Abstract

Physical Activity and Obesity's Relationship with Motor Skills in Children Ages 3 – 5 Years Old: National Youth Fitness Survey. by Aaron P. Wood April, 2018 (Director of Thesis: Dr. Katrina D. DuBose). Major Department: Department of Kinesiology

Purpose: The purpose of this study was 3-fold: (a) to examine the relationship between physical activity (PA) and motor skills in children ages 3-5 years old, (b) to examine the relationship between obesity and motor skills in children ages 3-5 years old, and (c) to examine the combined relationship of PA and obesity on motor skills. **Methods:** Secondary data analysis was performed using NHANES National Youth Fitness Survey (NNYFS) focusing on children between 3 – 5 years of age. NNYFS collected data on 342 children that were the appropriate age and had the variables of interest to this analysis. Collected measures that were used included a PA questionnaire (PAQ). All children had weight, height, and triceps/calf skinfolds measured. Using these measurements body mass index (BMI) and body fat percentage were calculated. The children also completed Test of Gross Motor Development – Second Edition. Subscales for locomotor and object control motor skills along with a motor quotient score were calculated. Mean, standard deviation, and frequencies of descriptive variables were calculated. Multiple regression analyses were conducted to examine the independent and combined relationships between PA days, PA types, weight status (BMI or percent body fat), and motor skill controlling for sex, race, and parent's socioeconomic status. **Results:** Of the 342 (176 boys, and 166 girls) children that participated the majority were Caucasian (52%) followed by Hispanic (26%). The number of days in which children participated in PA was not related to motor quotient score ($p=.30$). When the relationship between participation of a specific PA in the past seven days and total motor skill score was examined, not participating in bike riding ($\beta = -5.28$ (1.92), $p=.0071$), scooter riding ($\beta = -9.67$ (2.36), $p<.001$), swimming ($\beta = -4.04$ (1.03), $p<.001$), and jumping on a trampoline ($\beta = -7.38$ (2.91), $p=.0125$) were related to a lower motor quotient score. No statistically significant relationships were observed between weight status and gross motor quotient and the subscales ($p>.05$). A significant interaction existed between BMI category and number of days participating in PA for locomotor ($p=.0002$) and object control ($p=.027$) standard scores, but not with the gross motor quotient score ($p>.05$). Among overweight/obese children participating in more days of physical activity (4-6 or 7) were related to lower locomotor motor skill standard scores. In contrast, the object control motor skills were lower for the overweight/obese children than the healthy weight children who participated in 0-3 days of PA ($p=.027$). When overweight/obese children participated in PA that was focused on object control activities, they had lower object control standard scores than healthy weight children who participated in only object control types of PA ($p<.05$). For overall motor skills, as determined by gross motor quotient, the weight status of the child and the type of PA that the child engages in does not jointly impact overall motor skills. **Conclusion:** Not participating in specific PA was related to poorer motor skills. Weight status was not related to motor skills in pre-school aged children. Regarding the joint relationships, overweight and obese children had lower locomotor skills even if they participated in more days of PA, but this finding was not observed in the healthy weight children. In contrast, fewer days of PA were related to lower object control score among overweight/obese children compared to health weight children. Finally, weight status and type of PA was related to object control scores, where the overweight/obese children had lower object control scores compared to healthy weight children even when they participated in PA that focused on this motor skill.

Physical Activity and Obesity's Relationship with Motor Skills in Children Ages 3 – 5 Years Old: National Youth Fitness Survey

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Chapter I: Introduction

Motor skills play an important role in children's health and development. A motor skill is defined as a coordinated pattern of movements acquired through practice involving the ability to execute movements effectively to achieve intended outcomes (Dictionary of Sport and Exercise Science and Medicine). The development of motor skills are key components to a child's ability to complete daily tasks. Further, motor skills are the foundation for a child to be physically active (Wrotniak, Epstein, Dorn, Jones, & Kondilis, 2006). Youth with better motor proficiency may find it easier to be physically active and may be more likely to engage in physical activity (PA) versus peers with poorer motor skill competence. In contrast, children with poor motor proficiency may subsequently choose a more sedentary lifestyle to avoid these movement difficulties (Wrotniak et al., 2006).

The age group from infancy, to toddler, to preschool is a crucial time in development of motor skills for later in life. The importance of motor skill development in the preschool age group is highlighted within *Healthy People 2020* by including an objective focusing on motor skills. *Healthy People 2020* has a goal to increase the number of states that require activity programs providing large muscle or gross motor activity, development and/or equipment in child care centers, large family homes, and small family homes from a baseline of 25 states to 35 states (*Healthy People 2020*).

Since the 1990s there has been an increase in the rates of overweight and obesity in all children including toddlers and preschoolers (Ogden, Carroll, Kit, & Flegal, 2012). While the rates have declined, about 23% of children ages 2–5 years living in the United States are either overweight or obese (≥ 85th percentile) (Ogden et al., 2015). Short term health consequences of childhood obesity include asthma, chronic low-grade systemic inflammation, development of type 2 diabetes, and cardiovascular risk factors, and psychological issues, such as, low self-esteem (Nervik, Martin, Rundquist, & Cleland, 2011). Furthermore, the long-term consequences of childhood obesity include adverse effects on socioeconomic status, persistence of obesity into adulthood, premature mortality, and cardiovascular disease development (Nervik et al., 2011).

Not only is obesity a problem in the preschool population so is a lack of PA. What are the PA guidelines for preschool aged children? The guidelines are for young children to accumulate three hours of total physical activity/day including light-, moderate-, and vigorous-intensity activities (Pate & O'Neil, 2012). This all with a goal of obtaining ≥ 15 min/hour of PA. Recently the PA levels in preschool aged children has been investigated. Pate et al. (2015) reported that only 41.6% to 50.2% of 3-5 year old children are meeting PA guidelines. Like with older children, among 3-5 year old children it has been reported that more males than females engage in PA (Pate et al., 2015; Schmutz et al., 2017); however, others have reported no difference in PA levels among preschool aged boys and girls (Odense, Denmark Olesen et al., 2014).

An inverse relationship exists between obesity and PA, which is alarming due to the high prevalence of both physical inactivity and obesity in children. In one study, PA measures were different between overweight and non-overweight boys (Trost, Sirard, Dowda, Pfeiffer, & Pate 2003). Among overweight boys, regardless of the PA variable they participated in less PA than non-overweight boys ($p < .05$). Notably, weight status did not impact PA levels in girls (Trost et al., 2003). Data from Pate et al. (2015) indicated that the relationship between obesity and PA in preschool aged children is not as consistent. Using data from two large scale studies (CHAMPS and SHAPES) involving preschool children both obesity and PA were measured. In the CHAMPS sample, more overweight children (58.3%) met the PA guideline than normal weight children (37.9%; $p = .01$). A similar trend was observed in the SHAPES sample, although the difference between weight status groups was not statistically significant (Pate et al., 2015). These studies, underscore the inconsistency in the literature regarding the relationship between PA and obesity in the preschool population.

Limited research also exists for the relationship between PA, obesity, and motor skills. Nervik et al., (2011) examined the relationship between obesity and motor skills in children 3 – 5 years of age. A negative association between BMI and gross motor skills was reported, where 58% of the overweight/obese group scored below average on the motor skills test compared to 15% of the non-overweight group. Vameghi, Shams, & Dehkordi, (2013) also found a negative relationship between BMI and the stair climbing skill ($\beta = -.212$, $p < .05$). However, they reported a positive effect of BMI on kicking and striking skills ($\beta = .50$, $p < .05$; $\beta = .61$, $p < .05$, respectively). Not only is obesity related to motor skills, so is PA. Loprinzi & Frith (2017) examined if greater motor skill development was associated with higher PA levels among preschool-aged children. Using data from the 2012 National Youth Fitness Survey they found that meeting PA guidelines was not related to PA or motor skills ($p > .05$), and no significant associations were observed when PA was treated as a continuous variable.

Research is exceptionally sparse examining in the combined relationship of PA and obesity, on motor skills. Loprinzi & Frith, (2017) examined this association between motor skills and meeting PA guidelines among preschool children where a gross motor skills increase (OR = .99, CI = .96–1.02), locomotor skills increase (OR = .96, CI = .82–1.12), and object control skills increase (OR = 1.00, CI = .84–1.19) PA was positively related to agility, but after adjusting for percent body fat, the association between baseline PA with baseline agility was no longer significant ($r = -.10$ to $-.11$, $p \geq .14$). Healthy weight compared to overweight children had higher levels of TPA (610 ± 211 vs 587 ± 201 cpm) and higher basic motor score (12.59 ± 3.43 vs 11.91 ± 3.55) and integral motor score (14.41 ± 3.82 vs 13.43 ± 3.81) (Bonvin et al., 2012).

It has been shown in multiple studies that poor motor skills in children are associated with lower ability to perform PA. With a decline in PA there is an increase in the risk for obesity development, which can lead to adverse short and long term health effects (Nervik, 2011). The existing literature does not clearly answer a few questions that are needed to improve PA, obesity level, and motor skill proficiency in pre-school aged children. The role PA and obesity has on motor skills has been studied extensively in older children (≥ 6 years), but limited research exists in young children. Further, there is limited research based in the U.S. Finally, few studies have examined the combined effect of PA and obesity, on motor skills.

Therefore, the purpose of this study is threefold: (a) to examine the relationship between PA and motor skills in children ages 3-5 years old, (b) to examine the relationship between obesity and motor skills in children ages 3-5 years old, and (c) to examine the combined relationship of PA and obesity on motor skills. It is hypothesized that children with higher PA levels will have better proficiency in motor skills. It is also hypothesized that as obesity levels increase there will be a decrease in proficiency of motor skills. Lastly, it is hypothesized that children with lower PA levels and are obese will have poorer proficiency of motor skills compared to those with higher PA levels at healthy weight.

Delimitations

1. BMI categories will be created using the Center for Disease Control cut-points instead of others like the World Health Organization.
2. Data for this study is from the National Youth Fitness Study.
3. Data analysis will be restricted to children 3 – 5 years of age.

Limitations

1. The cross-sectional nature of this study cannot determine causality.
2. Physical activity was measured through questionnaires, so recall bias and misremembering of information could be possible.
3. The TGMD-2 motor skills test was used. Due to the numerous motor skills tests that exist, comparison of results across studies will be impacted.

Definitions

Motor Skills – defined as a coordinated pattern of movements acquired through practice involving the ability to execute movements effectively to achieve intended outcomes (Dictionary of Sport and Exercise Science and Medicine).

- **Gross Motor Skills -** involves the coordinated use of large muscle groups, such as when kicking a ball.
- **Fine Motor Skills -** involves the ability to manipulate small objects, such as picking up a bead with the fingers.
- **Object Control Motor Skills** – involves striking a stationary ball, stationary dribble, kick, catch, overhand throw, and underhand roll.

- **Locomotor Motor Skills** – involves activities such as run, gallop, hop, leap, horizontal jump, slide.

Physical Activity – any bodily movement produced by skeletal muscles that requires energy expenditure. World Health Organization (http://www.who.int/topics/physical_activity/en/).

- **Light –** > 1.5 - < 4.0 METs (less than 3.5 kcal/min)
- **Moderate -** > 4.0 to < 6.0 METs (3.5 to 7 kcal/min)
- **Vigorous -** ≥ 6.0 METs* (more than 7 kcal/min)

(Trost, Drovandi, & Pfeiffer, 2016).

Body Mass Index (BMI) – is calculated from height and weight to determine the weight status of a person.

Overweight - defined as a BMI at or above the 85th percentile and below the 95th percentile for children and teens of the same age and sex (https://www.cdc.gov/obesity/childhood/defining.html).

Obesity – defined as a BMI at or above the 95th percentile for children and teens of the same age and sex (https://www.cdc.gov/obesity/childhood/defining.html).

Chapter II: Literature Review

Physical Activity

Physical activity (PA) is important for people of all ages, therefore there are PA recommendations for adults and children. Recommendations for children ≥ 6 years of age include 60 minutes of aerobic activity daily (https://www.cdc.gov/physicalactivity/basics/children/). The PA recommendations include either moderate-intensity aerobic activity, such as brisk walking, or vigorous-intensity activity, such as running. Children are encouraged to do vigorous-intensity aerobic activity on at least 3 days per week. It is also stated that children should do muscle strengthening activities, (such as gymnastics or push-ups) and bone strengthening activities (jumping rope) at least 3 days per week as part of a child's 60 or more minutes (https://www.cdc.gov/physicalactivity/basics/children/).

All children from birth to age 5 should engage daily in PA that promotes movement skillfulness and builds a foundation of health-related fitness. While national PA recommendations do not exist for children < 6 years of age, different groups recommend PA for young children (http://www.shapeamerica.org/standards/guidelines/activestart.cfm). For example, the SHAPE organization recommends that preschoolers should accumulate at least 60 minutes of structured PA each day, engage in at least 60 minutes – and up to several hours of unstructured PA each day. Further, children this age should not be sedentary for more than 60 minutes at a time, except when sleeping.

Preschoolers should be encouraged to develop competence in fundamental motor skills that will serve as the building blocks for future motor skillfulness and PA (http://www.shapeamerica.org/standards/guidelines/activestart.cfm). More specifically preschool aged children are recommended to accumulate 15 minutes of PA per hour for 12 hours, (i.e., 3 hours per day), and should incorporate light-, moderate-, and vigorous-intensities of PA (Pate & O'Neil, 2012). The importance of motor skills in the preschool age group is highlighted within *Healthy People 2020* including an objective focusing on motor skills in this age groups. *Healthy People 2020* has a goal to increase the number of states that require activity programs providing large muscle or gross motor activity, development and/or equipment in child care centers, large family homes, and small family homes from a baseline of 25 states to 35 states (Healthy People 2020). While many different groups are highlighting the importance of PA in the preschool aged-population, the number of young children who meet recommended PA levels is low.

Olesen, Kristensen, Ried-Larsen, Grøntved, and Froberg (2014) examined 627 children 5 – 6 years of age attending 43 randomly selected preschools in Odense, Denmark to describe gender differences in relation to, motor skills, and PA, including PA patterns by the day type and time of day. The results from this study important to this section are revolved around PA. No difference was found in the weekly mean ± SD PA level between boys and girls (818 ± 190 versus 785 ± 187, p = .11), or between children in the urban versus rural areas (799 ± 173 versus 816 ± 247, p = .46). Boys' weekly PA level were higher than girls' when the preschool was located in a rural area (862 ± 202 versus 773 ± 161, p = .02). No gender differences in weekly PA were identified across parental educational groups or in their mother's country of birth (Olesen et al., 2014).

Pate et al., (2015) determined the compliance with the preschool PA guidelines (defined as ≥ 15min/hr of total PA) in two independent samples of preschool children. Participants in the first sample were enrolled in the Children's Activity and Movement in Preschool Study (CHAMPS), an observational study of 286 3- to 5-year-old children attending preschools. Twenty-two preschools participated in the study, including commercial (n = 11), faith-based (n = 7), and federally supported Head Start programs (n = 4). Participants in the second sample were enrolled in the Study of Health and Activity in Preschool Environments (SHAPES), a 3-year intervention study designed to increase PA and decrease sedentary behavior in preschool children. The SHAPES study was conducted in 16 preschools (eight public and eight private preschools) and the sample consisted of 337 children and only the baseline data from the children was included in this study. PA was measured by ActiGraph accelerometers and data from 5 consecutive weekdays (≥ 8 hours wear time) was used in the analysis. In the CHAMPS sample, 42.7% of children were male and 52.8% were African American, and mean age was 4.2 ± .7 years. Children wore the accelerometers for an average of 13.4 hours per day. In the SHAPES sample, 51.3% of children were male and 48.1% were African American, and mean age was 4.5 ± .3 years. The children wore the accelerometers for an average of 12.4 hours per day. Total PA was 14.5 and 15.2 min/hr in the CHAMPS and SHAPES samples, respectively. The prevalence of meeting the PA guideline was 41.6% and 50.2% in the CHAMPS and SHAPES samples, respectively. In both samples, males accumulated more time in total PA and met PA guidelines than females ($p < .05$) (Pate et al., 2015). Approximately one half of children in two independent samples met the guideline for PA in young children. This shows that even through different samples many preschool children are not meeting PA guidelines.

Yet another study by Schlechter, Roenkranz, Fees, and Dzewaltowski (2017) aimed to characterize the pattern of physical activity across the preschool day. Observations were conducted in 2 university sponsored preschool centers in a Midwestern town. The study sample included approximately 73 children aged 3 – 6 years, (4.36 ± .85 years), with 47% being boys and 53% were girls. PA was measured using Actigraph accelerometers on three days and through direct observation. Age specific cut-points were used to determine time spent sedentary/inactive (≤ 373 counts/15seconds) and in total PA (> 373 counts/15seconds) from the accelerometers (Schlechter et al., 2017). Classroom PA was also video recorded on 3 days and then the videos were uploaded to a video analysis software. For each observation day, the day was split into multiple segments (i.e., morning indoor, morning outdoor, after lunch indoors, after lunch outdoors. A subsample of the morning (8:30AM—morning outdoor time) was split into smaller segments (hereafter referred to as episodes) defined by a change in social pattern and assigned a mutually exclusive pattern code (i.e., activity centers, small group, whole group). Activity center was defined as a pattern where children had a physical space divided into multiple activity areas, and each child had a choice of which area he or she wanted to be in. Small group was defined as a pattern when a child was performing an activity with more than one other child, but less than the full class. Whole group was defined as a pattern where all children in the class were participating in a single activity. Coding was completed independently by 2 research assistants who had been trained on the coding scheme and demonstrated reliability (≥ 80% agreement to pre-coded, gold standard video). Episodes were randomly selected by classroom and day to determine percentage of agreement. The inter-observer percentage agreement was 80.1%. The results indicated that children were observed 385.07 ± 89.42 minutes each day. Children spent approximately 69.5 ± 12.4% time sedentary/inactive and 30.5 ±13.5% time in total PA. No significant differences were found between the morning and afternoon for percentage of time spent sedentary/inactive or in total PA ($t = .12$, $p = .904$). Further, there were no significant differences between indoor time during the morning and afternoon for percentage of time spent sedentary/inactive or in total PA ($t = .75$, $p = .456$), or outdoor time during the morning and afternoon for percentage of time spent sedentary/inactive or in TPA ($t = 1.06$, $p = .289$). Children spent a significantly greater percentage of time in total PA while outdoors compared to indoors ($t = 10.00$, $p < .001$). For the subsample of episodes derived from morning indoor time, children spent significantly more time being active while in a small group compared to whole-group arrangement ($t = 3.35$, $p = .009$). There were no significant differences for percentage time spent in activity for activity centers compared to whole group ($t = .95$, $p = .344$) or small group ($t = 1.77$, $p = .077$) (Schlechter et al., 2017). Overall, children spent approximately 30% of the preschool day in total PA. This study highlighted not just the amount of PA that these children are accumulating, but how much of their time at preschool is engaging in PA.

Not only is outside time important for PA in preschool children, the type of preschool could play a role in how much PA preschool children obtain. Pate et al., (2014) compared the PA levels of children attending Montessori and traditional preschools. Montessori preschools met the following criteria: (1) accredited by or a member of at least one national Montessori association; and (2) employed certified Montessori teachers. Of the 12 Montessori preschools that met the study criteria, 9 agree to participate in the study. Eight traditional preschools were recruited to participate in the study from a pool of 62 that met the study criteria. The study included 301 children who met the prescribed standard for compliance with the accelerometry protocol and for whom complete data were available for all study variables. The number of study children per preschool ranged from 8 to 31 in Montessori preschools and from 5 to 37 in traditional preschools. PA was measured across 3 time periods: In-School, Non-School, and All Day using ActiGraph accelerometers. Due to variations in actual in-school hours among the preschools, children had to wear the accelerometer for at least 50% of the In-School period for their data from that day to be considered valid. Children must have worn the accelerometer for at least 4 hours during the Non-School period for their data from that day to be considered valid. Valid all day data required both valid In-School and Non-School data for that day. Days that children were absent from preschool and days on which total wear time ≥ 18 hours were excluded from the analyses because they do not represent typical school days (Pate et al., 2014). During the In-School period, children attending Montessori preschools accumulated more light (7.7 ± .4 min/hr), MVPA (7.7 ± .5 min/hr) and total PA (15.4 ± .9 min/hr) than children attending traditional preschools (light: 6.5 ± .4 min/hr; MVPA: 6.5 ± .5 min/hr; Total PA: 13 ± .9 min/hr), after adjusting for sex, race/ethnicity, BMI, and parent education. For the Non-School and all day periods, children in Montessori preschools (accumulated more MVPA 8.5 ± .5 min/hr and 8.5 ± .3 min/hr, respectively) than children in traditional preschools (6.2 ± .4 min/hr and 7.6 ± .3 min/hr, respectively). During each of the 3 time periods, boys were more active than girls ($p<.05$). There were no significant interactions between sex and type of preschool for any of the physical activity variables ($p>.05$) (Pate et al., 2014). The major findings for this study is that children attending Montessori preschools are more active than children in traditional preschools and this might carry over throughout the day. Further, even at this young age boys were more active than girls regardless of type of preschool.

In a recent study Schmutz et al., (2017) aimed to determine factors related to promote PA and decrease sedentary time in 394 preschool children (2-6 year old's). Children were recruited from 84 childcare centers in five areas of Switzerland, which comprises about 50% of the Swiss population in 2013. PA and sedentary behavior were objectively monitored using an ActiGraph accelerometer. A minimum of three days, including one weekend day, with at least 10 h of recorded activity per day was required for inclusion in analysis. BMI-for-age percentiles were constructed for boys and girls separately using the WHO Child Growth Standards and categorized as normal (< 85th percentile) vs. overweight and obese (≥ 85th percentile). Parental weight status was defined as normal-weight (BMI ≤ 25) vs. at least one overweight/obese parent (BMI > 25 kg/m^2) (Schmutz et al., 2017). Included participants (n = 394) provided an average of 5.6 ±.9 days of valid PA data with a mean wearing time of 12.8 ±.6 h per day (i.e., from 7 am to 9 pm). Mean age was 3.9 ± .7 years and 54% were boys. On average, children spent 93 ± 30 and 374 ± 48 min/day in MVPA and sedentary behavior, respectively. Mean total PA was 624 ± 150 cpm. Participants included in the analysis did not vary from those excluded (p > .05). Of the 13 variables associated with total PA in the full multilevel analysis (p ≤ .1), eight (sex, age, gross motor skills, family structure, activity temperament, time outdoors, fixed toys, and season) were identified as correlates in the final model (all p ≤ .028). Results showed that boys were more active than girls (p = .005). Similarly, children from single parent families had a higher level of activity than those living with two parents (p = .021). Age (p < .001), time outdoors (p = .009), number of fixed play items (p = .013) and child's activity temperament (p < .001) were positively associated with total PA. Moreover, children spent more time active in the spring and autumn months compared to summer (p = .028). For MVPA, six of a total of 11 variables associated with the outcome in the full model were identified as correlates in the final model (all p ≤ .032). Boys accumulated more MVPA than girls (p < .001). Furthermore, MVPA was positively associated with age (p < .001), birth weight (p = .032), child's activity temperament (p < .001), and gross motor skills (p = .001) (Schmutz et al., 2017). Like for total PA, children spent more time in MVPA in spring and autumn compared to summer (p = .007). The fixed effects in the final models explained 28%, 30% and 17% of the variance (marginal R^2) in total

PA, MVPA and sedentary behavior, respectively. The proportion of variance explained in total PA, MVPA and sedentary behavior including all fixed effects plus the random effect (conditional R^2) was 28%, 32% and 22%, respectively, indicating that the random factor did not capture a lot of additional variance. Age was found to be the most important correlate of both, total PA and MVPA; older children were more active than younger ones. Another factor of importance to PA was sex of the child; boys more active than girls. For total PA, the number of fixed toys and time spent outdoors were also important. For MVPA, gross motor skills and birth weight played a major role in PA level (Schmutz et al., 2017). This study showed that many factors impact a preschooler's PA levels. In addition, some of these factors could be modified to further support a child's PA level.

In summary, participation in PA is a lifestyle choice which has been shown to be protective against development of obesity, hypertension, and type 2 diabetes, and improves muscle and bone development in children *(*https://www.cdc.gov/obesity/childhood/causes.html; https://health.gov/paguidelines/guidelines/chapter3.aspx). Based on limited research it appears even at a young age, many children (~50%) are not engaging in adequate PA levels for appropriate health and development. Thus, promotion of adequate levels of PA is an important part of the international public health agenda. Throughout these studies PA levels vary depending on certain criteria (in school, out of school, sex, etc.). Some studies showed that boys had higher PA levels than girls and some showed no difference between the two.

Obesity

Obesity is an epidemic in youth that effects their health in a wide variety of ways. Short term health consequences of childhood obesity include asthma, chronic low-grade systemic inflammation, type 2 diabetes, cardiovascular risk factors, and psychological issues such as low self-esteem (Nervik, Martin, Rundquist, & Cleland, 2011). Furthermore, the long-term consequences of childhood obesity include adverse effects on socioeconomic status, persistence of obesity into adulthood, premature mortality, and cardiovascular disease development (Nervik et al., 2011).

Pulgarón (2013) conducted a review of the literature pertaining to increased risk for physical and psychological co-morbidities due to childhood obesity. Medical co-morbidities examined included asthma, metabolic risk factors, dental health, etc. Psychological co-morbidities investigated included ADHD, internalizing/externalizing disorders, and sleep patterns. Even in areas where rates of obesity were very low, there were some associations between obesity and asthma (adjusted OR = 2.36; 95% CI: 1.02 – 5.44; n = 2926). Differences between boys and girls have been reported, with some supporting a relationship between obesity and asthma for boys, but not for girls (adjusted OR = 2.36; 95 % CI: 1.02 – 5.44; n = 2926) and others vice versa (Girls: OR = 2.73; 95% CI: 1.09 – 6.85; Boys: OR = 1.74; 95% CI: .83 – 3.73; n = 854) (Pulgarón, 2013). Similar trends regarding high blood pressure and obesity have been reported in American youth, especially in the last 10 years. Obese youth are twice as likely to have hypertension (SBP > 140 mm Hg: OR = 2.24; 95% CI: 1.46 – 3.45, and for DBP > 90 mmHg: OR = 2.10; 95% CI: 1.06 – 4.17) and high blood pressure has been documented as a co-morbidity of obesity in minority and immigrant samples as well (Pulgarón, 2013). Childhood obesity also impacts gastrointestinal problems. A study of 1156 children by, Stordal, Johannesdottir, Bentsen, Carlsen, and Sandvik (2006) found that overweight children were nearly twice as likely to report GERD than healthy weight peers (OR = 1.8; 95% CI: 1.2 – 2.6). In a second study, which compared obesity rates of 757 patients from a gastrointestinal clinic and

255 matched controls, results indicated significantly higher rates of obesity for those from the gastrointestinal sample ($p < .001$) (Stordal et al., 2006).

Related to psychological issues, overweight/obese children were twice as likely (95% CI: 1.23 – 3.11) to have an ADHD diagnosis; however, this finding is not consistent in the literature, where others reported lower ADHD levels in obese adolescents (Pulgarón, 2013). Obesity may also impact sleep patterns in children. To illustrate this point, compared to healthy weight peers, overweight children slept about 22 minutes less on average ($\beta = -.174$; $p = .02$), had lower sleep efficiency ($\beta = -.027$; $p = .01$), and lower REM density ($\beta = -.256$, $p = .02$). In addition to the duration and quality of sleep, the presence of obstructive sleep apnea syndrome in obese children was higher (Pulgarón, 2013). This review highlighted the numerous co-morbidities that are associated with obesity in children.

Due to the large health risk associated with obesity in children, determining the prevalence of obesity is an important issue. In 2010, the global prevalence in overweight and obesity in preschool aged children was determined (de Onis, Blossner, & Borghi, 2010). Cross-sectional data on the prevalence of overweight and obesity were obtained from 450 national nutrition surveys from 144 counties which were included in the WHO Global Database on Child Growth and Malnutrition. About 38% of the surveys (171 surveys) were conducted between 1991 and 1999, 16% (70 surveys) dated from 1990 and earlier, and 46% (209) were performed in 2000 or later (de Onis et al., 2010). The earliest survey (from the United States) dates from 1969, whereas the most recent surveys (Bhutan, Cambodia, Chile, Egypt, and Vietnam) were conducted in 2008. All surveys included boys and girls, and age groups ranged from birth to 5 years of age. Surveys applied standard measuring protocols, i.e., supine length was measured in children up to 24 months of age, and standing height was measured in those aged ≥ 24 months of age. A data file was constructed by using the following variables: region, sub-region, country, survey year, sample size, prevalence of 1 SD above the weight-for-height median, prevalence of 2 SDs above the weight-for-height median, prevalence of 1 SD above BMI-for-age median, prevalence of 2 SDs above the BMI-for-age medians, and population of children aged 5 years old during the survey year. To obtain comparable prevalence's across countries, surveys with available raw data (321 of 450) were analyzed following a standard format with use of the WHO Child Growth Standards. In the case of the remaining 129 surveys (28.7%) for which raw data were not available, a conversion method was applied to transfer prevalence's based on the NCHS reference to prevalence's based on the WHO standards (de Onis et al., 2010).

The data reviled that worldwide, the prevalence of childhood overweight and obesity increased from 4.2% (95% CI: 3.2 – 5.2%) in 1990 to 6.7% in 2010 (95% CI: 5.6 – 7.7%), for a relative increase of 60% (de Onis et al., 2010). This trend is expected to continue and reach a prevalence of 9.1% (95% CI: 7.3 – 10.9%) in 2020, for a relative increase of 36% from 2010 (de Onis et al., 2010). Developing and developed countries followed a similar pattern of increased prevalence for the study period, but at different levels. In 2010, the prevalence of childhood overweight and obesity was estimated to be 11.7% (95% CI: 8.9 – 15.3%) in developed countries and 6.1% (95% CI: 5.0 – 7.2%) in developing countries; however, the relative percentage change was higher in developing countries (an increase of 65% between 1990 and 2010) than developed countries (an increase of 48% between 1990 and 2010). For 2010, it was estimated that 43 million preschool children had a weight-for-height .2 SDs from the WHO median, 35 million of whom live in developing countries. It was estimated that the number of overweight and obese children will increase to close to 60 million in 2020 (de Onis et al., 2010). Trends in overweight and obesity were available for 111 countries (countries with more than one survey). Of these, 31 showed no obvious changes in the prevalence of overweight and obesity (yearly change rate between - .1 & .1), 53 showed a rising trend (≥ .1), and 27 showed a falling trend (≤ - .1). Nationally, there was great variation in rates of children overweight. Very high rates appeared in countries such as Albania, Bosnia and Herzegovina, and Ukraine, with levels > 25% in most recent surveys. At the other end of the spectrum, levels < 1% are found in Nepal and the Democratic People's Republic of Korea (de Onis et al., 2010).

Worldwide, 14.4% (95% CI: 12.5%, 16.3%) of children (92 million) aged 0 – 5 years of age were estimated to be at risk of overweight (de Onis et al., 2010). Of these, almost half live in Asia (44 million), with Eastern Asia contributing the highest number (20 million) of all the sub-regions. In developed countries, the estimated prevalence and number of children at risk of overweight in 2010 was 21.4% (95% CI: 19.7 – 23.1%) and 15 million, respectively. The corresponding estimates in developing countries were 13.6% (95% CI: 11.4 – 15.7%) and 78 million children (de Onis et al., 2010). This study highlighted the overwhelming issue in preschool aged overweight/obesity status as it spans across the globe. This highlights how the obesity issue at this young age is not just a localized situation to developed countries, but childhood obesity is an issue that transcends borders.

Recently, Cheng et al. (2016) conducted a study in Chile and found that at age 5, 20.4% of children were overweight and 21.7% were obese. At age 10, 22.9% were overweight and 18.1% were obese (Cheng et al., 2016). As the studies above indicate, overweight and obesity in young children is an issue world-wide and not only is an issue for developed, but developing countries.

In a study, which focused on 3-6 year old children living in the United States, the percent of children who were overweight increased from 10% in year 1 to 15% in year 3, and the percent of obese children also increased from 6% in year 1 to 10% in year 3 (Jago, Baranowski, Baranowski, Thompson, & Greaves, 2005). Using data from the National Health and Nutrition Examination Survey (NHANES), the prevalence of obesity in the United States population was examined over a 12-year period from 1999-2011 (Ogden et al., 2012). The authors reported an increase in obesity rates in 2009-2010 among male children and adolescents aged 2 through 19 years (OR= 1.05, 95% CI: 1.01 – 1.10), but this increase was not found in females (OR= 1.02, 95% CI: .98 – 1.07). This translates into an annual increase in the odds of obesity prevalence by 1.03 (95% CI: 1.01 – 1.05) for males and 1.01 (95% CI: .99 – 1.03) for females (Ogden et al., 2012). While these data indicate that obesity is an issue for all youth, certain sub groups are more at risk for obesity than others.

The CDC (2013) highlighted that the prevalence of obesity remains high among all youths, including low-income preschool-aged children. The data came from the CDC's Pediatric Nutrition Surveillance System (PedNSS), a state-based public health surveillance system that monitors the nutritional status of low-income children from birth through age 4 years. Data was primarily collected from participants in the Special Supplemental Nutrition Program for Women, Infants, and Children (CDC, 2013). The data included for analysis was on approximately 12.1 million children aged 2 – 4 years from 43 PedNSS contributors, including 40 states, the District of Columbia, and two U.S. territories (U.S. Virgin Islands and Puerto Rico) between the years 2008–2011. Children's heights and weights were directly measured by trained clinical staff using standardized protocols. All data was submitted electronically to CDC. One randomly selected clinical record per child, per year, was used in this study. Obesity was defined as having an age- and sex-specific BMI ≥ 95th percentile per the 2000 CDC growth charts (CDC, 2013). There was no statistically significant change in the obesity prevalence between 2007 – 2008 and

2009 – 2010. During 2009 – 2010, the prevalence of obesity was 12.1% among U.S. children aged 2 – 5 years with higher rates among some subgroups including non-Hispanic black (18.9%) and Hispanic (16.2%) children (CDC, 2013).

During 2008–2011, a total of 19 states/territories reported significant downward trends in obesity prevalence among low-income preschoolers (CDC, 2013). Among them, the largest decline in obesity prevalence was in the U.S. Virgin Islands (OR = .92, 95% CI: .87 – .97), where there was a decrease in the prevalence of obesity from 13.6% in 2008 to 11.0% in 2011, an absolute decrease of 2.6 percentage points. In five additional states (Florida, Georgia, Missouri, New Jersey, and South Dakota) the absolute decrease in obesity prevalence from 2008 to 2011 was ≥ 1 percentage point. Across the 19 states/territories with significant downward trends, the absolute decrease in obesity prevalence from 2008 to 2011 ranged from .3 to 2.6 percentage points. The relative decreases in obesity prevalence among the 19 states/territories ranged from 1.8% to 19.1% (CDC, 2013). An additional 21 states/territories experienced no significant change in obesity prevalence. Whereas, three states experienced a significant upward trend in obesity prevalence ranging from .6 to .7 percentage points. The relative increase in obesity prevalence among the three states ranged from 5.2% to 6.4%. Analysis of the 34 states/territories that had complete data on household income, household income was added to the logistic regression model. After including income in the model, only Montana went from no significant trend to a significant decrease in the prevalence of obesity (OR = .97, 95% CI: .94 – 1.00). In 2011, the prevalence of obesity among states/territories in the study ranged from 9.2% to 17.9%. Ten states/ territories had an obesity prevalence ≥ 15%, with the highest prevalence in Puerto Rico (17.9%). Six states/territories had an obesity prevalence < 12%, where the lowest obesity prevalence was in Hawaii (9.2%) (CDC, 2013). Though this study delved further into the prevalence of obesity it is still unclear what causes the differences in prevalence across the United States.

Given the high obesity rates in children, it is important to understand the factors related to obesity development. There are several reasons thought to be involved in the increase of obesity, such as genetics, a poor diet, and physical inactivity to name a few. Jago et al. (2005) examined the development of cardiovascular risk factors and associated behaviors in families of young children over a 3-year period. They collected physiological and anthropometric assessments at baseline and at the end of every year (Jago et al., 2005). Data from PA monitors were recorded for an entire day over 4 days per year during the first 2 years and then for 3 days in the 3rd year. Children's heart rates were assessed on a minute-by-minute basis using heart rate telemetry. On an appointment basis, a research technician arrived at each child's home at approximately 0700 hours. A heart rate monitor preprogrammed to record for the entire day was attached to each child's chest and later removed by a technician. Four days of monitoring per year were attempted during observation years 1 and 2; and 3 days were attempted during observation year 3. Acceptable heart rate values were between 50 and 220 bpm; the 4.0% of values outside this range were treated as outliers. A valid day consisted of at least 504 min (70%) of usable heart rate values. The average number of minutes that participants spent with mean heart rates 4140 bpm/h was interpreted as the number of minutes engaged in MVPA (Jago et al. 2005). Further, a five-level observational rating system designed to record minute-by-minute PA in situations encompassing a variety of activities and intensities, was used to record the child's sedentary behavior (Jago et al., 2005). Level one was categorized as stationary/ nonmoving; level two was stationary/limb movement but not trunk movement; level three was translocation/slow walk; level four was translocation/fast walk, and level five was translocation/running. Each child was also observed for approximately 6–12 h per day while the heart rate values were measured. Observers recorded the activity level at the start of each minute and then recorded any subsequent activity level changes during that minute. Minutes in which only levels 1 or 2 were observed, and not levels 3, 4 or 5 were coded as minutes of sedentary behavior. In addition, observers recorded whether the child was watching television during each minute of observation (Jago et al. 2005). Dietary consumption was recorded on the same days as direct observation of PA and TV viewing. Briefly, trained teams of observers recorded participant's dietary consumption. Observers followed each child wherever he or she went (home, day care, school, etc.). All foods eaten by the child, nutrient-related characteristics of purchase and preparation and portion size consumed were recorded throughout the observation period. The observer also questioned the food preparer about ingredients and preparation practices as necessary. Food descriptions were entered onto 24-h recall forms and analyzed for nutrient content. Mean daily caloric intake, percent calories from fat, protein and carbohydrate was then calculated across the observation days in each year (Jago et al., 2005).

The results indicated that minutes of sedentary behavior per hour were negatively associated with percent calories from fat ($r = -.19$, $p < .05$) and positively associated with percent calories from carbohydrates ($r = .23$, $p < .05$) in year 1. The interaction between minutes of monitored PA per hour by year on the female gender was significant for year 1 ($\beta = -.19$, $p = .002$) and was close to significance for year 2 ($\beta = -.11$, $p = .054$) when compare to year 3. While monitored, PA was positively associated with BMI in year 1 ($r = .105$, $p > .05$), it was negatively associated in years 2 ($r = -.027$, $p > .05$) and 3 ($r = -.027$, $p > .05$). Minutes of TV viewing per hour in year 2 were negatively associated with minutes of heart rate monitored PA per hour ($r = -.24$, $p < .05$) and positively associated with minutes of sedentary behavior per hour ($r = .27, p < .01$). Minutes of heart rate monitored PA per hour were negatively associated with minutes of sedentary behavior per hour ($r = -.27, p < .05$) and percent calories from fat ($r = -.17, p < .05$) in year 2 (Jago et al., 2005). The data also indicated that there was a significant difference in minutes of heart rate monitored PA per hour across the 3 years ($F(2, 96) = 5.89, p = .004$). Paired t-tests yielded significant differences in minutes of heart rate monitored PA per hour between years 1 and 3 ($t = 3.10, p < .002$) and years 2 year 3 ($t = 2.15, p < .034$). Those heart rate monitor PA values varied slightly from year to year with year 1 (4.2 ± 3.6 PA/hour) and year 2 values being higher than (4.2 ± 3.0 PA/hour) year 3 (3.6 ± 3.6 PA/hour). Moreover, there was a significant difference in BMI across the 3 years ($F(2, 107) = 220.1, p < .001$). Paired t-tests yielded significant differences in BMI between years 1 and 2 ($t = 2.60, p < .011$), years 1 and 3 ($t = 6.76, p < .001$) and years 2 and 3 ($t = 6.98, p < .001$). BMI in year 1 was the lowest (15.4 ± 1.31 kg/m^2), with year 2 seeing a small increase (15.6 ± 1.86 kg/m^2), and year 3 seeing the largest increase (16.28 ± 2.23 kg/m^2) (Jago et al., 2005). Knowing diet and PA are related to obesity make it easier to develop future interventions that would reduce levels of obesity in children.

Another study examined the prevalence and correlates of overweight and obesity among preschoolers in Lebanon (Nasreddine, Hwalla, Saliba, Akl, & Naja, 2017). A national cross-sectional survey (Early Life Nutrition and Health in Lebanon) was conducted amongst 2 – 5 years old children ($n = 525$). Survey data used in this study included demographic, socioeconomic, and parental characteristics, eating habits, anthropometric measurements, as well as dietary intakes. Information on birth weight of the child was obtained from the mother. Anthropometric measurements were performed, including weight and height of both mothers and children. Overweight and obesity among mothers were assessed using the WHO criteria for

BMI. For children, the prevalence of overweight and obesity was assessed using the WHO-2006 criteria based on sex and age specific BMI z-scores. Dietary intake of children was assessed by a single multiple pass 24 hour recall (Nasreddine et al., 2017). The mean age of preschoolers was of 3.3 ± .87 years, with 53.5% begin boys and 46.5% were girls. Most parents had intermediate level education (62.8% of fathers and 61.5% of mothers). The majority of mothers did not work (85.1%) and most of the households did not have a household helper (84.1%). Average maternal BMI was estimated at 26.71 ± 5.18 kg/m^2 (Nasreddine et al, 2017). Father's education, mother's BMI, presence of a paid helper, and crowding index made significant contributions ($p < .05$) to the prediction of overweight/obesity among study participants. After controlling for the socioeconomic and parental characteristics, these variables significantly improved the prediction of overweight/obesity to reach 21% ($p < .01$). Eating in front of the TV was associated with an 8% increase in the odds of overweight/obesity (OR= 1.08, 95% CI: 1.02 – 1.1), while a higher score of satiety responsiveness was associated with lower odds of overweight/obesity in the study population (OR= .8, 95% CI: .68 – .99) (Nasreddine et al., 2017). This study showed multiple influences on overweight and obesity status in preschool aged children. One factor that this study did not measure was PA which has been reported to have an impact on children's overweight/obesity status.

Obesity and physical activity. As previously stated a relationship exists between obesity and PA. Though how strong that relationship is, is a matter of discussion. One of the earlier studies examining this relationship between obesity and PA in preschool aged children was by Trost et al., (2003). The primary aim was to compare the PA levels of overweight and non-overweight 3- to 5-y-old children while attending preschool. A secondary aim was to evaluate weight-related differences in hypothesized parental determinants of child PA behavior

(Trost et al., 2003). A total of 245, 3- to 5-y-olds (127 girls, 118 boys) and their parent(s) (242 mothers, 173 fathers) recruited from nine preschools. Overweight status determined using the age- and sex-specific 85th percentile for body mass index (BMI) from CDC Growth Charts. Direct observation was used to measure physical activity. PA level was quantified using an instrument called the Observation System for Recording Activity in Preschools. A research assistant observed the activity of a child continuously for 15s, followed by 15s of recording. PA within each 15s-observation period was rated on five-point scale with stationary/motionless and fast movement serving as end points. In addition to activity level, observers recorded the child's physical location, the structure or context of the observed behavior, the type of activity being performed, the presence or absence of interactors, and the frequency of activity-related prompts from interactors. From the observation data, mean activity rating over the 1-h observational period (Mact), and the percentage of observations with an activity rating of three or greater (%MVPA) were calculated and then Mact and % MVPA scores for the three observation days were each averaged to provide an index of daycare physical activity participation (Trost et al., 2003). In addition to direct observation, PA was quantified using an uniaxial accelerometer and only children with at least 3 days of monitoring data were included in the analyses (Trost et al., 2003). From the accelerometers, total counts per hour, number of vigorous intervals per hour, and the number of moderate to vigorous intervals per hour were determined. Parents completed a brief questionnaire assessing sociodemographic information, height, weight, and previously studied parental determinants of physical activity behavior including parental modeling, parental support for physical activity, park visitation, perceived competence of their child, time permitted for television watching, and number of active toys and sports equipment in the home. Height and weight assessments were also conducted in a private setting with children dressed in light clothing. Children were classified as overweight if their BMI was equal to or greater than the sex and age-specific 85th percentile from the Centers for Disease Control and Prevention's Growth Charts. The BMIs for overweight boys (17.6 ± .2 kg/m^2) and girls (18.8 ± .2 kg/m^2) were higher than non-overweight boys (15.3 ± 1.0 kg/m^2) and girls (15.2 ± .1 kg/m^2). PA measures were similar between overweight boys, non-overweight girls, and overweight girls ($p > .05$); however, PA measures were different between overweight and non-overweight boys. For overweight boys, there was a mean activity rating (2.4 ± .2), % time in MVPA (39 ± 12.5), total counts/h x 10^3 (50.5 ± 14.4), MVPA interval/h (27.2 ± 10.5), and vigorous PA intervals/h (4.9 ± 3.1) when compared to non-overweight boys (mean activity rating: 2.6 ± .19, $p < .05$; % time in MVPA: 47.6 ± 12.7, $p < .05$), total counts/h x 10^3: 60 ± 14.5, $p < .05$; MVPA interval/h: 33.7 ± 8.5, $p < .05$; and vigorous PA intervals/h:6.7 ± 2.8, $p < .05$). In this study, the major finding was that overweight boys participated in significantly less physical activity than non-overweight boys during the preschool day. Notably, no weight related activity differences were observed in girls (Trost et al., 2003). Also, the cross-sectional nature of this study does not allow for conclusions concerning cause and effect but does show a relationship.

More recently, Vale et al. (2013) studied the relationship between obesity and PA in 607 children 4 – 6 years old. They measured body composition, parent education, and PA through accelerometers. Among girls, the prevalence of overweight and obesity was 23.5 and 10.6%, respectively. In comparison, the prevalence of overweight and obesity among boys was lower at 17.2 and 8.9%, respectively. In all, 90.2 and 97.3% of girls met the ≥ 1-h moderate to vigorous PA and ≥ 3-h total PA recommendations, respectively. In comparison, 96.2 and 99.4% of boys met the ≥ 1-h moderate to vigorous PA and ≥ 3-h total PA recommendation, respectively (Vale et al., 2013). Multi-nominal regression analysis showed that overweight and obese girls were less likely to meet the > 1-h moderate to vigorous PA than their non-overweight counterparts (Vale et al., 2013). Further, the authors reported compliance with PA recommendations was significantly higher among boys than in girls. In this study, they found high participation in PA and that boys accumulated more PA than girls and inversely girls showed a higher prevalence of overweight and obesity.

In contrast to the above studies, data from Pate et al. (2015) indicated that the relationship between obesity and PA in preschool aged children is not as consistent. Using data from two large scale studies (CHAMPS and SHAPES) involving preschool children both obesity and PA were measured. In the CHAMPS sample, more overweight children (58.3%) met the PA guideline than normal weight children (37.9%; $p = .01$). A similar trend was observed in the SHAPES sample, although the difference between weight status groups was not statistically significant (Pate et al., 2015).

A paucity of research exists regarding the relationship between PA and obesity in preschool aged children; however, more research exists in older children. Trost, Kerr, Ward, & Pate (2001) was an early study that examined PA patterns in an ethnically diverse sample of obese (n=54) and non-obese (n=133) middle school children in the sixth-grade children (mean age of $11.4 \pm .6$ years). Height and weight assessments were conducted in a private setting with students dressed in light clothing. BMI was calculated as body weight in kilograms divided by height in meters squared (kg/m^2) (Trost et al., 2001). Participants were classified as obese if their BMI was equal to or greater than the sex-, race- and age-specific 95th percentile from the first National Health and Nutrition Examination Survey (NHANES-1). Objective assessments of PA behavior were obtained using an accelerometer, which students wore for 7 consecutive days. Students were also given a 7-day log sheet to record the times the monitor was worn and to provide information about participation in non-weight bearing activities such as swimming, cycling and weight training (Trost et al., 2001). The results indicated that compared to non-obese children, obese children exhibited significantly lower total counts per day ($28.3 \times 10^4 \pm 2.01 \times 10^4$ vs $37.7 \times 10^4 \pm 1.41 \times 10^4$, respectively; p = .003); daily participation in moderate PA (62.6 ± 4.5 vs 78.2 ± 3.2 min/day, respectively; p = .002); and daily participation in vigorous PA (7.1 ± 1.3 vs 13.5 ± .9 min/day, respectively; p = .001). Relative to their non-obese counterparts, obese children exhibited significantly fewer 5-min bouts (15.9 ± 1.8 vs 23.4 ± 1.3, respectively; p = .001), 10 min bouts (8.7 ± 1.1 vs 12.6 ± .7, respectively; p = .002), and 20 min bouts (3.9 ± .6 vs 5.8 ± .4, respectively; p = .009) of MVPA over the 7-day monitoring period (Trost et al., 2001). This study was important due to it paving the way for future studies in a related area.

One of those future studies was by Gunter, Nader, and John (2015) who evaluated the relationship between PA at school and BMI among 1482 rural elementary-aged children, 1st-6th graders (Gunter, Nader, & John, 2015). Height and weight were measured and BMI data was transformed to BMI z-scores based on the Centers for Disease Control and Prevention (CDC) growth charts. Children were classified as “overweight” or “obese” using the age- and sex-specific 85th and 95th (Gunter et al., 2015). PA was measured on four consecutive school days during the hour’s children were attending school. Classroom teachers were trained to distribute pedometers, log non-compliance, daily wear time (min/d), and school attendance, and assist children with putting the devices on at the start of each school day and removing them at the end of the school day (approximately 6.5 h). On average, children wore pedometers for 357 ± 25 min/d. This equates to approximately 92% of a 6.5-hour school day. Cumulative averages over the 4-day sampling period were calculated for wear time (min/d at school), total PA (combined light, moderate, vigorous PA), and MVPA (step count 120/min). Children with ≥ 3 valid monitoring days were included in the final analyses. While there were no differences in total PA or MVPA between children with 2, 3, or 4 days of valid PA data, only children with ≥ 3 days of PA monitoring were included in analyses. The combined overweight/obesity prevalence was 36.8% for girls and 39.3% for boys; obesity prevalence was 17.8% and 20.8% for girls and boys, respectively. The average participation in total PA during the school day was 46 ± 19 min/d and 55 ± 21 min/d, for girls and boys respectively. Girls averaged 16.5 ± 6.8 min/d of MVPA, while boys spent 19.4 ± 8.5 min/d in MVPA. Boys accrued more total PA and MVPA than girls at every grade ($p < .05$). MVPA was associated with lower BMI z-scores ($p < .001$), independent of sex, wear time or grade (Gunter et al., 2015). Multiple logistic regression models were constructed with BMI percentile categories as the outcome variable (overweight vs. healthy BMI percentile; obese vs. healthy BMI percentile). More children in the healthy weight category participated in MVPA (19 ± 8 min/d) compared to those children classified as obese (15 ± 7 min/d; $p < .001$). Obese children had 7.3% lower odds of participating in MVPA compared to children in the healthy weight group. Overall, children classified as overweight participated in less MVPA (18 ± 8 min/d) than children classified as healthy weight, but this difference was not statistically significant ($p = .18$). There was an inverse relationship between BMI and minutes of MVPA for both boys and girls. While there are numerous other factors that likely contribute to this relationship including PA outside of school and child eating behaviors, this study provides some insights into the dearth of PA provided in rural schools and the potential effects this may have on child weight status.

Another study by Galaviz et al. (2012) examined the relationship between PA and obesity in 5th and 6th graders. They took circumference measures, BMI, skinfolds, PA measures using pedometers, and cardiorespiratory fitness using a 20-meter shuttle run test. Fitness and PA were negatively related to the obesity measures in boys ($r = -.57$ to $-.64$) and girls and ($r = -.18$ to $-.23$), respectively. Significant differences in waist circumference, BMI, and skinfolds were observed between the lowest and highest fitness tertiles for boys and girls ($p < .01$). Age, gender, and PA adjusted fitness explained 23 to 34% of the variance on waist circumference ($r^2 = .23$, $p < .01$), BMI ($r^2 = .23$, $p < .01$), and skinfolds ($r^2 = .34$, $p < .01$) (Galaviz et al., 2012). The significant correlation between PA and obesity underscores the importance of these factors impacting the health and well-being in children.

Overall, obesity has shown to have a relationship with PA levels in preschool aged children. This is something that not only exist at this early age, but that tracks through childhood and on into adulthood. The compounded health consequences resulting from childhood obesity are of serious concern so knowing how to reduce it in those children is important. PA shows to be an important factor to prevent obesity, so making sure that there is as little to impede children's ability to be physically active as possible needs to be a high priority.

Motor Skills

Motor skills are thought to impact children's PA and obesity levels. A motor skill is defined as a coordinated pattern of movements acquired through practice involving the ability to execute movements effectively to achieve intended outcomes (Dictionary of Sport and Exercise Science and Medicine). Gross motor skill movement involves the coordinated use of large muscle groups, such as when kicking a ball. In contrast, fine motor skill movement involves the ability to manipulate small objects, such as picking up a bead with your fingers (Dictionary of Sport and Exercise Science and Medicine).

The development of motor skills are key components to a child's ability to complete daily tasks. Further, motor skills are the foundation for a child to be physically active (Wrotniak et al., 2006). Youth with better motor proficiency may find it easier to be physically active and may be more likely to engage in PA compared with peers with poorer motor skill competence. In contrast, children with poor motor proficiency may subsequently choose a more sedentary lifestyle to avoid these movement difficulties (Wrotniak et al., 2006). While PA is an important factor for motor skills, there are other factors that may be related to lower levels of motor skills in youth. For example, overweight or obese youth may have poorer motor skills than leaner youth, and this relationship may extend to infant weight and motor activity (Wrotniak et al., 2006). Motor skills may also be related to self-efficacy or confidence in PA. Decreased competence and confidence may lead children with movement difficulties to avoid participating in physical activities as a coping strategy (Wrotniak et al., 2006).

Multiple motor skills assessments have been created over the years. One study used the Bruininks-Oseretsky Test of Motor Proficiency Short Form (Wrotniak, Epstein, Dorn, Jones, & Kondills, 2006). This test includes eight subtests & assesses gross motor skills, including running speed and agility, balance, bilateral coordination, and gross and fine motor development, including upper limb coordination; and fine motor development, including response speed, visual-motor control, and upper-limb speed and dexterity. A total standard score, adjusted for child's age, is used to interpret test performance (Wrotniak et al., 2006). Another gross motor skill test is the Peabody Developmental Motor Scales 2nd edition (Nervik et al., 2011). This test is a standardized norm-referenced test for children from birth to 6 years that measures both fine and gross motor development, it can also be used to assess either fine motor or gross motor skills alone, if required. Gross motor scores range from 35 to 165 and are divided into categories very poor to very superior based on the gross motor score (Nervik et al., 2011). There is also the Körper koordination-Testfür-Kinder test which measures gross motor skills by walking backwards, hopping for height, jumping sideways, and walking sideways (Laukkanen, Pesola, Sääkslahti, & Finni, 2014; Lopes, Rodrigues, Maia, & Malina, 2011). The Test of Gross Motor Development – Second Edition is another norm-referenced test that is typically used to measure gross motor skills that develop early in life. The Test of Gross Motor Development – Second Edition is composed of two subtests for gross motor development, locomotor and object control both of which have six skills that assess a different aspects of gross motor development (https://www.cdc.gov/nchs/data/nnyfs/tgmd.pdf). While this not an all-inclusive list of motor skills tests, it is apparent that there are multiple ways to measure motor skills in children.

These are not the only methods to assess gross and fine motor skills, some studies have combined different tests. Olesen et al., (2014) examined 627 children 5 – 6 years of age attending 43 randomly selected preschools in Odense, Denmark to describe gender differences in relation to, motor skills. The results relevant to this section were centered around motor skills. Aiming and catching motor skills were assessed using subtests of the Movement Assessment Battery for Children–second edition and motor coordination motor skills were assessed by the Körper koordination-Testfür-Kinder (Olesen et al., 2014). There were two trained observers that aided in administering each motor skill test. The first trained observer assessed anthropometrics and the four product-oriented subtests from the Movement Assessment Battery for Children–second edition test: coins in a box (piggy bank), catching a bean bag and throwing a bean bag into a target, and one-legged balance. The second trained observer carried out the Körper koordination-Testfür-Kinder test: walking backwards on balance beams of decreasing width, jumping on one leg at a time over an increasing number of foam blocks, jumping laterally with feet together over a small beam for 15 seconds, and moving sideways, shifting between two platforms for 20 seconds. A test score was recorded for each subtest, and then converted into standard scores based on age-specific norm-referenced data for the Movement Assessment Battery for Children–second edition (mean/SD 10 ± 3) and Körper koordination-Testfür-Kinder (mean/SD 100 ± 15) test, respectively. Boys, compared to girls, had a higher mean norm-referenced score according to the Movement Assessment Battery for Children–second edition aiming and catching component ($p < .01$) and the Körper koordination-Testfür-Kinder test ($p < .05$). In contrast, girls performed better in the Movement Assessment Battery for Children–second edition balance subtest than boys ($p < .001$). Boys and girls performed similarly for the manual dexterity subtest from the Movement Assessment Battery for Children–second edition. Moreover, when participants were classified as having difficulty, being at risk, normal, good, or high motor skills relative to the original norm-referenced motor skills risk-classification cut-points no gender differences were observed for the aiming and catching skill with either the Movement Assessment Battery for Children–second edition ($p = .07$) or the Körper koordination-Testfür-Kinder tests ($p = .18$) (Olesen et al., 2014). This study highlights the issues of having multiple motor skill assessments, as the findings were different for boys and girls between the two different tests for many of the tasks.

In a more recent study the aim was to assess differences in motor skills between boys and girls, independently, and across the entire preschool period (Kokstejn, Musalek, & Tufano, 2017). Using the Movement Assessment Battery for Children–second edition, motor skills were tested in 325 preschoolers (4.9 ± 1.1 years, range 3–6) using a cross-sectional design. The Movement Assessment Battery for Children–second edition contains eight test items which assess three basic motor domains: manual dexterity, aiming and catching, and balance. All testing occurred in a quiet kindergarten classroom during morning class time, and children were tested in small groups (2–3 children per group). The order of all eight tests was randomized and were performed on the same day. Children were familiarized with each test and performed two practice attempts for each. Then, children completed a single formal attempt, and the score of that attempt was used for data analysis. The four motor tasks have different age appropriate conditions between the younger (3- and 4-year old) and older (5- and 6-year old) children. The raw scores from each of the eight tests were converted to standard scores and percentiles in accordance with age-specific normative values for the Czech population. The Movement Assessment Battery for Children–second edition manual allocates normative values for 5- and 6-year olds independently, while norms for 3- and 4-year olds are divided into two groups per age using 6-month categories, yielding four groups total (3 y 0 months to 3 y 6 months; 3 y 6 months to 4 y 0 months, etc.). For simplicity and clarity, these half-year categories were combined into a single score for each age, like the 5- and 6-year olds (Kokstein et al., 2017). The sex differences between preschool boys and girls were assessed for total test score, manual dexterity, aiming and catching, and balance. When collapsed across age, girls had greater total test score ($p < .01$), manual dexterity ($p < .01$), and balance ($p < .01$) scores compared to boys, but there were no differences in aiming and catching. At the age of 3, girls had higher total test score ($p < .01$, ES = .38), manual dexterity ($p < .01$; ES = .36), and balance ($p < .05$; ES = .31) scores than boys, but there were no differences in aiming catching. At the age of 4, girls also scored higher than in total test score ($p < .01$; ES = .33), manual dexterity ($p < .01$; $r = .31$) and balance ($p < .05$), with no differences in aiming and catching. At the age of 5, there were no differences between sexes for any test. At the age of 6, there was also no difference in total test score, manual dexterity, and balance between girls and boys; however, boys performed significantly better in the aiming and catching subtest ($p < .01$; $r = .48$) (Kokstein et al., 2017). This study showed the differences in motor skills through the 3 to 6 years old range and differences between boys and girls. This study also used yet another motor skills test which further highlights the variety in motor skills test that are used in this research.

In a recent study conducted by Kit, Akinbami, Isfahani, and Ulrich, (2017) measured motor skills among a nationally representative sample of children aged 3–5 years living in the United States using the Test of Gross Motor Development-2. Of the 339 children with complete data for locomotor and/or object control, the sample sizes were 107, 113, and 119 for 3, 4, and 5-year-old children, respectively (Kit et al., 2017). Approximately 15% were obese and 49% were low-income (FIPR < 1.85). As expected, there was an increase in locomotor and object control mean raw scores ($p < .05$ for linear trend in both) with age, where 3 year olds had a mean locomotor score of 20.5 versus 33.6 for 5 year olds. Compared to girls, boys had a lower mean locomotor raw score by 2.9 points and a higher mean object control raw score by 3.6 points. Non-Hispanic black children, compared to non-Hispanic white children, had higher mean locomotor and object control raw scores of 3.9 and 1.9, respectively. Kit et al. (2017) reported that neither weight status nor income impacted the locomotor and object control raw scores. Boys had a lower mean locomotor standardized score than girls (9.5 vs. 10.5, $p < .05$), but there were no significant differences in mean locomotor standardized scores by age, race/Hispanic origin, weight status category, or income (Kit et al., 2017). There were no significant differences in the mean object control standardized score by age, race/Hispanic origin, weight status category, or income. The prevalence estimates of locomotor scores for the children were 1.3% very poor, 7.6% poor, 15.8% below average, 54.8% average, 13.3% above average, 4% superior, and 3.3% very superior. On the other hand, the corresponding estimates for object control were

2.2% very poor, 7.3% poor, 24.9% below average, 61% average, 3.2% above average, 1.4% superior, and 0% very superior. For both subtests, approximately 9% of children aged 3–5 years had either very poor or poor motor skills: 1.3% and 7.6% respectively for the locomotor subtest and 2.2% and 7.3%, respectively for the object control subtest (Kit et al., 2017). This is the only study that has been completed in the United States using population based data to examine the motor skill levels in children.

Motor skills and obesity. As previously stated obesity is a serious issue with the prevalence of childhood obesity increasing world-wide and in the United States. Obesity may impact motor skills. A study that took place in the United States examined the relationship between BMI and motor skills in 50 children who were healthy aged 3 to 5 years (Nervik et al., 2011). BMI was calculated for the children and motor skills were assessed using the Peabody Developmental Motor Scales, 2nd edition. The majority of children were in the non-overweight/obese category (76%) and 24% were in the overweight/obese category. On the PDMS-2, gross motor skill scores ranged from 81 to 111 with a mean of 94.84 ± 6.77. The gross motor categories ranged from 3 to 5 with a mean of $3.76 \pm .47$. Thirteen subjects (26%) scored in the below-average category, 36 subjects (72%) scored in the average category, and 1 subject (2%) scored in the above-average category. No child scored in the very poor, poor, superior, or very superior categories. A significant correlation was found between BMI percentiles and gross motor skill category ($p = .002$); however, the correlation between BMI and a continuous gross motor skill score was not significant ($p = .165$). Non-significant correlations between gross motor skill and age ($r = -.041$) and gross motor skill and gender ($r = -.025$) were also found. (Nervik et al., 2011). In short, children aged 3 to 5 years with high BMIs may have difficulty with their gross motor skills, but depending on how motor skills are quantified (continuous versus categorical) impacts the findings. The results from this study indicate that further research is needed to elucidate the impact BMI has on gross motor skill in children.

Another study determined the relationship between BMI and motor skills (Lopes, Stodden, Bianchi Maia, & Rodrigues, 2012) in 7175 children (boy's n = 3616, girl's n = 3,559), between 6 and 14 years of age, living in four regions of Portugal. This longitudinal study of Azorean school children (Azores Islands, Portugal) was carried out between 2002 and 2007. Four cohorts were followed for five consecutive years. At the first evaluation, the children were 6, 10, 13 and 16 years of age (first, second, third and fourth cohorts, respectively). Data from the first cohort who were followed from 6 to 10 years of age are the focus of this study. All children attended public schools and were selected per the general characteristics of each region. Motor skill was evaluated by the following activities: balance, jumping laterally, hopping on one leg over an obstacle, and shifting platforms. Height and weight were measured to calculate BMI. Negative correlations between BMI and the different motor skills tasks has varied between -.05 and -.49 ($p < .05$), indicating that as BMI increased motor skills decreased in boys and girls (Lopes et al., 2012). Girls specifically had correlations ranging from -.16 to -.44 with an average of -.27 ($p < .001$). Boys correlation coefficients ranged from -.05 to -.49 with an average of -.26 ($p < .001$) (Lopes et al., 2012). When the children's BMI was grouped into categories (normal weight, overweight, and obese), differences in motor skill scores were found across the three BMI groups. Obese boys and girls had lower motor skill scores than overweight children, and overweight children had lower motor skill scores than healthy weight ($p<.001$). In summary, over all age groups there is a negative relationship observed between BMI and motor skills tasks proficiency. The results from this study shows the importance of the relationship between obesity and motor skills as it tracks from childhood into adolescences.

Roberts, Veneri, Decker, and Gannotti, (2012) in a large sample examined the impact weight status had on motor skills in 10,700 (5,450 males) children (average age of 5 years, 5 months) participating in, the Early Childhood Longitudinal Study–Birth Cohort (Roberts et al., 2012). The children's BMI, education level of both parents, occupation of both parents, and motor skills were determined. Motor skills were assessed using the Bruininks-Oseretsky Test of Motor Proficiency and the Movement Assessment Battery for Children. The results indicated that obese boys were 1.6 times less likely (95% CI: 1.3 – 2.0) to pass the left foot hopping test than healthy weight boys. Likewise, obese compared to healthy weight girls were less likely (OR = 2.2, 95% CI: 1.8 – 2.8) to pass the left foot hopping test. Similar findings were seen on the right foot as obese boys and girls were less likely to pass compared to their health weight counterparts (boys: OR = 1.6, 95% CI: 1.3 – 2.1; girls: OR = 2.0, 95% CI, 1.5 – 2.5) (Roberts et al., 2012). Obesity also negatively impacted balance among the boys and girls ($p < .05$). Moreover, obese girls were 1.3 times less likely (95% CI: 1.1 – 1.6) to be able to skip compared with healthy weight peers. Obese boys and girls were less able to walk backwards than their healthy weight peers (boys: OR = 1.3, 95% CI: 1.1 – 1.6; girls: OR = 1.4, 95% CI: 1.1 – 1.7) (Roberts et al., 2012). In summary, this study indicated that obesity negatively impacts gross motor skills in boy and girls.

Another study examined the relationship between obesity and motor skills in children 4 to 6 years of age in the United States through a nationally representative study (Castetbon & Andreyeva, 2012). Data from pre-school (n = 5,100; 2,450 boys; 2,650 girls) and kindergarten children (n = 4,700; 2,300 boys; 2,400 girls) were analyzed separately. For 4 year-old children, fine motor skill assessment evaluated the child's ability to build a tower from 10 blocks and a gate from 5 blocks. They were scored as "both passed", "one of them passed" or "none of them passed". Another fine motor test assessed the child's ability to copy 7 shapes. The 5-6 year-old children were asked to build a gate (assessed on a pass/fail basis) and copy 4 shapes. Each shape was scored as "pass" or "fail"; the total number of shapes successfully copied determined the copy form score (from 0 to 7 at age 4 and from 0 to 4 at age 5-6). Gross motor skills were assessed based on the child's ability to skip at least 8 consecutive steps, walk backwards along a line for at least 6 steps, catch a bean bag tossed out of 5 trials, jump from a standing start, balance on each foot for 10 seconds, and hop on each foot 5 times. All activities were demonstrated to the child by the interviewer. Except for the jump distance (measured in inches) and the number of successfully copied forms, other gross motor variables were coded on a pass/fail basis (Castetbon & Andreyeva, 2012). BMI was calculated as weight (kg) divided by height (m) squared and converted into BMI z-scores and percentiles for age and sex based on national normative values. The BMI percentiles were then grouped into the following categories: Underweight (BMI < 5th percentile), healthy weight (5th ≤ BMI < 85th percentile), overweight (85th ≤ BMI < 95th percentiles), and obesity (BMI ≥ 95th percentile). Association between BMI z-score and motor skills were measured between boys and girls within the two age groups (pre-school and kindergarten). The authors reported a significant association in pre-school aged girls between obesity (≥ 95th percentile) and the gross motor skill of balance on the left foot ($r = .77$, $p < .01$) (Castetbon & Andreyeva, 2012). In kindergarten, aged girls, a negative association was reported between BMI z-score and balancing on the left foot ($r = -.09$, $p < .05$). No other significant associations between balance and either obesity or BMI z-score were observed in pre-school or kindergarten aged girls. Further, among pre-school and kindergarten aged boys no significant associations were found between BMI z-score and balance ($p > .05$). A strong positive association between obesity and hopping was found in pre-school (right foot, r = .83, p <

.01; left foot, r = .80, p <.01) and kindergarten aged boys (right foot, r = .92, p < .05; left foot, r = .89, p <.01). Interestingly, a strong significant association between obesity and the hopping was only seen in the left foot for pre-school (r = .83, p < .01) and kindergarten aged girls (r = .93, p < .05). Also, a significant negative association was observed in pre-school aged girls between jump distance, BMI z-score (r = - .46, p < .05), and obesity (r = -1.69, p < .01). A significant negative association was also seen in kindergarten aged girls between jump distance, in BMI z-score (r = - .47, p < .05), and obesity (r = -1.58, p < .01). Among pre-school and kindergarten aged boys, jump distance was not related to either BMI z-scores (preschool: r = -.40, p > .05; kindergarten: r = -.15, p > .05) or obesity (preschool: r = - 1.04, p > .05; kindergarten: r = - 1.07, p > .05) (Castetbon & Andreyeva, 2012). These findings indicated that although significant associations were observed between young children those associations vary and warrant further study in how and why BMI z-scores and obesity relate to certain motor skills.

Yet another study examined the effect of age, sex, and obesity on motor skills in 400 preschool aged children (200 boys, and 200 girls) (Vameghi et al., 2013). Motor skills were assessed with using the Ohio State University Scale of Intra Gross Motor Assessment scale. This motor skill test is a criterion-referenced assessment and designed to evaluate 11 fundamental motor skills in age range of 2.5 to 14 years old. The motor skills were divided in to locomotor skills (walking, running, jumping, hopping, skipping, stair climbing and ladder climbing) and objective control skills (throwing, catching striking and kicking) and presented in four developmental levels (physical, cognitive, social and motor development). BMI was calculated as weight (kg)/height $(m)^2$ for each child and converted into BMI z-scores and age- and sex-specific percentiles (Vameghi et al., 2013). Normal weight, overweight, and obesity were defined by $5^{th} \leq$ BMI $\geq 85^{th}$ percentile, $85^{th} \leq$ BMI $\geq 95^{th}$ percentile, and BMI $\geq 95^{th}$ percentile, respectively. The results showed that age had a positive effect and BMI had a negative effect on the stair climbing skill ($\beta = .132, p < .05; \beta = -.212, p < .05$, respectively), but sex was not a significant factor influencing this skill ($p > .05$). Also, age, sex, and BMI variables had a significant effect on kicking and striking skills, with there being a positive effect with age on both skills ($\beta = .504, p < .05; \beta = .606, p < .05$, respectively). In contrast, sex a positive effect on kicking ($\beta = .228, p < .05$), but a negative association for striking ($\beta = -.328, p < .05$). Moreover, a negative effect was reported between BMI, kicking and striking skills ($\beta = -.213, p < .05; \beta = .156, p < .05$, respectively). Regarding jumping and skipping motor skills, there was a relationship between age, sex, and BMI, with there being a positive effect reported for age ($\beta = .367, p < .05; \beta = .88, p < .05$, respectively) and sex ($\beta = .268, p < .05; \beta = .3, p < .05$, respectively), and a negative effect found with BMI ($\beta = -.093, p < .05; \beta = -.144, p < .05$, respectively). Further, a positive effect was found between hopping and age ($\beta = .408, p < .05$), but a negative association was found for hopping, sex ($\beta = -.63, p < .05$), and BMI ($\beta = -.146, p < .05$). Lastly, age, sex, and BMI had a positive relationship with ladder climbing ($\beta = .145, \beta = .225, \beta = -.147$, respectively; $p < .05$) (Vameghi et al., 2013). This study was important because statistically significant relationships were found for age, sex, and BMI with a wide variety of gross motor skills.

Cheng et al. (2016) analyzed data from 668 children (54 % male, 46% female) to examine the temporal precedence between children's weight status and motor skills. Analyses also examined differences in gross and fine motor skills among healthy weight, overweight, and obese children using the Bruininks– Oseretsky Test of Motor Proficiency Short Form. The authors used three indices of weight status: BMI (kg/m^2), BMI z-scores, and age and sex-appropirate BMI percentile categories (obesity, ≥ 95th percentile and overweight a ≥ 85th perecentile). BMI and motor skills were assessed at ages 5 and 10 years. At 5 years of age, 20% of the children were overweight and 22% were obese, by the age of 10 years 23% were overweight and 18% were obese. A higher BMI at 5 years of age contributed to declines in motor skill from 5 to 10 years ($\beta = -.16$, $p<.001$). There was no support for the reverse; that is, poor motor skills at 5 years did not predict increases in relative weight from 5 to 10 years. Obesity at 5 years also predicted declines in motor skill. When compared to healthy weight children, obese children had significantly poorer total and gross motor skills at both 5 and 10 years. Overweight children also had poorer total and gross motor skills at 10 years, but not 5 years. The differences in total and gross motor skills among healthy weight, overweight, and obese children appear to increase with age. Finally, small differences existed in fine motor skill between obese, overweight, and healthy weight only among children at 5 years (Cheng et al., 2016). This study indicates that not only does obesity impact motor skills, but that this relationship tracks through preschool age into childhood.

Motor skills and physical activity. Just like with obesity, PA plays a vital role in motor skills. To highlight the importance of PA on motor skills, Fisher et al., (2005) recruited 394 children (mean age 4.2 ± .5 yr.) for the Movement and Activity Intervention in Glasgow Children randomized controlled trial. Baseline data was used for the data analysis to conduct this study. The authors measured height and weight to calculate BMI, PA was measured using accelerometers, and motor skills were assessed using the Movement Assessment Battery. This test involved a set of 15 tasks: jumps (vertical jump, running jump, and standing jump), balance (standing on one foot for two different time intervals), skips (four different forms of skipping), ball exercises (kicking a rolled ball, catching a ball, and catching a bounced ball), and throwing a beanbag into a target. They found that the total movement skills score was weakly but positively correlated with the percent of monitored time spent in MVPA ($r = .18$, $p > .001$) (Fisher et al., 2005). When the percent time spent in MVPA was compared to quartiles of motor skills score, among girls, time spent in MVPA was significantly higher in the upper quartile for motor skills than the lowest quartile (median difference .9%, 95%, CI: .2–1.6%,). Likewise, boys MVPA time was higher in the upper quartile for motor skills score than those in the lowest quartile (median difference .9%; 95% CI .0–.2%, $p = .04$) (Fisher et al., 2005). The results indicated that although weak there was a positive relationship between MVPA and motor skills with no notable difference in the relationship between sexes.

As a follow up to the previous study Reilly et al. (2006) examined the impact a PA intervention had on motor skills in preschool aged children in Glasgow Scotland. They randomly selected 36 of the 104 nurseries willing to participate. To ensure comparability of intervention and control groups, nurseries were stratified and pairs of nurseries randomly selected from the same stratum, one randomly allocated to intervention and one to control. The primary outcome was BMI expressed as a standard deviation score (Reilly et al., 2006). This was calculated at baseline and at six months and 12 months after the start of the intervention. Also, habitual levels of PA and sedentary behavior were objectively measured over six days with accelerometry at baseline and at six months. Motor skills were assessed at baseline and six months using the Movement Assessment Battery. They obtained data on motor skills in 489 (90%) children at baseline and 420 (86% of the children measured at baseline, 77% of entire sample) at six months. In regards to PA 3 major variables were calculated: total physical activity (cpm), median % monitored sedentary time, and median % monitored time in MVPA. This was done between two the intervention and the control groups. After the intervention, it was observed in relation to total PA, the boys and girls in the intervention group had lower (841 ±

183 cpm, & 782 ± 172 cpm, respectively) versus the control group (916 ± 228 cpm, & 881 ± 207 cpm, respectively). Regarding, the % monitored sedentary time the boys and girls in the intervention group [64.8 % (47 % – 82.9 %), 68.5 % (51.7 % – 86 %), respectively] had higher amounts of sedentary time than the control group [62.5 % (43.1 % – 79.9 %), 64.1 % (43.2 % – 81.6 %), respectively]. Furthermore, the % monitored time in MVPA was lower for the boys and girls in the intervention group [3.8 % (.5 % – 12.4 %), 3.1 % (.7 % – 9.5 %), respectively] than the control group [4.2 % (.7 % – 12.1 %), 3.8 % (.6 % – 12 %), respectively]. When the change score for motor skills was used in the analysis, the authors found that girls improved more than boys; the average difference in improvement was .7 units (.3 to 1.1, p = .001) (Reilly et al., 2006). There was a group effect for motor skills: children in the intervention nurseries improved their motor skills significantly more than children in the control nurseries, the average difference in improvement being .8 units (.3 to 1.3 units). At the nursery level, 83% of prescribed sessions of the PA program were actually offered. At the level of the child, 71% of prescribed sessions were attended (lower quartile 57%, upper quartile 81%) (Reilly et al., 2006). Overall the authors reported that while the PA intervention did not improve PA or BMI levels compared to those in the control group, motor skills were improved in the intervention group.

Another study examined the association between motor skills and objectively measured PA in preschool aged children in the preschool setting (Cliff, Okely, Smith, & McKeen, 2009). The sampling frame included all early childhood centers (n = 130) in the Wollongong, New South Wales, Australia. From which 30 centers were randomly selected using a computer-generated program, and the first 20 centers were approached, of that 11 preschools agreed to participate. The sample consisted of 25 boys and 21 girls [age = 4.3 ± .7 year, height = 105.2 ± 6.1 cm, median BMI = 15.9 (15.4, 16.8) kg/m^2, and median BMI z-score = .23 (-.13, .78)].

Children's BMI z-score was calculated based on their age and sex using lmsGrowth and the UK reference curves. Motor skill was assessed using the Test of Gross Motor Development-2nd Edition. The measure is comprised of locomotor (run, gallop, hop, leap, horizontal jump, and slide) and object-control (t-ball strike, stationary basketball dribble, catch, kick, overhand throw, and underhand roll) subtests, each assessing six skills. PA was objectively assessed using accelerometers. The mean duration of PA monitoring was 4.1 ± 1.0 days and 641.0 ± 95.9 min/day, and the sample spent approximately 23.0 (15.0, 44.2) minutes/day in MVPA (Cliff et al., 2009). Girls' mean locomotor subtest raw score was higher than boys' (26.4 vs. 20.2, $p = .009$), although no differences were found for the object control raw score (22.0 vs. 20.6, $p = .467$). As the object-control score standard score was adjusted for gender, girls scored higher than boys on both the locomotor (9.9 vs. 7.9, $p = .003$) and object-control standard scores (10.1 vs. 8.6, $p = .026$), and subsequently the gross motor skill (99.7 vs. 88.2, $p < .001$) (Cliff et al., 2009). For both boys and girls, BMI z-score and socioeconomic status were not related to PA outcomes. Age, however, was negatively associated with percent of time in moderate PA for boys ($r = -.48$, $p = .015$) and girls ($r = -.47$, $p = .032$). Among boys, locomotor standard score was not related to percent of time in MVPA ($r = .34$, $p = .098$); object-control standard score was positively related to percent of time in moderate PA ($r = .52$, $p = .008$) and MVPA ($r = .48$, $p = .015$), but was not related to total physical activity ($r = .37$, $p = .070$). Subsequently, gross motor skill was not related to percent of time in MVPA ($r - .38$, $p = .061$) and total PA in boys ($r = .39$, $p = .056$), but was related to percent of time in vigorous PA ($r - .46$, $p = .020$). For girls, object-control standard score was not related to PA outcomes; however, both locomotor standard score and gross motor skill were negatively related to percent of time in moderate PA ($r = -.52$, $p = .015$ and $r = -.44$, $p = 047$, respectively) and MVPA ($r = -.50$, $p - .022$ and $r - .46$, $p = .038$, respectively) (Cliff et al., 2009). This study found that boys and girls were equally proficient at performing object control skills, although girls scored higher than boys for locomotor skills and subsequently for the gross motor skill. Motor skills were positively correlated with objectively measured habitual PA in preschool boys and negatively correlated to habitual PA in preschool girls (Cliff et al., 2009).

In a more recent study, Laukkanen et al., (2013) examined the relationship between PA levels and motor skills in 53 pre-school and 31 primary school children. PA was measured using an accelerometer and motor skills were measured using the Körper Koördinations Test für Kinder test which involved walking backwards, hopping for height, jumping sideways, and walking sideways. Preschool aged boys performed better than preschool girls in overall motor skills ($t = 2.44$, $p < .05$), hopping for height ($t = 3.22$, $p < .01$), and jumping sideways ($t = 2.59$, $p < .05$). Motor skill was positively correlated with the time spent in sustaining impacts between .6 and 1.2 g ($.42 < r < .51$, $p < .05$) and with the time spent in light PA ($r = .51$, $p < .05$) and moderate intensity PA ($r = .55$, $p < .01$), and negatively with sedentary time ($r = -.52$, $p < .05$) in preschool boys. Among preschool girls, moving sideways was associated with the time spent sustaining impacts of 3.4 – 4.0, 4.2 – 4.4, and 4.8 – 5.4 g ($.39 < r < .47$, $p < .05$), but not with the time spent at any mean counts per minute (Laukkanen et. al, 2013). In primary school boys, no significant associations were found between gross motor skills and PA mean counts per minute. In contrast, among primary school girls, motor skill was positively associated with the time spent at .6–1.0, 1.4–1.6, and 5.6–6.0 g impacts ($.50 < r < .57$, $p < .05$) and with the time spent at vigorous intensity PA ($r = .56$, $p < .05$). Also in primary school girls, throwing and catching a ball was positively associated with the time spent sustaining impacts of .8–1 g ($r = .65$, $p < .01$). Further, walking backwards was positively related with impacts of 1.6–3.4 and 4.8–6.0 g (.50 < r

$< .61$, $p < .05$), and jumping sideways with impacts of .6 – 1.0 g ($.52 < r < .55$, $p < .05$). Moreover, throwing and catching a ball, walking backwards, and jumping sideways were positively correlated with vigorous intensity PA ($.50 < r < .57$, $p < .05$), while walking backwards was positively related with mean counts per minute ($r = .52$, $p < .05$) (Laukkanen et. al, 2013). Overall, boys accumulated more time than girls in g-force impact categories ($2.48 < t < 3.64$, $p < .05$) and less time at zero g-force (primary schoolers, $t = 2.31$, $p < .05$). Similarly, boys spent more time at count intensity categories ($2.26 < t < 3.33$, $p < .05$) and less time in sedentary time ($2.79 < t < 2.92$, $p < .01$). In general, primary school children spent more time at g-force impact categories ($2.15 < t < 3.38$, $p < .05$) and count intensity categories ($2.06 < t < 3.48$, $p < .05$) and were less sedentary ($t = 3.09$, $p < .01$) than preschool children. Additionally, mean counts per minute values, referring to the mean level of PA, were higher among primary school children (652 ± 200 counts/min) than preschool children (532 ± 142 counts /min, $p < .01$). While the mean PA levels was higher in primary school boys (742 ± 225 counts /min) than girls (587 ± 156 counts /min, $p < .05$), no significant differences were found between the sexes among preschool children (boys: 567 ± 162 counts/min versus girls: 502 ± 115 counts/min) (Laukkanen et. al, 2013). This study indicated that gross motor skills are positively in association with habitual PA and negatively associated with sedentary time in 5–8-year-old children.

Iivonen et al., (2013) evaluated the relationships between objectively measured PA and motor skills in 4-year-old children. This study was conducted with 37 children, 17 boys (age = $4.2 \pm .3$ years) and 20 girls (age = $4.0 \pm .3$ years), for whom had complete PA, anthropometry, and motor skills data (Iivonen et al., 2013). Seven test items from the APM Inventory manual and test booklet was used to assess motor skills. The test items were classified into the domains of balance, locomotor, and manipulative skills. Balance skills assessed static and dynamic balance, and the locomotor skills included a standing broad jump, sliding and galloping. Manipulative skills were measured by kicking a ball and throwing and catching activities. The intra-class correlations for test-retest reliability for children ages 4 to 7 years have ranged from .86 – .94 (Iivonen et al., 2013). PA was assessed using ActiGraph accelerometers where the monitoring period was five consecutive days. There were no significant sex differences for either age or anthropometry. The Mann-Whitney U test indicated one statistically significant sex difference in the measured variables: girls stood for approximately 10 sec. longer on one foot than boys. No significant sex differences were observed for either dynamic balance or locomotor skills. Although boys jumped approximately 5 cm further than girls, the difference was not statistically significant. The sum score of sliding and galloping was equal between the sexes. The sex differences in manipulative skills were not statistically significant, although boys scored more points on all three test items. Statistically significant sex differences were also not found on the total skill score. Overall, no statistically significant sex difference was observed in total PA (boys: 671 counts/minute; girls: 688 counts/minute). Regarding the average daily time spent in activities in the different intensity categories, both sexes spent the most time sedentary and the least time in the moderate category. There were no statistically significant sex differences in the means of time (min/day) spent in the different activity intensity categories. Both sexes accumulated approximately one hour of MVPA over the course of a day. The daily proportion of time spent sedentary was 85.8 % for boys and 85.1 % for girls. Standard multiple regression models controlled for sex, age in months, and BMI indicated significant associations between PA and motor skills variables. The total motor skill score had a statistically significant positive association with total (43.70 ± 15.10), light-to-vigorous (6.58 ± 2.15), and MVPA (5.00 ± 1.63) Sliding and galloping were significantly positively associated with MVPA (7.00 ± 3.23), and the throwing and catching combination was significantly associated with total (62.11 ± 19.27), light-to-vigorous (7.49 ± 2.77), and MVPA (5.92 ± 2.04). Of the seven skills measured, neither static balance, dynamic balance, standing broad jump, kicking a ball at a target, or throwing at a target were significantly associated with children's PA (Iivonen et al., 2013). This study measured PA and motor skills variables were also explored. Motor skills were expressed as a composite score of a set of gross motors skills across the three gross motor skill domains were positively associated with children's habitual PA. In the analysis in which the children's biological factors were included, the total motor skill score had a positive and statistically significant relationship to all the PA outcomes as shown above. The relationship between the total motor skill score and light-to-vigorous PA adds to the research evidence for a positive association between multiple intensities of PA and motor skill in 4-year-old preschool children (Iivonen et al., 2013).

In a very recent study, O'Neill et al., (2017) examined the relationship between children's motor skill levels and types of PA performed during preschool attendance. Another aim was to examine the relationship between motor skill and parent perception of athletic competence. Participants were 264, 3- to 5-year-old children from 22 preschools (commercial, faith-based, and Head Start). A standardized motor skill protocol was used to measure gross motor skill. The protocol was based on the Test of Gross Motor Development-2nd Edition and assessed the movement process characteristics of six locomotor and six object control skills (O'Neill et al., 2017). The Observational System for Recording Physical Activity in Children-Preschool Version was used to directly observe the specific types of physical activity the children performed. Five of 18 possible PA types were of interest: walk, run, jump/skip, dance, and throw. "Jump/skip" included jumping, skipping, hopping, and galloping, and "throw" captured throwing, kicking, catching, and rolling balls. "Dance" was defined as any dance or expressive movement such as spinning in circles or acting out instructions to a song. During the 2-week data collection period at each preschool, each child was randomly assigned observations across days, observation blocks, and observers. Each child was observed for 10–12, 30-min sessions, resulting in a total of 600 – 720 intervals per child. Kappa values for inter-observer reliability were above .80 for all categories, including activity type. Parents completed a survey that included a rating of their perception of their child's athletic competence; they rated their child's coordination compared with other children of the same age and sex. The mean age of children was 4.1 ± .6 years; the mean BMI was 16.3 ± 2.3 kg/m^2. Children engaged in sedentary behavior 87.2%, light activity 8.3%, and MVPA 2.6% of the time observed. During the preschool day, children in the highest locomotor tertile engaged in a higher percentage of intervals of dancing (.19 ± .04) than children in the lowest locomotor tertile (.07 ± .05) ($p = .04$). Although not significant, there was a trend for children in the highest locomotor tertile to participate in a higher percentage of intervals of jumping/skipping (.61 ± .07) than children in the lowest locomotor tertile (.45 ± .07) ($p = .08$). There were no significant differences in percentage of intervals of walking or running across tertiles of locomotor scores. Children in the highest object control tertile were observed throwing in a higher percentage of intervals (.14 ± .03) than children in the low and intermediate object control tertiles (.06 ± .03) ($p < .05$) (O'Neill et al., 2017). This study showed positive relationships existed between level of motor skill performance (locomotor and object control) and the specific types of activities children engaged in during the preschool day.

Recently Loprinzi and Frith (2017) examined if greater motor skill development is associated with higher PA levels among preschool-aged children. They used data from the 2012 National Youth Fitness Survey that included 329 preschool-aged children (3 – 5 years) living in the United States. The motor skills were assessed by the Test of Gross Motor Development-2nd Edition which has been referenced in previous studies. Parents of the preschool child were asked, ‘‘During the past 7 days, on how many days was your child physically active for a total of at least 60 minutes per day? Add up all the time your child spent in any kind of physical activity that increased his/her heart rate and made him/her breathe hard some of the time.’’ Meeting PA guidelines was defined as engaging in PA of this kind at least 60 minutes/day for all seven days. Of 329 preschool participants, 270 (82%) met this definition. The average age of the sample was 4.0 years ± .03, with mean standard motor skills score, locomotor, and object control scale scores. The observed in analyses examining the association between motor skills and meeting PA guidelines an association of 95.6 ± .8 ($p = .75$) in regards to motor skills, 10.0 ± .2 ($p = .59$) for locomotor, and 8.5 ± .1 ($p = .95$) for object control, respectively (Loprinzi & Frith, 2017). Motor skill level was not associated with meeting PA guidelines in the adjusted models ($p > .05$). Notably, results were not significant when considering unadjusted or minimally adjusted models ($p > .05$). Additionally, no significant associations were observed when PA was treated as a continuous variable. There was no evidence to suggest that motor skill level was associated with whether or not participants met PA guidelines either collectively or particular subpopulations (e.g., gender, race, or ethnicity) (Loprinzi & Frith, 2017). The main and unexpected finding of this study was that motor skill level was not associated with PA in this nationally representative sample. This finding is in contrast to what others have reported from different counties and indicates that additional research is needed.

Motor skills, PA, and obesity. Research suggest independent relationships exist between PA and obesity on motor skills. Although is there a combined relationship of PA and obesity on motor skills? Bȕrgi et al., (2011) investigated the relationship of objectively measured physical activity (PA) with motor skills (agility and balance), aerobic fitness and percent body fat in 217 young children (age 4–6 years, 48% boys). Data came from a randomized controlled trial (Ballabeina-Study), which took place in Switzerland. PA was measured over 6 consecutive days with an accelerometer. Agility and dynamic balance were two motor skills that were measured. Agility was assessed by an obstacle course. Dynamic balance was tested by balancing forward barefoot on a balance beam. The BMI was calculated as weight (kg) per height $(m)^2$. Overweight and obesity were classified according to International Obesity Task Force criteria. Percent body fat was measured by a four-polar single frequency bioelectric impedance analysis (Bȕrgi et al., 2011). Positive associations were found between PA and balance ($p < .04$). There was a negative association between PA and agility score time. After adjusting for percent body fat, the association between baseline PA with baseline agility ($r = -.10$ to $-.11$, $p \geq .14$) as well as the change in balance ($r = .13$ to $.15$, $p \geq .05$) did not remain significant. Overall, in the studied preschool population, PA was related to agility, and balance, but this effect was lost after adjusting for body fat percentage for agility (Bȕrgi et al., 2011).

Following from there Bonvin et al., (2012) examined the differences in motor skills and in PA according to weight in 529 children (3 – 5 years). Standing height was determined and body weight was measured using an electronic scale and BMI was calculated as weight kg/m^2. Children were classified into two BMI-groups “healthy weight” and “overweight” group (including both overweight and obese children) according to the International Obesity Task Force criteria. Motor skills were measured using a modified version of the Zurich Neuromotor Assessment. In this test, the five motor skills were performed in two obstacle courses (one called the Cat and the other Monkey. In the “Cat” course, children stood up from a chair, ran three meters to a pole, went around it, ran back and climbed up and down a three-step stairs while removing a sticker from the wall on the top of the stairs. The motor skills running and climbing up and down the stairs were scored. In the "Monkey" course, children balanced on a beam, passed under a tunnel, got up and jumped from a case (height of the first step of the stairs). The motor skills balancing, getting up and landing after jumping were scored. To further differentiate children with excellent motor skills, children were additionally asked to jump on one leg as many times as they could. Each motor skill was evaluated using a scale ranging from zero (unable to perform the task) to four (excellent). Two motor scores were calculated to determine an overall motor skills score: 1) an "Integral Motor Score" (sum of six motor skills) that included the additional and most difficult task "jumping on one leg". This score ranged from zero (unable to perform all six motor skills) to 24 (best performance on all tasks), and 2) a "Basic Motor Score" (sum of 5 motor skills, regarded as the reference score) that did not include this task and whose score ranged from 0 - 20. PA was measured over only one day at the child care center with an accelerometer and the accelerometer was worn around the hip (Bonvin et al., 2012). No weight status-related differences were found for any of the single motor skills ($p > .1$). However, a tendency for lower performance in the overweight children was observed in the total Basic Motor Score ($n = 529$, $p = .059$), but not in the total Integral Motor Score ($n = 411$, $p = .19$). Even after limiting the sample to those who had a valid integral motor score, differences in the total Basic Motor Score were not significant ($n = 411$, $p = .13$). No significant differences were found in total PA including sedentary activity between healthy weight and overweight children (all $p \geq .6$). They also tested if BMI was related to motor skills or PA. After adjustments for age and gender, increased BMI was related to a decreased score in the running task (beta coefficient of -.14 and 95% CI of -.28 to -.08, $p < .05$), but not to the other single motor skills ($p > .06$), both motor scores (both $p > .25$) or any of the PA (all $p > .2$). Restricting all analyses to the children with valid PA measures (n = 251) did not change the results regarding motor skills, except that overweight children performed less well in the balancing on a beam skill ($p = .046$) (Bonvin et al., 2012). Healthy weight compared to overweight children had higher levels of TPA (610 ± 211 vs 587 ± 201 cpm) and higher basic motor score (12.59 ± 3.43 vs 11.91 ± 3.55) and integral motor score (14.41 ± 3.82 vs 13.43 ± 3.81) (Bonvin et al., 2012).

In a study previously highlighted in the motor skill and PA section of this literature review, Loprinzi and Frith (2017) examined if greater motor skill development was associated with higher PA levels among preschool-aged children. This study also examined the combined relationship of PA, and obesity on motor skills. Again, they used data from the 2012 National Youth Fitness Survey of 329 preschool-aged children (3 – 5 years) living in the United States. The motor skills were assessed by the Test of Gross Motor Development-2nd Edition. The authors reported that motor skill level was not associated with meeting PA guidelines after adjusting for age, gender, race-ethnicity, asthma status, and weight status (BMI) ($p > .05$), and no significant associations were observed when PA was treated as a continuous variable.

In summary, obesity and physical inactivity have reached epidemic proportions which effects not only health, but the development of children. The impairment of motor skills is one way in which a child's development is negatively impacted. PA and obesity seem to independently have a relationship with motor skills in young children. Unfortunately, the negative health and development consequences that occur in young children could impact them as they continue to grow and develop into adults. Understanding the independent and joint effects obesity and physical activity have on motor skills is important for the development of interventions.

Gaps In The Literature

One aspect of moving the scientific knowledge forward for a particular topic is developing studies which address questions that other studies either have not answered or not answered concisely. In other words, determining what is unclear or missing from the previous research. One major issue involving the motor skill research is the variety in motor skills test that are used. Past research has used at least six different motor skills tests, which makes comparisons across studies difficult and could play a role in the varying results reported for the relationship between PA, obesity, and motor skills. Motor skill tests that have been used include the Bruininks-Oseretsky Test of Motor Proficiency Short Form (Wrotniak et al., 2006, Cheng et al. 2016), the Peabody Developmental Motor Scales 2^{nd} edition (Nervik et al., 2011), the Körper koordination-Testfür-Kinder test (Laukkanen et al., 2011, Olesen et al., 2014, Laukkanen et al., 2013), the Movement Assessment Battery for Children–2^{nd} edition (Kokstein et al., 2017), the Test of Gross Motor Development-2 (Kit et al., 2017, Cliff et al., 2009, O'Neill et al., 2017, Loprinzi & Frith, 2017), the Ohio State University Scale of Intra Gross Motor Assessment scale (Vameghi et al., 2013), and the Movement Assessment Battery (Fisher et al., 2005, Reilly et al., 2006). In Roberts et al., (2012) used two motor skill tests, and the results highlighted how different tests can result in conflicting results even when working with the same population.

Another gap in the literature is the lack of information on the preschool age group. Some studies highlighted in the literature review above included older children to give some direction given limited research in the preschool age. Moreover, the majority of research related to motor skills in preschool aged children has been conducted in countries other than the United States, in this literature review eight studies were discussed to summarize the existing literature (Olesen et al., 2014, Kokstein et al., 2017, Vameghi et al., 2013, Fisher et al., 2005, Reilly et al. 2006, Cliff et al., 2009, Laukkanen et al., 2013, Iivonen et al., 2013). While this research is important and gives a better understanding of the role PA and obesity have on motor skills, it is unclear if the same relationships would be present in children from the United States. To the best of our knowledge only six studies focusing on this topic, in this age group, has have been conducted in the United States (Kit et al., 2017, Nervik et al., 2011, Roberts et al., 2012, Castetbon & Andreyeva, 2012, O'Neill et al., 2017, Loprinzi & Frith 2017).

Finally, most research has focused on the independent effects PA (Nervik et al., 2011, Roberts et al., 2012, Castetbon & Andreyeva, 2012, Vameghi et al., 2013) and obesity (Fisher et al., 2005, Reilly et al. 2006, Cliff et al., 2009, Laukkanen et al., 2013, Iivonen et al., 2013, O'Neill et al., 2017) have on motor skills. A paucity of research exists examining the combined effects of these factors on motor skills in the preschool aged population.

Therefore, due to these gaps in the literature there is ample reason for additional research focusing on the relationships between PA, obesity, and motor skills in preschool aged children, specifically in the United States. Thus, the purpose of this study is three-fold: 1) to examine the relationship between PA and motor skills in children ages 3-6 years old, 2) to examine the relationship between obesity and motor skills in children ages 3-6 years old, and 3) to examine the joint relationship of PA and obesity on motor skills.

Chapter III: Methods

The methods section describes how this study will be done. This section will discuss the National Health and Nutrition Examination Survey (NHANES), National Youth Fitness Survey (NNYFS), and the participants being studied including inclusion and exclusion criteria. From there, the study design, equipment and instruments, and measurement protocol will be explained. Following that are the data processing and reduction steps and statistical analysis.

National Health and Nutrition Examination Survey (NHANES)

NHANES began in the 1960s and included a variety of surveys to examine health outcomes in variety of different populations. The purpose of NHANES has been to provide vital statistics on the health of the nation. Each year, NHANES surveys 5,000 individuals representing the nation as a whole. The survey includes demographic, socioeconomic, dietary, and health-related questions. Moreover, physical examinations are done to measure health markers like blood pressure, lipids, BMI.

NHANES National Youth Fitness Survey (NNYFS)

NNYFS was the first national survey of PA and other markers of fitness in children (3 – 11 years) and adolescents (12 – 15 years) that was conducted in partnership with NHANES in 2012. The data on PA and fitness levels of youth were collected through interviews, wearing of activity monitors, and a variety of fitness tests. The inclusion of fitness tests, in the NNYFS for ages 3 – 15, provides additional information to evaluate the health of this age group. NNYFS interviewed and examined approximately 1,500 children and adolescents aged 3 – 15 years with approximately equal sample sizes for each single year of age. In addition, six analytic domains (males 3 – 5 years, females 3 – 5 years, males 6 – 11 years, females 6 – 11 years, males 12 – 15 years, and females 12 – 15 years) were defined for the survey. The NNYFS sample was designed so that data from components NNYFS were similar to NHANES in 2012, so that the body measures, physical activity monitor, muscle strength (grip strength), physical activity questionnaire, and dietary recall could be analyzed together. NNYFS included additional tests of cardiovascular capacity, performance endurance, core strength, upper and lower body strength, and gross motor skills.

Sampling

There was a step by step process in sampling for the survey. The nationally representative sample of children came from 15 primary sampling units (PSUs). These PSUs represented 3,000 counties across the Unites States. After the PSU have been identified, the NNFYS staff contacted an adult living in the house and that adult completed a screening survey via laptop. This screening survey collected demographics and other information to establish if those living in the house were eligible for further interviewing. For those who were eligible, the adult signed interview consent form for the family questionnaire. Then the questionnaire was administered to one adult family member from the household. Then consent for the selected child to participate in examination was obtained. Once consent was acquired an examination appointment was set up.

Participants

For this study, the participants were children ages 3 – 5 years old from the NNYFS database. Reasons for excluding participants from analysis were due to being out of age range or having incomplete data for any of the key variables, obesity, physical activity, and motor skills. The sample of children to select from before exclusion was over a 1,000 for each of three different terms within the time frame of 2012. The final sample when limiting to the age range of 3 – 5 years was 352 (179 males, and 173 females).

Design

This is a cross-sectional study where data came from NNYFS during the year of 2012 for analysis. NNYFS has been approved by an Internal Review Board via the Centers for Disease Control. The data used in this study included PA measures, body composition, and motor skill proficiency. The PA measures were assessed by PA questionnaire completed by the parent of the child. Measures of body composition included weight, height, and skinfolds. BMI was calculated by height and weight provided from the NNYFS database. Body fat percentage was calculated from calf and triceps skinfold measurements. NNYFS used Test of Gross Motor Development – 2^{nd} Edition to assess motor skills specifically locomotor and object control.

Measurement Protocol

The NNYFS survey consisted of interviewer-administered questionnaires conducted in the participants' home by trained staff, followed by standardized medical examinations by physicians and health technicians that were conducted in Mobile Examination Centers. The questionnaires included information about age, ethnicity, sex, geographic area, PA and nutritional habits, and current medical conditions. Medical examinations were performed to evaluate anthropometric, blood pressure, blood assays, and, for a subset of the population, a response to an oral glucose tolerance test.

Equipment & Instrumentation

Physical activity questionnaire. NHANES uses the Computer Assisted Personal Interview PA questionnaire. The questions/items in the survey take into account a wide variety of PA factors about an individual (https://www.cdc.gov/nchs/data/nnyfs/paq.pdf). The survey had 45 questions, of which three questions were asked to children in the age range of 3 – 5 years old. Questions focused on how much PA children were obtaining and the intensity level of the PA. Further, questions asked about specifics such as types of PA, time spent watching TV, and time spent playing video games. An example of one of the questions is, "during the past 7 days, on how many days {were you/was SP} physically active for a total of at least 60 minutes per day? Add up all the time {you/he/she} spent in any kind of physical activity that increased {your/his/her} heart rate and made {you/him/her} breathe hard some of the time". An example of the questions that were asked regarding specific physical activities that children could have done are as follows: What physical activities did {you/SP} do during the past 7 days? Don't include activities {you/SP} did during gym or PE.". The parents were instructed to identify all the activities that their child engaged in over the past seven days. The outcome variables for the questionnaire will be the number of days of 60 min + of PA, and PA type.

The outcome variable of number of days of 60 min + of PA was separated into three categories. Those categories were if the child participated in 0-3 days of 60 min + of PA, 4-6 days of 60 + min, and 7 days of 60 min + of PA in a week. Regarding PA type, four categories were formed, none, locomotor focused, object control focused, and both. First, the activities were dived into activities that were either locomotor or object control focused; this was done by considering the type of activity and what was the primary focus of that activity. If the PA had a primary focus of locomotor motor skill (e.g., running) then the activity was considered locomotor focused, if the PA had a primary focus of object control motor skill (e.g., baseball) then the activity was considered object control focused. Then it was determined which activities each child was reported to have completed. If the parent reported that the child did not participate in PA the child was placed in the none group, if the parent reported that the child completed only locomotor focused PA then the child was placed in the locomotor focused group, if the parent reported that the child completed only object control focused PA then the child was placed in the object control focused group, and lastly if the parents reported that their child participated in multiple activities where some were locomotor focused and some were object control focused then the child was coded as both.

Anthropometrics. The NNYFS anthropometry or body measures examination was conducted in the mobile examination center. All NNYFS participants were eligible for the anthropometry examination component. Specific measurements were completed dependent on the age of the participant (https://www.cdc.gov/nchs/data/nnyfs/body_measures.pdf). All children had weight, height, and triceps/calf skinfolds measured. Height (measured in centimeters) was measured using a stadiometer with a fixed vertical bar and an adjustable headpiece. Weight, measured in kilograms, was found by having the participant place one foot on each scale and combining the results to approximate the total weight of the individual. The skinfold measurements were taken at the triceps, and medial calf using calipers calibrated using the step wedge standard. BMI was calculated using the following equation weight in kg/height in meters^2. Then BMI age- and sex- adjusted percentiles were calculated and children were placed in to the BMI categories: normal weight (5th to < 85th percentile), overweight (85th to < 95th percentile), or obese (≥ 95th percentile) (https://wwwn.cdc.gov/Nchs/Nnyfs/Y_BMX.htm). Body fat percentage will also be calculated based off the triceps, and calf measurements collected, using the following equation of .735 (Triceps + Calf) + 1.0 for boys and .610 (Triceps + Calf) + 5.1 for girls (http://www.skyndex.com/resources/Slaughter-Lohman-Children-Skinfold-Formula.html).

Motor skills. The gross motor skills assessed from the NNYFS was the first nationally representative data for locomotor and object control skills for children ages 3 - 5. The Test of Gross Motor Development – Second Edition (TGMD-2) was used to test the motor skills of all 3-5-year-olds participating in the NNYFS. The TGMD-2 is a norm-referenced measure of common gross motor skills that develop early in life. The TGMD-2 is composed of two subtests for gross motor development, locomotor and object control, both of which have six skills that assess a different aspect of gross motor development. For locomotor skills the participant's ability to run, gallop, hop, leap, horizontal jump, and slide was assessed. For object control skills the participant's ability in striking a stationary ball, stationary dribble, kick, catch, overhand throw, and underhand roll was measured. Tool used were balls, bat, and assorted colors poly spots (CDC, 2016 National health and nutrition examination survey). The TGMD-2 was found to produce reliable measures of motor skills, with intra class correlation coefficient of .78 for locomotor, .76 for object control, and .91 for gross motor skill proficiency (Issartel et al., 2017).

Below is a description of each motor skill test. The first locomotor subtest was the run test. A child ran as fast as possible from one cone to another. The cones were 50 feet apart from each other. The next test was the gallop, where two cones were placed 25 feet apart and the child was told to gallop from one cone to the other. Next was the hop subtest which was conducted by asking the child to hop three times on each foot. The fourth test was the leap locomotor test. For this test a piece of tape was placed on the floor with a beanbag ten feet away. The child was asked to run up to and leap over the beanbag. Next test was the horizontal jump, the child stood behind the starting line and jumped as far as possible. The final locomotor subtest was the slide test. Two cones were set 25 feet apart on top of a line placed on the floor and the child slid from one cone to the other.

Next were the six object control subtests. The first test was the striking a ball. For this test, a ball was placed on a batting tee at the child's belt level, and then the child was instructed to hit the ball hard. Next was the dribble subtest for object control, where the child dribbled the ball four times, using one hand, standing in place they then stopped the ball by catching it. The third object control subtest was the catch test. The child and administer stood 15 feet apart and the administer tossed the ball underhanded to the child. Only tosses that were between the child's shoulders and belt were recorded. The fourth test was kick the ball. A line was marked off 30 feet away from the wall and another line 20 feet from the wall. The ball was placed on a beanbag on the line closest to the wall. The child was instructed to stand on the other line and run up and kick the ball hard at the wall. Next came the overhand toss, for this test the child stood 20 feet from the wall and threw a ball hard at the wall. Lastly in the object control subtest, the underhand roll subtest was administered. Two cones were placed against the wall four feet apart and a piece of tape on the floor 20 feet from the wall. The child was told to roll the ball hard, so that it goes between the cones.

For each subtest performance criterion existed (https://www.cdc.gov/nchs/data/nnyfs/tgmd.pdf). If the child performed a performance criterion correctly, the examiner recorded a “1.” If the child did not perform the skill correctly, the examiner recorded a “0.” Partial scores to show that the child displayed the criterion, but was inconsistent, are not allowed. If the child refused to perform the skill, he or she was coded as “Did Not Participate”. For the motor skill test a 1 (passed) or 0 (failed) is recorded for each test then scores were summed to obtain locomotor, object control, and total motor skill score.

Statistical Analysis

Mean, standard deviation, and frequency of descriptive variables were calculated. Correlations then were performed to determine the relationship between PA, obesity, and motor skills. PA’s relationship with motor skills were then assessed for total motor skills, locomotor skills, and object control each individually. PA questionnaire results and total motor skills, locomotor, and object control each were assessed individually through correlation analysis. The same was done with obesity where correlations were examined in the relationships between BMI and total motor skills, locomotor, and object control each individually through correlation analysis. Correlations were also conducted between body fat percentage and total motor skills, locomotor, and object control. Multiple regression analyses were conducted to examine the independent and combined relationships between PA, obesity, and motor skill controlling for sex, race, and parent’s socioeconomic status. Statistical significance was set at $p < .05$

Chapter IV: Results

Participants

Of the 342 (176 boys, and 166 girls) children that were included in the analysis the majority were Caucasian, with the second largest percentage being Hispanic (Table 1). Regarding weight status, most were a healthy weight, with 31% being considered overweight/obese (Table 1). Further, there was a similar amount of boys and girls in the study ($p>.05$) and the average age of the children was 4.04 ± .04 years. Sex differences were not observed across the different races and BMI categories ($p>.05$). The average family income to poverty ratio was 2.11±.12, meaning that most families were not in poverty. Nineteen percent of the head of households did not complete high school, 24% had a high school education, 30% attended some college, and 27% achieved a college degree. Further, 69% were married, 11% were either divorced or separated, and 10% were never married. Regarding the sex of the head

Table 1.
Demographics Of The Participants By Overall, Boys, And Girls

Variable	**All N=342 Percent (%)**	**Boys n=176 Percent (%)**	**Girls n=166 Percent (%)**
Race			
African American	15	15	15
Caucasian	52	54	51
Hispanic	26	26	26
Other	7	6	8
Body Mass Index Category			
Underweight	2	3	1
Healthy	67	61	73
Overweight	16	22	10
Obese	15	14	17
Sex			
Boys	52		
Girls	48		

of household, 53% were males and 47% were females.

Purpose 1: Physical Activity & Motor Skills

Table 2 shows the number of days parents reported their children participated in physical activity for at least 60 minutes in the past seven days. Parents reported that most of the children participated in seven days of PA (83%) and very few participated in either 4-6 days or 0-3 days ($p<.05$). There was no difference in the number of days for PA participation between boys and girls ($p>.05$).

Table 2.
Days Of Physical Activity > 60 Min Participation By Children In The Last Seven Days

PA Participation (Days)	**All N=342 Percent (%)**	**Boys n=176 Percent (%)**	**Girls n=166 Percent (%)**
0 – 3	8	7	9
4 – 6	9	6	11
7	83*	87	80

PA = physical activity | *p < .05, 7 days versus 0-3, & 4-6 days

Table 3 shows the motor skill focus of the PA in which the children participated in over the last seven days. Most children engaged in PA that was focused on only locomotor, the next common type of PA the children participated in was considered having a locomotor skills and object control focus. Very few children participated in PA that focused only on object control (4%) in the last seven days.

Table 3.
The Motor Skill Type Related To The Physical Activity That Children Engaged In The Last Seven Days

Motor Skill Type of PA	**All N=342 Percent (%)**	**Boys n=176 Percent (%)**	**Girls n=166 Percent (%)**
None	17	17	18
Locomotor	48	37	59
Object Control	4	7	2
Both	30	39	21

PA = physical activity

Table 4 shows the top physical activities that parents reported their children participated in over the last seven days. For the locomotor PA reported, most participation was reported in running (43%), playing outdoor games (35%), riding a bike (34%), playing active games (19%), and walking (17%). For the object control activities, the top three activities reported were soccer (15%), baseball (10%), and basketball (9%).

Table 4.
Percentage Of Participation In Physical Activities That Are Focused On Either Locomotor Motor Skill or Object Control Motor Skill In The Last Seven Days For All Children

Physical Activity Type	**Percent (%)**
Locomotor	
Aerobics	2
Cheerleading	1
Dancing	12
Gymnastics	5
Hiking	4
Jumping Rope	6
Jumping On A Trampoline	7
Martial Arts	2
Playing Active Games	19
Playing Outdoor Games	35
Riding A Bike	34
Riding A Scooter	11
Riding A Skateboard	2
Rollerblading	1
Running	43
Swimming	12
Walking	17
Wrestling	4
Object Control	
Baseball	10
Basketball	9
Field Hockey	2
Football	5
Frisbee	2
Golf	1
Soccer	15
Tennis	0
Volleyball	1

Table 5 shows the standard scores and percentiles for total motor skills and its subscales. The standard scores for the locomotor and object control motor skills subscales were similar to each other. The locomotor standard score was in the 50th percentile, object control standard score was in the 37th percentile, and gross motor quotient standard score was in the 37th percentile, all of which are considered "average" by the TGMD-2 test descriptive ratings. When examining percentiles as shown in Table 5 it was observed that the locomotor proficiency was highest, but overall motor skill proficiency was below 50th percentile.

Table 5.
Demographic Information For Motor Skills Standard Score And Percentile Of All Participants

Motor Skill Score	**Mean (SE)**
Standard Score	
Locomotor	9.99 (.16)
Object Control	8.52 (.14)
Gross Motor Quotient	95.57 (.68)
Percentile	
Locomotor	50 (1.33)
Object Control	34.83 (1.45)
Gross Motor Quotient	41.43 (1.36)

In Tables 6-11, the relationships between PA and motor skills were examined through the number of days of doing 60 min of PA (a continuous variable), and days of PA categories, with each aspect of motor skills (locomotor, object control, and gross motor quotient). No statistically significant relationships were observed with either completing 60 min of PA (continuous variable) or number of days engaged in PA (categorical variable) and locomotor, object control, or gross motor quotient ($p>.05$). However, it was observed that girls had a higher locomotor motor skill scores than the boys ($p<.05$; Table 6). No other associations between sex and motor skill scores were observed. Further, race and poverty index were not related to motor skill scores.

Table 6.

Regression Analysis For Number Of Days Doing 60 Min Of Physical Activity And Locomotor Motor Skills Standard Score Adjusted For Sex, Race, And Poverty Index.

Variable	Locomotor Motor Skill Score β (SE)	p-value
Days of Doing 60 min of PA	-.12 (.12)	.31
Sex		
Boys	-	-
Girls	.98 (.41)	**.02**
Race		
Caucasian	-	-
African American	.99 (.58)	.09
Hispanic	.59 (.48)	.22
Other	-.63 (1)	.53
Poverty Index	-.11 (.16)	.47

PA = Physical Activity

Table 7.

Regression Analysis For Number Of Days Doing 60 Min Of Physical Activity And Object Control Motor Skills Standard Score Adjusted For Sex, Race, And Poverty Index.

Variable	Object Control Motor Skill Score β (SE)	p-value
Days of Doing 60 min of PA	.04 (.09)	.68
Sex		
Boys	-	-
Girls	-.23 (.3)	.46
Race		
Caucasian	-	-
African American	.38 (.27)	.17
Hispanic	.39 (.36)	.28
Other	-.74 (.69)	.28
Poverty Index	-.06 (.11)	.62

PA = Physical Activity

Table 8.

Regression Analysis For Number Of Days Doing 60 Min Of Physical Activity And Gross Motor Quotient Standard Score Adjusted For Sex, Race, And Poverty Index.

Variable	Gross Motor Quotient Score β (SE)	p-value
Days of Doing 60 min of PA	-.27 (.59)	.65
Sex		
Boys	-	-
Girls	2.27 (2.02)	.26
Race		
Caucasian	-	-
African American	4.05 (2.39)	.09
Hispanic	2.97 (2.43)	.23
Other	-4.30 (5.08)	.4
Poverty Index	-.5 (.76)	.51

PA = Physical Activity

Table 9.
Regression Analysis For Doing Seven Days Or Less Of Physical Activity And Locomotor Motor Skills Standard Score Adjusted For Sex, Race, And Poverty Index.

Variable	Locomotor Motor Skill Score β (SE)	p-value
Days of PA Categories		
0-3 days	.56 (84)	.51
4-6 days	.28 (.88)	.75
7 days	-	-
Sex		
Boys	-	-
Girls	.99 (.4)	**.02**
Race		
Caucasian	-	-
African American	1 (.59)	.09
Hispanic	.60 (.49)	.22
Other	-.65 (.99)	.51
Poverty Index	-.11 (.15)	.46

PA = Physical Activity

Table 10.
Regression Analysis For Doing Seven Days Or Less Of Physical Activity And Object Control Motor Skills Standard Score Adjusted For Sex, Race, And Poverty Index.

Variable	**Object Control Motor Skill Score β (SE)**	**p-value**
PA Days		
0-3 days	-.97 (.54)	.07
4-6 days	.86 (.61)	.16
7 days	-	-
Sex		
Boys	-	-
Girls	-.24 (.29)	.41
Race		
Caucasian	-	-
African American	.43 (.31)	.16
Hispanic	.45 (.37)	.23
Other	-.83 (.65)	.20
Poverty Index	-.07 (.11)	.54

PA = Physical Activity

Table 11.
Regression Analysis For Doing Seven Days Or Less Of Physical Activity And Gross Motor Quotient Standard Score Adjusted For Sex, Race, And Poverty Index.

Variable	**Gross Motor Quotient Score β (SE)**	**p-value**
PA Days		
0-3 days	-1.20 (3.77)	.75
4-6 days	3.42 (4.46)	.44
7 days	-	-
Sex		
Boys	-	-
Girls	2.27 (1.97)	.25
Race		
Caucasian	-	-
African American	4.23 (2.5)	.09
Hispanic	3.18 (2.49)	.20
Other	-4.39 (4.90)	.37
Poverty Index	-.56 (.76)	.46

PA = Physical Activity

Further, the associations between PA type (locomotor focus, object control focus, or both) and motor skill scores (locomotor, object control, and gross motor quotient) were examined. The results are shown in Tables 12-14. The only statistically significant relationships were found between not participating in PA, locomotor focused PA, and object control motor skill scores (p=.05, and p=.04, respectively). Meaning that the object control motor skill scores were lower in children who either did not participate in PA or participated in locomotor focused PA (Table 13). Like in completing 60 min of PA or number of days engaged in PA, girls had higher locomotor motor skill scores than boys (p<.05; Tables 12).

Table 12.
Regression Analysis For The Type Of Physical Activity And Locomotor Motor Skills Standard Score Adjusted For Sex, Race, And Poverty Index.

Variable	**Locomotor Motor Skill Score β (SE)**	**p-value**
PA Type		
None	-.35 (.43)	.42
Locomotor	-.42 (.44)	.34
Object Control	1.10 (.79)	.17
Both	-	-
Sex		
Boys	-	-
Girls	1.19 (.39)	**.003**
Race		
Caucasian	-	-
African American	.93 (.53)	.08
Hispanic	.57 (.46)	.21
Other	-.53 (1)	.6
Poverty Index	-.13 (.15)	.38

PA = Physical Activity

Table 13.
Regression Analysis For The Type Of Physical Activity And Object Control Motor Skills Standard Score Adjusted For Sex, Race, And Poverty Index.

Variable	Object Control Motor Skill Score β (SE)	p-value
PA Type		
None	-.85 (.43)	**.05**
Locomotor	-.73 (.35)	**.04**
Object Control	-.10 (.65)	.88
Both	-	-
Sex		
Boys	-	-
Girls	-.08 (.33)	.8
Race		
Caucasian	-	-
African American	.33 (.24)	.17
Hispanic	.35 (.35)	.31
Other	-.71 (.76)	.35
Poverty Index	-.08 (.12)	.53

PA= Physical Activity

Table 14.
Regression Analysis For The Type Of Physical Activity And Gross Motor Quotient Standard Score Adjusted For Sex, Race, And Poverty Index.

Variable	Gross Motor Quotient Score β (SE)	p-value
PA Type		
None	-3.55 (2.06)	.09
Locomotor	-3.39 (2.03)	.1
Object Control	3.28 (3.65)	.37
Both	-	-
Sex		
Boys	-	-
Girls	3.38 (2.05)	.1
Race		
Caucasian	-	-
African American	3.7 (2.1)	.08
Hispanic	2.77 (2.33)	.24
Other	-3.72 (5.34)	.49
Poverty Index	-.63 (.74)	.4

PA = Physical Activity

When the relationship between participation in a specific PA in the past seven days and total motor skill score was examined, the results indicated that not participating in certain physical activities was related to a lower motor quotient score (Table 15). This relationship was observed in the following activities: bike riding (p=.0071), scooter riding (p<.001), swimming (p<.001), and jumping on a trampoline (p=.0125). For soccer this relationship approached significance and was in the appropriate direction (p=.055). No other relationships between specific physical activities and motor quotient score were found.

Table 15.
The Relationship Between Motor Quotient Score And Different Types Of Physical Activity That Children Did Not Complete In The Last Seven Days Adjusted For Race, Sex, And Poverty Index.

Specific PA	**Motor Quotient Score β (SE)**	**p-value**
Baseball	.74 (4.28)	.8625
Basketball	-1.94 (3.64)	.5941
Bike Riding	-5.28 (1.92)	**.0071**
Dancing	.24 (3.28)	.9414
Football	.24 (4.87)	.9607
Gymnastics	-4.03 (2.99)	.1799
Jumping Rope	.80 (3.41)	.8148
Jumping on a Trampoline	-7.38 (2.91)	**.0125**
Playing Active Games	2.12 (2.61)	.4187
Playing Outdoor Games	-1.35 (1.71)	.4299
Riding a Scooter	-9.67 (2.36)	**.0001**
Running	.40 (2.13)	.8521
Soccer	-5.79 (2.99)	.0551
Swimming	-4.04 (1.03)	**.0002**
Walking	1.84 (1.86)	.3236
Wrestling	-1.50 (3.91)	.7013

PA = Physical Activity

Purpose 2: Weight Status & Motor Skills

In the second purpose, the relationships between weight status and motor skills were examined. Whether weight status was determined by either BMI category or body fat percentage, no statistically significant relationships were observed between weight status and locomotor, object control, or gross motor quotient (Tables 16-21). Although no relationships were found between weight status and motor skill proficiency, it was observed that girls performed better than boys in regards to locomotor motor skill proficiency (Tables 16 & 19).

Table 16.
The Relationship Between Locomotor Skills Standard Score And BMI Category In Children Adjusted For Sex, Race, And Poverty Index.

Variable	**Locomotor Motor Skill Score β (SE)**	**p-value**
BMI Category		
Underweight	-1.25 (1.47)	.40
Healthy	-	-
Overweight	-.41 (.50)	.42
Obese	-.53 (.63)	.40
Sex		
Boys	-	-
Girls	.96 (.45)	**.03**
Race		
Caucasian	-	-
African American	1.02 (.59)	.09
Hispanic	.66 (.48)	.17
Other	-.70 (.95)	.45
Poverty Index	-.12 (.16)	.45

BMI = Body Mass Index

Table 17.
The Relationship Between Object Control Motor Skills Standard Score And BMI Category In Children Adjusted For Sex, Race, And Poverty Index.

Variable	Object Control Motor Skill Score β (SE)	p-value
BMI Category		
Underweight	-.40 (1.10)	.71
Healthy	-	-
Overweight	-.45 (.45)	.32
Obese		
Sex		
Male	-	-
Female	-.30 (.35)	.40
Race		
Caucasian	-	-
African American	.36 (.27)	.18
Hispanic	.39 (.34)	.26
Other	-.72 (.66)	.28
Poverty Index	-.06 (.11)	.58

BMI = Body Mass Index

Table 18.
The Relationship Between Gross Motor Quotient Score And BMI Category In Children Adjusted For Sex, Race, And Poverty Index.

Variable	Gross Motor Quotient Score β (SE)	p-value
BMI Category		
Underweight	-4.98 (7.39)	.50
Healthy	-	-
Overweight	-2.38 (2.46)	.33
Obese	-1.86 (2.34)	.43
Sex		
Male	-	-
Female	2.04 (2.28)	.37
Race		

Caucasian	-	-
African American	4.10 (2.41)	.09
Hispanic	3.20 (2.43)	.19
Other	-4.45 (4.87)	.36
Poverty Index	-.55 (.77)	.48

BMI = Body Mass Index

Table 19.
The Relationship Between Locomotor Motor Skills Standard Score And Body Fat Percentage In Children Adjusted For Sex, Race, And Poverty Index.

Variable	**Locomotor Motor Skill Score β (SE)**	**p-value**
Body Fat (%)	-.07 (.05)	.18
Sex		
Male	-	-
Female	1.23 (.56)	**.03**
Race		
Caucasian	-	-
African American	.80 (.62)	.20
Hispanic	.53 (.49)	.27
Other	-.69 (1.07)	.52
Poverty Index	-.12 (.17)	.48

Table 20.
The Relationship Between Object Control Motor Skills Standard Score And Body Fat Percentage In Children Adjusted For Sex, Race, And Poverty Index.

Variable	**Object Control Motor Skills Score β (SE)**	**p-value**
Body Fat (%)	.03 (.04)	.55
Sex		
Male	-	-
Female	-.39 (.46)	.40
Race		
Caucasian	-	-
African American	.37 (.26)	.17
Hispanic	.32 (.36)	.38
Other	-.76 (.76)	.32

Poverty Index	-.05 (.11)	.65

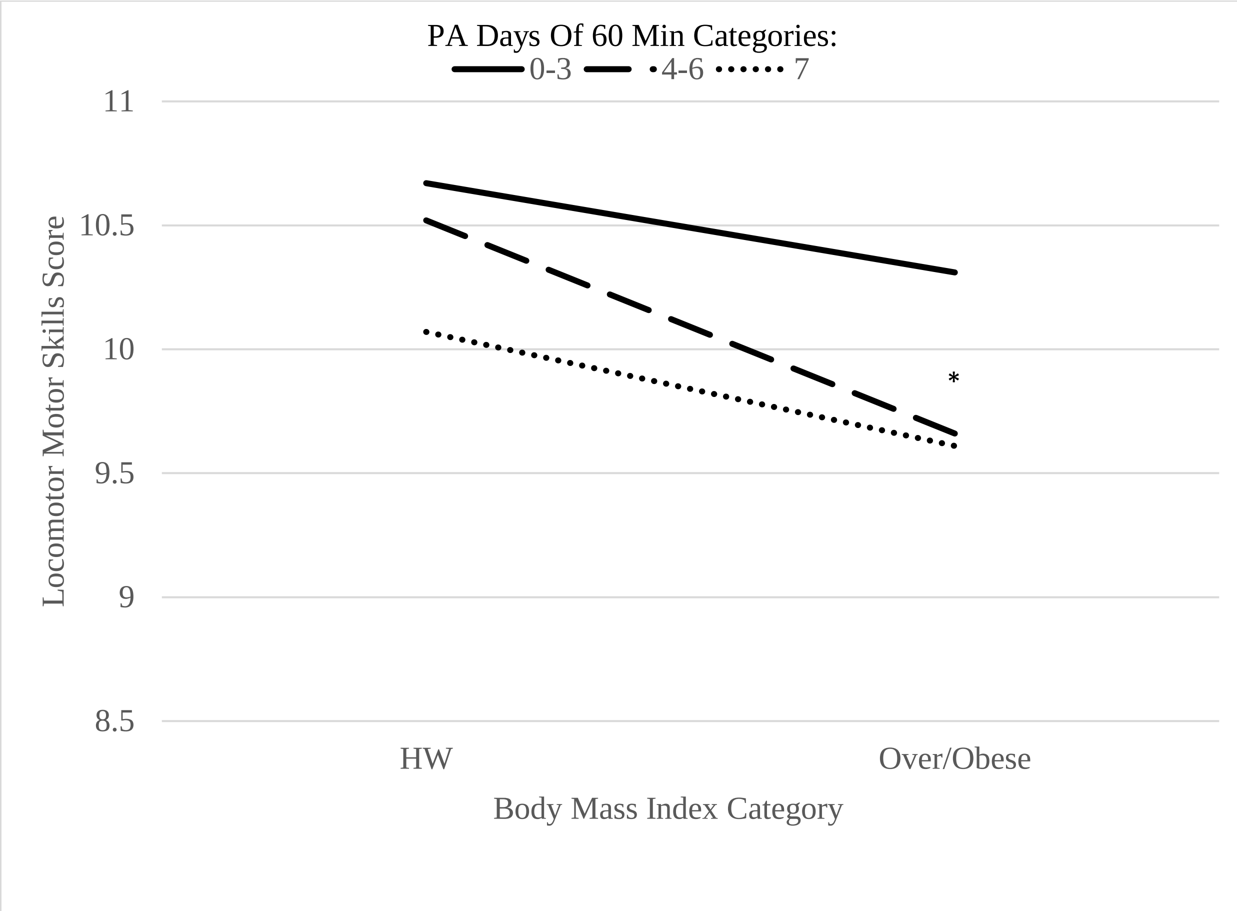
Table 21.
The Relationship Between Gross Motor Quotient Score And Body Fat Percentage In Children Adjusted For Sex, Race, And Poverty Index.

Variable	**Gross Motor Quotient Score β (SE)**	**p-value**
Body Fat (%)	-.13 (.28)	.63
Sex		
Male	-	-
Female	2.51 (2.94)	.40
Race		
Caucasian	-	-
African American	3.44 (2.40)	.15
Hispanic	2.60 (2.42)	.29
Other	-4.52 (5.50)	.41
Poverty Index	-.49 (.72)	.5

Purpose 3: Joint relationships of PA, weight status, and motor skills.

In the 3rd purpose, the joint relationships between PA, weight status, via (BMI), and motor skills were examined. The results indicated that a significant interaction existed between BMI category and number of days participating in PA for the locomotor ($p=.0002$) and object control ($p=.027$) standard scores, but not with the gross motor quotient score ($p>.05$). Figure 1 shows the interaction between BMI and PA days of locomotor motor skills. Among the healthy weight children, the locomotor skill scores are similar regardless of how many days they participate in PA; however, among the children who were overweight or obese participating in more days of physical activity (4-6 or 7) were related to lower locomotor motor skill standard scores.

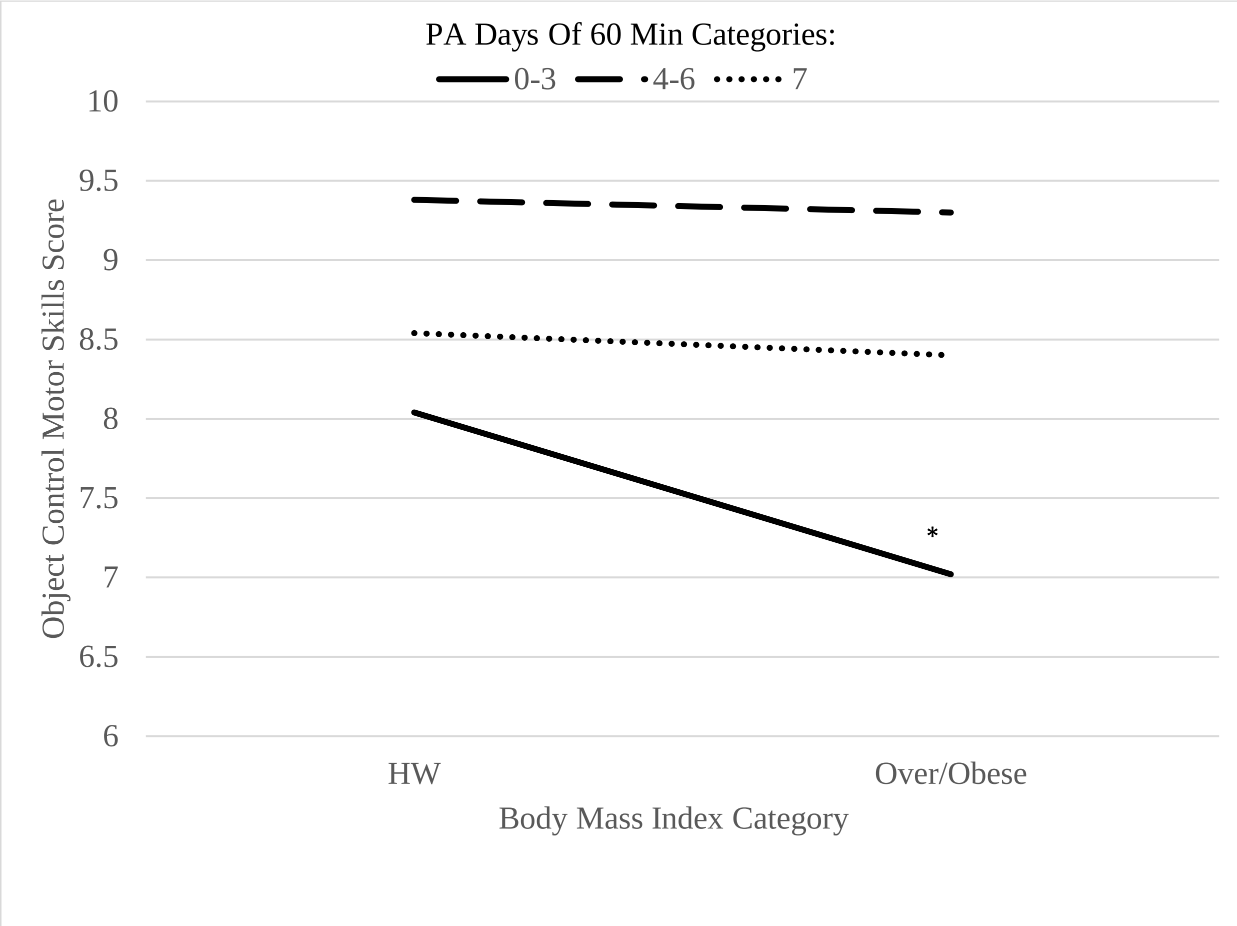
Figure 1. Interactions Between BMI and PA Days On Locomotor Motor Skills Adjusting For Sex, Race, and Poverty Index.



* = p<.05, interaction effect; PA= physical activity HW= healthy weight, Over/Obese = overweight and obese

In Figure 2, interaction between BMI and PA days on object control motor skills were assessed. There was no difference in the object control standard scores between healthy weight and overweight/obese children if they participated in 4-6 or 7 days of PA. In contrast, the object control motor skills were lower for the overweight/obese children than the healthy weight children who participated in 0-3 days of PA (p=.027).

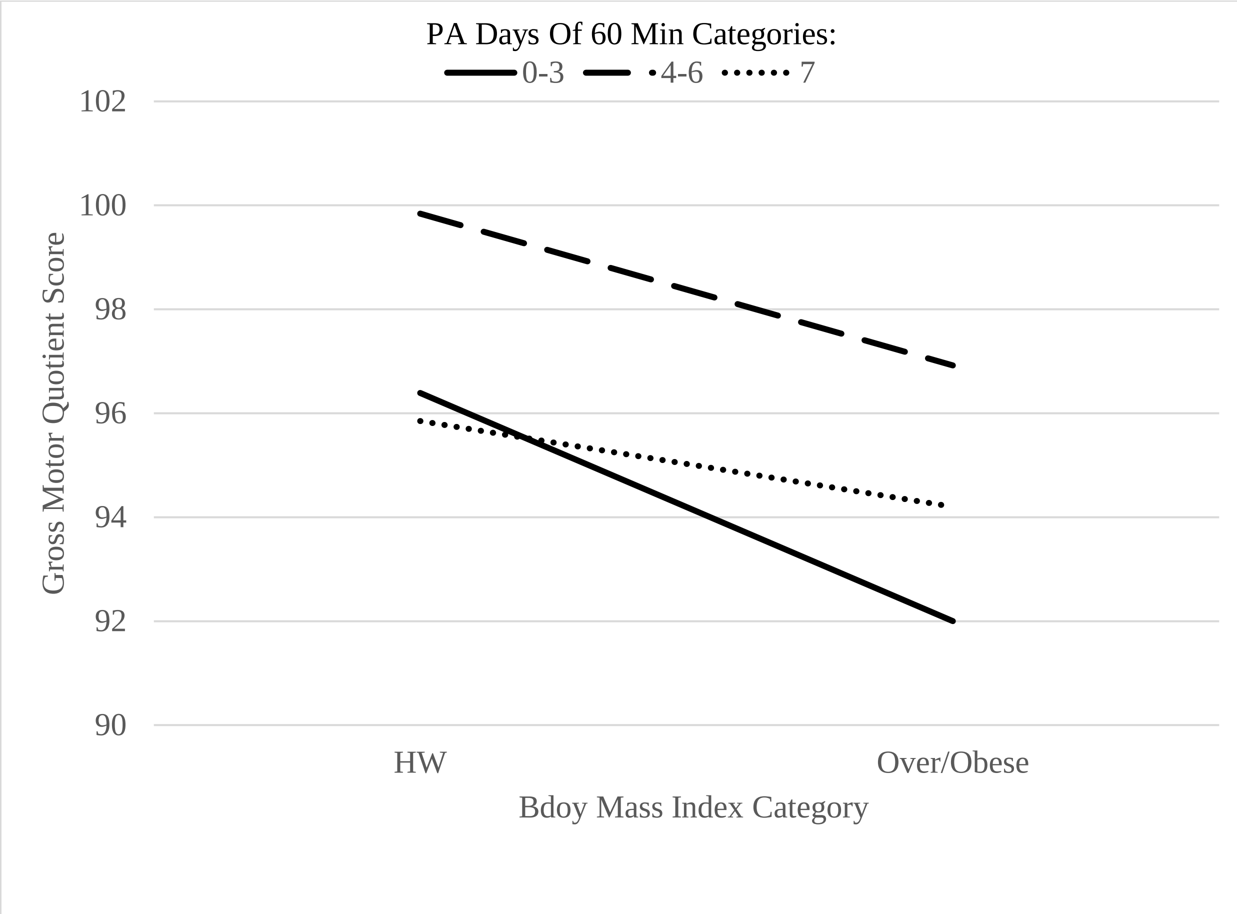
Figure 2. Interactions Between BMI and PA Days On Object Control Motor Skills Adjusting For Sex, Race, and Poverty Index.



* = p<.05, interaction effect; PA= physical activity HW= healthy weight, Over/Obese = overweight and obese

Figure 3 shows the joint relationship between BMI categories and PA days on gross motor quotient. No interaction effects were present between weight status and PA participation with total motor skills, i.e. the number of days a child participated in PA and his/her weight status did not have an impact on the child's overall motor skills score.

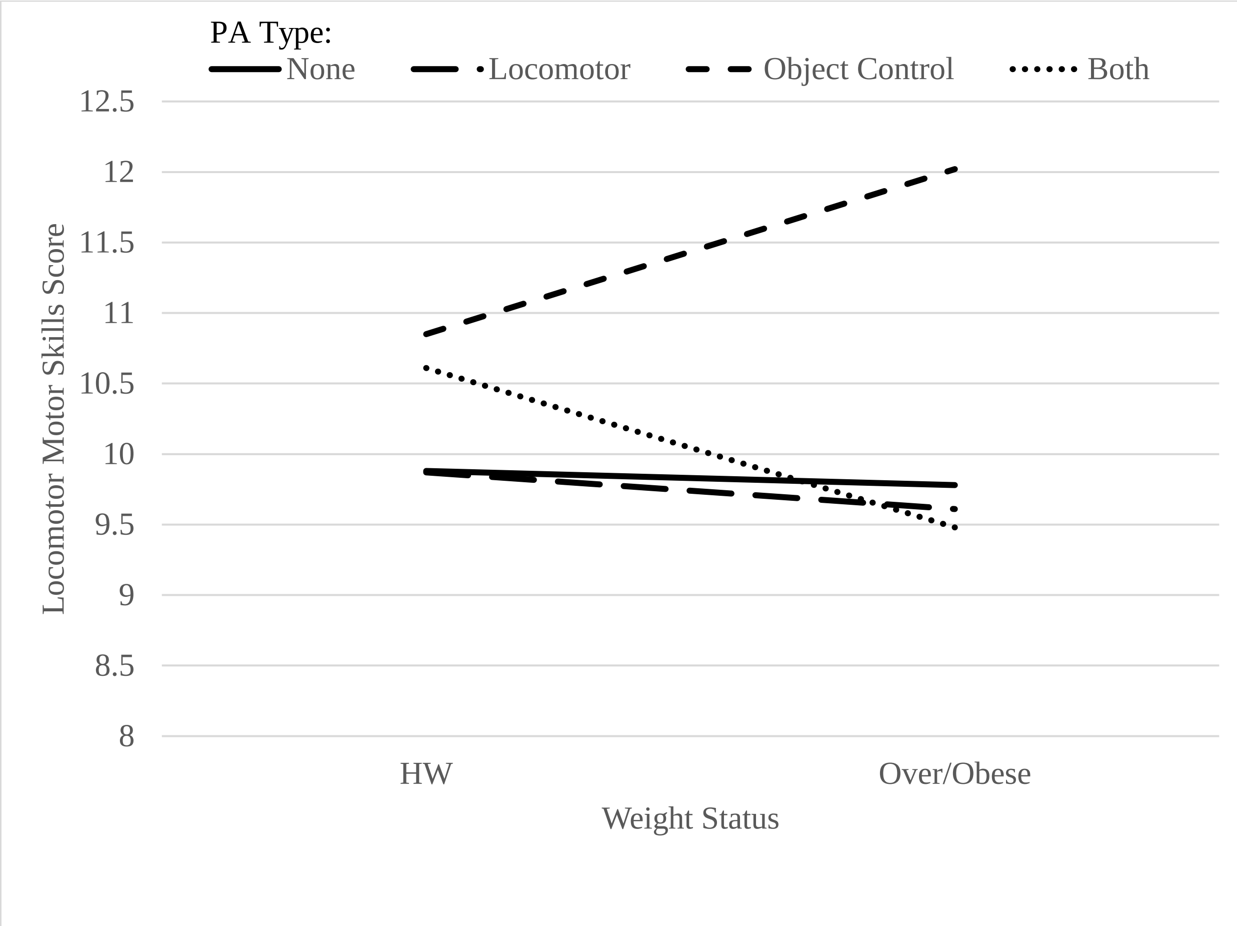
Figure 3. Interactions Between BMI and PA Days On Gross Motor Quotient Adjusting For Sex, Race, and Poverty Index.



PA= physical activity HW= healthy weight, Over/Obese = overweight and obese

The relationship between the combination of weight status (BMI category) and PA type on motor skills score was also assessed (Figures 4-6). Figure 4 shows the joint relationship between BMI category and type of PA the child participated with the locomotor standard scores. While there appears to be an interaction effect, this was not statistically significant (p=.28).

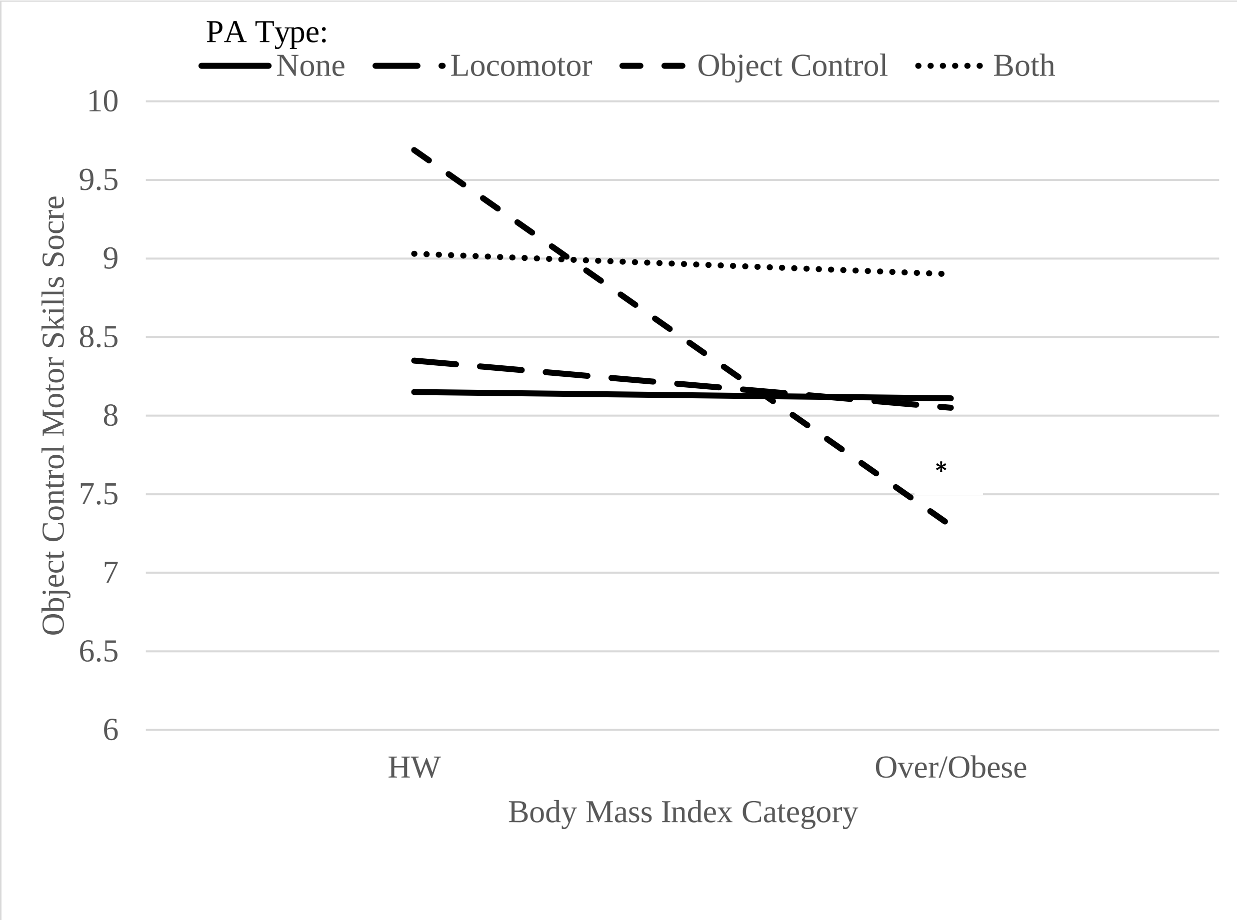
Figure 4. Interactions Between BMI and PA Type On Locomotor Motor Skills Adjusting For Sex, Race, and Poverty Index.



PA= physical activity HW= healthy weight, Over/Obese = overweight and obese

Figure 5 displays the interactions between BMI and PA type on object control motor skills score. The object control standard scores were similar between the healthy weight and overweight/obese children who participated in no PA, locomotor focused PA and a combination of locomotor and object control PA. In contrast, when overweight/obese children participated in PA that was focused on object control activities, they had lower object control standard scores than healthy weight children who participated in only object control types of PA.

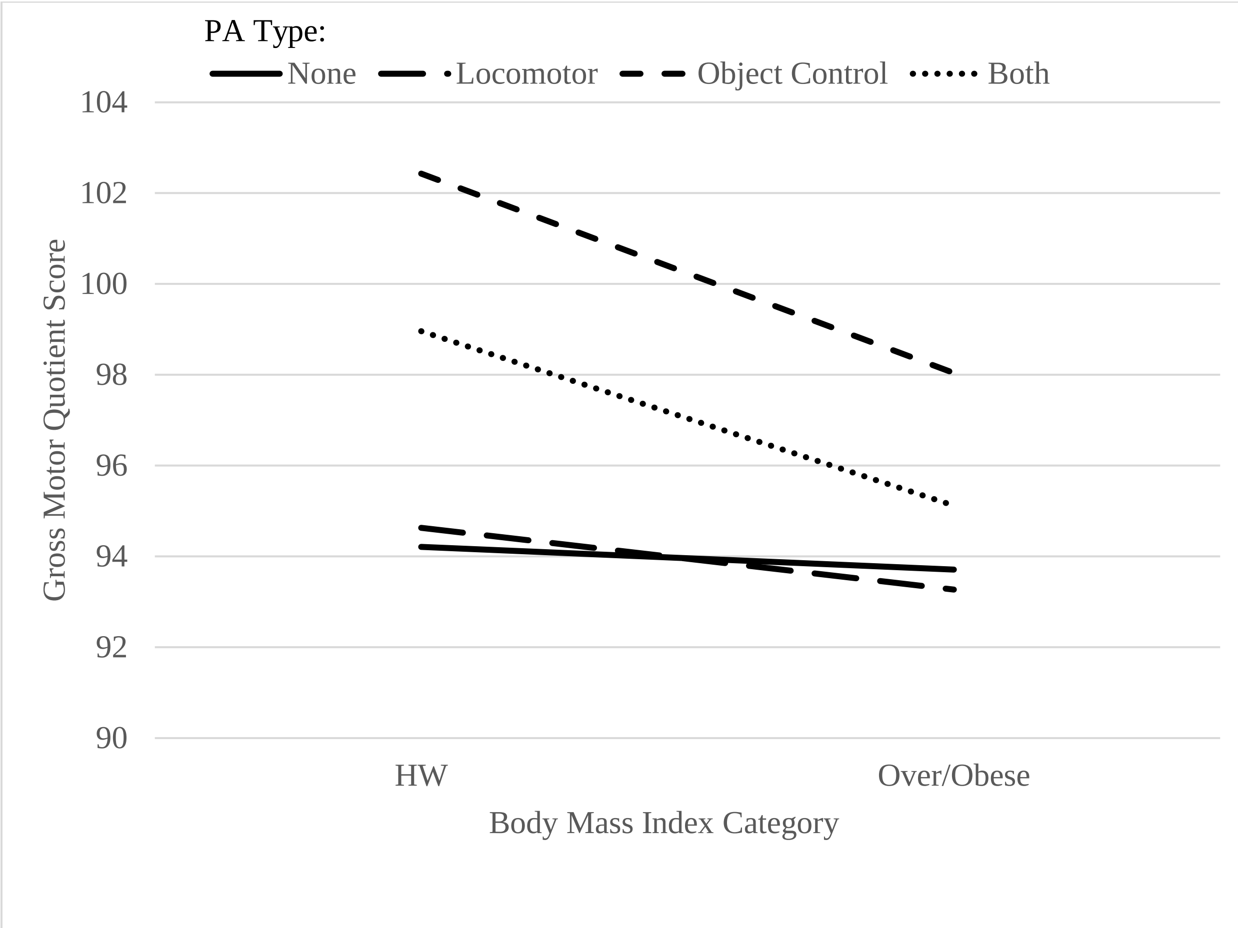
Figure 5. Interactions Between BMI and PA Type On Object Control Motor Skills Adjusting For Sex, Race, and Poverty Index.



*= p<.05 for interaction effect; PA= physical activity HW= healthy weight, Over/Obese = overweight and obese

In Figure 6, interactions between BMI and PA type on gross motor quotient score are displayed. While there appears to be an interaction effect, this was not statistically significant (p=.09). Thus, for overall motor skills as represented by gross motor quotient, the weight status of the child and the type of PA that the child engages in does not jointly impact overall motor skills.

Figure 6. Interactions Between BMI and PA Type On Gross Motor Quotient Score Adjusting For Sex, Race, and Poverty Index.



PA= physical activity HW= healthy weight, Over/Obese = overweight and obese

Chapter V: Discussion

The purpose of this study was to examine the independent and joint relationships of PA, weight status, and motor skills in a nationally representative sample of young children. The key findings indicated that parents reported that the majority of the children participated in seven days of PA (83%) and PA participation was similar between boys and girls. The most common types of activities that children participated in were running (43%), playing outdoor games (35%), riding a bike (34%), playing active games (19%), walking (17%), soccer (15%), baseball (10%), and basketball (9%). Overall, most physical activity participation was of a locomotor motor skill focus. Independent relationships were not found between different PA constructs, different weight status constructs, and motor skill scores. The only exceptions were between the type of PA and motor skill focus, where not participating in PA and only participating in locomotor focused PA were related to lower object control motor skills. Moreover, not participating in specific physical activities like riding a bike or scooter, swimming, and jumping on a trampoline was related to a lower overall motor skill score. When examining the combined relationships of BMI, PA, and motor skills, overweight/obese children had lower locomotor motor skill scores even if they engaged in more days of PA. For example, overweight/obese children had lower locomotor motor skill scores when reaching 4-6 days of PA of 60 + min than healthy weight children that reached 0-3 days of PA of 60 + min. In contrast, fewer days of PA were related to lower object control score among overweight/obese children compared to health weight children. Finally, weight status and type of PA had an effect on object control motor skill scores, where the overweight/obese children had lower object control scores compared to healthy weight children even when they participated in PA that focused on object control motor skills.

Young Child PA Participation.

Parents reported that most children in this study participated in 60 minutes of PA on a daily basis. Further, boys and girls participated in the same amount of PA. These findings are different than what other researchers have reported (Pate et al., 2015). Pate et al., (2015) reported that among young children the prevalence of meeting the PA guideline was 41.6% and 50.2% in the two different samples of 3-5 year old's. Likewise, findings have varied on whether the amount of PA differs between boys and girls. Past research we examined found that preschool aged boys accumulated more PA than girls (Olesen et al., 2014; Pate et al., 2014; Pate et al., 2015). The differences in study findings could be in part due to the way that the data was collected. The PA data used in the present study was obtained from a questionnaire compared to accelerometers, which were used in past research and could be a reason for differences in the findings. This is because the adults completing the questionnaire could have overestimated the number of days or duration of the PA, whereas accelerometers measure the PA as it occurs, therefore eliminating the possibility of recall issues. Further, the data in the current study was drawn from the NNYFS data base which comes from participants across the country, whereas other studies were fixed to localized areas.

Young Child Weight Status.

In regard to weight status, the results from this study agree with past research regarding the percentage of children found to be either overweight or obese. de Onis et al., (2010) found the prevalence of overweight and obesity to be 11.7% (95% CI: 8.9 – 15.3%) in developed countries and 6.1% (95% CI: 5.0 – 7.2%) in developing countries. In the US, the prevalence of obesity in 0-5 years old has reported to range from 9.2% to 17.9% (CDC, 2013).

Young Child PA and Motor Skills.

This study showed no relationships between PA days of participation and motor skills. Past research has inconsistent reports regarding the relationships between PA and motor skills, some have found no association (Loprinzi & Frith, 2017; DuBose, Gross McMillan, Wood, Sission, 2018), others have reported weak associations (Fisher et al., 2005), and some have found associations with some motor skill subscales but not with other subscales (Laukkanen et. al, 2013, & Cliff et al., 2009). These differences might be attributed to a variety of different factors. This study for example, focused on days of PA participation and days reaching 60 minutes of PA compared to gross motor skills and its subscales, whereas other studies measure of PA has been centered around minutes spent in MVPA (Fisher et al., 2005, Cliff et al., 2009, Iivonen et al., 2013), or some variation of light, moderate, and vigorous PA (Reilly et al., 2006) and gross motor skills and its subscales. Another factor that could explain the inconsistences in the findings is the lack of a specific motor skill test that is used across studies; past studies have used the Körper Koördinations Test für Kinder, Movement ABC-2, and the TGMD-2. Though Olesen et al., (2014) examined differences between boys and girls and not PA, it was an example where two different motor skill test were used that yielded different results. The Movement ABC found aiming and catching was higher in boys and girls had better balance scores. The Körper Koördinations Test für Kinder found boys had higher overall motor skill scores than girls. These differences between the two tests were seen on the same population of children.

A novel aspect to this study was examining the relationships between the type of PA participation and gross motor skills. The results indicated that not participating in PA and only participating in locomotor focused PA were related to lower object control motor skills, indicating that to improve a child's object control motor skills participating in PA is important and incorporating activities that include object control tasks, like playing catch or kicking a ball, would be necessary. Further, for a child to have higher overall motor skills, participating in bike riding, jumping on a trampoline, riding a scooter, and swimming were found to be important activities for a child to engage in. These relationships to our knowledge have not been examined in any previous research. It is important to know the types of PA along with how much PA children are involved in for future success in increasing gross motor scores. If we know what types of PA the children participate in most then future interventions geared towards increasing PA levels can incorporate that for better success.

Young Child Weight Status and Motor Skills.

This study found no statistically significant relationships between weight status, via BMI, and motor skills scores. Past research is also mixed regarding the relationship between weight status and motor skill scores. Some research has shown strong negative relationships between BMI and motor skill scores (Lopes et al., 2012; Roberts et al., 2012; and Vameghi et al., 2013). Whereas, Nervik et al., (2011) reported mixed results with significant associations between BMI percentiles and gross motor skill category; however, the relationship between BMI and a continuous gross motor skill score was not significant. In our review we did not find any studies comparing body fat percentage and motor skills in preschool aged children. The current study's findings of no relationship between body fat percentage, total motor skills, and its subscales provides new information about this age group to the literature. Factors like the way weight status is assessed (i.e., BMI, BMI categories, BMI z-score, and body fat percentage) may explain the differences in findings in the literature. For example, both Lopes et al., (2012) and Nervik et al., (2011) used BMI categories for their analysis and found a negative relationship between BMI group and motor skill score; however, when BMI was used as a continuous variable no relationship was found with motor skill score (Nervik et al., 2011). One study has used BMI z-scores in the analysis and found a strong negative relationship between weight status and motor skill score (Vameghi et al., 2013). Based on the findings from these three studies it appears that how weight status is quantified might impact the findings. Another possibility is that as children in the present study were considered average on overall motor skill score, and the lack of variability in the values may have blunted the impact of the children's weight status on motor skill proficiency.

Young Child PA, Weight Status, and Motor Skills.

The results found that joint effect of weight status and PA impacted some aspect of motor skills in preschool aged children, but not all. Locomotor standard scores were poorer in overweight/obese children even when they had more days spent in PA. In contrast, the object control scores were higher for overweight/obese children with more days spent in PA. Interestingly, the number of PA days did not impact healthy weight children's locomotor or object control standard scores. When examining the different types of PA (none, locomotor focus, object control focus, both) object control scores were only poorer in overweight/obese children who only did activities with an object control focus. There is a paucity of research examining the combined relationship of PA and weight status on motor skills in preschool aged children. To the best of our knowledge only two studies exist, and suggest that the interaction of weight and PA might be important to consider. For example, in one study the preschool children's PA was related to agility, and balance, but this effect was no longer significant for agility after adjusting for body fat percentage (Bὺrgi et al., 2011). Another study by DuBose et al. (2018), which included children aged 3-10 years, found that among overweight/obese children a positive relationship between balance and moderate PA ($p<.05$) and MVPA ($p<.05$)

existed and among healthy weight children, more time spent in PA was related to higher aiming and catching motor skill scores ($p<.05$). In our examination of PA days, weight status, and motor skills some relationships may have been affected by the number of children in the categories of 0-3 days, and 4-6 days of PA of 60+ min. There were very few in each of these categories (8 and 9%, respectively), opposed to the 83% meeting the 7 days of PA of 60+ min. Also, the fact that children who were overweight/obese did worse on object control score even when they engaged in PA specifically focused on object control motor skills may have been affected by the very low number of children that engaged in object control only focused PA. Given the limited amount of research which has been conducted examining the joint effect of weight status and PA on motor skills additional studies are needed to better understand these complex relationships on a child's development.

Strengths.

There are strengths of this study that add to the existing literature. The assessment of PA participation through specific activities, not just days of PA was novel. Categorization of those activities into their associated motor skill focus was also a strength of this study. The quality of the data itself was a strength as well. The data in this study is from the NNYFS database which provided a substantial sample size that pulled from multiple locations across the United States. This allowed for a heterogenous sample to be measured. It also provided a variety of demographic information about the participants, such as socioeconomic status, which allowed for this potential confounder to be controlled for in the analysis. Past research has not always been able to address this factor. The use of the TGMD-2 was another strength to this study. Each TGMD-2 subtest emulates PA that a child would engage in on a day to day basis. This makes the comparison to PA a lot easier. For example, other motor skill test might focus on things which don't necessarily translate directly to a lot of activities children participate in, like balancing on one foot, balance beam, etc. The TGMD-2 in both the locomotor motor skill category, and object control motor skill category, have test like running, moving side to side, throwing a ball, kicking a stationary ball, all of which translate specifically to PA that children would engage in like tag, baseball, and soccer. This makes findings more directly relatable to what children are doing.

Limitations.

There were some limitations in this research. While the methodology used to collect the data was rigorous and a multitude of information was collected, there were some limitations associated with the data. Certain information, like date of birth was not release, which prohibited calculation of BMI z-scores. Using this continuous variable would have increased the statistical power to determine if a relationship between weight status and motor skill scores existed. Further, the use of data from the PA questionnaire could have impacted the study findings. It is possible that the parents overestimated the amount of time and days their child spent participating in PA. Also, there was little to no range in PA days with 83% being in the 7 days category. This may have affected perceived relationship in the 0-3-day, 4-6 day categories. While NNYFS did collect PA data from accelerometers, unfortunately this data was not available at the time that this analysis was done. Although the PA questionnaire was valid and reliable, the addition of accelerometer data on the participants would have added to the assessment of possible relationships. The addition of accelerometer data would probably have resulted in a wider range of physical activity data unlike what was seen with the questionnaire data. Further, given the likelihood of over estimation by the parent in the questionnaire, it is likely that fewer children would have met the 60 minutes of PA for 7 days if accelerometer data was used. This increase variability in the PA data could have possibly showed more/stronger relationships in the analysis involving PA measures.

Public Health Implications

The possible public health implications of these findings are vast in nature. This research improves the understanding on how the joint relationships of PA and obesity influences motor skill proficiency in preschool aged children. Based on these findings the strategies used to improve children's motor skill ability may need to be different depending on the weight status of the child. Improved knowledge of these interactions along with a better understanding of the types of PA that best promote motor skills improvement could lead to more specific recommendations and better developed interventions for this age group. For parents, preschools teachers, and others working with this population the results suggest that increasing the opportunities for children to play (at home or during the school day) will give them the best recipe for better motor skillfulness. Further, encouraging preschool aged children to engage in a variety of different physical activities, to promote all motor skill development, would be necessary. Focusing on development of motor skills proficiency, physical activity habits, and weight maintenance in this age groups is important because all three track into childhood and into adulthood. Therefore, it is important to not only have a better understanding the joint impact of these factors, but to also promote physical activity as a method to improve motor skills in preschool age children, because motor skills not only affects their current health and development, but their future well-being as well.

Conclusion

The key findings indicated that parents reported that the majority of the children participated in seven days of PA and PA participation was similar between boys and girls. The most common types of activities that children participated in were running, playing outdoor games, riding a bike, playing active games, walking, soccer, baseball, and basketball. Overall, most physical activity participation was of a locomotor motor skill focus. Independent relationships were not found between different PA constructs, different weight status constructs, and motor skill scores. The only exceptions were between the type of PA and motor skill focus, where not participating in PA and only participating in locomotor focused PA were related to lower object control motor skills. Moreover, not participating in specific physical activities like riding a bike or scooter, swimming, and jumping on a trampoline was related to a lower overall motor skill score. Regarding the joint relationships, overweight and obese children had lower locomotor skills even if they participated in more days of PA, but this finding was not observed in the healthy weight children. In contrast, fewer days of PA were related to lower object control scores among overweight/obese children compared to health weight children. Finally, weight status and type of PA had an effect on object control scores: where the overweight/obese children had lower object control scores compared to healthy weight children even when they participated in PA that focused on this motor skill. This study provided a good basis for future research in the area of preschool aged children and motor skill proficiency. Future research could examine the combined relationships of physical activity, weight status, and cognitive function on motor skills in preschool aged children. Another direction for research could focus on the role that siblings have on not only physical activity levels, but motor skill development as well. This study shows that specific PA activities, such as, running, swimming, and soccer, may be more important to engage in to improve motor skill proficiency in preschool aged children. Overall, this research speaks to the complexities and depth of this topic as well as indicates that the combination of PA and weight status are impacting motor skill proficiency in preschool age children.

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