FUNDAMENTAL MOTOR SKILL PROFICIENCY IN NORMAL WEIGHT AND OVERWEIGHT CHILDREN

by

JAMES ALLAN ZAGRODNIK

(Under the Direction of Phillip D. Tomporowski)

ABSTRACT

This investigation was conducted for two reasons: First, to observe the relationship between normal weight and overweight children on fundamental motor skill performance. Second, to determine the effect a physical activity intervention program has on fundamental motor skill performance in overweight children. In the first study, 113 overweight children (BMI > 85^{th} percentile, mean age 9.25 SD 1.14) were compared to 41 normal weight children (15^{th} < BMI < 75^{th} percentile, mean age 9.79 SD 1.06) on performance of the Bruininks-Oseretsky Test of Motor Proficiency – Short Form (BOTMP – Short Form). In the second study, 104 overweight children were divided into a Control group (n = 40), a 20 minute exercise group (n = 31), and a 40 minute exercise group (n = 33) and completed a 14 week physical activity program, performed with the goal of maintaining a heart rate of at least 150 bmp. Participants' fundamental motor skill proficiency was measured pre and post exercise intervention using the BOTMP – Short Form. Normal weight children were superior in performance than their overweight peers on the Bruininks-Oseretsky Test of Motor Proficiency as a whole ($t_{152} = 7.78$, $p < 0.001$, $d = 2.08$) and on 9 of the 14 items. Normal weight boys and girls differed on only one item, Copying a Circle with Preferred Hand ($t_{33.29} = 2.42$, $p = 0.021$, $d = 0.84$), as girls were superior in performance than boys. Overweight boys were superior to overweight girls on Total Score ($t_{96.93} = 3.51$, $p = 0.001$, $d = 0.67$), and four items. Overweight girls performed better than overweight boys on Tapping Feet Alternately While Making Circles with Fingers ($t_{100.74} = 2.37$, $p = 0.020$, $d = 0.46$). No significant differences occurred between the three exercise groups for Total Score or on any of the 14 items of the BOTMP – Short Form following the 14 week exercise intervention. In conclusion, a large gap between non-overweight and overweight children on fundamental motor skill performance exists with many gender differences between overweight children. An exercise intervention, alone, does not appear to improve the fundamental motor skill performance in overweight children. This study supports the need for the instruction of fundamental motor skills to be a part of the physical education curriculum.

INDEX WORDS: FUNDAMENTAL MOTOR SKILLS, OVERWEIGHT, NORMAL WEIGHT, BRUININKS-OSERETSKY TEST OF MOTOR PROFICIENCY

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by

JAMES ALLAN ZAGRODNIK

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JAMES ALLAN ZAGRODNIK

Major Professor: Phillip D. Tomporowski

Committee: Michael Horvat
Bryan McCullick

Electronic Version NOT Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
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CHAPTER I

INTRODUCION

A fundamental movement pattern is an observable performance of basic locomotor, manipulative, or stability movements that involves combining movement patterns of two or more body segments and the integration of developmentally appropriate arm, trunk, and leg actions (Gallahue & Ozmun, 2002). Fundamental movements occur when solid foundations in reflexive and rudimentary movements have been established and allow the child to further explore and manipulate his or her environment. Fundamental motor skills typically learned include running, jumping, hopping, galloping and skipping, throwing, catching, and kicking (Horvat, et al., 2003). Development of fundamental motor skills are essential for interacting and responding to environmental challenges in both recreational and non-recreational activities and are considered basic to the motor development of children (Gallahue & Ozmun, 2002).

Fundamental motor skill development is predicated on the growth and enhancement of a child's postural control. Postural control is defined as the ability to control the body's position in space to accomplish both stability and body orientation. (Shumway-Cook & Woollacott, 2001, p. 164) Postural control emerges from the interactions among the individual, the environmental constraints, and the task at hand. The necessary processes needed for adequate postural control include sensory processes, motor processes, and high-level integration processes. Postural control is essential for appropriate growth and development of an individual as it enables an individual to develop and refine skills throughout life. A component of postural control, and often synonymous to postural control, is postural stability, or balance. Balance is the ability of an individual to maintain his or her projected center of mass within the limits of a base of support (Shumway-Cook & Woollacott, 2001, p. 165). The sensory processes necessary for balance involve visual, somatosensory, and vestibular inputs while the motor processes of balance include muscle and postural tone and muscle synergies. Establishing proper postural control and balance aids in the development of motor skills by providing a sound base for movement.

Developing a solid foundation in fundamental motor skills may foster the participation in physical activity which is an integral part in obesity prevention (Goran, Reynolds, & Lindquist, 1999). The rate of obesity in America has grown at an alarming rate. In 1991, the Centers for Disease Control and Prevention reported only four states with an obesity prevalence between 15 -19 percent, while no state reported more than a 20 percent prevalence. In 2004 an alarming number of states (33) reported obesity prevalence at 20 -24 percent and nine other states had more than a prevalence of 25 percent. In addition, over 17% of children were considered overweight. (CDC, 2005) Potential consequences of obesity include a decrease in physical activity, and an increase in Type II diabetes, psychological problems, cardiovascular disease, and earlier death (Reilly, et al., 2006).

Many studies have examined the link between obesity and fundamental motor skills. These studies have shown an association between obesity and decreased performances in fundamental motor skill proficiency of children. (Jaffe & Kosakov, 1982; Du Toit & Pienaar, 2003; McKenzie et al., 2002; Biskanaki et al., 2004; Reeves, Broeder, Kennendy-Honeycutt & East, 1999; Graf, Koch, Kretshman-Kandel, et al., 2004; Okely, Anthony, Booth, & Chey, 2004) However, many of these studies focused on product based observations of a select few gross fundamental motor skills.

Additionally, few studies have examined the effects of obesity on balance, especially in child populations. Obese individuals require more effort and modifications of the mechanisms necessary for postural control (Corbeil, Simoneau, Rancourt, Tremblay, & Teasdale, 2001), have difficulty in sit-to-stand movements (Galli, et al., 2000), and demonstrate a different walking pattern than non-obese individuals (Hills & Parker, 1991; McGraw, McClenaghan, Williams, Dickerson, & Ward, 2000). Finally, studies have shown that weight reduction of obese individuals improved postural control (i.e. improved stability) in static stance in middle-aged males (Paquette, Teasdale, Prud'homme, & Tremblay, 2000) and in the gait of teenagers (Colne, et al., 2004). Collectively, these studies suggest that impairment in the development and proficiency of fundamental motor skills and balance may lead to difficulty in future skill performance.

Only one study has examined the impact of an exercise intervention program intended to increase energy expenditure and improve fundamental motor skills in children (Graf, Koch, Falkowski, et. al., 2005). The exercise intervention was only a 5 minute period prior to the beginning of classes. Consequently, no effect of the exercise intervention on fundamental motor skills was found.

There is a need for a study to determine: 1) the fundamental motor skill proficiency of overweight and normal weight children using a test battery which has been developed and used extensively to test fundamental motor skill proficiency; and 2) to assess the impact that an intervention program designed to decrease fat mass through extended periods of physical activity at a moderate-to-vigorous intensity, has on fundamental motor skills in overweight children.

Specific Aims

The specific aims of this study are to: 1) compare the fundamental motor skill proficiency of overweight and normal weight children; and 2) to determine the effect of an intervention program, designed to decrease fat mass of overweight children, on fundamental motor skill performance.

Hypotheses

The research hypotheses for the study are:

1. Overweight children, compared to normal weight children, will be less proficient in fundamental motor skill proficiency

2. Boys will be more proficient in gross motor skills and less proficient in fine motor skills than girls regardless of weight.

3. Exercise training of overweight children will improve fundamental motor proficiency.

Significance

Identifying the associations among fundamental motor skills, obesity, and physical activity has implications for developing interventions to address childhood obesity. Although a negative correlation between several fundamental motor skills and obesity has been established, the impact of an exercise intervention in overweight children on the performance of fundamental motor skills is unknown. Overweight children who participate in physical activity may improve their fundamental motor skills, and in turn may be more willing to participate in more physical activity. The increase in physical activity may lead to reduced accretion of fat or even a decrease in fat mass and an increase in muscle mass. Physical education teachers and parents may become aware of the need to stress the importance of proper fundamental motor skill execution at an early age to foster the competence and willingness of children to engage in complex physical activities. School boards concerned about the significance of recess may become aware of the importance of physical activity providing a means for practicing and refining fundamental motor skills. Knowledge of the relationships between fundamental motor skills, obesity, and exercise is particularly important because fundamental motor skills are the framework for confident movements in physical activity and daily movements. Proper execution of fundamental motor skills may lead to increased physical activity, and increased physical activity may lead to a prevention of obesity in normal weight children, and/or a decrease in fat mass in overweight children, thus optimizing children's health.

CHAPTER II

REVIEW OF THE RELATED LITERATURE

Fundamental Motor Skill Development

Motor development can be organized into four layers of movement: random and reflexive; rudimentary; fundamental; and functional (Horvat, Eichstaedt, Kalakian, & Croce, 2003). Fundamental movements occur when solid foundations in reflexive and rudimentary movements have been established and allow the child to further explore and manipulate their environment. A fundamental movement pattern is an observable performance of basic locomotor, manipulative, or stability movements that involves combining movement patterns of two or more body segments and the integration of developmentally appropriate arm, trunk, and leg actions (Gallahue & Ozmun, 2002, p. 471). Three categories of fundamental motor skills are recognized: 1) locomotor skills such as walking, running, jumping, and hopping; 2)non-manipulating skills such as turning and balancing; and 3) manipulative skills such as kicking, throwing, catching, striking, bouncing, pulling and pushing (Jürimäe & Jürimäe, 2000, p. 118). Development of these fundamental motor skills are essential for interacting and responding to environmental stimuli in both recreational and non-recreational activities and are considered basic to the motor development of children (Gallahue & Ozmun, 2002, p. 181).

Fundamental motor skill development is predicated on the development and enhancement of a child's postural control. Postural control is the ability to control the body's position in space to accomplish stability and orientation (Shumway-Cook & Woollacott, 2001, p. 164). Postural control emerges from the interactions among the individual, the environmental constraints, and the task at hand. The necessary processes needed for adequate postural control include sensory processes, motor processes, and high-level integration processes. Postural control is essential for appropriate growth and development of an individual as it enables him or her to develop and refine skills throughout life. A component of postural control, and often synonymous to postural control, is postural stability, or balance. Balance has been defined as the ability to maintain the projected center of mass of an individual within the limits of a base of support (Shumway-Cook & Woollacott, 2001, p. 165). The sensory processes necessary for balance involve visual, somatosensory, and vestibular inputs while the motor processes of balance include muscle and postural tone and muscle synergies. Establishing proper static and dynamic postural control and balance aids in the development of motor skills by providing a sound base for movement.

Jürimäe & Jürimäe (2000) identified and summarized several gender differences in fundamental motor skill acquisition. Boys perform in a superior fashion to girls in manipulative skills such as throwing, kicking, and catching. Girls perform better than boys on non-manipulative skills, such as balancing, hopping, and skipping. Girls often perform better at fine motor tasks while boys typically outperform girls in gross motor skills. Seefeldt and Haubenstricker (1982) identified the order and ages at which 60% of children were able to perform a series of fundamental movement skills. Boys first achieved running (4 years old) followed by throwing (5 years old), skipping (6.5 years old), catching (7 years old), kicking (7 years old), striking (7 years old), hopping (7.5 years old), and jumping (9.5 years old). Girls first achieved running at age 5 then skipping (6 years old), catching (6.5 years old), hopping (7 years old), kicking (8.5 years old), striking (8.5 years old) , throwing (8.5 years old), and jumping (10 years old). In general, girls lag boys in motor skill development by about one year (Jürimäe & Jürimäe, 2000).

A meta-analysis on the gender differences of motor skill performance found that the differences in the fundamental motor skills performances of running, jumping, throwing, and catching were low to moderate prior to puberty, however after puberty the differences became large and in favor of males (Thomas & French, 1985). Boys typically demonstrate a higher quality of overall motor skill performance and are more proficient in manipulative and gross motor skills then girls with improved performance being maintained in childhood and increasing in adolescence.

While many clear trends between boys and girls have been established, summarizing the research on fundamental motor skills is complicated by three factors. First, studies often focus on either process (the necessary movements taken to perform a skill, such as standing sideways to the target, bringing the ball by the ear, stepping with the opposite foot, shifting of weight and rotation of the trunk, and follow through to describe an overhand throw) or product (the end result of a movement, such as measuring the distance the ball was thrown) observations rather than combining the two measurements to estimate a true level of fundamental motor skill development. Typically, boys perform better on tests of product measurement while girls perform better on tests focusing on process development. Second, two approaches to describe movement patterns have emerged as the way to measure fundamental motor skill development. The *total body configuration* is based on the assumption that fundamental motor skills develop as the whole body becomes cohesive enough to perform a particular skill. Researchers who favor the total body configuration approach to fundamental motor skill development often focus on product performance measurements. (For example, the over-hand throw will progress in performance as the body matures and grows to allow for proper stepping, hip and trunk rotation, follow through, etc.) The *body component approach* prescribes that fundamental motor skills develop via intra-task components in which different parts of the body develop at different rates to perform a skill. Researchers who support the body component approach favor process performance observations. (For example, the over-hand throw develops as the child learns each part of the throw, such as stride length and proper hip rotation, separately as his/her body grows.) Third, many researchers focus on only one skill (often throwing), or a combination of skills to determine the fundamental motor skill level of children. Few researchers have utilized measurement batteries, such as the Bruininks-Oseretsky Test of Motor Proficiency or the Movement Assessment Battery, which have been developed to identify the fundamental motor skill proficiency of multiple skills in children. The inconsistent use of the batteries allows researchers to pick skills which may favor one gender over another or develop their own assessment rubrics which may yield different results from batteries which have been shown to be reliable and valid. Thus, researchers are neglecting the suggestions of Campbell and Stanley made over 40 years ago to avoid an interaction of selection bias and the independent variable. Therefore, the generalizability of the existing research to other fundamental motor skills and the overall fundamental motor skill proficiency of children is limited.

In summation, fundamental motor skills provide the basis for more complex movements and the expression of these complex movements are influenced by the development of the postural control system. Boys typically outperform girls on gross and manipulative fundamental motor skills and demonstrate proficiency of most fundamental motor skills at an earlier age. Girls are typically more proficient at fine motor and non-manipulative fundamental motor skills. Research in fundamental motor skills has been plagued by the inconsistent use of both process and product measurements and the multiple approaches to identify fundamental motor skills. In addition, the lack of well-established batteries in the literature hinders the generalizability of most findings.

Physical Activity and Fundamental Motor Skill Performance in Non-overweight Children

One of the first studies to examine the relation between physical activity and fundamental motor skill performance in a non-overweight population was published by Ulrich in 1987. A total of 250 children in kindergarten through 4th grade (25 boys and 25 girls from each grade) were examined while performing a battery of motor skills. The battery consisted of nine items: 1) broad jump; 2) flexed arm hang; 3) sit-up test; 4) side-step test; 5) sixty-yard shuttle run; 6) playground ball dribble; 7) soccer ball dribble; 8) softball repeated throw; and 9) soccer ball throw. The battery was also broken into two categories; items 1- 5 were considered motor ability items, and items 6 – 9 were considered sport specific-skill items. Each child completed a questionnaire concerning his or her participation in organized sport programs. Of the 250 children, 128 were classified as sport participants (K: 8 boys, 6 girls; Grade 1: 18 boys, 6 girls; Grade 2: 14 boys, 12 girls; Grade 3: 16 boys, 9 girls; Grade 4: 20 boys 13 girls) and 122 were classified as non-participants. Upon completion of the motor test, results indicated that children who participated in organized sport programs performed better then nonparticipating children on each motor skill item, with the largest differences occurring among the sport specific skill items. Identifying if motor skill competence and proficiency was established prior to sport participation or after sport participation was not able to be determined from this study.

Okely, Booth, and Patterson (2001) found similar results while investigating the relationship between fundamental motor skills and physical activity in adolescents. Adolescents from the 8th and 10th grades (N =1844, 8th grade: males = 517, females = 465, 10th grade: males = 470, females = 392) were examined on six fundamental motor skills: 1) run; 2) vertical jump; 3) catch; 4) overhand throw; 5) forehand strike; and 6) kick. Each skill was examined and scored based on the number of components of the skill performed correctly (process-based examinations). Each participant completed a self-report of physical activity which was broken into two parts, participation in organized and non-organized physical activity. Performances of fundamental motor skills was significantly related to participation in organized sport and accounted for 3% of the total variation. In addition, adolescents who spent a large amount of time in organized physical activity performed significantly better then those who spent a large portion of time in non-organized physical activity.

Fisher et al. (2004) objectively measured the relation between physical activity and fundamental motor skills in children. Three-hundred ninety-four children (age range 3.6 – 5.0 years) performed 15 tasks of the Movement Assessment Battery: vertical jumping, standing jump, standing on 1 foot for 1 second, standing on 1 foot for 6 seconds, 4 types of skipping, kicking catching and throwing a ball. BMI was calculated for each child, with a mean of 16.37. Physical activity was measured by having each child wear an accelerometer on his or her right hip for 6 days. Results indicated a statistically significant positive, but weak (r = .10), correlation between total fundamental motor score and concurrent physical activity, regardless of the intensity. Further inspection revealed that total fundamental motor score was not significantly correlated with light-intensity activity but was significant and positively correlated with moderate and vigorous activity (r = .18). The evidence, from this study, indicates that participating in physical activity only minimally contributes to fundamental motor skill performance.

A positive, but weak, relationship between physical activity and fundamental motor skill performance has been found in each of the studies described above, suggesting that the amount and type of physical activity contributed only a small portion to fundamental motor skill development in non-overweight children. Despite this weak relationship, it is important to note that the relationship becomes stronger as the type of physical activity increases from light to moderate and vigorous as shown by Fisher et al. (2004). These studies focused on similar gross fundamental motor skills (running, jumping, throwing) so their agreement is not surprising. The relationship between performance on fine fundamental motor skills and physical activity has not been established.

Fundamental Motor Skill Performance in Overweight Children

Peatman and Higgons (1942) were the first to study the effects of being overweight on the motor development of infants. The authors examined the age, weight, and height at which 349 full-term infants performed independent sitting, standing, and walking. There were no significant correlations between age and weight for the three tasks, revealing that having a larger body mass does not influence the age at which an infant can perform sitting, standing and walking. In conclusion, this early study indicates the heavier infants performed the tasks of sitting, standing, and walking at similar ages as normal weight infants.

More recent research does not support the findings of Peatman and Higgons; however. Jaffe and Kosakov (1982) examined gross and fine motor functioning of 135 infants (79 normal body weight, 45 overweight and 11 obese). The authors did not discuss their methods of testing gross and fine motor functioning; however, they report that extra body weight increased the incidence of motor delay. Upon a one-year follow up, 10 out of 14 overweight and obese infants who demonstrated delays in motor development had become normal in weight and motor development. One infant remained overweight but demonstrated normal motor development. Three infants who remained overweight or obese remained motor delayed. It should be pointed out that the majority of overweight or obese infants (39 out of 56) displayed normal motor development at the original testing. Therefore, it appears excess body fat only delays the motor development in a minority of overweight and obese babies, and many of the motor delayed overweight and obese babies catch up to their peers within a year.

Du Toit and Pienaar (2003) explored the relationship between overweight or obese 3 and 4 year olds and their fundamental motor skill proficiency. Three fundamental motor skills, hopping, one-legged balance, and catching, were performed by 130 young children (19 overweight and obese, 111 normal weight). BMI and triceps and subscapular skinfold measurements were taken for each child. There was no significant relationship between weight and fundamental motor skills among 3 year olds. However, there was statistical significance among the 4 year olds (10 overweight and obese: 56

non-overweight) in that overweight and obese 4 year olds performed worse on balancing and catching skills which require good balancing and perceptual/spatial abilities in order to perform successfully.

McKenzie et al. (2002) examined the fundamental motor skill performance of 207 four-, five- and six-year old children in relation to the sum of skinfold measurements taken at the triceps and subscapular regions. The three fundamental motor skills examined were catching a ball, balancing on one foot, and lateral jumping. A statistically significant negative relationship was obtained between skin folds and jumping ($r = -0.23$ for boys), balancing ($r = -0.29$ for boys, -0.21 for girls), and total skill index ($r = -0.22$ for boys), indicating that greater adiposity is associated with lower fundamental motor skill performance. (Negative non-significant relationships were obtained for boys catching ($r = -0.02$), girls jumping ($r = -0.05$), and girls skill index ($r = -0.04$). A positive non-significant relationship was obtained for girls and catching ($r = 0.11$).)

Obesity has also been shown to have a negative relationship with fundamental motor skill proficiency in a sample of 8 year olds. Biskanaki et al. (2004) examined 411 8 year olds (195 boys and 216 girls) on four fundamental motor skills: 1) 30 meter run, 2) 20 meter shuttle run, 3) standing jump and reach, and 4) 1 kg medicine ball throw. Each child was classified as obese (>20.1 for boys and > 21.7 for girls) or non-obese. Boys demonstrated statistically significant increases in performance in each of the fundamental motor skills when compared to girls across both weight groups. Obesity was negatively related with the fundamental movement skills requiring movement through space (the 30 meter run and 20 meter shuttle run) and positively related for object control skills such as throwing. There was no relationship found for the standing jump and reach.

Similar results have been observed by Okely, Booth and Chey (2004). Their study focused on the relation between body composition and fundamental motor skills among 4th, 6th, 8th, and 10th graders. Six fundamental motor skills were examined: 1) run, 2) vertical jump, 3) catch, 4) overhand throw, 5) forehand strike, and 6) kick. Body composition was determined by both BMI and waist circumference measurements. A strong negative relationship was observed between excess weight and fundamental motor skill proficiency for the locomotor tasks (run and vertical jump) and a weak negative relationship with the object control tasks (catch, overhand throw, forehand strike, and kick).

In summary, the evidence concerning the fundamental motor skill performance of overweight children is consistent; fundamental motor skill performance decreases as adiposity increases. This trend occurs across an age span of 4 – 16 year olds (Du Toit and Pienaar, 2003; McKenzie et al., 2002; Biskanaki et al., 2004; and Okely, Booth & Chey, 2004). Children under the age of four may not be affected by excess body fat (Jaffe & Kosakov, 1982 and Du Toit & Pienaar, 2003). However, there are some fundamental motor skills performed by overweight children, mainly object manipulation skills such as throwing, which are superior to non-overweight children. Yet, this increase in performance was typically examined with product-based observations rather than process-based observations. For example, hypothetically, overweight children may use their weight to throw an object over a greater distance, but their throwing motion may be different and less efficient than non-overweight children.

Relation among Physical Activity/Fitness, Fundamental Motor Skills, and Body Fat

Malina et al. (1994) examined the relationships between fat mass and fundamental motor skills in 6, 700 girls between the ages 7 and 17. The sum of five skinfolds (triceps, biceps, suprailiac, subscapular, and medial calf) was taken to estimate fatness. Each girl also underwent a fitness battery comprised of 12 tests: 1) flamingo stand; 2) plate tapping; 3) sit and reach; 4) vertical jump; 5) explosive strength; 6) arm pull; 7) bent arm hang; 8) leg lifts; 9) sit-ups; 10) shuttle run; 11) pulse recovery after a one minute step test; and 12) submaximal power output. Significant and negative correlations for nearly all tests at each age group (r = -0.12 to -0.37) were found among weight correlated with performance (four correlations between the flamingo stand and the sum of skinfolds were negative but not significant). The only positive correlation is for 9 year olds on plate tapping, however it is not significant. The leanest girls perform consistently and significantly better than the fattest girls with the largest differences in body projection (i.e. vertical jumps), rapid movement, and support off the ground body movements (i.e. bent arm hang). In conclusion, excess fat has a negative influence on health and performance related physical fitness of girls especially at the extremes of body weight.

Reeves, Broeder, Kennendy-Honeycutt and East (1999) compared the performances of 5 and 6 year old children (n = 51) on a battery of fitness tests and on a battery of motor skills. The fitness battery consisted of six tests: 1) the half mile run/walk; 2) the Progressive Aerobic Cardiovascular Endurance Run (PACER); 3) curl-ups; 4) trunk lift; 5) flexed arm hang; and 6) the back saver sit-and-reach. Body composition was calculated by the sum of right–side triceps and calf skinfolds. Four subsets of the Bruininks-Oseretsky Test of Motor Proficiency Short form were used to examine fundamental motor skill performance: 1) running speed and agility; 2) balance;

3) bilateral coordination; and 4) strength. In this particular study, greater levels of body fat were significantly and positively related to balance, bilateral coordination, and strength, but negatively related to run time.

Graf, Koch, Kretshman-Kandel, et al. (2004) identified the relationship between physical activity, fundamental motor skills, and BMI in a population of 5 – 8 year olds (n = 668). Physical activity was identified by interviews of the parents and children. Fundamental motor skill proficiency was determined by the Körperkoordinationstest für Kinder (KTK), (Body Coordination Test for Children). The KTK measures four gross motor skills: 1) balancing backwards; 2) one-legged obstacle jumping; 3) jumping from side to side; and 4) sideways movements. Endurance was determined by performance of the 6–minute run. BMI was calculated for each child. A weak negative relationship (r = - 0.16) was found between BMI and gross motor skill performance and a negative relationship (r = - 0.20) between BMI and endurance. Furthermore, the authors reported that the obese children performed gross motor skills at a level which would classify them as having a moderate motor disorder and overweight children performed at a level slightly worse than normal weight children. The evidence suggests that a higher BMI correlates with lower gross motor and endurance performance.

Based on the findings of Graf, Koch, Kretshman-Kandel, et al. (2004) an intervention program was implemented by the same authors that investigated the effects of an intervention on BMI and fundamental motor skills. This study is the only study which has incorporated an intervention of any kind while examining fundamental motor skill performance. Six-hundred fifty-one children (age range 5.7 – 9.0 years) participated in a project whose aims were to increase total energy expenditure from physical activity, to optimize physical education lessons and to enhance pupils' health knowledge. Children participated in at least five minutes of morning exercises aimed at increasing total energy expenditure and to improve fundamental motor skills, the remainder of the intervention was weekly health education lessons (classroom instruction) totaling 20 – 30 minutes per week. The intervention duration was 20 months. Similar to the previous study, BMI was obtained and the children performed the six-minute run to test endurance performance, however only one subset (lateral jumping) of the KTK was used to measure motor skill performance. The overweight and obese children showed the poorest improvement in motor ability across time and there were no significant differences between the intervention group and the control group. Non-overweight children did show an improvement in fundamental motor skill performance following the intervention, however. Thus, no effect of this exercise intervention was detected for overweight children but did improved non-overweight children's' fundamental motor skill performance.

Raudsepp and Jürimäe (1997) examined the relation of physical activity, fat mass, fundamental motor skill, and physical fitness in 255 7 to 10 year old girls. Physical activity was measured with a seven-day physical activity recall. BMI, skinfolds (triceps, biceps, subscapular, abdominal, and medial calf), girths (arm, chest, thigh, calf) and widths (humerus and femur) were measured for each child. Fundamental motor skill performance was determined by quantitative and qualitative assessments of the overhand throw. In addition, each child completed the EUROFIT battery to determine fitness. The EUROFIT is a 9 test item battery comprised of 9 skills: 1) standing long jump; 2) 10 X 5 meter shuttle run; 3) bent arm hang; 4) sit-and-reach; 5) plate tapping; 6) flamingo balance; 7) handgrip strength; 8) sit-ups; and 9) 20 m endurance shuttle run. Many of these items also test fundamental motor skills. Significant negative correlations (r = -0.27 to -0.39) between fatness and the motor skill fitness items (shuttle run, standing long jump, bent arm hang, and the 20 meter shuttle run) and a positive (non-significant) correlation between fatness and throwing (r = .05 to .16) across 7, 9, and 10 year olds support previous observations that an increase in fat mass relates to poor fundamental motor skill performance except for throwing skills.

In conclusion, several cross sectional studies have shown that an increase in body fat negatively correlates with fundamental motor skill performance. Only one study attempted an intervention program (Graf, Koch, Falkowski, et al., 2005). The intervention did not alter children's fundamental motor skills. However, it should be emphasized that the intervention was limited to only 5 minutes of additional physical activity each morning for 20 months.

Balance and Movement Characteristics in Overweight Children

Studies examining the relation between obesity and postural control in children are limited and with inconsistent results. Hills and Parker (1991a) were the first to objectively examine the walking patterns of obese children. Ten obese and ten normal weight children (age range 8.5 – 10.9 years) were filmed walking ten meters at a normal, slow (10% slower than normal), and fast speed (30% faster than normal). Obese children were significantly slower across all speeds in the cadence and relative velocity of walking, had longer cycle durations (toe off, swing phase, heel strike), and spent more time in double support (when both feet are in contact with the floor). In conclusion, the walking gait of obese children is slower and more tentative than normal weight children.

McGraw, McClenaghan, Williams, Dickerson, and Ward (2000) found similar results while examining the gait and stability of obese boys. Ten obese and ten non-obese boys (8 to 10 years old) were examined while walking at a normal, slow (10% slower than normal), and fast speed (30% faster than normal). Each child also was examined while performing two standing (normal and heel-to-toe stance) positions while having full vision, no vision, or conflicted vision. The obese boys spent statistically significant longer periods in double support for all walking activities and in stance activities. While in quiet stance, the obese boys demonstrated statistically significant increases in: 1) maximum displacement in the medial–lateral direction while in normal and heel-to-toe stance with no vision; 2) total energy of displacement in the medial–lateral direction while in normal and heel-to-toe stance with no vision and in distorted vision; 3) greater variability in the medial–lateral direction while in normal and heel-to-toe stance with no vision and in distorted vision; 4) total energy of displacement in the anterior-posterior direction while in heel-to-toe stance with normal and no vision; and 5) greater variability in the anterior-posterior direction while in normal and heel-to-toe stance with full vision and no vision. In conclusion, obese boys have a more difficult time in dynamic and static stability, particularly in areas where the postural system is challenged.

Bernard et al. (2003) examined the balance and postural performance of obese adolescent females. Nine obese females (14 – 16 years old) were compared to 7 normal weight females. Each individual stood on a force plate (a platform which can detect ground reaction forces and sway movements) with eyes open and eyes closed, with and without a foam cushion while recovering from perturbations. There were no statistically significant differences between the obese and non-obese females in any of the conditions, except the obese females demonstrated significantly longer delays returning to center of pressure while standing on the foam cushion. In conclusion, obesity does not affect the stability or postural control of female adolescents except the obese individual requires a longer time to regain her center of pressure after a perturbation.

The limited evidence on the relation between obesity in children and balance suggests obesity may negatively impact balance and gait characteristics in children. However, these studies are limited in their generalizability with small sample sizes, especially Bernard et al. (2003) who concedes the lack of a relationship found was likely due to their small sample sizes. Nonetheless, the evidence suggests that excess body weight hinders balance and alters the movement patterns for walking.

Balance and Movement Characteristics of Obese Individuals Following an Exercise Intervention

Few studies, with mixed results, have investigated the effects of an intervention program on the balance and movement characteristics of obese children. Hills and Parker (1991b) examined the effects of an intervention program on the gait characteristics in obese children. Twelve obese children were randomly assigned to two groups. Seven obese children were provided a 16 week diet and exercise intervention aimed at reducing body fat and improving motor skill levels. Control groups of five obese children and four normal weight children were also examined. Each child was filmed while walking at a normal, slow (10% slower than normal), and fast speed (30% faster than normal). Significant improvements in each symmetry indicator and significant improvements in body composition, as measured by the sum of four skinfold measurements, occurred for the intervention group as compared to controls. In conclusion, the diet and exercise intervention lowered fat mass, which contributed to the improvement in stability and a symmetrical gait in obese children.

Colne et al. (2004) examined the gait initiation of obese teenagers who took part in a seven month weight loss intervention. Gait initiation is the transition phase between the steady state of an upright standing position to the dynamic state of a steady state movement through space, such as walking. Obese individuals were not statistically different in their velocities of walking after the weight loss intervention. However, a statistically significant increase in anticipatory postural adjustments was observed following the intervention program. Anticipatory postural adjustments are needed to create the propulsion forces of gait and to control the equilibrium of posture. In conclusion, the intervention, which decreased fat mass, did not improve gait initiation and the lengthening of the anticipatory postural adjustments suggests the motor pattern for walking had been maintained despite the loss of fat mass.

Pacquette, Teasdale, Prud'Homme & Tremblay (2000) observed a significant decrease in the velocity of movement and sway path in six obese men who took part in a 12 week aerobic training-based weight-loss intervention program. The authors reported a reduction in weight improved the balance performance of obese men.

The evidence that an exercise intervention program may improve the balance and movement characteristics of obese children is limited but promising. Only one study has examined the influence of an intervention on obese children and the performance of balance and movement tasks (Hills & Parker, 1991b). Additional studies in adolescents (Colne, et al., 2004) and adults (Pacquette, Teasdale, Prud'Homme & Tremblay, 2000) have shown similar findings in improving balance and movement characteristics after an exercise intervention.

Summary

Fundamental motor skills are observable movement performances of basic locomotor, manipulative, or stability movements and form the basis for future skilled movements. Before fundamental motor skills can mature, development of the postural system must occur to provide the body with the stable support necessary for dynamic and stable body movements. Boys typically develop gross and manipulative fundamental motor skills earlier than girls and are more proficient in these motor skills through growth and adulthood. However, girls tend to develop and are more proficient at non-manipulative motor skills at an earlier age.

Many gaps exist in the current literature investigating fundamental motor skills and obesity. A majority of studies lack the use of a full test battery developed to identify fundamental motor proficiency. There are, however, a few studies which have taken subtests of a developed battery, but the full battery has not been used. Many studies examine one (often the overhand throw), or only a few fundamental motor skills which favor one gender over another. In addition, few studies examine both process and product measurements of fundamental motor skills. Non-overweight children who participate in physical activity perform slightly better in fundamental motor skills than non-overweight children who do not participate in physical activity, suggesting that the type and amount of physical activity a child participates in contributes minimally to fundamental motor skill performance. These studies focused on gross fundamental motor skills; the relationship between obesity and fine motor skills has not been established. In overweight children, fundamental motor skill performance is consistently lower than non-overweight children across a wide age range, 4 – 16 years old. Participation in an intervention study did not improve fundamental motor skills in overweight and obese children (Graf, Koch, Kretshman-Kandel, et al., 2004); however the study contained a very low period (5 minutes) of exercise. The only fundamental motor skill on which obese children was superior to that of than non-overweight children was the overhand throw. However, studies examining this relationship were primarily product based (i.e. focused on the distance the ball was thrown) and not the process of the throw which may differ between these groups. Overweight and obese children also demonstrate worse balance and gait characteristics than non-overweight children, and intervention programs have shown to be useful in reducing fat mass and improving balance and gait characteristics in overweight and obese children and adults. Therefore, there is a need for a study to determine the fundamental motor skill proficiency of non-overweight and overweight children using a battery which has been developed and used extensively to test fundamental motor skill proficiency, and to identify the impact an intervention program, designed to decrease fat mass through extended periods of regular, vigorous physical activity, has on fundamental motor skills in overweight children.

CHAPTER III

METHODS

Participants.

Two hundred forty children ages 7 – 11 were contacted through an elementary school in the Athens-Clarke County area. A packet containing an introductory letter stating the purpose of the study, parental consent forms, child assent forms, and a demographic questionnaire were provided to each child. Eighty packets (33.33%) were returned; three respondents desired not to participate in the study. Of the seventy-seven remaining participants, forty-one (41) were eligible for the study based on body mass index (BMI) inclusion criteria of being within the 15^{th} and 75^{th} percentile for their age. Subject physical characteristics (mean ± standard deviation) were: age = 9.79±1.06 yr., mass = 34.93±5.57 kg, height = 142.97±8.30 cm, and BMI = 16.97±1.11. A $5 gift card was presented to each child upon completion of the study and parents were provided an information sheet describing their child's fundamental motor skill performance.

In addition, 113 overweight children were recruited from elementary schools in the Augusta-Richmond County area. The overweight children were randomly assigned to three groups: a Control group; a 20 minute exercise group; and a 40 minute exercise group (n = 43, n = 34, and n = 36 respectively). The participants were elementary school children ages 7 – 11 with a Body Mass Index (BMI) above the 85^{th} percentile. Subject physical characteristics (mean ± standard deviation) were: age = 9.25±1.14 yr., mass = 51.87±15.27 kg, height = 140.36±9.66 cm, and BMI = 25.90±4.93. Each study was approved by the University's Institutional Review Board, the Clarke County School

District, and Medical College of Georgia Institutional Review Board. Written informed consent was obtained from participating children and parents/guardians prior to testing.

Research Design

A two group comparison design was used to examine the hypothesis that non-overweight and overweight children differ in their performance of fundamental motor skills as measured by the Bruininks-Oseretsky Test of Motor Proficiency – Short Form. The fundamental motor skill performances of a sample of 40 non-overweight children, as classified by BMI, were compared to the performances of fundamental motor skills of the Control group (n = 43) and all 113 overweight children.

A three group pretest-posttest design was used to examine the hypothesis that exercise training of overweight children will improve fundamental movement skills. One hundred thirteen (113) children were randomly assigned to three conditions: 1) 20 minute exercise intervention; 2) 40 minute exercise intervention; and 3) a control group who attend a healthy lifestyle class once a month. The 113 overweight children are part of a larger study (Policy Leadership for Active Youth (PLAY) Project) conducted at the Georgia Prevention Institute at the Medical College of Georgia.

Protocol and Procedures

BMI Measurement. Height and weight were measured for each child and BMI was calculated as kg/m^2. Age adjusted BMI inclusion criteria were set between the 15^{th} and 75^{th} percentile for non-overweight children and above the 85^{th} percentile for overweight children according to the recommendations of Rosner, Prineas, Loggie, and

Daniels, (1997) and Cole, Bellizzi, Flegal, and Dietz (2000). The use of BMI as a measure of adiposity among children has been widely validated (see Pietrobelli, et al., 1998).

Fundamental Motor Skill Measurement. Fundamental motor skills were measured using the Bruininks-Oseretsky Test of Motor Proficiency – Short Form. The Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) is a test designed to measure the fundamental motor skill functioning of children who are 4½ to 14½ years old. The short form consists of 14 items among 8 subtests and takes approximately 20 minutes to complete (Bruininks, 1978). The use of the short form in children 9 – 11 years old has been shown to have acceptable test-retest reliabilities (r = 0.76 – 0.86) (Bruininks, 1978; Hassan, 2001; and Moore, Reeve, & Boan, 1986), inter-rater reliability (r = 0.63 – 0.97) (Bruininks, 1978), and validity (Bruininks, 1978 and Hassan, 2001). The Bruininks-Oseretsky Test of Motor Proficiency – Short Form has been used in special populations and has shown to be an accurate measure of identifying fundamental motor skill proficiency. (Connolly & Michael, 1986; Miles, Nierengarten, & Nearing, 1988) Each child was examined individually, in seclusion from other participants, and was provided instruction on how to complete the test according to guidelines provided by Bruininks (1978). The fundamental motor skills evaluation of the non-overweight sample occurred during one examination for each child during the child's regularly scheduled P.E. class. While seclusion was attempted, 15 children were tested in the presence of others due to rainy days. Overweight children were examined prior to, and following, the interventions. The same individual scored the overweight children pre and post intervention and was blinded to which exercise condition each child participated in.

Exercise Interventions. During the exercise interventions, overweight children took part in aerobic games and activities designed to maintain a minimum heart rate of 150 beats per minute for 20 or 40 minutes per day. The exercise intervention included a 5 minute warm-up period of stretching and moderate activity followed by either 20 minutes or 40 minutes of moderate to vigorous activity, and finished with a cool down phase of stretching and light activity. Heart rate monitors (S610i: Polar Electro, Oy, Finland) with a 30 second epoch recording, were worn by each participant. Average heart rates for each child were recorded following the exercise session. The activities (i.e. tag games, modified soccer) were selected based on their safety, level of participant interest and enjoyment. The selected activities were not intended to promote skill development or competition. The exercise conditions took place Monday through Friday for 14 weeks and each child was expected and encouraged by small prizes to attend at least 4 days a week.

Statistical Analysis

Statistical analyses were performed using SPSS v. 11.0 for Windows (SPSS, Inc., Chicago, IL). Independent sample t-tests were performed to measure the mean differences in fundamental motor skill performance between non-overweight and overweight children, and between boys and girls, with α set at .05. Degrees of freedom reported are predicated on the Levene's test for equal variances. Pre-test scores for the overweight children were compared to the scores of the normal weight children. Pearson correlations were used to describe the relationship between BMI and performance of fundamental motor skills, with α set at .05. Analysis of Covariance (ANCOVA) was used to examine differences at posttest scores among children assigned to the three experimental conditions (control, 20 min, 40 min). Type one error (α) was set at 0.05. Means, standard deviations, and point scores are reported unless specified otherwise. Cohen's *d* is reported as an estimate of effect size. Inter-rater reliability between the rater at the Medical College of Georgia and the researcher who scored the normal weight children in Athens, GA on the BOTMP was determined by comparing the scores of 5 overweight children. Inter-rater reliability of the researcher in Athens, GA was also measured by comparing the scores of 10 children to another rater who was trained in administering the BOTMP-Short Form. The sample size for comparing the mean differences in fundamental motor skill performance between non-overweight and overweight children is sufficient to detect an effect size of $d = 0.65$ using a two-tailed t-test for independent samples at $\alpha = 0.05$ and statistical power of 0.80. The sample size for comparing the mean differences in fundamental motor skill performances among overweight participants is sufficient to detect an effect size of $d = 0.25$ using an ANCOVA at $\alpha = 0.05$ and statistical power of 0.80.

CHAPTER IV

RESULTS

Hypothesis I: Overweight children, compared to non-overweight children, will be less proficient in fundamental motor skills.

Descriptive information concerning the sex, age, height, weight, BMI, race, and parental education of the Control group overweight (n = 43) and 41 normal weight children are contained in Table 1. Weight, height, and BMI were all significantly different between the two groups ($t_{52.060} = 6.73$, $p < 0.001$, $t_{40} = 2.12$, $p = 0.040$, and $t_{45.901} = 11.305$, $p < 0.001$ respectively). Overweight children were approximately 18 kg heavier, 3 cm shorter, and were nearly 9 points higher on the BMI scale than their normal weight peers. No significant differences occurred between the two groups on any of the remaining variables.

The results comparing normal weight children to the Control Group (n = 43) overweight children are presented for the Total Score and all 14 items of the BOTMP – Short From in Table 2. Normal weight children were superior in performance than their overweight peers on the Bruininks-Oseretsky Test of Motor Proficiency – Short Form as a whole ($t_{82} = 6.67$, $p < 0.001$, $d = 1.47$) and specifically on 8 of the 14 items: Running Speed and Agility ($t_{82} = 4.04$, $p < 0.001$, $d = 0.89$); Standing on Preferred Leg on Balance Beam ($t_{62.486} = 5.40$, $p < 0.001$, $d = 1.37$); Tapping Feet Alternately While Making Circles with Fingers ($t_{78.099} = 2.80$, $p = 0.007$, $d = 0.63$); Jumping Up and Clapping Hands ($t_{82} = 6.73$, $p < 0.001$, $d = 1.49$); Standing Broad Jump ($t_{82} = 6.93$, $p < 0.001$, $d = 1.53$); Catching a Tossed Ball with Both Hands ($t_{78.392} = 2.29$, $p = 0.025$, $d = 0.52$); Response

Speed (t_{82} = 6.31, $p < 0.001$, d = 1.39); and Sorting Shape Cards with Preferred Hand (t_{82} = 2.31, p = 0.023, d = 0.51).

A priori t-tests compared the 41 normal weight children to the pre-test scores of all overweight children in the three exercise groups (n = 113). Descriptive information concerning the sex, age, height, weight, BMI, race, and parental education of the 113 overweight and 41 normal weight children are contained in Table 3. There was a significant difference between normal weight children and overweight children in age (t_{152} = 2.644, p = 0.009) with the normal weight children approximately 6 months older than the overweight group. Weight, height, and BMI were all significantly different between the two groups ($t_{151.980}$ = 10.084, $p < 0.001$, $t_{40.465}$ = 2.075, p = 0.044, and $t_{138.001}$ = 18.041, $p < 0.001$ respectively). Overweight children were approximately 17 kg heavier, 3 cm shorter, and were nearly 7 points higher on the BMI scale than their normal weight peers. No significant differences occurred between the two groups on any of the remaining variables.

There were no significant differences between Control group only (n = 43) and all overweight children (n = 113). Results comparing normal weight children to all 113 overweight children are reported below and in subsequent charts and figures. Normal weight children were superior in performance than their overweight peers on the Bruininks-Oseretsky Test of Motor Proficiency – Short Form as a whole (t_{152} = 7.78, $p < 0.001$, d = 1.43) and specifically on 8 of the 14 items: Running Speed and Agility (t_{152} = 4.67, $p < 0.001$, d = 0.86); Standing on Preferred Leg on Balance Beam ($t_{137.01}$ = 7.44, $p < 0.001$, d = 1.44); Tapping Feet Alternately While Making Circles with Fingers ($t_{91.09}$= 3.02, p = 0.003, d = 0.72); Jumping Up and Clapping Hands (t_{152} = 8.51, $p < 0.001$, d =

1.56); Standing Broad Jump ($t_{152} = 9.12$, $p < 0.001$, $d = 1.67$); Catching a Tossed Ball with Both Hands ($t_{90.61} = 2.27$, $p = 0.026$, $d = 0.54$); Response Speed ($t_{152} = 6.85$, $p < 0.001$, $d = 1.26$); and Sorting Shape Cards with Preferred Hand ($t_{152} = 3.41$, $p = 0.001$, $d = 0.63$). Means and standard deviations are presented for the Total Score and all 14 items in Table 4. Figure 1 depicts the means of the two groups on the 14 items of the BOTMP.

Total Score and five items (Running speed and agility, Standing on Preferred Leg on Balance Beam, Jumping Up and Clapping Hands, Standing Broad Jump, and Response Speed) had significant negative correlations, ranging from -0.18 to -0.48. Making Dots in Circles with Preferred Hand was the only item to have a significantly positive correlation (0.18). Table 5 contains the correlation coefficients and effect sizes for Total Score and all 14 items. Figure 2 depicts the correlation between BMI and Total Score. Inter-rater reliability between the rater at the Medical College of Georgia and the rater in Athens, Georgia for Total Score and the 14 items of the BOTMP are presented in Table 6.

Hypothesis II: Boys will be more proficient in gross motor skills and less proficient in fine motor skills than girls regardless of weight.

Normal weight boys and girls significantly differed on Copying a Circle with Preferred Hand ($t_{33.29} = 2.42$, $p = 0.021$, $d = 0.84$), as girls were superior in performance than boys. No other items, nor Total Score, were significant; however, Copying Overlapping Pencils with Preferred Hand approached significance ($t_{39} = 1.98$, $p = 0.055$). Overweight boys and girls differed on Total Score ($t_{96.93} = 3.51$, $p = 0.001$, $d = 0.67$) with boys scoring 6 points higher than girls. In addition, overweight boys performed significantly better on 4 individual items; Running Speed and Agility ($t_{111} = 3.97$, $p < 0.001$, $d = 0.76$); Jumping Up and Clapping Hands ($t_{111} = 3.16$, $p = 0.002$, $d = 0.60$); Standing Broad Jump ($t_{111} = 3.65$, $p < 0.001$, $d = 0.70$); and Response Speed ($t_{111} = 3.15$, $p = 0.002$, $d = 0.60$). Overweight girls significantly performed better on Tapping Feet Alternately While Making Circles with Fingers ($t_{100.74} = 2.37$, $p = 0.020$, $d = 0.48$). Means, standard deviations, and effect sizes for the statistically different scores are presented in Table 7.

Hypothesis III: Exercise training of overweight children will improve fundamental movement skills.

Of the original 113 overweight children at pretest, 104 (92.0%) completed the 14 week program and post-test session. Upon the end of the study, the control group consisted of 40 participants, the 20 minute exercise group consisted of 31 participants, and the 40 minute exercise group consisted of 33 participants. Table 8 documents the characteristics and demographics of each group, pre and post the exercise intervention. A 3 (Group: control, 20 min, 40 min) X 2 (Time: pre-post) mixed analysis of covariance (ANCOVA) with α set at .05, was performed to measure the significance of the mean differences among age, gender, weight, height, BMI and body fat. Pre-test and post test height, and post test body fat were found to be significantly different. Post hoc analysis revealed all three groups were significantly different in height pre and post, while only the 40 minute exercise group was significantly different from the control group in body fat following the intervention. No additional significant differences occurred between the groups.

No significant differences in means occurred between the three groups for Total Score or on any of the 14 items of the BOTMP following the 14 week exercise program. Figure 3 depicts the mean Total Score between groups following the exercise intervention. Means, standard error, F tests, and significance for Total Score and the 14 items are presented in Table 9. A paired samples t-test between the post-test mean of the 104 overweight children and 57, the 50^{th} percentile point score as identified by the BOTMP Manual, revealed that overweight children performed significantly lower than the 50^{th} percentile for their age related peers ($t_{103} = 4.72$, $p < 0.001$, $d = 0.53$).

CHAPTER V

CONCLUSION AND DISCUSION

Conclusion.

Results from this study indicate normal weight children run faster, have better static balance (stork stance on a balance beam), better control over simultaneous feet and hand movements, greater strength, can catch better, have quicker reaction, and can sort more efficiently, which results in overall superior motor skill proficiency than their overweight peers. In addition, moderate to strong negative relationships were found between BMI and overall motor skill proficiency, running speed, static balance, jumping and clapping, strength, response speed, and making dots inside circles. These results support the hypothesis that overweight children are less proficient than normal weight children in fundamental motor skills. However, the results also indicate children are similar in performance in specific motor skills regardless of adiposity. These motor skills include dynamic balance (walking on a balance beam), and many fine motor skills such as drawing lines, replicating drawings (such as circles and pencils), and rapid hand-eye coordinated movements. Therefore, this study points toward greater performance of gross motor skills in normal weight children which results in an overall greater performance in fundamental motor skills as identified by the short-form BOTMP.

Gender specific differences which have been summarized by Jürimäe and Jürimäe (2000) and were the basis for the hypothesis that gender differences will remain similar for boys and girls regardless of weight were not supported by this study. Normal weight boys and girls only differed on one item of the short form BOTMP, Copying a Circle with Preferred Hand. Established gender differences, such as boys demonstrating greater performance on gross motor skills and girls performing better on fine motor skills were not identified. While there was difference on Copying a Circle with Preferred Hand, this is only one item of three (Drawing a Line Through a Straight Path with Preferred Hand, and Copying Overlapping Pencils with Preferred Hand are the other two items) which on the short form BOTMP describes the motor skill, visual-motor control. Hence, this study did not observe any gender specific differences in motor skills in normal weight children.

Among overweight children, however, gender differences were observed. Overweight boys have a higher performance overall on motor skills than overweight girls. In addition, overweight boys performed superior on two gross motor skills; running and standing broad jump. Overweight boys were also found to have faster response speed, a fine motor skill. Overweight boys performed better on Jumping Up and Clapping Hands while overweight girls performed better on Tapping Feet Alternately While Making Circles with Fingers. Both of these items are used to determine the gross motor skill of bilateral coordination. It appears that overweight children display gender specific differences in motor skills while their normal weight peers do not when being measured by the short form BOTMP.

Finally, the results did not support the hypothesis that an exercise intervention would improve motor skill performance for overweight children in overall performance or for any specific motor skill, even despite a significant loss of body fat for children in the 40 minute exercise group. In addition, it was observed that the overweight children were below the 50th percentile performance in fundamental motor skill proficiency for their age-related peers.

Discussion.

The present findings are consistent with previous research examining the relationship between excessive adiposity in children and fundamental motor skill performance (Biskanaki et al., 2004; McKenzie et al., 2002; Okely, Booth and Chey, 2004). However, correlations between fundamental motor skills and BMI observed in this study are higher than previously reported. For example, the Total Score on the short form BOTMP had a correlation of -0.48 compared to -0.29 as found by Okely, Booth and Chey (2004) on their standardized fundamental motor skill index for 4th graders. The large disparity in correlations may be due to this being one of the few studies to use a test battery designed to measure fundamental motor skill proficiency to examine the differences in normal weight and overweight children.

The present study did not support the previously founded gender differences in normal weight children. It did, however, upheld these differences in overweight children. Future research should examine the relationship between gender, age, and fundamental motor skills in overweight children.

Graf, Koch, and Falkowski (2005) were the first to attempt an exercise intervention in overweight children and determine its impact on fundamental motor skill performance. The authors observed overweight children did not improve in fundamental motor skill proficiency following a 20 month intervention. The exercise intervention consisted of five minutes of activities which included focused on improving coordination, balance, relaxation, rhythm, creativity, back training, and group participation. One interesting finding was the observation that normal weight children improved in fundamental motor skill performance. Despite an exercise intervention of moderate-vigorous activity, and for 20 or 40 minutes for 14 weeks, the current study failed to observe improvements in fundamental motor skills in overweight children. While the current study did not have an intervention program designed to improve fundamental motor skills, as did the intervention program by Graf, Koch, and Falkowski (2005), the duration of physical activity was considerably longer. It would be important for future research to focus on intervention programs designed to improve fundamental motor skills and decrease adiposity in overweight children.

The evidence obtained from the present study and Graf, Koch, and Falkowski (2005) points to the need for structured physical education classes for overweight children that emphasize fundamental motor skill development. There is a large gap in performance of motor skills between normal weight and overweight children. Physical education practitioners should design lessons that assist in the development of motor skills in these children. Physical education teachers should also be aware that teaching fundamental motor skills to overweight children is needed. In addition, P.E. practitioners should be aware that a loss in body fat, independent of teaching fundamental motor skills, will not necessarily mean an improvement in fundamental motor skill proficiency. Establishing sound fundamental motor skills in children is essential for future motor skill achievement and success (Gallahue & Ozmun, 2002). Overweight children lacking sound fundamental motor skills may be less willing to participate in physical activity due to such psychological determinants as, motivation, self-efficacy, and sense of control. Goran, Reynolds, and Lindquist (1999) identify the importance of overcoming psychological determinants as a critical milestone for overweight children to begin participating in physical activity. Children, both normal weight and overweight, who establish a solid foundation in fundamental motor skills may be more likely to participate in regular physical activity, such as basketball and volleyball. In turn, overweight children may establish behaviors which support the continuation of physical activity in adulthood.

In conclusion, a large gap between normal weight and overweight children on fundamental motor skill performance exists with many gender differences between overweight children. An exercise intervention, alone, does not appear to improve the fundamental motor skill performance in overweight children, even if a decrease in body fat occurs. This study supports the need for fundamental motor skills to be part of the physical education curriculum and developing a sound base of fundamental motor skill proficiency may be an avenue toward continued physical activity and reaching the goals of 'Healthy People 2010'.

Table1: Control Group Overweight and Normal Weight Participant Characteristics and Demographics

Group	N	Age* (yrs)	Gender Boys:Girls	Weight** (kg)	Height* (cm)	BMI**	Race+ African American: Caucasian	Education+
Overweight	43	9.38 ±1.18	18 : 25	52.68 ±16.33	140.30 ±1.00	26.27 ±5.27	26 : 17	5.00 ±0.96
Normal Weight	41	9.79 ±1.06	21 : 21	34.93 ±5.70	143.05 ±8.29	16.97 ±1.11	20 : 19	5.03 ±1.58

*Significance at $p < 0.05$
**Significance at $p < 0.01$
+Race and Parental Education were assessed from a voluntary demographic questionnaire completed by parents/legal guardians, therefore total respondents of questionnaire may not be equal to the number of children tested.
Parental Education Scale: 1 = less than 7th Grade, 2 = 8th or 9th Grade, 3 = 10th or 11th Grade, 4 = High School diploma, 5 = Partial College, 6 = College Graduate, 7 = Post-Graduate.

Table 2: Point Scores of Normal Weight and Control Group Overweight Children on the BOTMP– Short Form

	Mean Point Scores		Standard Deviation				
BOTMP Item[1]	Normal Weight	Overweight	Normal Weight	Overweight	Sig.	E.S.	Range[2]
Total[3]	65.34	52.70	8.98	8.43	Yes	1.47	0 – 98
Run[4]	11.61	9.67	2.12	2.27	Yes	0.89	0 – 15
Stand	5.59	3.65	1.05	2.09	Yes	1.37	0 – 6
Walk	2.95	3.14	1.26	1.18	No		0 – 4
Tap Feet	0.83	0.56	0.38	0.50	Yes	0.63	0 – 1
Jump-Clap	3.59	2.37	0.87	0.79	Yes	1.49	0 – 5
SBJ	9.22	6.63	1.78	1.65	Yes	1.53	0 – 16
Catch	2.83	2.49	0.59	0.77	Yes	0.52	0 – 3
Throw	2.20	1.98	0.64	0.80	No		0 – 3
RS	9.54	5.53	3.32	2.45	Yes	1.39	0 – 17
Line	3.63	3.63	0.80	0.62	No		0 – 4
Circle	1.66	1.74	0.53	0.44	No		0 – 2
Pencils	1.37	1.35	0.77	0.69	No		0 – 2
Sorting	5.15	4.47	1.44	1.26	Yes	0.51	0 – 10
Dots	5.17	5.49	1.58	1.30	No		0 – 10

[1]Total = Total Score on the BOTMP; Run = Running Speed and Agility; Stand = Standing on Preferred Leg on Balance Beam; Walk = Walking Forward Heel-to-Toe on Balance Beam; Tap Feet = Tapping Feet Alternately While Making Circles with Fingers; Jump-Clap = Jumping Up and Clapping Hands; SBJ = Standing Broad Jump; Catch = Catching a Tossed Ball with Both Hands; Throw = Throwing a Ball at a Target with Preferred Hand; RS = Response Speed; Line = Drawing a Line Through a Straight Path with Preferred Hand; Circle = Copying a Circle with Preferred Hand; Pencils = Copying Overlapping Pencils with Preferred Hand; Sorting = Sorting Shape Cards with Preferred Hand; Dots = Making Dots in Circles with Preferred Hand.

[2]Range signifies the range of scores attainable for the test and each item, not the range of scores of the participants.

[3]Percentile Rank of 50 equals a Total Score of 57 for this age group. (Bruininks, R. H. (1978). *Manual: Bruninks-Oseretsky Test of Motor Proficiency*. Circle Pines, MN: American Guidance Service.)

[4]Higher the point score the faster the child ran.

Table 3: All Overweight and Normal Weight Participant Characteristics and Demographics

Group	N	Age* (yrs)	Gender Boys:Girls	Weight** (kg)	Height* (cm)	BMI**	Race+ African American: Caucasian	Education+
Overweight	113	9.25 ±1.14	50 : 63	51.87 ±15.27	140.36 ±1.05	25.90 ±4.93	71 : 42	4.95 ±1.08
Non-Overweight	41	9.79 ±1.06	21 : 21	34.93 ±5.7	143.05 ±8.29	16.97 ±1.11	20 : 19	5.03 ±1.58

*Significance at $p < 0.05$
**Significance at $p < 0.01$
+Race and Parental Education were assessed from a voluntary demographic questionnaire completed by parents/legal guardians, therefore total respondents of questionnaire may not be equal to the number of children tested.
Parental Education Scale: 1 = less than 7th Grade, 2 = 8th or 9th Grade, 3 = 10th or 11th Grade, 4 = High School diploma, 5 = Partial College, 6 = College Graduate, 7 = Post-Graduate.

Table 4: Point Scores of Normal Weight and Overweight Children on the BOTMP– Short Form

	Mean Point Scores		Standard Deviation				
BOTMP Item[1]	Normal Weight	Overweight	Normal Weight	Overweight	Sig.	E.S.	Range[2]
Total[3]	65.34	53.19	8.98	8.41	Yes	1.43	0 – 98
Run[4]	11.61	9.81	2.12	2.18	Yes	0.86	0 – 15
Stand	5.59	3.68	1.05	2.09	Yes	1.44	0 – 6
Walk	2.95	3.01	1.26	1.22	No		0 – 4
Tap Feet	0.83	0.60	0.38	0.49	Yes	0.72	0 – 1
Jump-Clap	3.59	2.35	0.865	0.767	Yes	1.56	0 – 5
SBJ	9.22	6.62	1.78	1.48	Yes	1.67	0 – 16
Catch	2.83	2.57	0.59	0.75	Yes	0.54	0 – 3
Throw	2.20	1.93	0.64	0.79	No		0 – 3
RS	9.54	6.09	3.32	2.53	Yes	1.26	0 – 17
Line	3.63	3.58	0.80	0.65	No		0 – 4
Circle	1.66	1.73	0.53	0.47	No		0 – 2
Pencils	1.37	1.32	0.77	0.67	No		0 – 2
Sorting	5.15	4.33	1.44	1.27	Yes	0.63	0 – 10
Dots	5.17	5.59	1.58	1.24	No		0 – 10

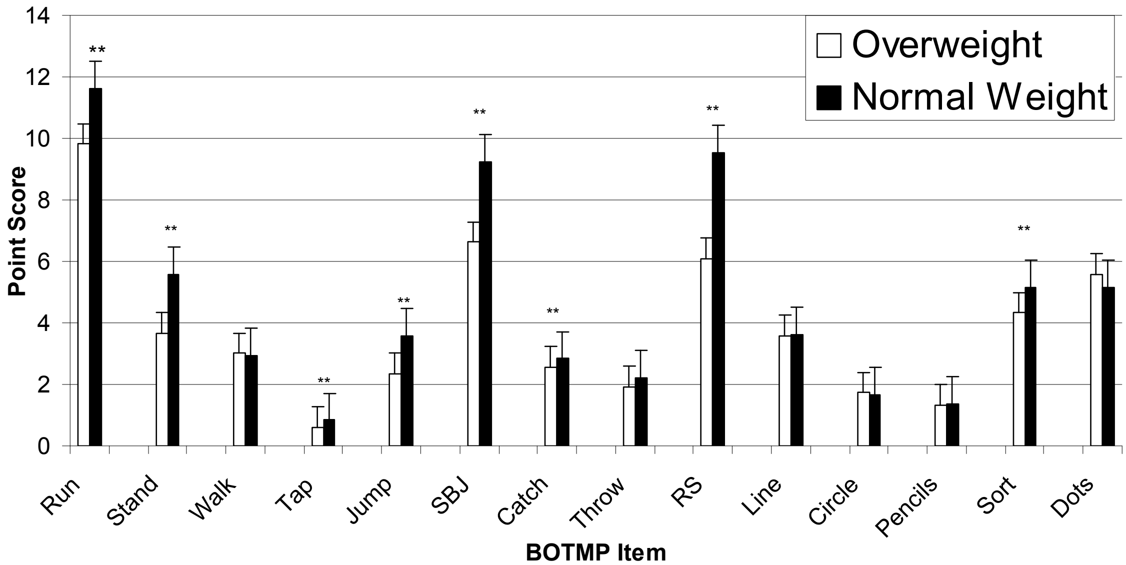
[1]Total = Total Score on the BOTMP; Run = Running Speed and Agility; Stand = Standing on Preferred Leg on Balance Beam; Walk = Walking Forward Heel-to-Toe on Balance Beam; Tap Feet = Tapping Feet Alternately While Making Circles with Fingers; Jump-Clap = Jumping Up and Clapping Hands; SBJ = Standing Broad Jump; Catch = Catching a Tossed Ball with Both Hands; Throw = Throwing a Ball at a Target with Preferred Hand; RS = Response Speed; Line = Drawing a Line Through a Straight Path with Preferred Hand; Circle = Copying a Circle with Preferred Hand; Pencils = Copying Overlapping Pencils with Preferred Hand; Sorting = Sorting Shape Cards with Preferred Hand; Dots = Making Dots in Circles with Preferred Hand.

[2]Range signifies the range of scores attainable for the test and each item, not the range of scores of the participants.

[3]Percentile Rank of 50 equals a Total Score of 57 for this age group. (Bruininks, R. H. (1978). *Manual: Bruninks-Oseretsky Test of Motor Proficiency*. Circle Pines, MN: American Guidance Service.)

[4]Higher the point score the faster the child ran.

Figure 1



*Significance at $p < 0.05$
**Significance at $p < 0.01$

Run = Running Speed and Agility (0 – 15); Stand = Standing on Preferred Leg on Balance Beam (0 – 6); Walk = Walking Forward Heel-to-Toe on Balance Beam(0 – 6) ; Tap Feet = Tapping Feet Alternately While Making Circles with Fingers (0 – 1); Jump-Clap = Jumping Up and Clapping Hands (0 – 5); SBJ = Standing Broad Jump (0 – 16); Catch = Catching a Tossed Ball with Both Hands (0 – 3); Throw = Throwing a Ball at a Target with Preferred Hand (0 – 3); RS = Response Speed (0 – 17); Line = Drawing a Line Through a Straight Path with Preferred Hand (0 – 4); Circle = Copying a Circle with Preferred Hand (0 – 2); Pencils = Copying Overlapping Pencils with Preferred Hand (0 – 2); Sorting = Sorting Shape Cards with Preferred Hand (0 – 10); Dots = Making Dots in Circles with Preferred Hand (0 – 10).

Table 5: Relationship between BMI and Point Scores of BOTMP – Short Form

BOTMP Item[1]	Correlation	Effect Size
Total	- 0.48**	1.10
Run	- 0.43**	0.94
Stand	- 0.37**	0.80
Walk	- 0.10	
Tap Feet	- 0.08	
Jump-Clap	- 0.48**	1.09
SBJ	- 0.60**	1.48
Catch	- 0.08	
Throw	- 0.06	
RS	- 0.43**	0.94
Line	+ 0.05	
Circle	+ 0.03	
Pencils	- 0.02	
Sorting	- 0.14	
Dots	+ 0.18*	0.63

*Significance at $p < 0.05$
**Significance at $p < 0.01$

[1]Total = Total Score on the BOTMP; Run = Running Speed and Agility; Stand = Standing on Preferred Leg on Balance Beam; Walk = Walking Forward Heel-to-Toe on Balance Beam; Tap Feet = Tapping Feet Alternately While Making Circles with Fingers; Jump-Clap = Jumping Up and Clapping Hands; SBJ = Standing Broad Jump; Catch = Catching a Tossed Ball with Both Hands; Throw = Throwing a Ball at a Target with Preferred Hand; RS = Response Speed; Line = Drawing a Line Through a Straight Path with Preferred Hand; Circle = Copying a Circle with Preferred Hand; Pencils = Copying Overlapping Pencils with Preferred Hand; Sorting = Sorting Shape Cards with Preferred Hand; Dots = Making Dots in Circles with Preferred Hand.

Table 6: Inter-rater Reliability (IRR) of Total Score and Item scores of the BOTMP – Short Form

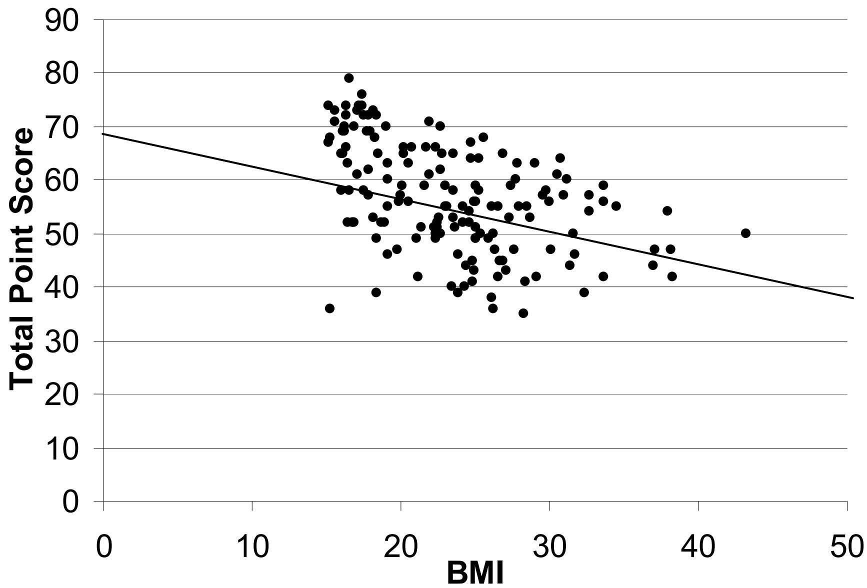
BOTMP Item[1]	IRR Overweight (n = 5)	IRR Normal Weight (n = 10)
Total	0.99	0.99
Run	0.99	0.94
Stand	1.00	0.99
Walk	1.00	0.97
Tap Feet	1.00	1.00
Jump-Clap	1.00	0.88
SBJ	0.98	0.98
Catch	1.00	0.90
Throw	0.87	0.93
RS	1.00	0.99
Line	1.00	1.00
Circle	0.87	1.00
Pencils	0.93	0.90
Sorting	1.00	1.00
Dots	1.00	1.00

*Significance at $p < 0.05$
**Significance at $p < 0.01$

[1]Total = Total Score on the BOTMP; Run = Running Speed and Agility; Stand = Standing on Preferred Leg on Balance Beam; Walk = Walking Forward Heel-to-Toe on Balance Beam; Tap Feet = Tapping Feet Alternately While Making Circles with Fingers; Jump-Clap = Jumping Up and Clapping Hands; SBJ = Standing Broad Jump; Catch = Catching a Tossed Ball with Both Hands; Throw = Throwing a Ball at a Target with Preferred Hand; RS = Response Speed; Line = Drawing a Line Through a Straight Path with Preferred Hand; Circle = Copying a Circle with Preferred Hand; Pencils = Copying Overlapping Pencils with Preferred Hand; Sorting = Sorting Shape Cards with Preferred Hand; Dots = Making Dots in Circles with Preferred Hand.

Figure 2

Relationship between BMI and Total Score on the BOTMP – Short Form



r = - 0.48

Table 7: Point Score Means and Standard Deviations for Significant Gender Differences

	Mean Point Scores		Standard Deviation			
Non-Overweight						
BOTMP Item[1]	Boys n = 21	Girls n = 20	Boys	Girls	Effect Size	Range[2]
Circle	1.48	1.85	0.60	0.37	0.84	0 – 2
Overweight						
BOTMP Item[1]	Boys n = 50	Girls n = 63	Boys	Girls	Effect Size	Range[2]
Total[3]	56.16	50.16	8.67	7.45	0.67	0 – 98
Run[4]	10.64	9.14	2.09	1.91	0.76	0 – 15
Tap Feet	0.48	0.70	0.51	0.46	0.48	0 – 1
Jump-Clap	2.60	2.16	0.78	0.70	0.60	0 – 5
SBJ	7.16	6.19	1.45	1.37	0.70	0 – 16
RS	6.90	5.44	2.24	2.58	0.60	0 – 17

[1]Total = Total Score on the BOTMP; Run = Running Speed and Agility; Tap Feet = Tapping Feet Alternately While Making Circles with Fingers; Jump-Clap = Jumping Up and Clapping Hands; SBJ = Standing Broad Jump; RS = Response Speed; Circle = Copying a Circle with Preferred Hand

[2]Range signifies the range of scores attainable for the test and each item, not the range of scores of the participants.

[3]Percentile Rank of 50 equals a point score of 57 for this age group. (Bruininks, R. H. (1978). *Manual: Bruninks-Oseretsky Test of Motor Proficiency*. Circle Pines, MN: American Guidance Service.)

[4]Higher the point score the faster the child ran.

Table 8: Overweight Participant Characteristics and Demographics

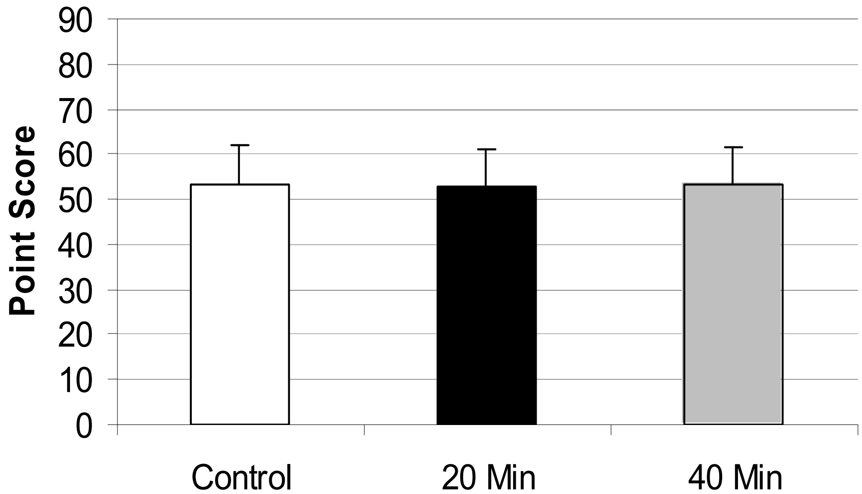
Group	N	Age Pre (yrs)	Age Post (yrs)	Gender Boys:Girls	Weight Pre (kg)	Weight Post (kg)	Height Pre (cm)	Height Post (cm)	BMI Pre	BMI Post	Body Fat Pre (%)	Body Fat Post (%)
Control	40	9.38 ±1.18	9.71 ±1.17	16:24	52.56 ±16.30	55.81 ±17.10	140.30 ±10.10[**1]	142.50 ±10.07[**2]	26.27 ±5.27	26.78 ±5.36	39.51 ±7.26	39.31 ±6.40
20 Min Exercise	31	9.08 ±0.94	9.44 ±0.96	14:17	49.83 ±12.07	51.27 ±11.87	139.03 ±7.85[**]	141.01 ±8.12[**]	25.67 ±3.87	25.51 ±3.92	39.82 ±6.40	38.15 ±5.55
40 Min Exercise	33	9.25 ±1.14	9.67 ±1.27	16:17	52.83 ±17.55	53.63 ±17.83	141.68 ±10.70[**]	144.46 ±10.56[**]	25.90 ±5.47	25.03 ±5.44	38.55 ±6.23	35.74 ±6.45[*3]

[*]Significance at $p < 0.05$
[**]Significance at $p < 0.01$

[**1]All three groups significantly differ.
[**2]All three groups significantly differ
[**]3Post 40 Minute Exercise group is significantly different from Post Control Group only.

Figure 3

Total Point Scores on the BOTMP – Short Form Following an Exercise Intervention



*Significance at $p < 0.05$
**Significance at $p < 0.01$
Test range is 0 – 98

Table 9: Results of a 14 Week Exercise Intervention on Fundamental Motor Skill Proficiency

BOTMP Item[1]	Exercise Group	Pre - Exercise	Standard Error	Post - Exercise	Standard Error	F-Test	Significance Level
Total[2]	Control	52.83	1.34	53.4	0.81	0.19	0.831
	20 Min	52.19	1.62	52.6	0.93		
	40 Min	55.55	1.36	53.1	0.90		
Run[3]	Control	9.65	0.36	9.44	0.27	0.39	0.679
	20 Min	9.75	0.35	9.11	0.30		
	40 Min	10.15	0.38	9.39	0.30		
Stand	Control	3.78	0.33	3.56	0.31	0.20	0.823
	20 Min	3.58	0.39	3.84	0.35		
	40 Min	4.03	0.37	3.63	0.34		
Walk	Control	3.10	0.19	2.60	0.20	0.44	0.654
	20 Min	2.65	0.23	2.62	0.23		
	40 Min	3.12	0.22	2.36	0.22		
Tap Feet	Control	0.55	0.08	0.52	0.07	1.68	0.191
	20 Min	0.58	0.09	0.58	0.08		
	40 Min	0.64	0.09	0.71	0.08		
Jump-Clap	Control	2.35	0.13	2.44	0.09	0.92	0.402
	20 Min	2.35	0.14	2.31	0.10		
	40 Min	2.30	0.13	2.50	0.10		
SBJ	Control	6.53	0.26	6.68	0.19	1.54	0.221
	20 Min	6.35	0.25	6.21	0.22		
	40 Min	6.91	0.22	6.64	0.21		
Catch	Control	2.53	0.12	2.57	0.10	0.39	0.680
	20 Min	2.61	0.15	2.45	0.11		
	40 Min	2.70	0.11	2.55	0.11		
Throw	Control	1.98	0.83	1.92	0.11	0.11	0.894
	20 Min	1.71	0.74	1.88	0.12		
	40 Min	2.12	0.82	1.97	0.12		
RS	Control	5.60	0.39	6.60	0.32	1.28	0.283
	20 Min	6.35	0.46	6.05	0.37		
	40 Min	6.48	0.41	6.84	0.35		
Line	Control	3.63	0.10	3.62	0.10	0.61	0.543
	20 Min	3.55	0.11	3.56	0.11		
	40 Min	3.64	0.11	3.72	0.11		
Circle	Control	1.75	0.07	1.70	0.07	0.48	0.622
	20 Min	1.77	0.09	1.71	0.08		
	40 Min	1.70	0.08	1.79	0.08		
Pencils	Control	1.35	0.70	1.37	0.09	0.388	0.679
	20 Min	1.32	0.65	1.39	0.10		

	40 Min	1.33	0.65	1.27	0.10		
Sorting	Control	4.47	0.21	4.40	0.15	0.43	0.428
	20 Min	4.00	0.21	4.70	0.17		
	40 Min	4.58	0.23	4.50	0.16		
Dots	Control	5.58	0.20	5.87	0.16	0.16	0.856
	20 Min	5.61	0.21	5.74	0.18		
	40 Min	5.85	0.22	5.83	0.18		

[1]Total = Total Score on the BOTMP; Run = Running Speed and Agility; Stand = Standing on Preferred Leg on Balance Beam; Walk = Walking Forward Heel-to-Toe on Balance Beam; Tap Feet = Tapping Feet Alternately While Making Circles with Fingers; Jump-Clap = Jumping Up and Clapping Hands; SBJ = Standing Broad Jump; Catch = Catching a Tossed Ball with Both Hands; Throw = Throwing a Ball at a Target with Preferred Hand; RS = Response Speed; Line = Drawing a Line Through a Straight Path with Preferred Hand; Circle = Copying a Circle with Preferred Hand; Pencils = Copying Overlapping Pencils with Preferred Hand; Sorting = Sorting Shape Cards with Preferred Hand; Dots = Making Dots in Circles with Preferred Hand.

[2]Percentile Rank of 50 equals a point score of 57 for this age group. (Bruininks, R. H. (1978). *Manual: Bruninks-Oseretsky Test of Motor Proficiency*. Circle Pines, MN: American Guidance Service.)

[3]Higher the point score the faster the child ran.

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