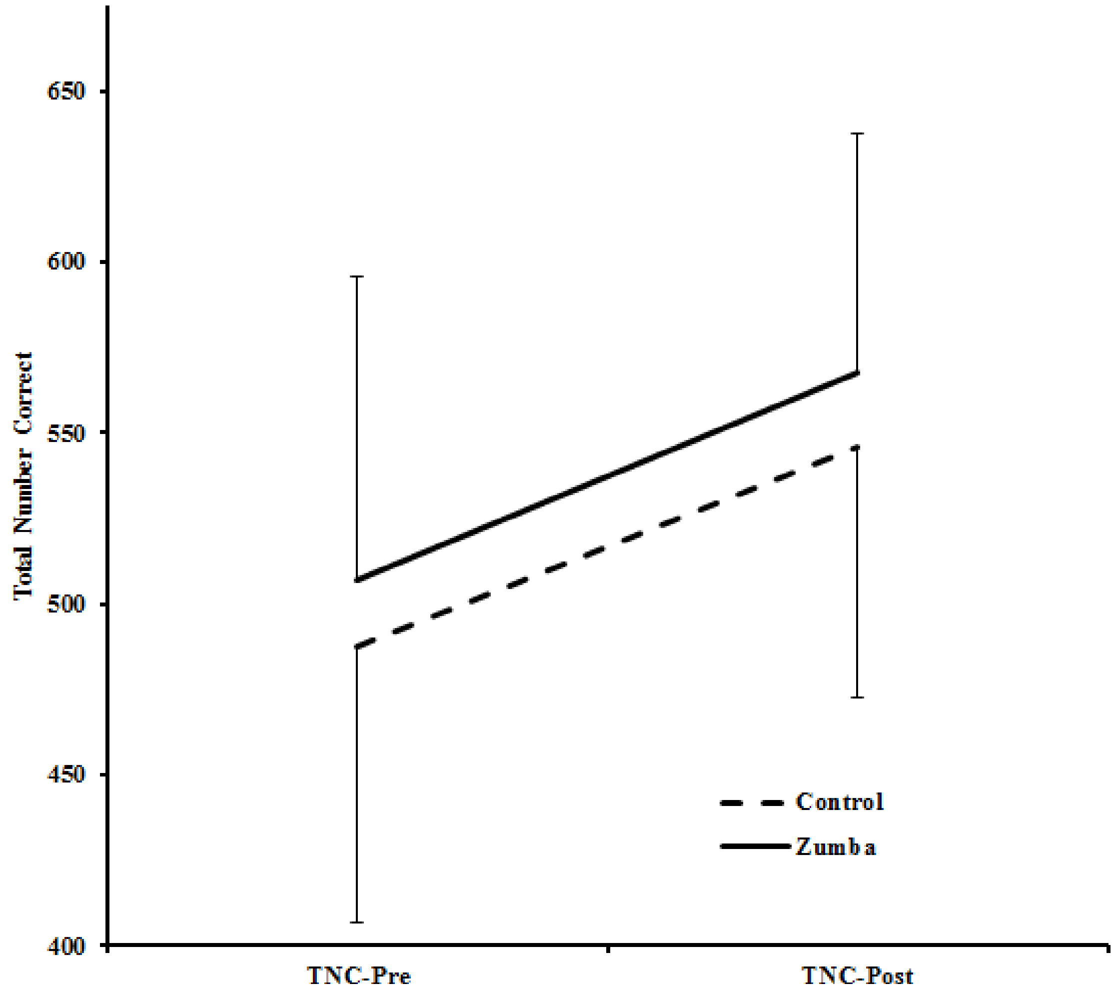

Figure 2- Comparison of scores (mean ± SD) on the d2 Test of Attention for Total Number Correct (TNC) pre- and post-testing for the Control and Zumba group.

Appendix

Experimental Trial

Subject ID # ______________

1) Based on the Rating of Perceived Exertion Scale below, I would rate the average intensity of my effort during Zumba as ______ (rating 6-20)

RATING OF PERCEIVED EXERTION	
6	
7	Very, Very Light
8	
9	Very Light
10	
11	Fairly Light
12	
13	Somewhat Hard
14	
15	Hard
16	
17	Very Hard
18	
19	Very, Very Hard

Rating of Perceived Exertion Instructions

"This feeling should reflect your total amount of exertion and fatigue, combining all sensations and feelings of physical stress, effort and fat Don't concern yourself with any one big factor such as leg pain, short of breath or exercise intensity, but try to concentrate on your total, inn feelings of fatigue. Try not to underestimate or overestimate your feel of exertion; be as accurate as you can be."

2) Have you ever taken a Zumba class before today?_______If Yes, approximately, how many?______

3) Approximately how many hours of sleep did you get last night to the nearest hour? _____

4) What is your age? _______years

5) What is your gender? Male Female

6) During the two hours prior to this test circle the best description of your meal size?

   Did not eat during the prior 2 hours Snack Small Meal Normal Meal Large Meal

7) How many times a week do you exercise at a vigorous intensity (vigorous means an intensity similar to that required for running slowly or faster) for at least 20 minutes? _______

8) How many times a week do you exercise at a moderate intensity (moderate means an intensity similar to that required for brisk walking) for at least 20 minutes? _______

9) Have you ever been diagnosed with, or told by a medical authority, that you have a learning disability? (This information is confidential and is necessary for us to understand the effect of physical activity on concentration). Yes No

Control Trial

Subject ID # ____________

10) Approximately how many hours of sleep did you get last night to the nearest hour? _____

11) During the two hours prior to this test circle the best description of your meal size?

Did not eat during the prior 2 hours Snack Small Meal Normal Meal Large Meal

12) How many times a week do you exercise at a vigorous intensity (vigorous means an intensity similar to that required for running slowly or faster) for at least 20 minutes? _______

13) How many times a week do you exercise at a moderate intensity (moderate means an intensity similar to that required for brisk walking) for at least 20 minutes? _______

d2 Test of Attention Administering Script:

Adapted from: Brickenkamp, R., & Zillmer, E. (1998). *The d2 test of attention.* Cambridge, MA: Hogrefe Publishing.

"With the help of the following task, I would like to see how well each of you can concentrate on a particular assignment." Please fill in your subject number, age, sex, handedness, years of education, and occupation. "Please pay attention. After the word 'Examples' on your recording blank you see three small letters marked with dashes. These are the letter 'd' as in 'dog', and each is marked with two dashes. The first' d' has two dashes on the bottom, the second has two on the top, and the third 'd' has one dash on the top and one on the bottom, still making two dashes all together. I would like you to cross out every letter 'd' that has two dashes by making a single line through the letter. Try doing this first with the three examples, then try the practice line. You are not supposed to cross out the other letters. Thus a 'd' which has more than two or fewer than two dashes should not be crossed out, and the letter 'p' as in 'pig' should never be crossed out, no matter how many dashes it has. Do you have any questions right now?" "Let's take a look at whether you have crossed out all the right letters. Every one of the letters in the practice line has a number underneath it. I'll slowly read out the numbers of the letters which you were asked to cross out. You can see whether you have overlooked any of the letters, or whether perhaps crossed out too many. You were expected to cross out the first one, then the letters numbered 5, 6, 9, 12, 13, 17, 19 and 22. "Are there any other questions? "Please do not turn your recording blank over yet. Put your pencil down for a moment and listen carefully now. On the other side of your recording blank you will see 14 lines with the same letters you have worked on in the practice line. For each one of the 14 lines you should start on the left side, work to the right and cross out each 'd' with two dashes. This is exactly the same task you did in the practice line. Start with the first line. After 20 seconds I'll say 'Stop, next line' and you will stop working on that line and immediately start working on the next line. After another 20 seconds I'll say 'Stop, next line' and you will immediately start working on the next line. Work as quickly as you can without making mistakes." Are there any questions? "Now, please turn the page over, so that the first line is on top. In the upper left hand corner you will see an arrow pointing to where you should start working on the first line. Pick up your pencil and when I give the order start working on the first line. Ready! Set! Go!"

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	**1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	**2. Do you feel pain in your chest when you do physical activity?**
☐	☐	**3. In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	**4. Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	**5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	**6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	**7. Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME ____

SIGNATURE ____ DATE ____________________

SIGNATURE OF PARENT ________________________________ WITNESS ____________________
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

continued on other side...

...continued from other side

PAR-Q & YOU

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

Canada's **Physical Activity Guide** to Healthy Active Living

Physical activity improves health.

Every little bit counts, but more is even better – everyone can do it!

Get active your way – build physical activity into your daily life...

- at home
- at school
- at work
- at play
- on the way

...that's active living!

Choose a variety of activities from these three groups:

Endurance
4-7 days a week
Continuous activities for your heart, lungs and circulatory system.

Flexibility
4-7 days a week
Gentle reaching, bending and stretching activities to keep your muscles relaxed and joints mobile.

Strength
2-4 days a week
Activities against resistance to strengthen muscles and bones and improve posture.

Starting slowly is very safe for most people. Not sure? Consult your health professional.

For a copy of the *Guide Handbook* and more information: **1-888-334-9769**, or **www.paguide.com**

Eating well is also important. Follow *Canada's Food Guide to Healthy Eating* to make wise food choices.

Get Active Your Way, Every Day–For Life!

Scientists say accumulate 60 minutes of physical activity every day to stay healthy or improve your health. As you progress to moderate activities you can cut down to 30 minutes, 4 days a week. Add-up your activities in periods of at least 10 minutes each. Start slowly... and build up.

Time needed depends on effort

Very Light Effort	Light Effort *60 minutes*	Moderate Effort *30-60 minutes*	Vigorous Effort *20-30 minutes*	Maximum Effort
• Strolling • Dusting	• Light walking • Volleyball • Easy gardening • Stretching	• Brisk walking • Biking • Raking leaves • Swimming • Dancing • Water aerobics	• Aerobics • Jogging • Hockey • Basketball • Fast swimming • Fast dancing	• Sprinting • Racing
	Range needed to stay healthy			

You Can Do It – Getting started is easier than you think

Physical activity doesn t have to be very hard. Build physical activities into your daily routine.

- Walk whenever you can – get off the bus early, use the stairs instead of the elevator.
- Reduce inactivity for long periods, like watching TV.
- Get up from the couch and stretch and bend for a few minutes every hour.
- Play actively with your kids.
- Choose to walk, wheel or cycle for short trips.
- Start with a 10 minute walk – gradually increase the time.
- Find out about walking and cycling paths nearby and use them.
- Observe a physical activity class to see if you want to try it.
- Try one class to start – you don t have to make a long-term commitment.
- Do the activities you are doing now, more often.

Benefits of regular activity:	Health risks of inactivity:
- better health - improved fitness - better posture and balance - better self-esteem - weight control - stronger muscles and bones - feeling more energetic - relaxation and reduced stress - continued independent living in later life	- premature death - heart disease - obesity - high blood pressure - adult-onset diabetes - osteoporosis - stroke - depression - colon cancer

Health Canada Santé Canada

Canadian Society for Exercise Physiology

Source: Canada's Physical Activity Guide to Healthy Active Living, Health Canada, 1998 http://www.hc-sc.gc.ca/hppb/paguide/pdf/guideEng.pdf

FITNESS AND HEALTH PROFESSIONALS MAY BE INTERESTED IN THE INFORMATION BELOW:

The following companion forms are available for doctors' use by contacting the Canadian Society for Exercise Physiology (address below):

The **Physical Activity Readiness Medical Examination (PARmed-X)** – to be used by doctors with people who answer YES to one or more questions on the PAR-Q.

The **Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for Pregnancy)** – to be used by doctors with pregnant patients who wish to become more active.

References:

Arraix, G.A., Wigle, D.T., Mao, Y. (1992). Risk Assessment of Physical Activity and Physical Fitness in the Canada Health Survey Follow-Up Study. **J. Clin. Epidemiol.** 45:4 419-428.

Mottola, M., Wolfe, L.A. (1994). Active Living and Pregnancy, In: A. Quinney, L. Gauvin, T. Wall (eds.), **Toward Active Living: Proceedings of the International Conference on Physical Activity, Fitness and Health.** Champaign, IL: Human Kinetics.

PAR-Q Validation Report, British Columbia Ministry of Health, 1978.

Thomas, S., Reading, J., Shephard, R.J. (1992). Revision of the Physical Activity Readiness Questionnaire (PAR-Q). **Can. J. Spt. Sci.** 17:4 338-345.

For more information, please contact the:

Canadian Society for Exercise Physiology
202-185 Somerset Street West
Ottawa, ON K2P 0J2
Tel. 1-877-651-3755 • FAX (613) 234-3565
Online: www.csep.ca

The original PAR-Q was developed by the British Columbia Ministry of Health. It has been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gledhill (2002).

Disponible en français sous le titre «Questionnaire sur l'aptitude à l'activité physique - Q-AAP (revisé 2002)».

Supported by: Health Canada Santé Canada