PHYSICAL ACTIVITY AND BODY COMPOSITION IN CHILDREN WITH CEREBRAL PALSY

by

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PHYSICAL ACTIVITY AND BODY COMPOSITION

IN CHILDREN WITH CEREBRAL PALSY

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ABSTRACT

The purpose of this study was to examine the effects of Gross Motor Functional Classification System (GMFCS) level on habitual physical activity in children with cerebral palsy and to determine whether physical activity has a significant impact on body composition in this population. Height calculated from knee height, weight, and percent body fat calculated from skinfolds was collected from 19 participants, and each individual wore an accelerometer for one week. Participants ranged in age from 7 to 19 years old, and all five GMFCS levels were represented. Significance was found between light physical activity (LPA) and GMFCS ($p=0.049$). No significant correlation was seen between sedentary activity (SED) or LPA and body mass index (BMI) percentile ($r_{SED}=0.39$, $p_{SED}=0.10$; $r_{LPA}=-0.27$, $p_{LPA}=0.26$) or percent body fat ($r_{SED}=0.35$, $p_{SED}=0.14$; $r_{LPA}=-0.28$, p_{LPA}-0.25). The results from this study support both hypotheses and indicate that youth with CP participate in much less physical activity than their peers despite the lack of significant correlation found between physical activity and body composition.

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INTRODUCTION

Cerebral Palsy

Cerebral palsy (CP) describes a large range of non-progressive neuromuscular disorders caused by a lesion of the cerebral motor cortex (Koman, Smith, & Shilt, 2004). One of the most prevalent causes of childhood disability, CP's onset occurs before or during birth or within the first two years after birth and causes lifelong postural and motor impairments (Clover, Fairhurst, & Pharoah, 2014). People with CP can show symptoms such as spasticity or hypotonia and decreased range of motion in any combination of body parts or can be affected globally and display a vast range of muscle tones.

Individuals with CP can fall anywhere on a large spectrum of impairment. One of the most common ways to classify the severity of CP is through use of the Gross Motor Functional Classification System (GMFCS) developed by Palisano, Rosenbaum, Bartlett, and Livingston (2008). This system classifies individuals with CP on a scale from I to V based on voluntary movement in daily life. Levels I and II describe people who ambulate independently with distinctions being made based on balance and distance they are able to walk. Children in level III use hand held mobility devices, but are still able to ambulate, while individuals in levels IV and V require much more support and use wheelchairs for transportation. Distinctions are made between these two levels based on head and trunk control, ability to assist with transfers, and ability to self-propel a manual wheelchair.

Body Composition and its Measurement

For many years, body composition has been considered an important component in determining physical health. Body Mass Index (BMI) and skinfolds are two common ways of determining obesity status that are both easy to perform and inexpensive. In all people, and especially those with CP, body composition is highly correlated with quality of life since obesity affects one's ability to perform functional tasks and activities of daily living (Tarsuslu Simsek & Tuc, 2014). Specifically, BMI is a measure of mass(kg)/height(m)^2. Since BMI only takes into account weight and height and does not consider the actual composition of the tissue, it is often not as applicable to those with abnormal body composition such as athletes or those with disabilities including CP. In particular, children with CP often have "increased total body water, severely depleted fat stores, minimally depleted muscle stores, severe short stature, and decreased bone density," which skews their BMIs (Samson-Fang & Stevenson, 2000). When calculating BMI for children with CP, those who are more affected tend to be underweight due to poor oral motor function and high energy expenditure while more mildly affected children have a higher rate of obesity than their typically developing peers primarily due to limited opportunities for adapted physical activity (Tarsuslu Simsek & Tuc, 2014).

Since BMI does not account for the proportions of different types of tissue present in the body, using skinfolds to determine percent body fat often provides a more accurate look at the person's overall health and nutrition status (Samson-Fang & Stevenson, 2000). In addition, skinfold measurement also eliminates the challenges associated with measuring weight and height in this population since many people with CP cannot stand independently and have muscle contractures that prevent accurate height measurement. As a result of these factors, the pediatric skinfold equations developed by Slaughter et al.

(2008) are considered the best measurement method despite the fact that they consistently underestimate percent body fat in this population (Gurka et al., 2010).

Physical Activity and its Measurement

Regular physical activity is an important mechanism in maintaining health for all people, especially those with CP. According to Carroll, Leiser, and Paisley (2006), people with CP are at an increased risk of developing conditions such as osteoporosis, respiratory disorders, and early-onset arthritis. In addition, this population also experiences weakness, and many individuals have decreased range of motion as a result of spasticity. Physical activity has been shown to improve health, strength, and flexibility in people with CP, which contributes to increases in function and quality of life. It is recommended that people, including those with disabilities, get at least 30 minutes of moderate-intensity physical activity most days of the week (Carroll et al., 2006). However, activity is often significantly reduced in this population due to functional limitations and a lack of resources.

While it is generally agreed upon that habitual physical activity is an important component in maintaining health, little previous research has been done using accelerometers to look at the amount of physical activity performed by people with significant mobility issues. Accelerometers provide a safe and unobtrusive way to look at habitual physical activity. Washburn and Copay (1999) performed one of the first studies using this method to study physical activity during wheelchair pushing. They concluded that wrist worn accelerometers provide an accurate way to measure physical activity in this population. Another study performed by Nightingale, Walhim, Thompson, and Bilzon (2014) confirms this finding. They studied manual wheelchair users and compared the results of accelerometers placed at the wrist, upper arm, and waist. These results indicated that the wrist worn accelerometer accounted for the most variance while exhibiting the lowest random error.

Compared to other disabilities, even less research has been done specifically looking at physical activity in individuals with CP. In a systematic review performed by Clanchy, Tweedy, and Boyd (2011) only 11 studies were found that they determined to have reliably studied habitual physical activity in children with CP. These 11 studies used seven different methods of measuring physical activity and none of them considered GMFCS levels IV and V. At the conclusion of the research, it is stated that while CAPE (Children's Activity Participation and Enjoyment Scale) was found to be most valid and reliable, since this method uses self-report, it is difficult to use for people with intellectual disabilities, and there may be recall bias associated with the results. As a result of these issues with CAPE, this article suggests that accelerometers may be more appropriate for use with this population.

A second systematic review performed by Carlton, Taylor, Dodd, and Shield (2013) examined the combined results when all methods of studying habitual physical activity were viewed together. This study only found six articles that met their basic criteria of having a mean age of participants less than 18 years and having a comparison group of typically developing children. Standardized mean differences were used to allow all studies to be compared to each other despite using different data collection methods. The results confirmed previously held beliefs that children with CP of all GMFCS levels are less active than other children and have much more sedentary time than the recommended levels. They also noted the importance of physical activity in improving functional abilities and the need for more recreational opportunities that cater to this population.

Three studies were found that specifically examined the use of ActiGraph accelerometers to measure physical activity in children with CP. It is important to note that only one of these studies looked at a small number of people in GMFCS level IV and none of them studied people in level V, so all previous research using this method has been focused on ambulatory individuals. Capio, Sit, and Abernethy (2010) performed one of the first studies on the validity of ActiGraph use for children with CP. Their study looked at 31 children between the ages of 6 and 14 years who were able to walk with or without aids (GMFCS levels I-III) and were able to follow two-step commands. Participants wore an accelerometer at the right hip and engaged in two activity sessions: structured activity with increasing intensity and unstructured play. During these sessions, heart rate was monitored and SOFIT (System for Observing Fitness Instruction Time) was used to record the child's activity level every 15 seconds. These results were then compared to the activity counts from the accelerometer. It was determined that ActiGraph had a strong association with physical activity as measured by SOFIT and may be a better tool for measuring physical activity in free living conditions than the heart rate monitor. However, they noted that the cut-points they used for moderate to vigorous physical activity (MVPA) did not seem appropriate, and accuracy my have been affected by non-voluntary movements and participants with hemiplegia who wore the accelerometer on their impaired side.

A further study was performed by Clancy, Tweedy, Boyd, and Trost (2011) in order to find intensity-related ActiGraph cut-points that apply directly to children with

CP. While much previous research had been done to determine valid and reliable cut-points for typically developing children, there were no studies that looked specifically at the applicability of these cut-points to children with CP. Children ages 8-18 in GMFCS levels I-III were asked to walk around a track at three different paces while wearing both an accelerometer worn at the waist and a portable indirect calorimeter. The data collected from these two methods was then compared with known cut-points to determine accuracy. This study found that impairments in gait pattern common in individuals with CP did not negatively impact data collected using ActiGraph.

Gorter, Noorduyn, Obeid, and Timmons (2012) later expanded on the findings of Capio et al. (2010) and Clanchy et al. (2011). This is the only known study to look at non-ambulatory individuals with CP and also the only one to assess habitual physical activity over a period of time rather than in a laboratory-type setting. Participants were children ages 10 to 20 years at GMFCS levels I-IV. They were instructed to wear the accelerometer over the right hip for seven days during all waking hours except when they could come in contact with water. Participants were also told to log when the accelerometer was taken on and off. Data was then placed into categories ranging from sedentary to vigorous physical activity based on the cut-points developed by Clanchy et al. (2011). The researchers found their results to be consistent with those recorded by Capio et al. (2010) and Clanchy et al. (2011). They noted, though, that there is some question about whether these cut-points are applicable to people in GMFCS levels III and IV who have less functional mobility and also that placing the accelerometer at the waist may not have accurately captured all of the activity of these participants who rely more on their arms for movement.

Project Significance

There is a significant lack of research on physical activity in children with cerebral palsy especially that including children in GMFCS levels IV and V with no known studies using accelerometers as their method of data collection incorporating people in level V. Additionally, results from this study could be useful to allied health professionals as they attempt to understand the relationship between body composition and physical activity as it relates to level of impairment in this population.

Purpose and Hypothesis

The purpose of this study was to examine the effects of GMFCS level on habitual physical activity in children with CP and to determine whether physical activity has a significant impact on body composition in this population. It was hypothesized that individuals at a higher GMFCS level would be less physically active due to decreased independent motor function. People classified at the higher GMFCS levels rely on others to transfer them in and out of their wheelchairs and assist with all tasks. This was expected to significantly limit their ability to perform daily physical activity. In addition, it was hypothesized that there would be little to no correlation between BMI percentiles or percent body fat and physical activity in children with CP. In typically developing children those who are less physically active normally have higher BMIs. However, people with CP, especially those with hypertonia, expend large amounts of energy through involuntary muscle contractures, so they were not expected to show this same correlation.

METHODS

Participants

Participants included 19 youth (9 males and 10 females) with a primary diagnosis of CP between the ages of 7 and 19 years old (12.9 ± 3.5). Participants from all GMFCS levels were included with three classified at GMFCS level I, three level II, five level III, four level IV, and four level V. Participants with comorbid conditions were assessed on a case-by-case basis, and those who were determined to have a secondary condition(s) that affected their mobility and, therefore, that would negatively affect study results were excluded. For example, children who have both CP and Spina Bifida or CP and a chromosomal abnormality were excluded.

Participants were recruited from Easter Seals of Greater Houston and the Houston area through flyers and existing contacts. The study protocol was explained to each participant, and he or she gave verbal assent by expressing a willingness to participate in the study. In addition, each participant's parent/guardian signed a university approved consent form.

Instruments

Habitual physical activity was measured using GT3X ActiGraph accelerometers (Pensacola, FL) attached to Velcro straps so that they could easily be taken on and off. These uniaxial accelerometers are used to record vertical acceleration (and therefore activity) over a prolonged period of time (Clanchy et al., 2011). They have been shown to have high positive correlation with other methods of measuring activity such as indirect calorimetry, doubly labeled water, and heart rate monitors, which gives them good validity, and their only major limitation is that they do not account for tasks that require increased energy expenditure such as carrying things or climbing stairs (Trost, 2007). In addition to having high validity, accelerometers are also a preferred method for collecting physical activity data because they are small in size and lightweight making them relatively unobtrusive to wear. Furthermore, a standard digital scale was used to measure weight in kilograms, and knee height in centimeters was measured using a knee height caliper. Lange skinfold calipers (Santa Cruz, CA) were used to measure tricep and calf skinfolds.

Procedure

Anthropometric Measurements

Participants reported to a predetermined location for initial data collection. Parents self-reported age, GMFCS level, type of CP (spastic, athetoid, hemiplegic, diplegic, etc.), and any comorbid conditions. Following this, weight and height were measured to the nearest 0.1kg and 0.1cm respectively. Since many children with CP cannot stand independently, a wood board was placed on the scale with a chair on the board. The scale was then calibrated to zero before the child was placed in the chair for the final weight reading.

Additionally, due to contractures and other conditions such as scoliosis, accurate standing or recumbent height cannot be measured, so height was calculated from knee height using the CP specific equation: Height = 2.69 x knee height + 24.2 (Stevenson, 1995). Knee height was measured using a knee height caliper with the child in a sitting position and both feet on the floor or wheelchair footrest. This measurement is defined by Stevenson as the distance from the heel to the anterior surface of the thigh over the femoral condyles with both the knee and ankle flexed at 90°. Knee height was chosen over other segmental measures because it has been shown to be the most reproducible method of predicting height in this population (Stevenson, 1995).

Skinfold thickness was measured at the triceps and calf on the least affected side of the body or handedness side in cases with no noticeable difference in function (Gurka et al., 2010). These sites were chosen for their minimal invasiveness and widespread use in pediatrics (Slaughter et al., 1988).

All measurements were taken twice, recording the average of the trials. Weight and height were then used to determine BMI percentile based on standard pediatric percentiles. Body fat percentage was calculated using gender-specific equations for children developed by Slaughter, et al. (1998): Percent Fat = 0.735 (Triceps + Calf) +1.0 for males and Percent Fat = 0.610 (Triceps + Calf) + 5.1 for females.

Physical Activity Measurement

Following anthropometric measurements, participants were given an accelerometer and instructed to wear it around their least affect wrist during all waking hours for seven days except when bathing, swimming, or doing other water activities. This site for wearing the accelerometer was chosen over the more common waist site to better account for all movement of children in GMFCS levels IV and V who are non-ambulatory. Parents were also given a log to record when the accelerometer was taken on and off and why. After one week, they returned the accelerometer and log sheet to the researcher in a provided preaddressed, stamped envelope.

Statistical Analysis

This study was a between groups design with the independent factor being GMFCS level. Dependent measures were sedentary activity, light physical activity, and moderate-to-vigorous physical activity as measured by the accelerometer, BMI percentile, and percent body fat. Once collection was completed, data from the accelerometers was downloaded and coded by intensity based on CP specific cut-points developed by Clanchy et al. (2011). In order to be included in the study, the accelerometer must have been worn for a minimum of ten hours a day for at least four days including at least one weekend day. All variables were described using means and standard deviations. A one-way ANOVA was performed to identify significant differences in physical activity and level of impairment. When significance was found, a Scheffe post hoc test was completed to determine which means accounted for this. Furthermore, Pearson correlations were calculated between BMI percentile and time spent in sedentary activity and light physical activity and between percent fat and sedentary activity and light physical activity. Significance was determined at the 0.05 alpha level for all tests.

RESULTS

Group statistics were expressed with means and standard deviations by GMFCS as shown in Table 1. Participants performed a mean of 537.7 ± 112.2 minutes of sedentary activity (SED) per day and 228.5 ± 131.6 minutes of light physical activity (LPA) per day with no moderate-to-vigorous physical activity (MVPA) being recorded for any participant (Figure 1). BMI percentiles and were used to classify participants into body composition categories with the mean BMI percentile for all participants being 37.8% ± 32.5. 36.8% of participants were classified as underweight, 52.6% as normal weight, 5.3% as overweight, and 5.3% as obese (Figure 3). The mean percent body fat for the group was 22.0% ± 10.4 (Figure 4).

An independent samples t-test showed significant differences between the sexes only for percent body fat. All other variables showed no significant difference for sex. A one-way ANOVA showed significance only between GMFCS and LPA ($p=0.049$).

No significant correlations were found between BMI percentile and SED ($r=0.39$, $p=0.10$) or LPA ($r=-0.27$, $p=0.26$). There was also no significant correlation between percent body fat and SED ($r=0.35$, $p=0.14$) or LPA ($r=-0.28$, $p=0.25$) (Figure 2).

DISCUSSION

The purpose of this study was to examine the effects of GMFCS level on habitual physical activity in children with CP and to determine whether physical activity has a significant impact on body composition in this population. The results of this study support both hypotheses. A significant difference was found between GMFCS level and LPA ($p = 0.049$), and no significant correlations were found between SED or LPA and BMI percentile ($r_{SED}=0.39$, $p_{SED}=0.10$; $r_{LPA}=-0.27$, $p_{LPA}=0.26$) or percent body fat ($r_{SED}=0.35$, $p_{SED}=0.14$; $r_{LPA}=-0.28$, $p_{LPA}-0.25$)

Hypothesis 1: GMFCS and Physical Activity

As GMFCS level increases, SED increases and LPA decreases (Figure 1). This trend is consistent with the findings of Gorter et al. (2012) and is a result of the reduced independent motor function seen in individuals classified at the higher GMFCS levels. This relationship holds true for all groups except GMFCS level III. The discrepancy here is likely caused by the way children are classified into level III and disqualified from being included in level II or IV. In order to be classified into level II, individuals must be able to ambulate independently without the use of assistive devices such as a walker or crutches, and in order to be included in level IV, individuals must have limited self-mobility including ability to self propel a manual wheelchair, crawl, or ambulate using assistive devices (Palisano et al., 2008). Therefore, GMFCS level III includes a wide range of functional mobility levels including both those people who can ambulate proficiently with the use of mobility aids and those who can only ambulate for short distances and use wheelchairs in all community settings resulting in the group being very heterogeneous.

Additionally, the results also indicate that children with CP of all GMFCS levels are less physically active than their typically developing peers. As published in the 2014 United States Report Card on Physical Activity for Children and Youth (2014), typically developing children generally spend 427.7 minutes/day in SED and 369.0 minutes/day in LPA and MVPA combined (indicated by horizontal lines in Figure 1). This is compared to means of 447.2 ± 97.0 and 603.5 ± 69.1 minutes/day SED for ambulatory and non-ambulatory participants respectively and only 321.1 ± 119.8 and 161.1 ± 96.2 minutes/day in LPA with no MVPA recorded for either group. In addition to reduced mobility, this decreased amount of physical activity seen in those with CP is also due to the severe lack of adapted exercise programs available to people with physical disabilities especially CP. The majority of physical activity and sports opportunities for children with special needs cater towards those with intellectual disabilities leaving out individuals who are cognitively able to participate in activities at grade level. Programs that do exist for children with physical disabilities are usually designed for individuals with normal ability to use their arms such as various wheelchair sports. These programs are not ideal for most individuals with CP. Those in GMFCS levels I-III would benefit most form activities that involve whole body exercise while people in GMFCS levels IV-

V cannot participate in existing manual wheelchair sports due to their reduced ability to propel themselves independently.

Hypothesis 2: Physical Activity and Body Composition

In typically developing youth, mean minutes of physical activity per day decreases as BMI percentile increases (Belcher et al., 2010). However, this trend does not hold true for individuals with CP. In this population, there is no significant correlation between time spent sedentary and BMI percentile as seen in Figure 2. In fact, those in GMFCS level V (who performed the least amount of physical activity) display the lowest BMI percentiles, all being classified as underweight (Figure 3). This is likely a result of the extreme spasticity seen in the individuals included in this homogeneous level. Additionally, this lack of relationship is seen in the other GMFCS levels for the same reason, but to a lesser degree. In typically developing individuals, skeletal muscle contraction causes movement and leads to caloric expenditure, so there is an inverse relationship between physical activity and percent body fat. However, people with CP, while not performing much dynamic movement that would be recorded by the accelerometer (especially that is voluntary), expend a large amount of energy through involuntary flexion caused by spasticity. In addition to their spasticity, these individuals experience a higher energy cost of movement than their typically developing peers due to strength deficits, co-contraction, and inefficient energy transfers between body segments (Johnston, Moore, Quinn, & Smith, 2004). Furthermore, people with CP also often experience oral motor deficits that make it difficult for them to take in the extra calories needed to offset their increased energy expenditures. Figures 3 and 4 also displays the same increase in variability for GMFCS level III that was seen in Figure 1 again due to the large range in mobility and function of individuals in this level.

BMI percentiles and percent body fat values are both reported due to the differences in the information they present as seen when comparing Figures 3 and 4. While BMI percentiles provide an easy way to compare the body composition of children with CP to that of their typically developing peers, they do not take into account the physiological differences of people with CP especially those who are more severely affected. For example, several participants had enlarged heads resulting from hydrocephalus, which increases their BMI while having no affect on percent body fat. In addition, the extreme difference between the body composition of people in level V compared to those in the other four GMFCS levels that can be seen in Figure 3, but not in Figure 4 may be due to decreased muscle mass in these individuals, which would affect BMI, but not percent body fat. Individuals in level V generally have no form of independent mobility unless they can use a power wheelchair while those in levels I-IV are either ambulatory or at least have fairly proficient use of their trunk and limbs, leading to greater muscle mass when compared to those in level V.

Limitations

A limitation of this study was the timing of data collection. Data was collected during the summer when many children, especially those with CP, are less active as many extracurricular activities they may be involved in end at the end of the school year. In addition, during this time of year swimming is a common form of physical activity that was not measured to prevent the accelerometers from being exposed to water. Especially for individuals in GMFCS levels IV and V, swimming provides the best method of whole-body physical activity as it reduces the barrier of gravity on both the individual and an assistant. Further limitations of this study included the use of standard pediatric BMI percentiles and percent body fat equations, which may not be valid for children with CP and the use of physical activity cut-points that, while CP specific, were based on waist rather than wrist worn accelerometers on only ambulatory individuals, which may have altered the results.

Implications and Future Directions

As one of the first studies to look at physical activity using accelerometers in all five GMFCS levels, this research adds to the small body of work on this topic especially that concerning GMFCS levels IV and V. The low level of physical activity recorded for this population indicates a need for an increase in the number of adapted exercise and sport programs available for those with physical disabilities who are cognitively at grade level. In addition to the commonly recognized benefits of physical activity including increases in muscular strength, flexibility, and bone density, programs like this also provide the further benefit of creating opportunities for children with disabilities to socialize with others who are experiencing similar challenges. The information in this study can also be used by allied health professionals as they attempt to understand the relationship between body composition and physical activity as it relates to level of impairment in this population.

In the future, it will be important for researchers to further study the physical activity and energy expenditure of individuals with CP especially as this pertains to their overall health and quality of life. In order to do this successfully, more emphasis needs to be placed on studies that include people who are non-ambulatory and are more severely affected by CP who, at this point, are underrepresented in the literature.

FIGURES AND TABLES

Table 1

	GMFCS				
	I (n=3)	II (n=3)	III (n=5)	IV (n=4)	V (n=4)
BMI Percentile	48.7 ± 19.6	40.8 ± 22.3	46.0 ± 17.0	50.0 ± 13.6	5.0 ± 3.0
Percent Body Fat	24.2 ± 1.0	20.5 ± 7.4	26.8 ± 8.0	16.4 ± 2.0	20.8 ± 2.0
SED (min)	420.3 ± 52.2	516.4 ± 61.7	508.0 ± 54.7	581.0 ± 52.8	635.6 ± 10.9
LPA (min)	335.4 ± 90.4	233.2 ± 18.3	310.7 ± 71.3	169.2 ± 23.3	101.2 ± 21.0

Figure 1

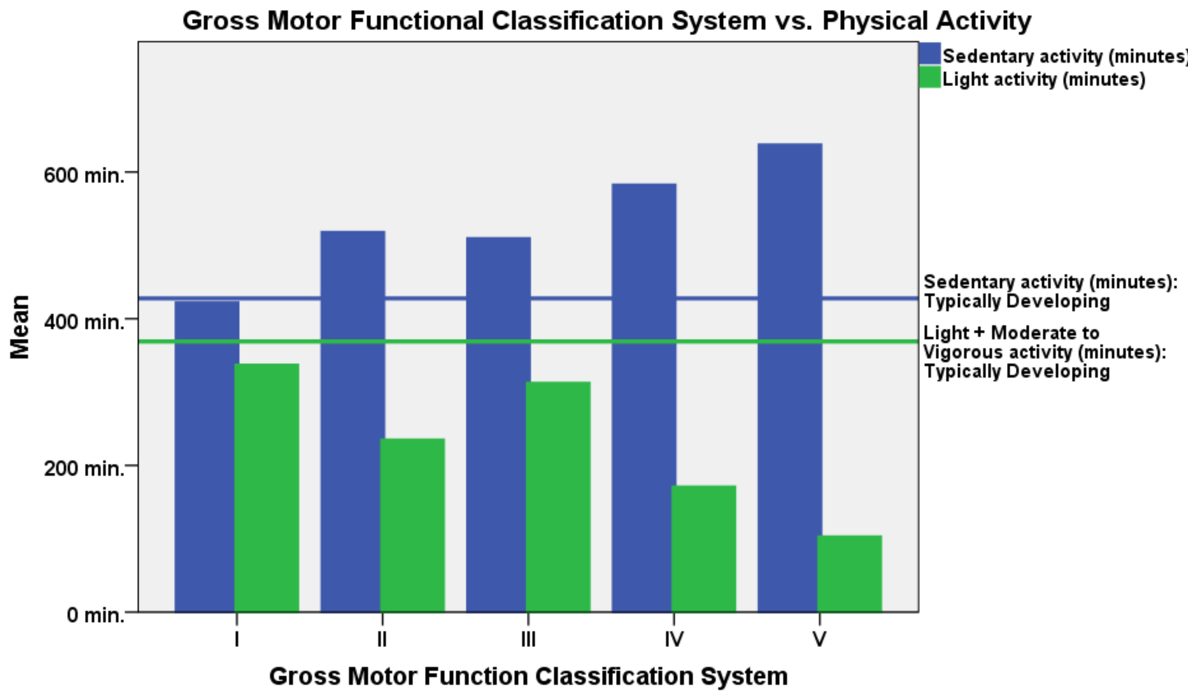

Gross Motor Functional Classification System vs. Physical Activity
Sedentary activity (minutes)
Light activity (minutes)
600 min.
400 min.
200 min.
0 min.
Mean
Sedentary activity (minutes): Typically Developing
Light + Moderate to Vigorous activity (minutes): Typically Developing
I
II
III
IV
V
Gross Motor Function Classification System

Figure 2

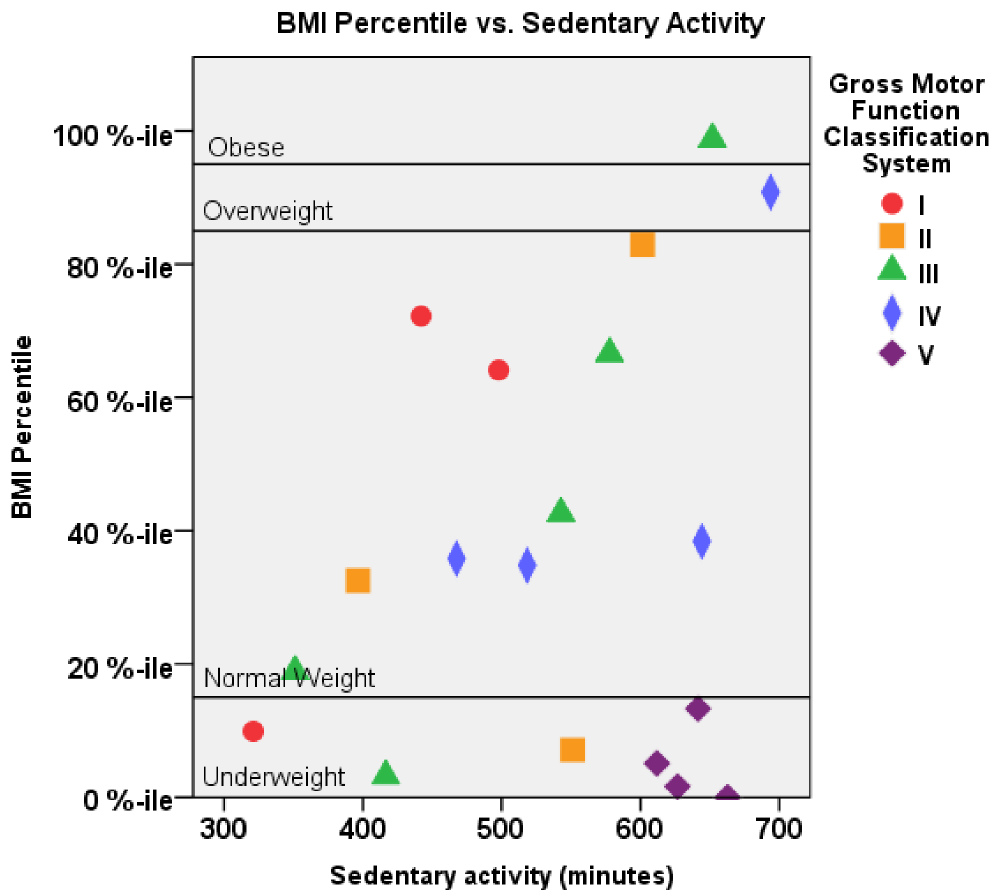

BMI Percentile vs. Sedentary Activity
Gross Motor Function Classification System
I
II
III
IV
V
Obese
Overweight
Normal Weight
Underweight
100 %-ile
80 %-ile
60 %-ile
40 %-ile
20 %-ile
0 %-ile
BMI Percentile
300
400
500
600
700
Sedentary activity (minutes)

Figure 3

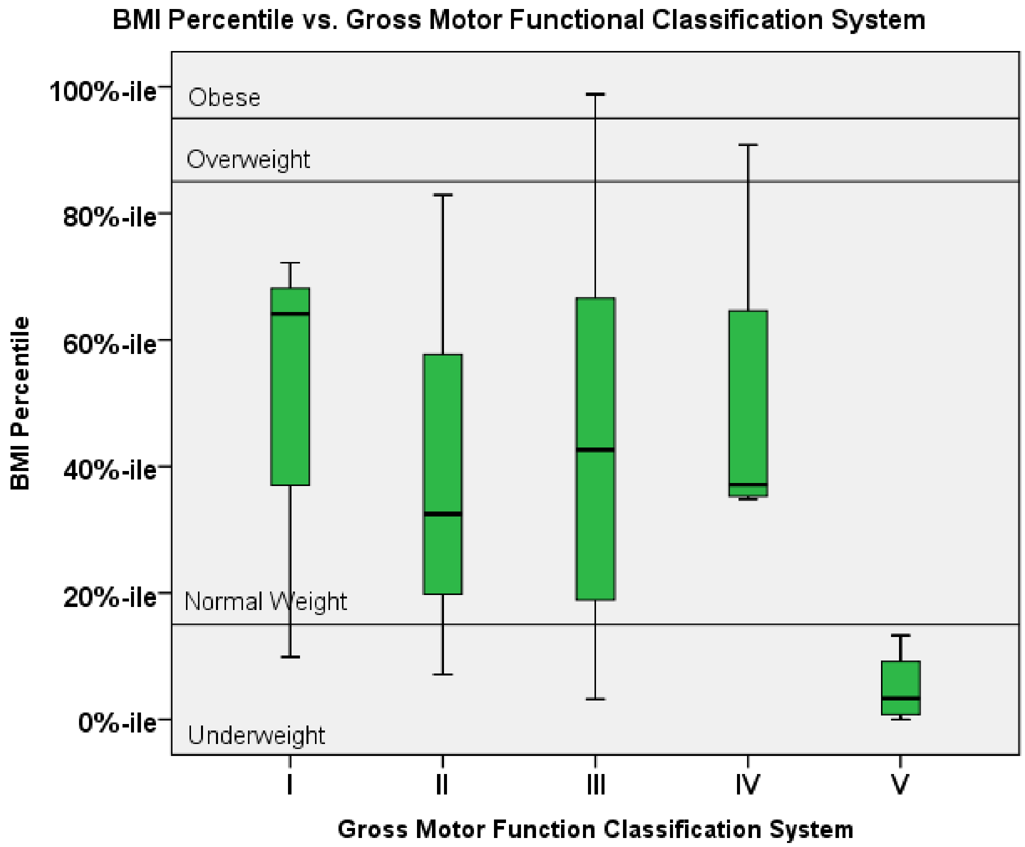
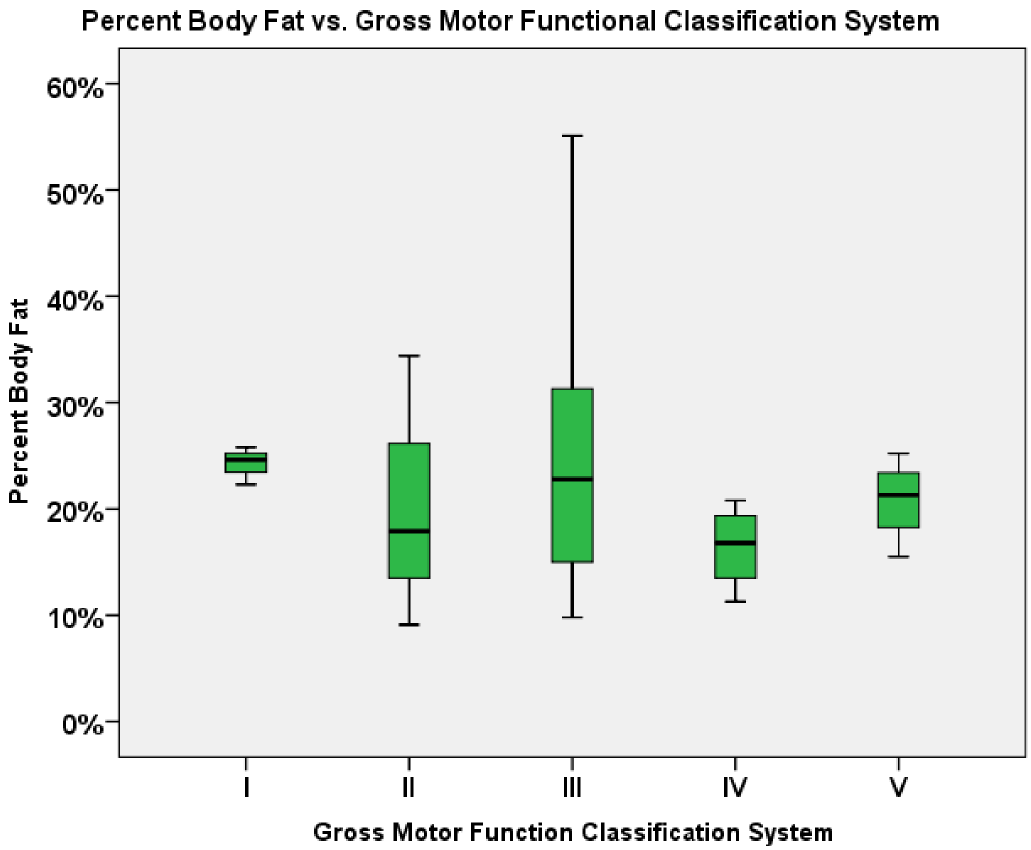

BMI Percentile vs. Gross Motor Functional Classification System
BMI Percentile
100%-ile
80%-ile
60%-ile
40%-ile
20%-ile
0%-ile
Obese
Overweight
Normal Weight
Underweight
I
II
III
IV
V
Gross Motor Function Classification System

Figure 4


Percent Body Fat vs. Gross Motor Functional Classification System
60%
50%
40%
30%
20%
10%
0%
Percent Body Fat
I
II
III
IV
V
Gross Motor Function Classification System

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