

VALIDATING ACCELEROMETRY AND SKINFOLD MEASURES IN
YOUTH WITH DOWN SYNDROME

by

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A dissertation submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Kinesiology)
in The University of Michigan
2012

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ACKNOWLEDGMENTS

I want to first thank Dr. Dale Ulrich. I truly appreciate your guidance and mentorship. You have been instrumental in my development as both a teacher and a scholar. I want to thank my committee members who all shared their unique insights and allowed me to ask and answer a research question slightly outside of my area of expertise. I want to thank Dr. Peter Bodary for your perspective; it really challenged me and strengthened this dissertation. I want to thank Dr. Joseph Hornyak, your clinical perspective was an invaluable resource to me as I completed this dissertation and throughout my doctoral studies here at the University of Michigan. I would also like to thank Dr. Dan Ferris. I have always valued your input and mentorship and was glad you chose to be part of my dissertation committee.

I want to thank my significant other, Dr. Kerri Staples for her love and support as I completed this dissertation. I would also like to thank recent University of Michigan kinesiology graduates; Dr. Megan MacDonald, Dr. Brett Fling, and Dr. Daniel Goble for their constant support and guidance and allowing me to learn from their experiences. I would also like to thank the people I interact with on a daily basis; Janet Hauck, Andy Pitchford, Irully Jeong, and Leah Ketcheson for making my time here at UM an enjoyable one.

This research was funded by U.S. Office of Special Education Programs leadership training grant, Blue Cross, Blue Shield Foundation of Michigan Foundation, Special Olympics Healthy Athletes Health Professions Student Grant, and the Rackham Graduate School at the University of Michigan. I would also like to thank Families Exploring Down Syndrome, the Down syndrome Support Team, the Down Syndrome Guild of Southeast Michigan and the Capital Area Down Syndrome Association who assisted with recruitment. Additional thanks to Nathan Hilliard, Adrienne Dusky, Lauren Jordan, and Alex Riordan for their assistance with data collection.

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ABSTRACT

Validating accelerometry and skinfold measures in youth with Down syndrome

by

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Current methods for measuring quantity and intensity of physical activity based on accelerometer output have been studied and validated in youth. These methods have been applied to youth with Down syndrome (DS) with no empirical research done to validate these measures. Similarly, individuals with DS have unique body proportions not represented by current methods used to estimate body composition. The purpose of this dissertation was (a) to examine the physical activity patterns in a large sample of youth with DS, (b) to examine the validity of the Actical accelerometer for measuring physical activity and (c) to investigate the accuracy of three published skinfold and anthropometric equations (Lohman, 1987; Slaughter et al., 1988; Kelly & Rimmer, 1987) used to estimate body composition in a sample of youth with DS. A total of 53 participants (27 with DS [15 males], 26 without DS [17 males]), between the ages of 8 and 18 years were included in the present study. The Actical accelerometer

was validated using a graded treadmill protocol. During the protocol participants wore a portable metabolic system. Heart rate, expired gases, and data counts from the Actical were collected, analyzed, and compared against current thresholds used for determining physical activity intensity. Anthropometric and skinfold measures were compared to results from a criterion measure (Bod Pod®). Results of this study indicate (a) youth with DS engage in disproportional amounts of sedentary activity and spend very little time in moderate-to-vigorous activity, (b) the Actical® accelerometer is a valid device for objectively measuring physical activity. However, current cut-points associated with physical activity intensities are likely to underestimate physical activity in youth with DS, and (c) Kelly and Rimmer's (1987) anthropometric equation demonstrated the most accuracy when compared to the criterion measure. When measuring physical activity and body composition in this sample of youth with DS, considering the unique characteristics of individuals with DS improved measurement accuracy. Based on these results, future research should be directed toward developing population specific methods of measuring and interpreting physical activity and body composition data in a practical way.

CHAPTER 1 INTRODUCTION

It is well recognized there is a positive relationship between physical activity and health. Physical activity plays an important role in maintaining a healthy body weight, improving cardiovascular health, muscular strength, and improving mental health (CDC, 2011a; U.S. Department of Health and Human Services, 2008, 2010b). This relationship has the potential to be even more important for individuals with disabilities. For individuals with disabilities physical activity can help to improve an individual's ability to perform activities of daily living, a critical factor in maintaining independence (Carmeli, Kessel, Merrick, & Bar-Chad, 2004; Cowley, et al., 2010; Torr, Strydom, Patti, & Jokinen, 2010).

With an increased amount of attention on the importance of physical activity and its associated health outcomes, such as body composition, there is a need for valid and reliable methods to accurately measure physical activity. Current methods for measurement and assessment do not consider the unique constraints associated with various disabilities. As a result, identifying health risks in these groups is likely to be compromised. The purpose of this dissertation is to examine current methods of measuring physical activity and body composition in youth with and without Down syndrome (DS).

Down syndrome

Down syndrome is a common genetic disorder occurring approximately 1.36 times in every 1000 live births in the United States (Parker, et al., 2010). It is estimated there are 350,000 individuals with DS living in the United States (Barnhart & Connolly, 2007). Trisomy 21, the most common cause of DS (95% of cases), occurs when there is an extra copy of the 21st chromosome. Presently there are 329 genes mapped to the 21st chromosome impacting brain structure, behavior, physical functioning, cognition, and speech (Roizen & Patterson, 2003). In total, there are over 80 clinical features occurring more frequently among individuals with DS than the population at large (González-Agüero, Vicente-Rodríguez, Moreno, Guerra Balic, Ara, & Casajús, 2010). This gene over-expression leads to a highly complex and variable phenotype, in which physical and cognitive development are significantly altered (Cebula & Wishart, 2008).

Infants with DS experience significant delays in the onset of early motor milestones and as toddlers display qualitative differences in movement patterns compared to typically developing children (Block, 1991; Morris, Vaughan, & Vaccaro, 1982; Palisano, et al., 2001; Sacks & Buckley, 2003). These delays in motor development have been attributed to muscle hypotonia, decreased muscular strength, immaturity of the central nervous system, weak postural control, and poor balance (Block, 1991; Davis & Kelso, 1982). All these factors combine with cognitive constraints to contribute to poor and atypical physical performance. Although these early variations cause motor delays in infancy, the

accumulation of these delays has the potential to have a significant impact on later acquisition of movement skills and participation in physical activity.

These impairments may be manifested in an altered walking stride or gait. The gait of individuals with DS has been characterized by atypical stride patterns, shorter steps, slower walking speeds, and more time spent in double support (both feet in contact with the ground) to maximize balance (Mendonça, Pereira, & Fernhall, 2009; Smith & Ulrich, 2008). In addition to these biomechanical differences, results of a recent study indicated that when individuals with DS exercise at the same intensity as their typically developed peers they do so at a higher percentage of their peak $\dot{V}O_2$ (Mendonça, et al., 2009). This combination of characteristics is one reason we believe methods of quantifying physical activity and physical activity intensity need to be validated and calibrated specifically for individuals with DS.

Cardiovascular differences in individuals with Down syndrome

Congenital heart defects are found in approximately 40% of all individuals with DS (González-Agüero, et al., 2010; Pueschel, 1990). The most common defect, the atrioventricular septal defect, accounts for 45% of heart defects. The vast majority of these are surgically corrected at birth or shortly thereafter. Once corrected these individuals do not have any exercise or physical activity restrictions. Another more likely cause for decreased cardiovascular fitness is chronotropic incompetence (Baynard, Pitetti, Guerra, & Fernhall, 2004; Fernhall & Pitetti, 2001). Chronotropic incompetence is the inability of the heart to increase its rate with an increased workload. In the DS population, this is

evidenced by lower peak heart rates. This inability to increase heart rate during physical activity is identified as a potential factor for decreased work capacity.

Along with chronotropic incompetence, individuals with Down syndrome have consistently shown reduced or suppressed work capacities when compared to their peers without Down syndrome. As a group, these individuals have lower peak oxygen consumption (VO_{2peak}) and lower maximum heart rates (Balic, Mateos, Blasco, & Fernhall, 2000; Baynard, et al., 2004; Fernhall & Pitetti, 2001; Fernhall, et al., 1996; Guerra, Llorens, & Fernhall, 2003). These results are summarized in Table 1.1.

Objective measurement of physical activity

Physical activity has been recognized as a primary health behavior in preventing obesity (Strath, Holleman, Ronis, Swartz, & Richardson, 2008). However, measurement of physical activity is not a dichotomous record, but also has to take into account the quantity and the quality of engagement. The frequency, duration, and intensity are often considered important dimensions for describing physical activity. The present method of choice for measuring physical activity is accelerometry. Accelerometers are objective, nonintrusive, and provide robust data on frequency, intensity, and duration of physical activity (Puyau, Adolph, Vohra, Zakeri, & Butte, 2004). Research has consistently demonstrated these devices are valid and reliable in many segments of the population including children and adults (Pfeiffer, Mciver, Dowda, Almeida, & Pate, 2006; Puyau, et al., 2004).

Researchers have acknowledged there is a need for population based calibration studies because of the variability inherent in different groups (Trost, Loprinzi, Moore, & Pfeiffer, 2011). Calibration studies are necessary to convert data produced from the accelerometer into meaningful data. Accelerometers use a piezoelectric element and a seismic mass to detect motion or acceleration in gravitational acceleration units. This motion causes a cantilever beam to compress piezoelectric crystals when acceleration occurs. The result is a voltage equivalent to the acceleration. The voltage generated is then amplified and filtered via analog circuitry and then passed into an analog to a digital converter. For this study, the process is repeated 32 times each second (this is a sampling frequency of 32 Hz) (Chen & Basset, 2005; Pfeiffer, et al., 2006). The end result is a data count based on acceleration. These data counts have no biological meaning. Calibration studies seek to convert these data counts into something meaningful such as physical activity intensity through regression equations. Physical activity intensity is typically based on energy expenditure or heart rate.

To calibrate accelerometers researchers have participants engage in a variety of physical activities at different intensities. These activities can be highly controlled, laboratory based activities or more structured free-living activities. Data from these activities, typically measures of energy expenditure or heart rate, are then regressed on data counts produced by the accelerometer. From these regression equations cut-points or thresholds are created to distinguish levels of

physical activity intensity based on public health recommendations. Examples of physical activity intensity indicators are displayed in Table 1.2.

The lack of cut points developed for individuals with DS is troubling considering the amount of research focused on physical activity interventions and understanding health outcomes based on physical activity. Of specific interest to researchers is understanding the amount of time spent at specific physical activity intensities. This allows researchers to compare physical activity participation to physical activity guidelines. As researchers and health professionals seek to evaluate interventions and their associated health outcomes it is necessary to have tools to measure outcome variables.

In general most methods used to measure and evaluate physical activity and associated outcomes have been created and validated using typically developing individuals without a disability. Therefore using the same measures with individuals with DS may be problematic due to their unique physiological and biomechanical constraints. These inherent differences make measurement of physical activity in this population increasingly difficult. As such, these unique characteristics need to be considered when selecting methods for measuring physical activity as well as the assessment of the activity.

Measuring and assessing physical activity in youth with DS

In general individuals with DS regardless of age have low fitness levels (Fernhall, et al., 1996; Pitetti, Climstein, Campbell, & Barrett, 1992). Their low fitness levels can be attributed to a largely sedentary lifestyle as well as phenotypic characteristics such as lower peak heart rates impacting their

cardiorespiratory capacity and fitness impacting their cardiorespiratory capacity and fitness. Recent research has started to converge to better explain these low fitness levels and the dose-response relationship between physical activity, fitness, and health. The promotion of physical activity is critical in this population not just for its well documented health benefits but for its ability to impact activities of daily living and vocational productivity (Cowley, et al., 2010; Fernhall, 1993; Rimmer, Braddock, & Pitetti, 1996).

Accelerometers for measuring physical activity have been successfully validated among typically developing youth (Brown, Pfeiffer, McIver, Dowda, Almeida, & Pate, 2006; Pate, et al., 2002; Puyau, et al., 2004). These devices have been used to objectively measure physical activity for population based surveillance studies and intervention or program evaluation. One issue to consider when using accelerometers is converting their output into something tangible and meaningful to researchers and practitioners. Most accelerometers produce unitless and meaningless data counts. The data counts are summarized over a specific time interval, such as minutes, hours, or days. These counts have no biological meaning. Typically data counts are given some form of biological meaning related to physical activity intensity or energy expenditure. These calibration studies rely on linking the relationship between data counts and physical activity intensity. Calibration studies quantify physical activity intensity through measurements of energy expenditure, oxygen consumption (VO_2), or heart rate.

These studies have calibrated physical activity data counts in structured (Freedson, Pober, & Janz, 2005; Trost, Way, & Okely, 2006) and unstructured (Evenson, Catellier, Gill, Ondrak, & McMurray, 2006; Mattocks, et al., 2007; Puyau, Adolph, Vohra, & Butte, 2002) settings. Structured settings include treadmill testing in a laboratory or using an indirect calorimetry room. Unstructured settings collect measures outside the laboratory. In these tests, children wore portable metabolic systems and were encouraged to play. Play included common indoor (e.g., reading, computer games, cleaning) and outdoor activities (e.g., climbing, swinging, running). From these measurements, researchers have created set criteria or thresholds for various levels of physical activity intensity. Cut-points for various levels of physical activity intensity can be found in Table 1.3.

With several choices caution should be exercised when selecting cut-points. The freedom to select cut points based on population-specific equations makes it difficult for researchers to compare results across studies. Selecting the wrong cut points can greatly under- or overestimate time spent in various levels of activity. This dilemma has been coined “the cut point conundrum” (Trost, 2007; Trost, et al., 2011). When considering measuring physical activity in individuals with DS it is necessary to consider their unique physiological response to exercise and physical activity. Applying cut points developed in individuals without DS is likely to underestimate their levels of physical activity. As a result of this, there exists a need for validated cut points for specific use with individuals with DS.

Calibration studies have not been done on youth with DS. Literature on accelerometer use in youth with DS is limited. The few studies using accelerometry to measure physical activity in special populations have used criterion measures validated in typically developing individuals (Foley, Bryan, & McCubbin, 2008). There is strong evidence suggesting physical and biological differences between the DS and typically developing populations (Baynard, Pitetti, Guerra, Unnithan, & Fernhall, 2008; Fernhall, Figueroa, Collier, Goulopoulou, Giannopoulou, & Baynard, 2005; Fernhall, et al., 2001). This is an area of concern to be addressed in order to continue collecting valid and reliable information on these individuals and to advance our understanding of health disparities seen in the DS population. Researchers have noted the importance of testing and calibrating accelerometers for use in specific populations (Brown, et al., 2006).

From previous research, we have information on the validation and calibration of accelerometers for use in youth using both heart rate and other metabolic criteria (Freedson, et al., 2005; Freedson, Melanson, & Sirard, 1998; Heil, 2006; Janz, 1994; Pate, Almeida, Mciver, Pfeiffer, & Dowda, 2006; Pfeiffer, et al., 2006; Puyau, et al., 2004; Trost, Ward, Moorehead, Watson, Riner, & Burke, 1998). We do not have this information for the specific population of youth with DS. We do however have literature and research on cardiovascular performance and function of individuals with DS (Fernhall, Millar, Pitetti, Hensen, & Vukovich, 2000; Fernhall, et al., 1996; Fernhall, et al., 1997; Pitetti & Fernhall, 1997; Pitetti, Millar, & Fernhall, 2000). One aim of this dissertation is to

successfully integrate these two established lines of research and validate the use of accelerometers as viable measures of physical activity among individuals with DS. This will be achieved by using established protocols regarding physical activity counts among typically developed children, and integrating research regarding the physiological differences commonly associated with DS and their participation in physical activity and responses to exercise.

Measuring body composition in youth with DS

Presently 17.9% of children between the ages of 2-19 years are classified as obese (CDC, 2011a). To be considered obese an individual must have an age and gender adjusted Body Mass Index (BMI) above the 95th percentile (see table 1.4). In general, individuals with disabilities display greater frequencies of being overweight when compared to their typically developing peers (CDC, 2011a; U.S. Department of Health and Human Services, 2010a). This is especially true of individuals with DS (Block, 1991; Cronk, et al., 1988; Draheim, Williams, & McCubbin, 2002).

Individuals with DS may be at increased risk for obesity due to phenotypic features associated with their disability. These features include hypothyroidism, muscle hypotonia (Bauer, Teufel, Doege, Hans-Juergen, Beedgen, & Linderkamp, 2003; Block, 1991; Latash, Wood, & Ulrich, 2008). This combination is likely to result in decreased energy expenditure (Fernhall, et al., 2005; Luke, Roizen, Sutton, & Schoeller, 1994). These genetic components could place these individuals at-risk for weight gain at an early age.

It is estimated that the number of individuals regardless of age with DS who are overweight or obese is between 46% and 89% (Braunschweig, Gomez, Sheean, Tomey, Rimmer, & Heller, 2004; Rubin, Rimmer, Chicoine, Braddock, & McGuire, 1998). However, these estimates are commonly based on research that has utilized body mass index (BMI) as a means to classify individuals. This measure is based on the relationship between negative health outcomes and increased body weight for a given height and should be considered as a tool for assessing if a person is at a healthy weight for their height.

BMI can be particularly problematic in the DS population because many individuals with DS are shorter than their peers without DS (Luke, et al., 1994). In addition to shorter statures, this population is at-risk for becoming overweight. One potential cause for increased weight gain in this group is their risk for hypothyroidism. Hypothyroidism is estimated to be present in 20-28% of children and 40% of adults with DS (Barnhart & Connolly, 2007; Finesilver, 2002).

Another potential cause for weight gain in this group is a decreased resting metabolic rate. Using doubly labeled water, Luke and colleagues found children with DS had lower resting metabolic rates and similar total daily energy expenditures as compared to peers without DS (Luke, et al., 1994). More recent research controlling for hypothyroidism in adults with DS found no differences in resting metabolic rates (Fernhall, et al., 2005). This however was not true in youth with DS. Youth with DS were found to have lower resting metabolic rates placing them at-risk for being overweight (Barnhart & Connolly, 2007).

Skinfolds are one of the most common methods for estimating body composition (Roche, Heymsfield, & Lohman, 1996). Skinfold measures are based on measuring the subcutaneous body fat with calipers. Researchers pull a small fold away from the muscle and measure the thickness of the fold. Skinfolds are taken at a variety of sites designed to measure all body segments. Skinfold measurements typically use two or more folds to predict percent body fat based on population specific regression equations (Roche, et al., 1996).

A recent report by the Centers for Disease Control and Prevention (CDC; 2011a) has suggested the need for developing valid and reliable methods to measure obesity and its associated health risks. The CDC has recognized common methods of measurement do not consider the unique constraints associated with various disabilities. As a result many of their previous reports are biased as they have not included specific disability groups. There is currently a need for population based measures to better estimate body composition to better understand the relationship between body fat and health for all individuals, including those with disabilities.

Equations are validated in a variety of typically developing populations including adults, children, and athletes (Jackson & Pollock, 1978; Jackson, Pollock, & Ward, 1980; Lohman, 1987; Slaughter, et al., 1988). Table 1.5 lists common skinfold equations and their associated skinfold sites. However, these equations are less accurate when they are used with atypical populations, such as DS, as they do not account for unique constraints. Due to their phenotype, individuals with DS often display body proportions unique from the populations

most prediction equations were derived from. The result is questionable validity. In an effort to have accurate measures and make correct evaluations with respect to body fat it is necessary to have methods of measurement that are accurate and reliable. In addition, ideal methods should minimize cost and participant burden while balancing accuracy and convenience. The second aim of this dissertation is to examine and validate the skinfold equations used to commonly measure body composition in youth with DS.

Physical activity and obesity in youth with DS

In the general population, there is a strong relationship between increased physical activity and maintaining a healthy body weight. This relationship among physical activity and body composition is not as clear among individuals with DS (Esposito, MacDonald, Hornyak, & Ulrich, in press; Fujiura, Fitzsimons, Marks, & Chicoine, 1997). While previous studies have examined the impact of various genetic, personal/behavioral, and environmental factors on body composition in the DS population, the majority have focused on the modifiable personal and environmental factors (CDC, 2011a).

Many studies seek to determine or identify the proportion of individuals meeting minimum recommended guidelines for physical activity (CDC, 2002; Matthews, et al., 2008; Pate, et al., 2002; Pate, Pfeiffer, Trost, Ziegler, & Dowda, 2004; Troiano, Berrigan, Dodd, Mâsse, Tilert, & McDowell, 2008; U.S. Department of Health and Human Services, 2008). Previous studies have reported conflicting results on the amount of physical activity youth with DS participate in. Many studies have shown these individuals spend a majority of

their time engaged in sedentary activities (Esposito, et al., in press; Fujiura, et al., 1997; Heller, Hsieh, & Rimmer, 2004; Sharav & Bowman, 1992). More recently, studies have demonstrated these individuals are indeed meeting the recommended guidelines for daily physical activity (Whitt-Glover, O'Neill, & Stettler, 2006).

Together, the Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine recommend that individuals accumulate a minimum of 30 minutes of moderate intensity physical activity most days of the week (Pate, et al., 1995). These recommendations are of particular importance for children and adolescents to maintain an optimal energy balance as well as developing strong bones and building muscle. It seems reasonable to believe that individuals with disabilities would benefit greatly from increased physical activity and sedentary behavior. In addition, although most chronic health conditions associated with a sedentary lifestyle are found in adults, these same health conditions are likely to develop at a much younger age (CDC, 2011a; Dubois & Girard, 2006; Hallal, Victora, Azevedo, & Wells, 2006). Physical activity habits established early in life are likely to set a positive trajectory for healthy physical activity habits in adulthood. There is strong evidence indicating children in general who are overweight at age eight will be severely obese as adults (CDC, 2009; Harrison, et al., 2011).

A unique trend in the literature has found many individuals with DS who are meeting the recommended physical activity guidelines but are still considered to be overweight or obese (Esposito, et al., in press; Whitt-Glover, et al., 2006).

To understand this trend better, studies have examined the environment. Potential factors include food intake, education about nutrition, and lack of supervision (Luke, et al., 1994; Rubin, et al., 1998). The study of physical activity and body composition in this population is complex. There is likely a diverse and dynamic interaction between individuals with DS and their genetic make-up and their environment.

Specific to individuals with DS, researchers are starting to examine the effects of genetic syndromes on regulating energy balance and obesity (Rimmer & Yamaki, 2006). Other genetic disabilities such as Prader-Willi syndrome and Fragile-X syndrome share some of the unique phenotypic characteristics that may contribute to obesity. These characteristics include: hypotonia, movement disorders, delayed growth, and cardiovascular abnormalities (Delrue, 2004). With this evidence it might be useful for researchers and practitioners to measure and assess physical activity and body composition as a function of diagnosis or level of function.

It is necessary to understand the underlying causes for increased weight gain in the DS population. The third and final aim of this dissertation is to examine the relationship between physical activity and body composition in a sample of youth with DS. The goal is to help allied health professionals minimize unnecessary and unhealthy weight gain in this already at-risk population. Once we better understand this relationship, interventions can be designed and tested to reduce the risk factors for obesity.

Summary

In comparison to other developmental disabilities DS has received a fair amount of attention from researchers and health professionals. Of particular interest are studies targeting health and well-being. With increased studies targeting population based surveillance and interventions, it is necessary to develop standardized protocols and techniques for measuring and assessing information. Physical activity is a single factor in understanding the physiological, behavioral, and environmental factors impacting the increasing prevalence of those who are overweight or obese. With this in mind it is necessary to have precise measures of physical activity as well as having the ability to interpret and assign meaning to these measures.

In order to have valid and reliable data our instruments and methods of measurement must be accurate and trustworthy. Without appropriate measurement, our decisions in educational and clinical settings, along with our research findings, can be questionable. This is increasingly problematic if these findings are to be used by allied health professionals to make informed decisions regarding options for treatment interventions. Presently there are limited studies validating the use of accelerometers in individuals with DS.

The purpose of this dissertation is to validate current criterion measures of physical activity and body composition for youth with DS. Current accelerometer criterion measures for levels of physical activity have been studied and validated in typically developing youth using energy expenditure and heart rate. These criterion measures have been applied to youth with DS with no empirical

research done to validate these measures. Similarly, skinfold equations used to estimate body composition among typically developing individuals could be incorrectly applied to youth with DS. The Down syndrome population is uniquely different from the populations used to develop specific skinfold regression equations being used to estimate body composition. A variety of anthropometric measures are available for measuring body composition, but they are often applied to individuals with DS without considering the unique features and body proportions of this population.

Without valid assessments, it is difficult to accurately quantify their levels of physical activity and body composition, making it difficult to plan, implement, and evaluate therapeutic interventions and conduct research designed to improve health and physical well-being in youth with DS. The first step in this process is to validate critical measures. With better, more systematic methods of measuring physical activity and assessing body composition researchers and health professionals can start to understand the potential link between physical activity and obesity among individuals with DS.

Table 1.1
Summary of aerobic parameters in youth with Down syndrome

Author(s)	Participants & mean age	Protocol	Peak VO ₂ (mL*kg ⁻¹ *min ⁻¹)	Peak HR (min ⁻¹)	Peak RER
Fernhall et al., 1989	11M, 3F, 18 years	Modified Balke	26.7	171	1.03
Fernhall et al., 2000	9M, 8F, 14 years	Individualized treadmill	39.4	182	
Fernhall et al., 1996	13M, 10F, 15 years	Individualized treadmill	32.8M	174M	1.11M
			25.7F	180F	1.13F
Fernhall et al., 1998	22M, 12F, 14 years	Individualized treadmill	36.6	186	1.08
Pitetti & Fernhall, 1997	17M, 12F, 14 years	Individualized treadmill	36.8M	183M	1.09M
			30.0F	188F	1.08F
Pitetti et al., 2000	12M, 11F	Individualized treadmill	45.9M	187M	1.09
			31.6F	182F	1.08F

Note: M = male; F = female; HR = heart rate, RER = respiratory exchange

Table 1.2
Indicators of physical activity intensity

	Heart rate	VO ₂	METs
Light activity	< 50% of maximum heart rate	< 40% of maximal oxygen uptake	1.6 - 2.9
Moderate activity	51-70% of maximum heart rate	40-65% of maximal oxygen uptake	3 - 6
Vigorous activity	70+% of maximum heart rate	65+% of maximal oxygen uptake	6 +

Table 1.3
Calibration studies and associated cut-points for the Actical accelerometer for children

Author (s)	Participants	Cut-points ¹
Pfeiffer, et al., 2006	N = 18	M: 715
	ages 3 - 5 years	V: 1411
Puyau, et al., 2004	N = 32	L: 100
	ages 7 - 18 years	M: 1500
		V: 6500
Corder et al., 2005	N = 39	L: 260
	ages 13.2 \pm 0.3 years ²	M: 323
		V: 640
Evenson et al., 2008	N = 33	L: 12
	ages 5 - 8 years	M: 508
		V: 719

Note: L = light; M = moderate; V = vigorous

¹ Data counts per minute

² Mean \pm standard deviation

Table 1.4
BMI-for-age and gender weight status categories, corresponding percentiles and health risk

Percentile range	Weight status category	Health risk
< the 5 th percentile	Underweight	Low
5 th – 85 th percentile	Healthy weight	Average
85 th – 95 th percentile	Overweight	Increased
≥ the 95 th percentile	Obese	Moderate-to-severe

Taken from, “About BMI for children and teens.” Retrieved July 17, 2009, from [http://www.cdc.gov/nccdphp/dnpa/healthyweight/assessing/bmi/childrens BMI/about childrens BMI.htm#What%20is%20BMI](http://www.cdc.gov/nccdphp/dnpa/healthyweight/assessing/bmi/childrens%20BMI/about%20childrens%20BMI.htm#What%20is%20BMI)

Table 1.5
Skinfold sites for gender specific equations

Lohman (1987)		Slaughter et al., (1988)	Kelly & Rimmer (1987)
Males	Females	Males & Females	Adults with intellectual disabilities (including DS)
Chest Abdomen Thigh	Triceps Abdomen Suprailiac	Triceps Calf	Waist circumference Forearm circumference Height Mass

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CHAPTER 2

PHYSICAL ACTIVITY PATTERNS OF YOUTH WITH DOWN SYNDROME

A primary health concern facing children and adults in North America is the prevalence of individuals who are overweight and obese. Physical inactivity is a contributing factor to this epidemic and has also been linked to type-2 diabetes, stroke, cardiovascular disease, and some cancers (U.S. Department of Health and Human Services, 2010a). Unfortunately, the rate of individuals classified as being overweight and obese has increased in all segments of the U.S. population (Troiano, et al., 2008). In a nation-wide attempt to counter this, the U.S. Department of Health and Human Services (USDHHS) has established guidelines for physical activity in an effort to decrease physical inactivity and promote healthy lifestyles (U.S. Department of Health and Human Services, 2008).

According to the *Physical Activity Guidelines for Americans*, the USDHHS recommend children and adolescents engage in a minimum of 60 minutes of physical activity daily (2008). In the document, specific guidelines are outlined for children and adolescents. These guidelines for children and adolescents include at least 60 minutes of daily moderate physical activity with at least three days of vigorous physical activity per week. Activities that exemplify these minimum criteria include bicycle riding, brisk walking, rollerblading, yard and house work, running, jumping rope, and active sport (basketball, tennis, hockey,

and swimming). Muscle and bone strengthening activities are also recommended and should occur at least three days per week (USDHHS, 2008).

The 60 minute guideline has been established as a minimum threshold amount of activity required to see health related benefits. In general, additional benefits are gained with increases in the amount of physical activity. These increases include greater intensity, increased frequency, and/or longer duration. Research suggests physical activity of more than 60 minutes is related to greater increases in health and a decrease in premature death (USDHHS, 2008).

Physical activity is also an important component in maintaining a healthy body weight. The Centers for Disease Control and Prevention (CDC) estimates that roughly 15% of youth are either overweight or obese (above the 85th and 95th percentile in body mass index (BMI) adjusted for age and gender respectively) (CDC, 2002). Childhood obesity puts children at an increased risk for developing diabetes, high cholesterol, and being overweight in adulthood (Foley, et al., 2008; Goran, Ball, & Cruz, 2003). According to Healthy People 2020, 17.9% of children without disabilities, ages 12-19 are considered obese. Childhood obesity appears to be more prominent among individuals with disabilities. Healthy People 2020 indicated that obesity in persons with disabilities was 32% greater than individuals without disabilities (U.S. Department of Health and Human Services, 2010a). More specifically, previous research indicates 28-59% of people with intellectual disabilities are overweight or obese (Illingworth, Moore, & McGillivray, 2003; Rimmer, Braddock, & Fujijura, 1993).

Down syndrome (DS) is a genetic disorder most commonly caused by the presence of extra genetic material or an extra copy of the 21st chromosome resulting in gene over-expression (Roizen & Patterson, 2003). Individuals with DS generally experience significant delays in the onset of developmental milestones, including early motor milestones such as standing and walking (Jobling, 1998; Latash, et al., 2008; Ulrich, Lloyd, Tiernan, Looper, & Angulo-Barroso, 2008; Ulrich, Ulrich, Angulo-Kinzler, & Yun, 2001). Some common phenotypic characteristics account for this delayed development including muscle hypotonia, immaturity of the central nervous system, poor postural control, and poor balance (Block, 1991; Davis & Kelso, 1982; Reid & Block, 1996). These factors are further compounded by lower aerobic capacities, lower peak heart rates, and decreased muscular strength (Balic, et al., 2000; Frey, Stanish, & Temple, 2008).

Motor delays in early childhood act as one barrier to physical activity participation for individuals with DS. Motor delays may persist in older children with DS and can be compounded with intellectual disabilities to impact the ability to learn new skills, activities and games adding another barrier to physical activity participation in older children. Other known barriers include facility and transportation restrictions, a lack of integrated program options, and low motivation for physical activity (Meneer, 2007). In one sibling study, children with Down syndrome were found to spend less time in and engage in shorter bouts of vigorous physical activity compared to their typically developing siblings (Whitt-Glover, et al., 2006). In general, the literature is limited on the physical activity of

children with disabilities, including children with DS (Fernhall & Unnithan, 2002; Foley, et al., 2008). The aim of this study is to examine the physical activity patterns of children with DS. With a better understanding of patterns and trends in physical activity we can improve current physical activity guidelines and future interventions for children with DS.

Methods

Participants

Approval for this study was obtained from the institutional review board. Prior to participating in the study parents provided signed informed written consent. Once consent was obtained from the parents, the children were asked if they would like to participate. At that time the children gave written assent. Both consent and assent were required for participation in the study. One-hundred and four participants with DS (57 males, 47 females) between 8-16 years of age were recruited from DS parent support groups and organizations throughout the state of Michigan to participate in a physical activity intervention. There was no attempt to include or exclude individuals based on the classification of DS: mosaicism, translocation or trisomy 21. Diagnosis was based on parent report from a physician. None of the participants had a physical disability or medical condition that would limit their physical activity participation.

Measurement

Physical activity was measured using the Actical® accelerometer (Mini Mitter/Respironics, Inc., Bend, OR) over a seven-day period. The data provided was time stamped and included information on the bout length and intensity of

physical activity. The Actical® accelerometer is one of the smallest accelerometers available (28x27x10 millimeters and 17 grams) and uses an omni-directional sensor with a 0.5-3Hz range capable of detecting movements in all planes to create a composite measure of movement. The voltage generated by the sensor is amplified and filtered via analog circuitry and then passed into an analog to a digital converter, and the process is repeated 32 times each second (32Hz). The resulting one-second value is divided by four and then added to an accumulated activity value for the duration of the specified 15-second epoch (Pfeiffer, et al., 2006). For this study, a 15-second epoch was selected based on literature related to the erratic and sudden bursts of activity common to youth (Pfeiffer, et al., 2006; Rowlands, 2007).

Participants wore the monitor for all waking hours of the day on the right hip just above the iliac crest using an elastic belt (see Figure 2.1). The monitor was to be worn for all activities except swimming, showering/bathing and sleeping. Parents/guardians of the participants were provided with a log to record any times when the monitor was not worn (i.e. swimming, bathing, forgetting to put it on in the morning, taking it off for comfort or any other reasons for which it may have been removed). Monitors were returned after a seven-day period via priority mail and were downloaded using an Actical Reader interface unit and associated software.

Data reduction

For inclusion in this study, the monitor had to be worn for a minimum of 10 hours per day, at least four days out of the seven-day monitoring period,

including one weekend day. These criteria have been previously established in the literature as suggested guidelines for obtaining valid and reliable accelerometry data (Mâsse, et al., 2005; Puyau, et al., 2004; Trost, McIver, & Pate, 2005). Based on a 15-second epoch the data were then reduced and assigned to one of the following categories: sedentary activity (counts <25 per minute), light physical activity (counts of 25 – 375 per minute), moderate physical activity (counts of 376-1625 per minute) or vigorous activity (counts > 1626 per minute). Data counts assigned to physical activity categories are related to energy expenditure validated in typically developing children (Puyau, et al., 2002). Table 2.1 lists common activities of children and their associated data counts.

Anthropometric measures

Height and body mass were measured without wearing shoes. Height was measured in centimeters to the nearest tenth of a millimeter with a portable stadiometer (SECA S-214 portable stadiometer). Two measurement trials were administered and the average of the trials was recorded. Mass was measured in kilograms to the nearest gram (Health O Meter H-349KL digital scale). Two measurement trials were administered and the average of the trials was recorded. Body mass index (BMI) was calculated using the standard formula: body mass (kg) divided by height (m²). Percentage of body fat was calculated using a gender-specific regression equation for children with triceps and calf skinfolds (Slaughter, et al., 1988). A physician experienced in measuring skinfolds, using Lange skinfold calipers took two skinfold thicknesses at each site

(triceps and calf) on the right side of the body. Measurements were taken twice at each site and rounded to the nearest tenth of a millimeter. The average at each site was used in the analysis.

Statistical methods

All analyses were conducted using SPSS version 17.0. Participants were divided into four age groups for the purpose of approximating grade level (i.e. grades 3, 5, 7, and 9). The age groups were as follows: 8-9 years (n = 25), 10-11 years (n = 38), 12-13 years (n = 27), and 14-15 years (n = 14). Physical activity patterns were examined for each group and each level of physical activity intensity. Relationships between percent body fat, body mass index, body mass index percentile, physical activity levels and age were also examined. Preliminary data analysis found no significant differences between female and male participants irrespective of age groups. As a result, all participants were combined for analysis. Based on physical activity recommendations, moderate and vigorous physical activity were combined to create an additional category for data analysis (USDHHS, 2008).

Results

Descriptive statistics and demographic information of the participants are displayed in tables 2.2 and 2.3 respectively. Results of physical activity for each age group are presented in Figures 2.2 to 2.6. Analysis of covariance (ANCOVA) was used to examine physical activity patterns across each age group while controlling for the average time spent wearing the accelerometer

(14.23 hours). Post-hoc Bonferroni corrections were used to look at pair-wise comparisons across age groups.

The general trend in physical activity demonstrated a marked decrease as children increase in age. The 14-15 year age group engaged in significantly more sedentary activity compared to their peers in the 12-13 year age group ($p < 0.05$) and both the 8-9 year and 10-11 year age groups ($p < 0.01$). The 14-15 year age group spent significantly less time in light physical activity compared to the 8-9 year age group ($p < 0.01$) and the 10-11 year age group ($p < 0.01$). In the area of moderate physical activity the 14-15 year age group was significantly less active than the 8-9 year and 10-11 year age groups ($p < 0.01$). No group differences were found in the area of vigorous physical activity. When aggregated into moderate-to-vigorous physical activity, the 14-15 year age group was significantly less active than the 10-11 year age group ($p < 0.01$).

The 12-13 year age group spent significantly more time in sedentary activity compared to the 10-11 year age group ($p < 0.01$) and significantly less time in moderate-to-vigorous activity compared to the 10-11 year age group ($p < 0.01$). The general trend in total daily physical activity patterns for this sample suggests lifestyles that are more sedentary as children age (see figures 2.2 to 2.4).

Data also suggests that the amount of daily physical activity has little influence on body composition in children with DS. Weak relationships exist between physical activity and BMI and physical activity and percent body fat (see Table 4). A small, statistically significant relationship between age and percent

body fat ($r = 0.23, p < 0.05$) as well as age and BMI ($r = 0.40, p < 0.01$) was found. Finally, the general trend of physical activity is decreasing with age, with the exception of the first two age groups. This decrease starts with a significant, positive relationship between age and time spent in sedentary activities and continues with negative, statistically significant decreases in both light ($r = - 0.31, p < 0.01$) and then moderate-to-vigorous physical activity ($r = - 0.32, p < 0.01$) as children with DS increase in age. In this sample, youth with DS are not meeting the minimum guidelines of 60 minutes of daily moderate or vigorous physical activity.

Discussion

The purpose of this study was to examine the physical activity patterns of children with DS. Results from this study indicate children with DS are not meeting the Surgeon Generals recommendations of accumulating 60 minutes of moderate or vigorous physical activity (USDHHS, 2010b). This is an area of concern given this is a population already at risk for being overweight. In this cross-sectional sample, physical inactivity is clearly demonstrated by a trend of increased sedentary physical activity and decreased amounts moderate and vigorous physical activity as youth increase in age. There was an exception among individuals in the age 10-11 group. This group engaged in the least amount of sedentary activity and was the most physically active.

The 14-15 year age group was the most sedentary and engaged in the least amount of light, moderate, and vigorous physical activity. These results corroborate previous studies that have found lower levels of physical activity in

typically developing adolescents when compared to younger children (Nyberg, Nordenfelt, Ekelund, & Marcus, 2009; Riddoch, et al., 2004; Troiano, et al., 2008). A recent study reported declines in moderate-to-vigorous physical activity between the ages of 9 and 15 (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008). This same pattern was displayed in this sample of youth with DS. Potential reasons for this decrease could be explained by the intermittent bouts of activity when children play. As children get older these informal bouts of activity or play decrease and are replaced with more structured activities. For individuals with DS a lack of structured activities and programming has been cited as a reason for not engaging in physical activity (Menear, 2007).

Our results indicate youth with DS follow a pattern of physical activity similar to their typically developing peers. This pattern indicates sharp declines in physical activity as children become adolescents. The participants in this study mirror their typically developing peers in both quantity and quality of physical activity but at a lower level. As a group, very few participants were engaging in vigorous activity.

The significant drop in moderate and vigorous physical activity as children age is an area of concern. This area of concern is particularly problematic because physical activity and physical fitness are related to outcomes other than improved health. Physical fitness in youth with DS has been found to predict performance on a variety of tasks of daily living, including job performance (Cowley, et al., 2010). A goal of allied health professionals should be to improve

or increase physical activity to keep these individuals independent and productive.

Within this sample of participants, 45.5% were overweight or obese for their age and gender based on CDC growth charts (CDC, 2002). These results support previous literature placing the percentage of individuals with an intellectual disability or DS as obese between 28-59% (Illingworth, et al., 2003; Rimmer, et al., 1993). This result is unique and might suggest the DS phenotype or other environmental factors may have a greater influence on maintaining a healthy body composition than physical activity. More research is needed in this area.

Also of importance are the implications of childhood physical activity patterns for adult behaviors. This lifespan approach is important for maintaining a healthy lifestyle. Childhood years are critical for maintaining and establishing a physically active lifestyle and a healthy weight for adulthood (USDHHS, 2008). Specifically, there is a pattern of overweight children becoming obese adults as evidenced by high BMI's and high levels of body fat in childhood being associated with increased body fat in adulthood (Field, Cook, & Gillman, 2005; Freedman, Khan, Serdula, Dietz, Srinivasan, & Berenson, 2005).

Various aspects of motor development also may be hindering children's engagement in physical activity (Jobling, 2001). This suspicion warrants further explanation since lifelong community participation has been positively linked to health-related benefits later in life for individuals with DS (Barnhart & Connolly, 2007; Fujiura, et al., 1997). As a result, interventions and programming options

need to address physical education and community programs to close gaps in motor development that exist between individuals with Down syndrome and their typically developing peers throughout the lifespan.

The following limitations should be observed when interpreting the results of this study. The waist was selected for accelerometer placement to increase compliance in this population. The children were more compliant when the monitor was not visually obvious. However the use of a single waist mounted accelerometer may have underestimated actual movement by not detecting upper body movements or specific non-weight bearing activities like cycling (Welk, 2002). In addition, the use of cut-points established for typically developing children may not be representative of energy expenditure in children with DS. Research has found that individuals with DS exercising at the same intensity as their typically developed peers were found to exercise at a higher percentage of their VO_2 peak and expend more energy (Mendonça, et al., 2009). Finally, because of the cross-sectional design of the study, it cannot be concluded that there is an age-related decline in physical activity, but rather difference among the age groups suggesting a potential decline in physical activity as children age.

Results of this study indicate a decline in physical activity as children with DS get older, similar to the general population ((Sallis, 1993, 2000; Trost, et al., 2002). These differences appear as a trend of decreased physical activity as age increased. Nearly 80% were engaging in moderate or vigorous activities for at least 30 minutes. Only 20.6% of the sample exceeded the recommended 60

minutes of moderate-to-vigorous physical activity combined. These results are interesting when considering the BMI's of the sample. Based on BMI, over 45% of the participants were either overweight or obese. One goal should be to better understand the role physical activity plays in moderating body weight and potentially body fat in this population.

Guidelines for physical activity have been established, and based on minimal criteria, the youth in this study are not meeting these basic guidelines of accumulating 60 minutes of physical activity daily and a majority of those minutes being moderate or vigorous in intensity. Closer examination of the breakdown of physical activity levels suggests these youth spend most of their time in sedentary activity. When these youths are physically active they spend more time in moderate physical activity and little time spent in vigorous physical activity. Many of these individuals might be missing out on the health benefits associated with vigorous activity. With a population already at-risk for becoming overweight, perhaps this population could benefit from additional activity beyond the minimum recommendations.

It is imperative to continue to examine, quantify, and understand the physical activity patterns of individuals with DS and the impact of physical inactivity to determine the risk for chronic diseases that can be attributed to inadequate physical activity (Draheim, McCubbin, & Williams, 2002). We have taken an initial step in globally describing the physical activity patterns of children and early adolescents with DS. Future studies should focus on the influence of

families, schools, and the community on physical activity as well as including both younger and older individuals to better understand this population.



Figure 2.1. Two participants wearing accelerometers

Table 2.1
Sample physical activity counts for common activities for children

Counts per epoch	Activity intensity
~ 14	Sedentary
~ 1179	Moderate
~ 2922	Vigorous
~ 3225	Vigorous
~ 3318	Vigorous

From Puyau, Adolph, Vohra, & Butte (2002)

Table 2.2
Descriptive statistics for participants

	Total sample (n = 104)	8 to 9.9 years (n = 25)	10 to 11.9 years (n = 38)	12 to 13.9 years (n = 27)	14 to 15.9 years (n = 14)
Age (years)	11.81 ± 2.21	9.26 ± 0.48	10.93 ± 0.68	13.03 ± 0.50	15.10 ± 0.56
Mass (kg)	40.65 ± 13.87	29.79 ± 6.42	37.42 ± 8.80	46.87 ± 14.18	57.13 ± 11.03
Height (cm)	142.51 ± 11.33	122.90 ± 7.02	132.52 ± 7.35	142.23 ± 6.52	148.55 ± 6.79
BMI (kg m ⁻²)	21.72 ± 4.67	19.61 ± 3.62	21.17 ± 3.83	22.01 ± 4.65	25.64 ± 4.74
BMI percentile	75.48 ± 22.66	71.12 ± 25.24	76.14 ± 23.19	72.48 ± 22.55	85.33 ± 12.62
Percent fat	26.40 ± 11.54	23.02 ± 10.26	25.35 ± 8.58	27.62 ± 14.47	32.51 ± 13.28
Number of males	57	14	18	17	8

Table 2.3
Demographic information

Race / Ethnicity	n	Percent of
Caucasian	89	85.6%
African-American	5	4.8%
Asian-American	2	1.9%
Hispanic / Latin descent	1	1.0%
Other (bi-racial)	5	4.8%
Missing / omitted	2	1.9%
Total	104	100.0%

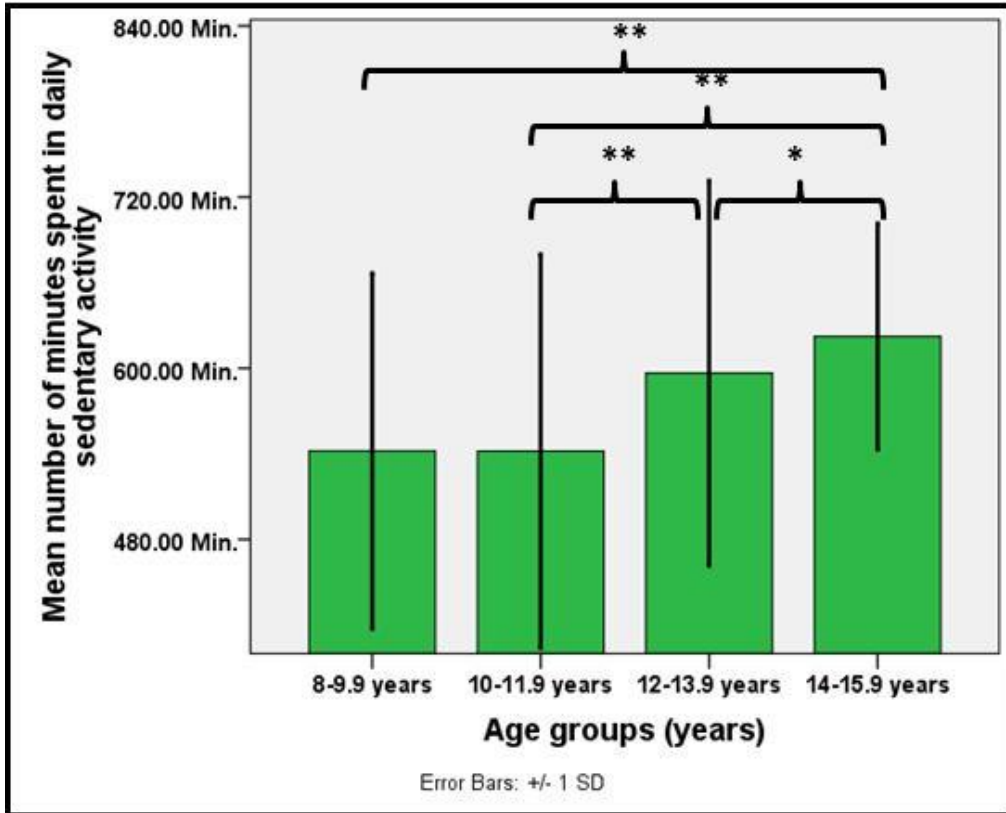


Figure 2.2 Daily time spent in sedentary activity by age

*Significantly different ($p < 0.05$)

**Significantly different ($p < 0.01$)

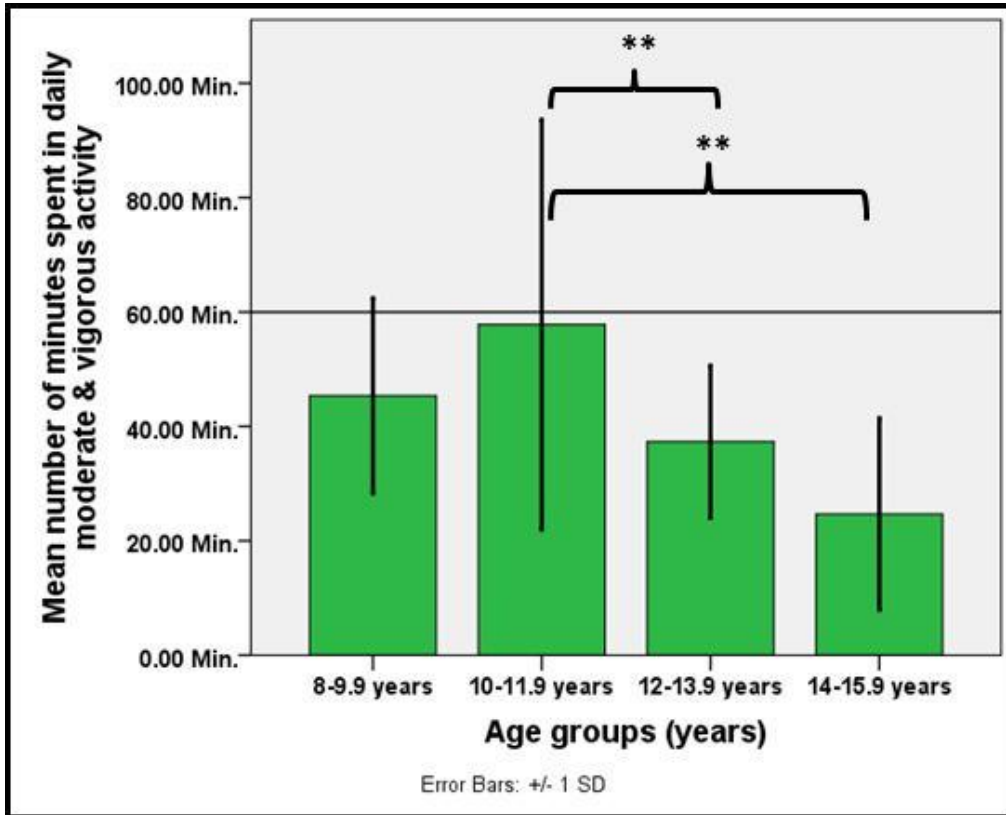


Figure 2.3 Daily time spent in moderate-to-vigorous activity by age
**Significantly different ($p < 0.01$)

Table 2.4

Correlations between age, percent body fat, BMI, BMI percentile, and physical activity levels

	Age	% fat	BMI	BMI %-ile	Sedentary PA	Light PA	Moderate PA	Vigorous PA	MVPA
Age	1	0.23*	0.42**	0.07	0.22*	-0.31**	-0.40**	-0.08	-0.32**
%-fat		1	0.86**	0.66**	-0.09	-0.19	-0.08	0.01	-0.05
BMI			1	0.76**	0.02	-0.16	-0.07	-0.01	-0.05
BMI %-ile				1	0.03	-0.10	0.09	0.08	0.11
Sedentary PA					1	-0.30**	-0.27**	-0.14	-0.26**
Light PA						1	0.44**	-0.22*	0.18
Moderate PA							1	0.33**	0.86**
Vigorous PA								1	0.76**
MVPA									1

Note. BMI = body mass index, PA = physical activity, MV = moderate-to-vigorous

*Significantly different ($p < 0.05$)

**Significantly different ($p < 0.01$)

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CHAPTER 3 VALIDATION OF ACCELEROMETER OUTPUT IN YOUTH WITH DOWN SYNDROME

Introduction

A primary public health concern facing youth in the United States is the prevalence of individuals who are overweight and obese (Strauss & Pollack, 2001; Troiano & Flegal, 1998). Based on body mass index (BMI) percentile, 16% of children and adolescents aged 2 to 17 years are obese (Bandini, Curtin, Hamad, Tybor, & Must, 2005; U.S. Department of Health and Human Services, 2010a). Physical inactivity is a contributing risk factor to this public health concern and has been linked to a variety of chronic health conditions such as type-2 diabetes, stroke, cardiovascular disease and some cancers (U.S. Department of Health and Human Services, 2010b). Although most chronic health conditions associated with a sedentary lifestyle are found in adults, they are likely to emerge at a much younger age (Dubois & Girard, 2006; Hallal, et al., 2006).

In a nation-wide attempt to counter this trend, the US Department of Health and Human Services (USDHHS) along with the Centers for Disease Control and Prevention (CDC) and the American College of Sports Medicine have established physical activity guidelines in a collective effort to decrease physical inactivity and promote healthy lifestyles (CDC, 2002, 2011a; Haskell, et al., 2007; U.S. Department of Health and Human Services, 2008, 2010a, 2010b)

These evidence based guidelines recommend that children engage in 30 to 60 minutes of physical activity most days of the week, with at least 10 to 15 of those minutes consisting of moderate to vigorous intensity (USDHHS, 2008).

Activity is considered to be of moderate intensity if a person's heart rate is at 50-70% of their age-predicted maximum heart rate (CDC). Examples of activities that meet moderate intensity criteria include bicycle riding, brisk walking, rollerblading, yard and house work, running, jumping rope, as well as active sport (basketball, tennis, hockey, soccer, and swimming). Presently 18.4% of youth are estimated as meeting these guidelines as measured by accelerometers and physical activity questionnaires (U.S. Department of Health and Human Services, 2010a). The target goal is 20.2% by the year 2020.

With these goals in mind, it is necessary to have objective and valid methods of measurement in order to determine if people are meeting these guidelines. In order to accurately determine if these goals were achieved there is a need for accurate tools of measurement. Measurement is a necessary component in understanding the association between physical activity and health (Troiano, 2005; Trost, 2007). There are a variety of methods available for measuring physical activity. Depending on the type of research question, amount of precision required, and cost (either financial or time) researchers can select a method to best fit their needs. For example, direct observation is very time intensive and can be highly subjective. Another subjective method is self-report which can be highly unreliable. More objective methods such as heart rate

monitoring and pedometry yield more valid and reliable information but can be costly.

Presently, accelerometry is the most widely accepted method for objectively measuring physical activity (Adamo, Prince, Tricco, Connor-Gorber, & Tremblay, 2009; Reilly, Penpraze, Hislop, Davies, Grant, & Paton, 2008; Welk, 2002). Many researchers consider accelerometry to be a criterion measure to validate and compare other methods used to measure physical activity (Ward, Evenson, Vaughn, Rodgers, & Troiano, 2005).

Measurement of physical activity

Accelerometry is an objective and robust method of measuring physical activity that allows for the examination of the quantity and intensity of physical activity and has been used to examine the physical activity patterns for several different populations. Accelerometers are small, lightweight, non-intrusive computer devices worn on the body and measure units of acceleration in a variety of planes. These monitors use integrated technologies to record frequency, duration, and intensity of activities. The information produced by these devices are arbitrary and unitless data counts. These data counts are aggregated over a specific user-defined time interval. These time intervals are known as epochs. Common epochs used in the measurement of physical activity for children are 15 seconds in length. These 15 second epochs are believed to be sensitive enough to capture the sudden and erratic bursts of activity common to children (Pfeiffer, et al., 2006; Rowlands & Eston, 2007).

A key issue in accelerometry is how to manipulate, analyze, and interpret accelerometer output. To facilitate the interpretation of data counts researchers have created cut-points based on physical activity intensity and energy expenditure. Both physical activity intensity and energy expenditure are more meaningful and easier to interpret than raw data counts. This is a very active area of study as researchers continue to create population based cut points based on age, specific activities, specific monitors, populations, and the criterion measure used (Ward, et al., 2005).

A common method for creating cut-points is testing the body's response to physical activity and exercise. Individuals with intellectual disabilities, including those with DS have been found to have VO_2 max values 25% lower than their peers without an intellectual disability (Fernhall, 2008; Fernhall & Unnithan, 2002). In addition to being low, these lower VO_2 values show very little variability (Millar, Fernhall, & Burkett, 1993; Pitetti, et al., 1992). These values are consistently low across a wide range of ages (Baynard, et al., 2008). Although researchers appear to get valid, maximal effort out of their participants it is difficult to tell if the lower VO_2 values are a physiological or a behavioral response (Fernhall, 2008). Partial explanations for low VO_2 values center around congenital heart defects, smaller oral and nasal cavities, and pulmonary hypoplasia (Fernhall, et al., 1996).

Along with decreased VO_2 max values individuals with DS also have lower maximal heart rates (Baynard, et al., 2004; Fernhall, et al., 2001). Maximal heart rates in youth with DS have been found to be lower by as many as 30 beats per

minute with an average maximal heart rate range of 168-175 beats per minute (Fernhall, et al., 1997; Pitetti, Yarmer, & Fernhall, 2001). In other words, individuals with DS have 20-25% lower maximal heart rates compared to their age matched peers without DS (Fernhall, et al., 2001). These decreased heart rates in combination with the decreased VO₂ max values help to partially explain the low fitness levels commonly found in this population.

There is also evidence individuals with DS have a lower resting metabolic rate when compared to typically developing youth (Allison, et al., 1995; Luke, et al., 1994; Murray & Ryan-Krause, 2010). These results along with lower aerobic capacity and lower peak heart rates suggest criteria used to establish physical activity criteria in typically developing youth may not apply to the DS population (Fernhall, et al., 2001; Mendonça, et al., 2009). These results also suggest for a given physical activity (sitting, walking, running, or swimming), individuals with DS may have lower energy expenditure.

With an increased focus on the role of physical activity and its impact on preventing, managing, and controlling chronic disability and disease there is a need for valid and reliable tools to objectively measure physical activity. Current physical activity research involving youth with DS may be incorrectly using cut points validated for use with typically developing youth (Foley, et al., 2008; Whitt-Glover, et al., 2006). A recent study examining activity counts in over ground walking in adults with DS noted a significant interaction between individuals with DS and their peers without DS with respect to activity-counts (Agiovlasitis, Motl, Fahs, et al., 2011). Their results indicated disconnect between metabolic

equivalent units (METs) and activity-counts produced by the accelerometer. Given the unique characteristics of this population it is likely this disconnect could also be present in youth with DS. To date, this has not been studied.

Based on the literature there are questions to be addressed in order to continue collecting and interpreting valid and reliable information on children and youth with DS. Researchers have noted the importance of testing and calibrating accelerometers for use in specific populations (Pfeiffer, et al., 2006). An important issue in the study of physical activity for individuals with DS is the correct application of cut-points used to quantify physical activity intensity. Most cut-points have established intensity criteria for various levels of physical activity based on research done on individuals without DS. These cut-points fail to consider the unique physiological responses to physical activity found in the DS population. As a result, measurements and assessments of physical activity engagement in this population are likely to be inaccurate.

If individuals with DS have lower work capacities and lower maximal heart rates, it would be reasonable to assume that applying physical activity cut-points developed on individuals in the absence of these traits, would underestimate the intensity of various physical activities. In an effort to maximize the quality of information produced from accelerometers it is necessary to understand the unique physiological differences between individuals with DS and their peers. From previous research, we have information on the validation and calibration of accelerometers for use in youth without disabilities or impairments. We do not have this information for the specific population of youth with DS. We do,

however, have literature and research on cardiovascular performance and function of individuals with DS. The purpose of this study is to integrate these two established lines of research to validate current criteria used to measure and establish levels of physical activity intensity in youth with DS. Results of this study will establish new scientific knowledge and facilitate our future understanding of the relationship between physical activity and health among children and youth with DS.

Methods

Best practices for accelerometer calibration studies recommend using a representative sample reflecting the unique characteristics and traits found in the population being studied (Ward, et al., 2005). Although this method is less precise than creating individual cut-point equations, it is more practical given the goal of creating specific population based estimates.

Participants

A total of 53 participants (27 with DS [15 males; 12 females], 26 without DS [17 males, 9 females]), between the ages of 8 and 18 years were included in the present study. Descriptive statistics for the sample are presented in Table 3.1. All participants with DS had a formal diagnosis from a physician and confirmed by the parent (based on parent report). No attempt was made to include or exclude individuals based on type of DS: mosaicism, translocation or trisomy 21. All participants were recruited from DS parent support organizations throughout Southeastern and central Michigan as well as existing contacts in the community. Control participants without DS were recruited from the same

support groups. Written informed consent was obtained from all parents or legal guardians and written assent was obtained from all participants prior to participation. All informed consent and assent documents as well as protocols were approved by the University of Michigan Institutional Review Board for the Health Sciences.

Exclusion criteria included having: (a) a physical disability limiting the ability to engage in physical activity, (b) a dual diagnosis (e.g., DS and autism), (c) a strong adverse negative reaction to new situations, which would impact their ability to complete the research protocol, (d) a history of cardiovascular disease, (e) a history of metabolic disease (e.g., diabetes), (f) to take medications to alter heart rate or metabolic responses, (g) asthma or other respiratory disorders, (h) been diagnosed with atlanto-axial instability, and (i) an uncorrected congenital heart defect.

Familiarization

Prior to beginning data collection and consenting to participate in the study, all parents and participants were given a tour of the laboratory. During the tour participants had the opportunity to learn about the testing protocol, meet other investigators, interact with the testing instruments, and become familiar with the tasks: wearing the monitors (heart rate monitor and physical activity monitor), and walking on a treadmill. Task familiarization has been cited as one of the most important aspects of assessment for research participants with DS (Balic, et al., 2000; Pitetti, Rimmer, & Fernhall, 1993; Rintala, McCubbin, & Dunn, 1995).

Anthropometrics

Height was measured in centimeters to the nearest half centimeter with a wall-mounted stadiometer (Scale Tronix). Participants removed their shoes and placed their heels together, and touched their heels to the wall. The head was positioned so participants were facing forward with the chin level. Two measurement trials were administered and the average of the trials was recorded. Body mass was measured without shoes in kilograms to the nearest gram (Stow-a-way, Scale Tronix). The process was done once (a second measurement of body mass was taken during the Bod Pod protocol). Body mass index (BMI) was calculated using the standard formula: body mass (kg) divided by height (m²). For the BMI calculation the body mass taken during the Bod Pod protocol was used because participants were wearing the least amount of clothing.

Body fat percentage was measured using the Bod Pod (Life Measurement, Inc., Concord, CA). For Bod Pod measures participants were instructed to wear minimal clothing (ideally a swimsuit) and a spandex swim cap. Spandex shirts and compression shorts were provided for those participants who did not bring appropriate attire. Participants were also asked to avoid eating for 60 minutes prior to measurements. These are standard protocols (McCroy, Gomez, Bernauer, & Molé, 1995). This was verified by research staff upon participants' arrival.

Each participant was weighed using the Bod Pod's attached scale prior to entering it. Their body volume was measured during two successive 60 second

trials. If these trials produced measurements within 150 ml of each other they were accepted and the mean of the two values was used for analysis. If the trials differed by more than 150 ml a third trial was performed. If there was agreement between two of the three trials, they were averaged and used. If two of three trials were not within 150 ml, the test was done a fourth time. A fourth trial was necessary on three occasions because participants moved too much during tests. Body volume was then computed using the Bod Pods computer software to correct for surface area artifact and thoracic gas volumes. Body volume was then converted to percent body fat using Siri (1961) and Lohman (1986) age-and gender-specific body density equations.

Instrumentation

The Actical (Mini Mitter/Respironics, Inc., Bend, OR) is presently one of the smallest accelerometers available (28x27x10 mm, 17 g.). It is a popular choice for measuring physical activity because it utilizes an omni-directional sensor (Pfeiffer, et al., 2006; Rowlands, 2007). Omni-directional accelerometers report motion in three orthogonal directions making it sensitive to a variety of movements. The monitor has a sensor with 0.5-3Hz range capable of detecting movements in all planes to create a composite measure of movement. The voltage generated by the sensor is amplified and filtered via analog circuitry and then passed into an analog to a digital converter, and the process is repeated 32 times per second (32Hz). The resulting one-second value is divided by four and then added to an accumulated activity value for the duration of the specified 15-second epoch (Pfeiffer, et al., 2006).

The accelerometer was placed just above the left hip to measure vertical acceleration at the center of mass with an elastic belt. Vertical acceleration has been previously used for its linear relationship to energy expenditure during locomotion (Kozey, Lyden, Howe, Staudenmayer, & Freedson, 2010). This relationship is not true at higher running speeds or non-locomotive activities (Cavagna, Thys, & Zamboni, 1976). With several accelerometer options available (Actical, Actigraph, Actiwatch, and RT3) previous research has indicated no monitor out performs another with respect to validity as measured by oxygen consumption or energy expenditure (Freedson, et al., 2005).

Oxygen consumption ($\dot{V}O_2$; measured in milliliters per kilogram) and carbon dioxide (VCO_2) were continuously measured on a breath-by-breath basis using a Cosmed portable metabolic system (Model K4b2, Rome, Italy). Instead of wearing the unit, the unit was affixed directly to the treadmill. This was done to avoid adding additional weight to the participants, which could potentially alter their metabolic responses. A flexible facemask (Hans Rudolph, Kansas City, MO) was placed over the participant's nose and mouth and held in place with an elastic harness. This mask is particularly well suited for use with youth with DS because of their smaller oral cavities. Attached to the mask is a bidirectional rotary flow, a measurement sensor and a sampling line. During the measurement $\dot{V}O_2$, heart rate, and percent heart rate were measured for comparison to physical activity counts from the Actical accelerometer. Prior to each participants arrival, the Cosmed and its associated oxygen and carbon dioxide analyzers and flow turbine were calibrated as per the manufacturer's instructions with a known gas

mixture of standard gases (CO₂: 5.03%, O₂: 16.02%, N₂: 78.95%). The Cosmed has been used previously to measure free-living tasks in validation studies. It was also selected as a more comfortable alternative to standard $\dot{V}O_2$ equipment which can be quite bulky, invasive, and potentially intimidating.

Heart rate was measured with a Polar Team-2 system. The Team-2 system includes a base station, a transmitter charger, individual transmitters, elastic chest belts, and computer software for reading and analyzing heart rate data. The Team-2 system integrates well with the Cosmed's ability to monitor expired gases and oxygen consumption. Heart rate was set to be sampled on a breath-by-breath basis. This allowed for the coupling of $\dot{V}O_2$ and heart rate data. The Team-2 system also uses Bluetooth technology to view and record heart rate in real time. Heart rate is another measure of estimating energy expenditure and examining actual workload.

Testing protocol

The protocol used for this study was a continuous, incremental, graded treadmill exercise test designed to measure cardiorespiratory fitness in individuals with intellectual disabilities, including individuals with DS (Fernhall & Tymeson, 1987). Previous studies have found this protocol to yield valid and reliable results (Fernhall, Millar, Tymeson, & Burkett, 1990; Fernhall, et al., 1996; Fernhall & Tymeson, 1987; Pitetti & Tan, 1990, 1991). The sub-maximal test utilizes treadmill speeds between 1.5-2.5 miles per hour (0.67-1.1 meters per second) for each participant. These speeds are similar to previous research examining the preferred walking speeds of individuals with DS (Agiouvasitis,

McCubbin, Yun, Pavol, & Widrick, 2009). Treadmill speed remained constant for the duration for the test and the grade of the treadmill increased 2.5% every three minutes. Since the purpose was validation, the intention of increasing the treadmill grade was designed to increase and vary the intensity of the task without increasing the speed. All participants were verbally encouraged throughout the test. The test was stopped after 18 minutes or if the participant was unable to maintain their speed. A member of the research team or the participant's parent or guardian could have also terminated the test.

This validation study follows Ward and colleagues recommendations for best practices when calibrating (Ward, et al., 2005). Their recommendations include: (a) selecting movements most accurately recorded with uni-axial accelerometers, (b) using a sample representative of the specific larger population, (c) examining the potential effect of age and body size (height, body mass, percent fat), and (d) choosing an age appropriate task.

Measurements

All measurements of oxygen consumption, heart rate, and activity related data counts were determined by averaging four, 15-seconds sampling intervals. For analysis the final minute of each stage (i.e., minutes 3, 6, 9, 12, and 15) was used. This was done to assume participants had reached a steady state for a given workload. Predicted maximal heart rate for participants without DS was determined using the equation, $HR_{max} = 220 - age$. For participants with DS the following equation was used (Fernhall, et al., 2001):

$$Heart\ rate_{max} = 210 = 0.56 * (age\ in\ years) - 15.5$$

Data analysis

The original intention was to recruit a sample large enough to detect statistical power of 80% at a statistically significant level of 5%. Utilizing previous research on individuals with DS and conservative assumptions about variance, we sought to recruit 23 individuals with DS and 23 control participants without Down syndrome. We were able to exceed these values and consistently obtain power values between 80-90% for most measures.

All data (Actical, heart rate, and $\dot{V}O_2$) were sampled at 15-second intervals and then summarized over one-minute intervals to allow participants to reach a steady state and smooth the effects of respiration. Multilevel modeling was used to examine the relationship between percent heart rate and activity counts produced by the Actical accelerometer. The dependent variable of interest was percent heart rate. Age and group, either with Down syndrome (DS) or without DS (TD) were fixed independent variables. Next individual equations for each group were developed to predict percent heart rate. Agreement between actual percent heart rate and predicted heart rate based on activity counts were evaluated using regression analysis and comparing the predicted values to actual values. The differences between actual and predicted values were evaluated using independent samples t-tests. All analyses were conducted using PASW 19 for Windows (SPSS Inc., Chicago, IL, USA). For all analyses an alpha level of 0.05 was used to establish statistical significance. Unless otherwise noted, all values are reported as means \pm standard deviation.

Results

Descriptive statistics for the sample can be found in Table 3.1. No age or body mass differences were found between groups. Participants with DS were found to be significantly shorter ($p < 0.01$) which is supported by previous research (Pitetti & Fernhall, 1997; Pitetti, et al., 2001). As a result, participants with DS also had significantly greater BMI's ($p < 0.05$) and BMI percentiles ($p < 0.01$). Individuals in the DS group also had significantly more body fat as measured by the Bod Pod ($p < 0.01$).

With the exception of the first stage, Table 3.2 demonstrates no differences between individuals with DS and their peers without DS in data counts produced by the Actical accelerometers. Table 3.3 demonstrates that individuals with and without DS were shown to have similar absolute heart rates. However, when heart rates were adjusted to consider the lower maximal heart rates exhibited by individuals with DS, the two groups differed significantly at each workload (Table 3.4). The line graph in Figure 3.1 shows that for identical workloads, youth with DS were working significantly harder as reflected by their percent of their age-predicted maximum heart rate.

When considering the reliability and validity of the Actical accelerometer, Pearson correlation coefficient between percent heart rate and data counts was $R = 0.22$ ($p < 0.01$). Table 3.5 presents current cut-points commonly used as thresholds for identifying physical activity intensity among individuals without DS. Based on the data from this study, these cut points appear to frequently underestimate physical activity intensity for individuals with DS.

The estimates of fixed effects for a multilevel model for predicting percent heart rate can be found in Table 3.6. Due to the significant group by activity count interaction effect, two independent models were created (see Table 3.7). The new group-specific models did not help to explain more variance than the single model ($R^2 = 0.23$, $p < 0.01$ compared to 0.10 , $p < 0.01$ and 0.08 $p < 0.01$ for the DS and TD only models respectively). A visual display of percent heart rate predicted by the equation was plotted against actual percent heart rate and is presented in Figure 3.2.

Discussion

The purpose of this study was to validate current criteria used to measure and establish levels of physical activity intensity in youth with DS. This study is one of the first studies to both examine and provide calibration data for Actical accelerometers in youth with Down syndrome. The results demonstrate the Actical accelerometer is a reliable measure for assessing physical activity in the DS population. This is positive outcome considering the atypical gait patterns exhibited by individuals with Down syndrome (Agiovlasitis, et al., 2009; Agiovlasitis, Motl, Ranadive, et al., 2011; Smith, Kubo, Black, Holt, & Ulrich, 2007).

It is recognized that both heart rate and oxygen consumption share a linear relationship with work. As workloads increase, both heart rate and oxygen consumption increase. With this relationship in mind, we examined heart rate as a practical method of measuring and assessing physical activity intensity. When looking at workload and absolute heart rate values there were no differences

between the groups. These results would suggest good validity in the DS population. There are, however, unique characteristics found among individuals with DS that warrant attention.

One of the unique characteristics is lower peak heart rates found among individuals with DS. Peak heart rates in youth with DS have been found to be lower by as many as 30 beats per minute with an average maximal heart rate range of 168-175 beats per minute irrespective of age (Fernhall, et al., 1997; Pitetti, et al., 2001). When adjusting absolute heart rate to consider the lower peak heart rates found in this population, the participants with DS worked greater effort for the same workload. Greater peak respiratory exchange ratios also indicated the DS participants (Table 3.8) performed at a greater effort. Considering the Actical produces similar data counts between the two groups and the two groups differ in effort, there is a need to examine how researchers interpret those data counts.

The physical activity cut-points do not reflect the decreased aerobic capacity commonly displayed in the DS group. Common cut-points used to establish physical activity intensity appear to under-estimate intensity for the individuals with DS. As results of these underestimations, individuals with DS are being described as less active (engaging in disproportionately more sedentary activity and less moderate or vigorous activity) than their peers. Given most cut-points utilize heart rate and energy expenditure data derived only from healthy individuals without disabilities, inclusion of individuals with DS are

needed when deriving these cut-points. This is especially true for researchers studying physical activity in the DS population.

With data from this study we created a multilevel model designed to predict percent heart rate. The results accounted for approximately 10% of the variance in predicted percent heart rate with the independent variables of age and activity counts. Although the model including only age and activity counts was statistically significant, there are clearly other variables of interest we did not measure that account for the remaining variance. One of these variables is present level of physical activity engagement or physical fitness. Previous research has found the relationship between physical fitness and physical activity to be highly variable with physical activity explaining anywhere between 16-80% of the variance with respect to physical fitness (Pitetti, Beets, & Combs, 2009). With so much variance unaccounted for, controlling for present level of physical fitness might not have added any additional value.

One limitation of the study was its sub-maximal nature. We selected a sub-maximal walking test because walking has been frequently identified as a preferred physical activity in this population (Draheim, Williams, McCubbin, 2002). It was also a task we believe most participants could complete and yield a range of data counts (light, moderate, and vigorous activity). Future research should include higher intensity activities as well as activities of daily living. We also recognize the inherent error associated with using estimated percent maximum heart rates. Previous research has found standard error of the estimate to be 11.8 (Fernhall, et al., 2001). Estimated maximal heart rates are

variable and can be affected by age, gender, body mass, and present level of physical fitness.

One common method of validating data counts is the use of metabolic equivalents (METs) to identify thresholds of physical activity intensity. METs were not used in this study due to the lower resting metabolic rates common to youth with DS. There is also additional variability in metabolic rates due to the high number of individuals with hypothyroidism.

Summary

Overall, results of this study appear to demonstrate the Actical accelerometer is a reliable and valid device for objectively measuring physical activity in youth with DS. Additional research is needed to create valid and reliable cut-points for physical activity thresholds in the DS population. Results of this study did show there is a difference between these two groups. When the work was identical for both groups, participants with DS worked at a higher percentage of their maximal heart rate. This study has demonstrated considering these unique traits provides better estimates of physical activity intensity as measured by percent heart rate. Although there is not going to be a perfect, universal equation for estimating physical activity intensity in all individuals, there are some unique traits associated with the DS phenotype warranting attention.

Future research should continue to focus on the role of maturation, age, height, body mass, BMI, and present level of activity in further developing prediction equations. As well as looking at other indicators of physical activity intensity. As the study of physical activity in this area evolves more precise

measures will result allowing researchers to more accurately quantify physical activity in this population.

Acknowledgements

This research was funded by U.S. Office of Special Education Programs leadership training grant, Blue Cross, Blue Shield Foundation of Michigan Foundation, Special Olympics Healthy Athletes Health Professions Student Grant, and the Rackham Graduate School at the University of Michigan. We would also like to thank Families Exploring Down Syndrome, the Down syndrome Support Team, the Down Syndrome Guild of Southeast Michigan and the Capital Area Down Syndrome Association who assisted with recruitment. Additional thanks to Nathan Hilliard, Adrienne Dusky, Lauren Jordan, and Alex Riordan for their assistance with data collection.

Table 3.1

Descriptive statistics for participants with and without Down syndrome

	Down syndrome (n = 27)	Control (n = 26)	p	Effect size+
Age (years.months)	14.4 ± 3.8	13.3 ± 3.9	0.29	0.30
Height (cm)	140.2 ± 13.1	153.2 ± 18.1	0.00	0.84
Body mass (kg)	47.4 ± 15.6	48.3 ± 20.0	0.86	0.05
BMI (kg/m ²)	23.3 ± 6.8	19.7 ± 4.7	0.03*	0.62
BMI percentile	74.3 ± 24.1	49.5 ± 32.3	0.00**	0.90
Percent body fat	20.5 ± 10.6	13.0 ± 8.7	0.01**	0.79

Notes.

* Groups are significantly different at $p < .05$.

** Groups are significantly different at $p < .01$.

+ Cohen's d, effect size.

Table 3.2
Activity counts at each stage

Time	Speed/grade	DS	TD	p	ES+
0-3 min.	1.1 meter/sec./0%	813.2 ± 593.0	1200.8 ± 514.7	0.02*	0.71
3-6 min.	1.1 meter/sec./2.5%	1003.5 ± 636.8	1325.4 ± 516.3	0.06	0.57
6-9 min.	1.1 meter/sec./5%	1168.6 ± 709.5	1335.8 ± 536.4	0.35	0.27
9-12 min.	1.1 meter/sec./7.5%	1182.1 ± 717.3	1350.8 ± 548.8	0.36	0.27
12-15 min.	1.1 meter/sec./10%	1254.9 ± 680.3	1429.2 ± 574.7	0.36	0.29
15-18 min.	1.1 meter/sec./12.5%	1405.6 ± 683.4	1606.9 ± 599.7	0.37	0.33

Notes. DS = Down syndrome; TD = Typical development.

* Statistically different at $p < 0.05$

+ Cohen's d, effect size.

Table 3.3
Absolute heart rate at each stage

Time	Speed/grade	DS	TD	p	ES+
0-3 min.	1.1 meter/sec./0%	101.1 ± 15.9	105.5 ± 20.4	0.44	0.25
3-6 min.	1.1 meter/sec./2.5%	109.8 ± 16.6	110.8 ± 21.7	0.87	0.05
6-9 min.	1.1 meter/sec./5%	117.3 ± 15.0	113.1 ± 22.0	0.47	0.23
9-12 min.	1.1 meter/sec./7.5%	118.1 ± 11.1	123.7 ± 20.8	0.29	0.35
12-15 min.	1.1 meter/sec./10%	124.5 ± 12.0	129.5 ± 17.1	0.30	0.34
15-18 min.	1.1 meter/sec./12.5%	128.9 ± 14.6	134.9 ± 19.8	0.35	0.34

Notes. DS = Down syndrome; TD = Typical development.
 + Cohen's d, effect size.

Table 3.4
Percent of age-predicted maximum heart rate at six workloads

Time	Speed/grade	Percent heart rate			
		DS	TD	p	ES+
0-3 min.	1.1 mps/0%	60.5 ± 10.3	51.0 ± 9.3	0.00**	0.99
3-6 min.	1.1 mps/2.5%	64.2 ± 9.4	53.4 ± 9.7	0.00**	1.15
6-9 min.	1.1 mps/5%	68.6 ± 8.2	54.6 ± 10.1	0.00**	1.58
9-12 min.	1.1 mps/7.5%	69.1 ± 6.1	59.8 ± 9.5	0.00**	1.20
12-15 min.	1.1 mps/10%	72.4 ± 7.0	62.6 ± 7.6	0.00**	1.37
15-18 min.	1.1 mps/12.5%	75.5 ± 8.6	65.2 ± 9.2	0.00**	1.19

Notes. DS = Down syndrome; TD = Typical development; mps = meters per second

* Groups are significantly different at $p < .05$.

** Groups are significantly different at $p < .01$.

+ Cohen's d, effect size.

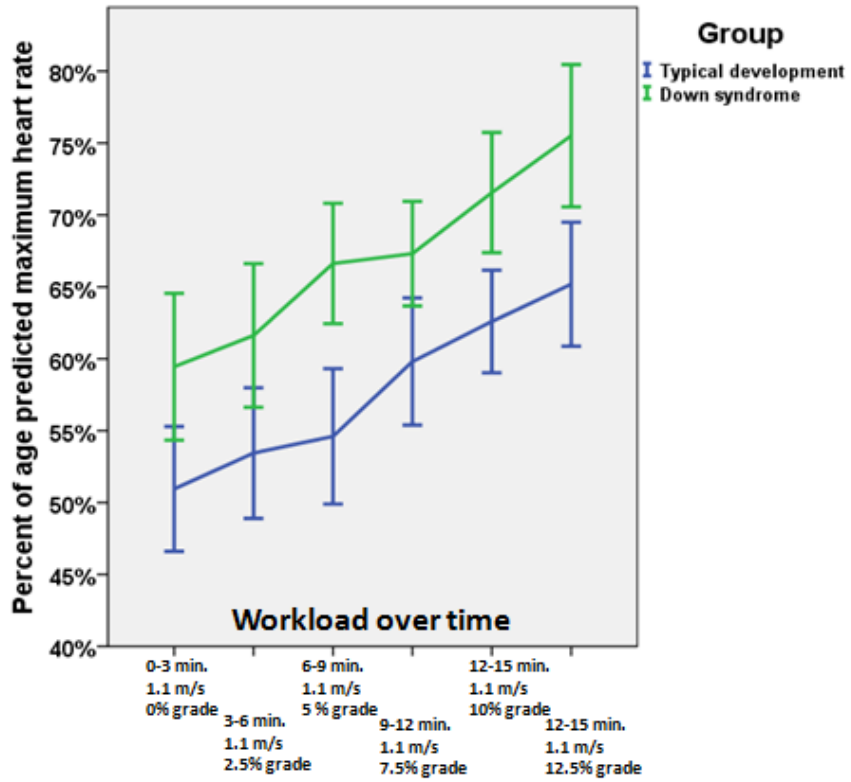


Figure 3.1. Age-predicted maximum heart rate during protocol

Table 3.5
Youth specific prediction equations and their estimation of physical activity intensity (based on percent of maximum heart rate)

	Cut-points	TD	DS
Freedson et al. 2005	LT: 100	< 50%	60.5%
	MD: 2220	50-70%	67.0%
	VG: 4136	70%	72.7%
Puyau et al. 2002	LT: 800	< 50%	62.7%
	MD: 3200	50-70%	69.9%
	VG: 8200	70%	84.9%
Treuth et al. 2004	LT: 100	< 50%	60.6%
	MD: 3000	50-70%	69.3%
	VG: 5200	70%	75.9%
Mattocks et al. 2007	LT: 100	< 50%	60.6%
	MD: 3581	50-70%	71.0%
	VG: 6130	70%	78.7%

Note: DS = Down syndrome; TD = Typical development.

Table 3.6

Estimates of fixed effects in a multilevel model predicting percent heart rate for individuals with and without Down syndrome

	b	Standard Error	p
Intercept	59.89	1.20	0.01**
Activity counts (per 60 seconds)	0.000	0.001	0.66
Group (0=TD; 1=DS)	9.76	0.85	0.01**
Age	-0.66	0.11	0.01**

Note: ** Significantly different ($p < 0.01$)

Table 3.7

Individuals estimates of fixed effects in a multilevel model predicting percent heart rate for individuals with and without Down syndrome

	DS			TD		
	b	Standard Error	p	b	Standard Error	p
Intercept	66.8	0.98	0.01**	66.54	1.90	0.01**
Activity counts (per 60 seconds)	0.003	0.001	0.01**	-0.004	0.001	0.01**
Age	-0.56	0.13	0.01**	-0.772	0.17	0.01**

*Note: ** Statistically significant different at $p < 0.01$*

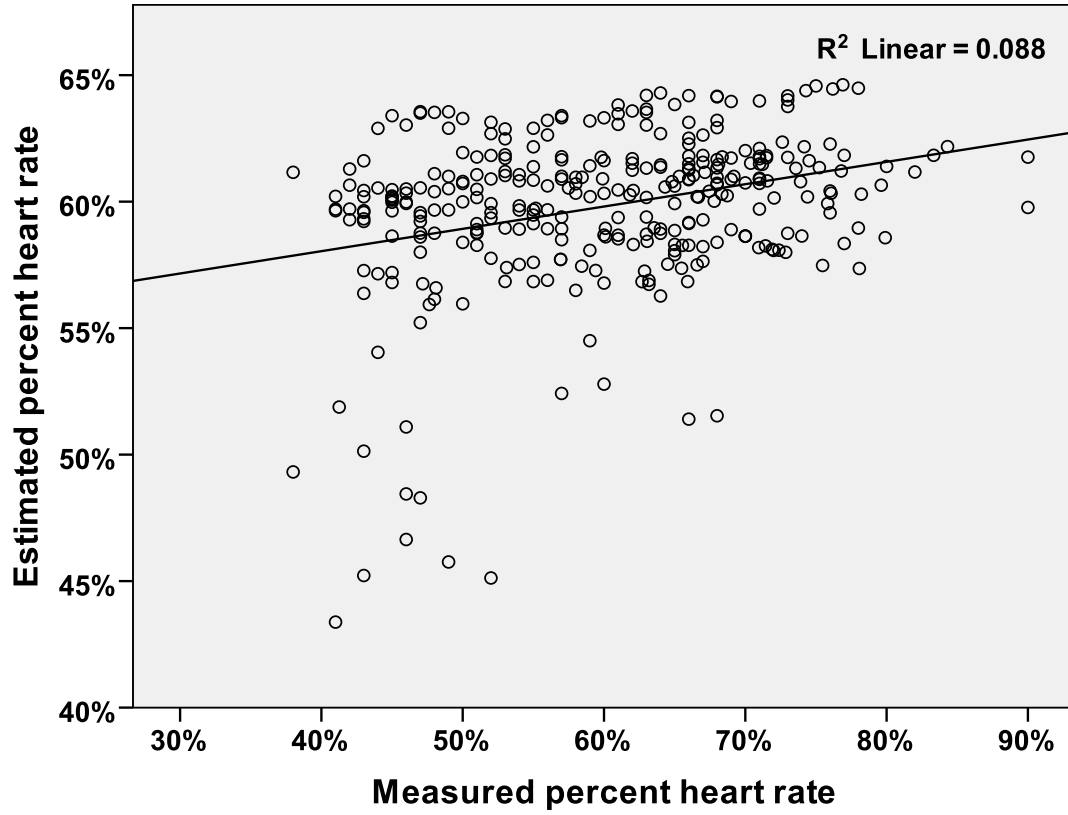


Figure 3.2. Relationship between estimated percent heart rate and measured percent heart rate.

Table 3.8
Oxygen consumption data

	DS	TD	p	ES+
$\dot{V}O_{2peak}$ (ml*kg ⁻¹ *min ⁻¹)	20.5 ± 7.7	26.4 ± 4.2	0.01**	0.96
$\dot{V}O_{2peak}$ (ml*lean kg ⁻¹ *min ⁻¹)	26.1 ± 8.2	30.3 ± 5.3	0.05*	0.62
RER _{peak}	1.01 ± 0.13	0.92 ± 0.6	0.01**	0.21
Percent heart rate _{peak}	79.4 ± 8.6	72.3 ± 9.7	0.01**	0.79
Heart rate _{peak}	134.5 ± 15.6	146.4 ± 22.5	0.05	0.63

Note: DS = Down syndrome; TD = Typical development.

* Statistically significant different at $p < 0.05$

** Statistically significant different at $p < 0.01$

+ Cohen's d, effect size

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CHAPTER 4 VALIDATION OF MEASURES OF BODY COMPOSITION IN YOUTH WITH DOWN SYNDROME

Introduction

A significant health problem in the United States is the incidence of individuals who are classified as being either overweight or obese (Ogden, Carroll, Curtin, Lamb, & Flegal, 2010). The terms overweight and obese are labels used to identify ranges of body weight considered to be unhealthy based on their relationship with various chronic health conditions. These chronic health conditions include insulin resistance, type 2 diabetes, cardiovascular disease, cancer and sleep apnea (Loke, 2002; Sinaiko, et al., 2005; Weiss, et al., 2004). For children to be considered overweight they must have a Body Mass Index (BMI) greater than the 85th percentile adjusted for age and gender. Obesity is classified as having a BMI percentile greater than the 95th percentile. These percentiles were developed by the Centers for Disease Control and Prevention (CDC) to indicate a child's relative position compared to peers of the same sex and age (Ogden, et al., 2010). Table 4.1 provides an overview of BMI percentiles and their associated health risks.

The condition of obesity and physical inactivity has become a significant public health problem in the United States. The prevalence of youth and adolescents who are overweight has tripled in the last 20 years (CDC, 2011a; U.S. Department of Health and Human Services, 2008). Data from the National

Health and Nutrition Examination Survey indicate 31.0% of children aged 6-19 years are classified as at risk for being overweight (Hedley, Ogden, Johnson, Carroll, Curtin, & Flegal, 2004). These numbers are even greater among children with disabilities. Recent obesity rates for children with disabilities are 22 to 38% higher than for children without disabilities (Bandini, et al., 2005; CDC, 2011a).

The majority of research on obesity focuses on the typical population, with relatively little work regarding those with disabilities. Down syndrome (DS) is the most common chromosomal disorder and can be characterized by multiple anomalies. Some of these anomalies include muscle hypotonia, developmental delay, and intellectual disability. With an approximate incidence of 1 in every 700 live births; DS is one of the most common causes of pediatric onset disability (CDC, 2011b).

It is generally recognized individuals with DS have lower aerobic capacities (Fernhall & Pitetti, 2001; Fernhall, et al., 1996). These decreased aerobic capacities are partially explained by lower maximal heart rates (Fernhall, et al., 2001; Fernhall, et al., 1997). In addition to these physical characteristics individuals with DS lead a largely sedentary lifestyle (Draheim, McCubbin, et al., 2002; Whitt-Glover, et al., 2006). This combination of factors helps to explain why individuals with DS are frequently overweight or obese.

Previous studies have documented individuals with DS tend to have higher BMI's than their peers with intellectual disabilities but without DS and their typically developing peers (Rimmer & Yamaki, 2006; Yamaki & Taylor, 2005). Prevalence rates of overweight and obesity in studies vary, but nearly all studies

report a prevalence of overweight in DS at nearly 50%, with values ranging from 46% to 89% (Braunschweig, et al., 2004; Rubin, et al., 1998).

However, many of these studies have used BMI to define levels of obesity among children with DS without considering the influence of height on the calculation. The short statures of individuals with DS are likely to inflate BMI scores (Pitetti, et al., 1993). Further complicating the use of BMI among individuals with DS is a variety of factors that impact weight gain in this population. These factors include hypothyroidism, decreased resting metabolic rate (RMR), muscle hypotonia, decreased physical activity levels, and increased nutrient intake (Murray & Ryan-Krause, 2010). Researchers have evaluated RMR in children with DS and found a lower RMR as compared to typically developing peers (Luke, et al., 1994). The lower RMR in children is thought to be due at least in part to skeletal muscle hypotonicity, which improves during adolescence and on into adulthood. In adults with DS, RMR is not decreased (Fernhall, et al., 2005). Lower RMR alone cannot account for the increased incidence of obesity in DS, but it can play a role in increasing the risk for overweight or obesity in childhood. Further complicating the relationship between energy expenditure and physical activity is hypothyroidism being present in approximately half of young people with DS (Barnhart & Connolly, 2007; Roizen & Patterson, 2003). All of these factors combine to result in individuals with DS having decreased energy expenditures placing them at-risk for a positive caloric balance and resulting weight gain.

Presently there are a several methods available for estimating body composition. These methods include underwater weighing, magnetic resonance imaging, air displacement plethysmography (commercially known as the Bod Pod), and various anthropometric measures. When selecting from these methods it is important to consider a variety of factors. Factors including accuracy desired, cost associated (i.e. time and money), and the difficulty in administering (both from a researcher and participant perspective). Considering these constraints, researchers often choose anthropometric measures such as skinfolds for practical reasons including low cost, ease of administration, and their ability to produce body composition estimates similar to more expensive methods such as air displacement plethysmography.

The Bod Pod (Life Measurements, Concord, CA) is a valid and reliable method for estimating body fat (McCrorry, et al., 1995). Its accuracy in children has been compared to “gold standard” methods such as dual-energy x-ray absorptiometry (DEXA) and underwater weighing (Claros, Hull, & Fields, 2005; Elberg, et al., 2004). Although these two methods are attractive choices for estimating body composition in clinical settings there are surprisingly few studies utilizing these techniques to estimate the body composition of children with disabilities.

Presently hydrostatic weighing along with DEXA scans are commonly administered as the “gold standard” in the measurement of body composition. Given the cost, task requirements and participant burden associated with hydrostatic weighing and DEXA scans, the Bod Pod is a better measure. To

successfully get an accurate measure using hydrostatic weighing participants have to completely submerge their head. While the head is completely submerged, participants need to exhale as much air as possible from their body while a researcher records their underwater body mass. This task is difficult to complete in youth with typical development and likely to be more challenging for individuals with DS (Usera, Foley, & Yun, 2005).

The Bod Pod is an attractive alternative due to its ease to administer, accurate results, and low burden on participants. A Bod Pod test requires participants to wear minimal clothing and sit in a plastic testing chamber. While in the testing chamber the Bod Pod measures how much air is displaced and as a result estimates the body volume of the individual. With a known body volume and body mass the Bod Pod's computer software can then provide an estimate of both body density and body fat. Although the Bod Pod is an excellent method for estimating body composition, anthropometric measures are still very common for their practicality.

Due to the short statures of most individuals with DS and various factors contributing to weight gain there is reason to believe using anthropometric measures such as BMI and skinfolds to estimate body fat might yield incorrect information. With shorter statures and increased body mass individuals with DS are likely to have muscle and fat distributions different from populations current skinfold equations were derived from. Although widely used to estimate body composition in individuals with DS, there is little research on the validity and

reliability of skinfolds and skinfold equations to estimate body composition in youth with DS.

With an increased focus on obesity and its ability to characterize health risks there is a necessity to have accurate methods of estimating body composition. The purpose of this study was to examine the accuracy of common skinfold equations used to estimate body fat in a sample of youth with and without DS using air displacement plethysmography as the criterion measure.

Methods

Participants

A total of 53 healthy participants between the ages of 9 and 18 years were enrolled in this study (27 with Down syndrome [15 males; 12 females], 26 without Down syndrome [17 males, 9 females]). Descriptive statistics for the sample are presented in Table 4.1. Participants with Down syndrome had a formal diagnosis from a physician. No attempt was made to include or exclude individuals based on distinction of mosaicism, translocation or trisomy 21. All participants were recruited from Down syndrome parent support groups throughout Southeastern and central Michigan as well as existing contacts in the community. Written informed consent was obtained from all parents or legal guardians and written assent was obtained from all participants. All informed consent and assent documents as well as protocols were approved by the University of Michigan Institutional Review Board for the Health Sciences.

Exclusion criteria included having: (a) a physical disability limiting ability to engage in physical activity, (b) a dual diagnosis with Down syndrome (i.e. Down

syndrome and Autism), (c) a strong adverse negative reaction to new situations, (d) a history of cardiovascular disease, (e) a history of diabetes or other metabolic disease, (f) to take medications to alter heart rate or metabolic responses, (g) asthma or other respiratory disorder, (h) been diagnosed with atlanto-axial instability, and (i) an uncorrected congenital heart defect.

Prior to arrival participants were instructed to refrain from eating and caffeine for two hours prior to their assigned measurement time. They were also asked to not exercise in the 12 hours preceding testing. As a result of these requirements, most testing sessions occurred in the morning. For Bod Pod measures participants were instructed to wear minimal clothing (ideally a swimsuit) and a spandex swim cap and to not eat for 60 minutes prior to measurements. Spandex shirts and compression shorts were provided for participants who did not bring appropriate attire.

Anthropometrics

Height was measured in centimeters to the nearest millimeter with a wall-mounted stadiometer (Scale Tronix). Participants removed their shoes and placed their heels together, and stood with their heels touching the wall. The head was positioned so participants were facing forward with the chin level. Two measurement trials were administered and the average of the trials was recorded. Body mass was measured in kilograms to the nearest gram (Stow-away, Scale Tronix). Also with their shoes removed, participants stood on the scale; their body mass was recorded. A second measurement of body mass was taken during the Bod Pod protocol. For data analysis the second body mass

measurement was used because participants were wearing as little clothing as possible.

Body mass index (BMI) was calculated using the standard formula: body mass (kg) divided by height (m²). Body fat percentage was measured using the Bod Pod (Life Measurement, Inc., Concord, CA).

Skinfolds

Prior to testing, the Lange skinfold calipers were calibrated using a graduated calibration block. All skinfold measures were taken on the right side of the body by both the principle investigator and a research assistant. Inter-rater reliability coefficients were calculated for measurements taken at each site. Intraclass correlations ranged from $R = 0.91$ to $R = 0.98$. Skinfold measures were administered using testing protocols outlined by Heyward and Stolarczyk (1996). To estimate body composition, the Slaughter and colleagues (1988) two-site skinfold equation (triceps and calf) was used. For the Lohman equation (1987) skinfolds were taken on males from the chest, abdomen, and thigh. Females had skinfolds taken from the triceps, suprailiac, and thigh. Anthropometric measures for Kelly and Rimmer's (1987) equation for individuals with intellectual disabilities, including those with DS used height, body mass, and both a waist and forearm circumference. All measures were taken in duplicate and recorded to the nearest half millimeter. If the two measurements differed by more than two millimeters, a third measurement was taken. The averages of each site were used to determine body density and percent body fat.

Air displacement plethysmography

Each participant was weighed a second time using the Bod Pod's attached scale prior to entering the Bod Pod. Once inside, their body volume was measured in two successive trials lasting 60 seconds each. If these trials produced measurements within 150 ml of each other, the mean of the two values was used. However, if the two trials differed by more than 150 ml, a third trial was performed. Trials were continued until agreement (within 150 mL) was found between any two of three trials. More than three trials were needed on three occasions because the participants moved too much during the tests. Body volume was then computed using the Bod Pods computer software to correct for thoracic gas volumes. Although previous studies have noted difficulty in obtaining thoracic lung volumes for participants with DS (Usera, et al., 2005), preliminary analysis in this study found no differences between estimated and actual lung volume for participants with DS ($p = 0.72$). Body volume was then converted to percent body fat using Siri (1961) and Lohman (1986) age-and gender-specific body density equations. When compared to DEXA scans and underwater weighing, the Bod Pod has consistently been found to be both valid and reliable in estimating body composition in a variety of populations, including youth with DS (González-Agüero, Vicente-Rodríguez, Ara, Moreno, & Casajús, 2011; Maddalozzo, Cardinal, & Snow, 2002; McCrory, et al., 1995; Usera, et al., 2005).

Data analysis

Regression analysis was used to determine the accuracy of three skinfold equations as compared to the Bod Pod which served as the criterion measure. Skinfold equations were considered to be accurate if their slopes did not significantly differ from one and their intercepts did not differ significantly from zero (González-Agüero, Vicente-Rodríguez, et al., 2011). These analyses were designed to test the hypotheses that percent body fat from the equations and percent body fat from the Bod Pod do not differ significantly from the line of identity (indicating a perfect, linear relationship). Shared variance values will be assessed using R^2 values from the above regression analyses. Bias between skinfold equations and the Bod Pod were examined by plotting predicted values against values derived from the Bod Pod.

Additionally, Pearson Product Moment correlations were calculated to determine concurrent validity between the three skinfold measures and the criterion measure (Bod Pod). Root-Mean-Squared-Error (RMSE) was also used to determine the amount of error between skinfold measures and the criterion measures. RMSE uses the square root of the differences between the estimated values produced by skinfold equations and the estimated criterion values produced from the Bod Pod. This particular analysis converts raw scores to absolute scores and represents the true difference between the methods allowing for comparison.

All analyses were completed using SPSS v 19 for Windows (SPSS Inc., Chicago, IL, USA). The data unless noted are displayed as mean \pm standard deviation. The level of statistical significance was set at $\alpha = 0.05$.

Results

The purpose of this study was to examine the accuracy of common skinfold measures used to assess body composition in youth with and without DS. Based on the physical attributes associated with the DS phenotype, present equations used to estimate body composition do not consider unique body proportions found in this group. This study examined two common skinfold equations (Lohman, 1987; Slaughter et al., 1988) used in children and one skinfold equation unique to individuals with intellectual disabilities, including those with DS (Kelly & Rimmer, 1987).

Descriptive characteristics of all participants can be found in Table 4.1. No age or body mass differences were found between groups. Youth with DS were found to be significantly shorter ($p < 0.01$). As a result of being shorter in stature, the youth with DS had significantly greater BMI scores ($p < 0.05$) and BMI percentiles ($p < 0.01$). Individuals with DS, regardless of the equation used, had significantly more body fat than their peers ($p < 0.01$).

All body fat results are displayed in Table 4.2. Percent body fat from the Bod Pod show significant group differences between individuals with and without DS, genders combined ($p < 0.01$). When comparing percent body fat among males there were no significant differences between males with and without DS. There were however, significant differences between females with and without DS (BMI, Bod Pod, and each skinfold equation; $p < 0.01$ and BMI percentile; $p <$

0.05). Previous research has found these differences to be true (Baptista, Varela, & Sardinha, 2005). Overall body composition classifications by gender and group are presented in Table 2. The results from Table 4.3 demonstrate the sample of participants with DS represents current estimations classifying approximately 50% as being overweight or obese based on BMI (Braunschweig, et al., 2004).

Table 4.4 shows the correlation values between skinfold estimates and the criterion measure. Correlation coefficients for the DS group range from $r = 0.64 - 0.78$. These values are all lower when compared to their TD peers ($r = 0.79 - 0.90$). All correlation coefficients were statistically significant ($p < 0.01$) in both groups. Table 4.4 also displays the RMSE values compared to the Bod Pod. These results represent the standard error associated with each method. For individuals without DS, each equation performs relatively well with error estimates between 3.8 and 5.5%. When these same measures are compared to individuals with DS, the error estimates were higher (6.7-8.3%). These results did show the Kelly and Rimmer (1987) equation provided the best estimate by producing the least amount of error for individuals with DS.

Regression analysis found each equation performed relatively well with no slopes or intercepts being significantly different from one and zero respectively (see Table 4.5). Specific to each group, body fat estimates for individuals without DS from the Lohman skinfold equation (1987) explained 81% of the variance in body fat estimates from the Bod Pod. For individuals with DS, the Kelly and Rimmer equation explained 61% of body fat variance in estimates from the Bod

Pod. These results confirm the population specific Kelly and Rimmer equation is a more accurate measure of estimating body fat than the other two methods (see Figure 4.1).

Figures 4.2 to 4.4 compare predicted body fat values to the criterion measure. For all equations, percent body fat was overestimated for both groups. These overestimations were greater and more variable for individuals with DS.

Discussion

In the Surgeon General's Vision for a Healthy and Fit Nation (U.S. Department of Health and Human Services, 2010b), obesity was declared a public health crisis. As a result of the increased attention to the incidence of individuals who are overweight or obese there is a need for valid methods of measuring body fat. The purpose of this study was to examine the accuracy of some common skinfold equations used to estimate body fat in a sample of youth with and without DS using air displacement plethysmography as the criterion measure. Results from this study indicate the Lohman (1987) and Slaughter et al. (1988) equations are not valid measures of estimating body composition in youth with DS. Although correlation coefficients were statistically significant and moderately high, there was a significant amount of error when compared to the criterion measure.

A common skinfold equation used in estimating body composition in youth is the gender-specific, two-site skinfold equation developed by Slaughter and colleagues (1988). This two-site method is advantageous because it uses two skinfolds (triceps and calf), both of which are easily accessible. This method of

estimating body composition is used in the public schools as part of Fitnessgram testing (Meredith & Welk, 2006). For individuals with DS in this sample, the Slaughter equation performed the poorest. It had the lowest correlation ($r = 0.64$) with the Bod Pod estimates and the most error (RMSE = 8.25) associated with it.

These results are similar to previous research examining the regional distributions of fat mass in youth with (González-Agüero, Ara, Moreno, Vicente-Rodríguez, & Casajús, 2011b). In previous research, females with DS were found to have greater concentrations of fat mass in their trunk and smaller amounts of fat mass in their lower limbs when compared to female peers without DS (González-Agüero, Ara, Moreno, Vicente-Rodríguez, & Casajús, 2011a). This same report found young males with DS to have more fat mass in their whole body and upper limbs and decreased amounts of fat mass in their lower limbs (González-Agüero, Ara, et al., 2011a). With these unique distributions in mind, some of the errors from these measures found in the current study are likely to be caused by individuals with DS distributing their lean and fatty tissue differently than their peers without DS. If individuals with DS are distributing a majority of their fat in their upper body and upper limbs, regression equations need to be sensitive to this and adjust body site specific coefficients.

The one equation specifically developed for adults with intellectual disabilities, including individuals with DS is the Kelly and Rimmer (1987) anthropometric equation. In the three equations used in this investigation, this equation performed the best in this sample. It had the lowest amount of error and the highest correlation with the criterion measure. This equation considers

some of the unique body proportions associated with Down syndrome. The equation is an anthropometric equation utilizing height, body mass, forearm, and waist circumference (Kelly & Rimmer, 1987). This equation considers this population's reduced physical stature as well as recognizing this group carries a majority of their mass in their torso and abdomen region. Although this equation was derived in adults it performed well in this sample of youth. One reason for the positive transfer could be that young people with DS show increased amounts of body fat in their torso as well decreased amounts of lean mass in their lower extremities. These distributions of tissue have been previously identified in adults with DS (Baptista, et al., 2005; Guijarro, Valero, Paule, Gonzalez Macias, & Riancho, 2008).

Results from Table 2 comparing gender and across disability groups found females with DS had significantly greater amounts of body fat compared to their female peers without DS. These results support previous findings of females with DS having greater amounts of body fat compared to peers without DS (González-Agüero, Ara, et al., 2011b). This is in stark contrast to the males with DS. Although the males with DS had more body fat for each method, there were no significant differences between them and their peers without DS.

These results can be partially explained due to sampling errors. The sample of participants with DS was representative of current estimations classifying approximately 50% of individuals with DS as being overweight or obese based on BMI (Braunschweig, et al., 2004). We did however have several

control participants without DS who met classification criteria to be considered underweight. These individuals could have amplified the group differences.

Results from the current study demonstrate that validity of measurement is reduced when population specific characteristics are not considered when developing anthropometric equations. This study is consistent with previous research on anthropometric equations and DS (González-Agüero, Ara, et al., 2011a; Usera, et al., 2005). The better performance of the Kelly and Rimmer (1987) equation highlights a need for more population derived methods of measurement. In this instance, considering the unique features of this population yielded a more accurate measurement.

The current results are not without some limitations. It is difficult to isolate if the differences between methods are a function of measurement error or error inherent in the equations themselves. There is likely to be some variability and error due to the prediction equations being derived from populations with known differences in body mass distribution and body proportions uniquely different from those of individuals with DS (Bronks & Parker, 1985; Usera, et al., 2005; Wade, vanEmmerik, & Kernozek, 2000). Skinfolds also require a high degree of tester skill and results can be greatly influenced by tester error.

Future calibration studies should focus on regional analyses (trunk, upper and lower limbs) of fat and lean masses using highly accurate DEXA scans. These studies will help us better understand where individuals with DS are distributing their body mass and allow researchers to develop anthropometric measures to more accurately reflect the unique body proportions found in this

population. In addition, researchers and allied health professionals could potentially identify alternative measures other than BMI for assessing cardiovascular risks such as waist circumference (Moreno, Pineda, Rodriguez, Fleta, Sarria, & Bueno, 2002).

Summary

Population based surveillance of overweight and obesity status is an important area of public health concern. With increased focus on specific populations designed to better understand specific groups of people there is a need for more specific methods for measuring body composition. There is a need for methods reflective of the populations they are designed to measure. Most epidemiological and public health studies use anthropometric measurements, specifically BMI or other anthropometric measures to estimate body composition.

A recent CDC publication has noted BMI and some anthropometric measures are not valid measures in certain populations, specifically those with disabilities (CDC, 2011a). The same publication recommends developing newer, more objective methods of measuring body composition. Understanding obesity and having accurate tools to measure obesity is important considering its relationship to chronic health conditions. By developing more precise measures of body composition, specific to certain populations, researchers can gain a more complete understanding of body composition and its relationship to health.

The goal of this paper was to examine some common skinfold equations used to estimate body composition in youth with DS. It is generally well

recognized individuals with DS are shorter in stature and typically overweight. As a result, these individuals have unique body shapes and proportions atypical from most populations skinfold equations were derived from. It is from this framework Kelly and Rimmer (1987) developed an anthropometric equation to estimate body fat in adults with intellectual disabilities, including individuals with DS. Results from this study found the population specific Kelly and Rimmer (1987) anthropometric equation provided the best estimates of body fat when compared to other common skinfold equations used in youth without DS.

Table 4.1
Descriptive statistics for participants with and without Down syndrome

	Down syndrome (n = 27)	Control (n = 26)	p	Effect size+
Age (years. months)	14.4 ± 3.8	13.3 ± 3.9	0.29	0.30
Height (cm)	140.2 ± 13.1	153.2 ± 18.1	0.00**	0.84
Body mass (kg)	47.4 ± 15.6	48.3 ± 20.0	0.86	0.05
BMI (kg/m ²)	23.3 ± 6.8	19.7 ± 4.7	0.03*	0.62
BMI percentile	74.3 ± 24.1	49.5 ± 32.3	0.00**	0.90

Notes. Values are means ± standard deviations.

Abbreviations: BMI, body mass index

* Statistical significance at $p < 0.05$.

** Statistical significance at $p < 0.01$.

+ Effect size is Cohen's d

Table 4.2
Percentage of body fat displayed by gender and group

Method	All				Males				Females			
	DS (n = 24)	TD (n = 24)	p	ES	DS (n = 14)	TD (n = 8)	p	ES	DS (n = 11)	TD (n = 16)	p	ES
Bod Pod	20.5 ± 10.6	13.0 ± 8.7	0.01**	0.80	14.4 ± 8.0	12.5 ± 10.2	0.58	0.23	28.3 ± 8.2	13.9 ± 5.1	0.01**	2.29
Lohman (1987)	22.9 ± 8.0	16.0 ± 6.5	0.01**	0.97	18.9 ± 6.1	16.3 ± 7.6	0.32	0.41	27.3 ± 7.7	15.6 ± 3.8	0.01**	2.13
Slaughter et al., (1988)	30.2 ± 11.3	24.4 ± 10.1	0.06	0.55	24.5 ± 9.0	24.3 ± 11.9	0.97	0.02	36.4 ± 10.5	24.7 ± 5.7	0.01**	1.52
Kelly & Rimmer (1987)	22.0 ± 7.1	15.7 ± 4.2	0.01**	1.12	19.5 ± 3.9	16.1 ± 5.0	0.05	0.82	24.8 ± 8.7	14.8 ± 2.3	0.01**	2.93

Note: DS = Down syndrome, TD = typical development

** statistically significant at the p < 0.01 level

ES = Cohen's d effect size

Table 4.3
Body composition classifications based on BMI and percent body fat (Bod Pod)

	DS	TD
BMI		
Underweight (< 5 th percentile)	0	4
Healthy weight (5 th -85 th percentile)	14	14
Overweight (85 th -95 th percentile)	7	5
Obese (> 95 th percentile)	6	1
Percent body fat (Bod Pod)		
Underweight	6	14
Health weight	9	6
Overweight	5	3
Obese	5	1

Note: DS = Down syndrome; TD = Typical development

Table 4.4

Correlation matrix and error measurements for each method of body composition

	Percent body fat		Root mean squared error		Correlation with criterion measure	
	DS	TD	DS	TD	DS	TD
	(male & female)	(male & female)				
Bod Pod ®	20.5 ± 10.6	13.0 ± 8.7	-	-	-	-
Kelly & Rimmer (1987)	22.0 ± 7.1	15.7 ± 4.2	6.65**	4.09**	0.78**	0.89**
Lohman (1981)	22.9 ± 8.0	16.0 ± 6.5	6.90**	3.88**	0.76**	0.90**
Slaughter (1988)	30.2 ± 11.3	24.4 ± 10.1	8.25**	5.45**	0.64**	0.79**

Note. ** Statistically significant at $p < 0.0$

Table 4.5
Summary of regression analyses for percent body fat

Method		R ²	Intercept (kg)	p	Slope	p	SEE (% fat)
Lohman (1987)	Percent body fat (DS)	0.58	7.3 ± 10.4	0.15	3.6 ± 8.6	0.49	6.9
	Percent body fat (TD)	0.81	3.7 ± 9.7	0.39	3.9 ± 8.9	0.47	3.9
Slaughter et al., (1988)	Percent body fat (DS)	0.41	9.1 ± 11.0	0.10	3.5 ± 8.6	0.51	8.3
	Percent body fat (TD)	0.63	5.0 ± 9.2	0.24	3.8 ± 9.0	0.49	5.5
Kelly & Rimmer (1987)	Percent body fat (DS)	0.61	7.1 ± 11.2	0.18	3.6 ± 8.6	0.49	6.7
	Percent body fat (TD)	0.79	3.3 ± 12.5	0.55	3.9 ± 8.9	0.46	4.1

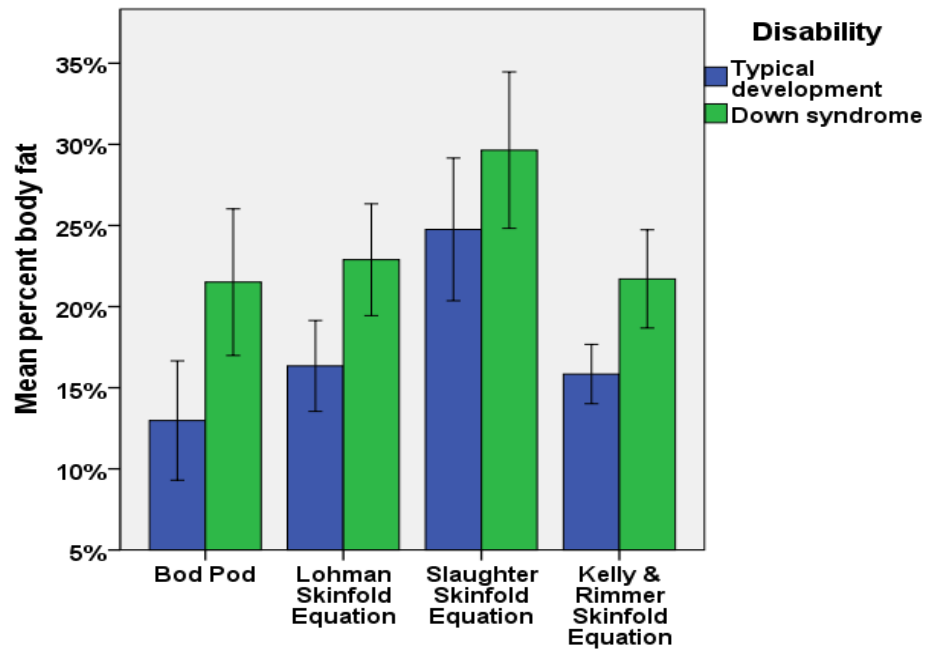


Figure 4.1. Comparison of methods to estimate body composition

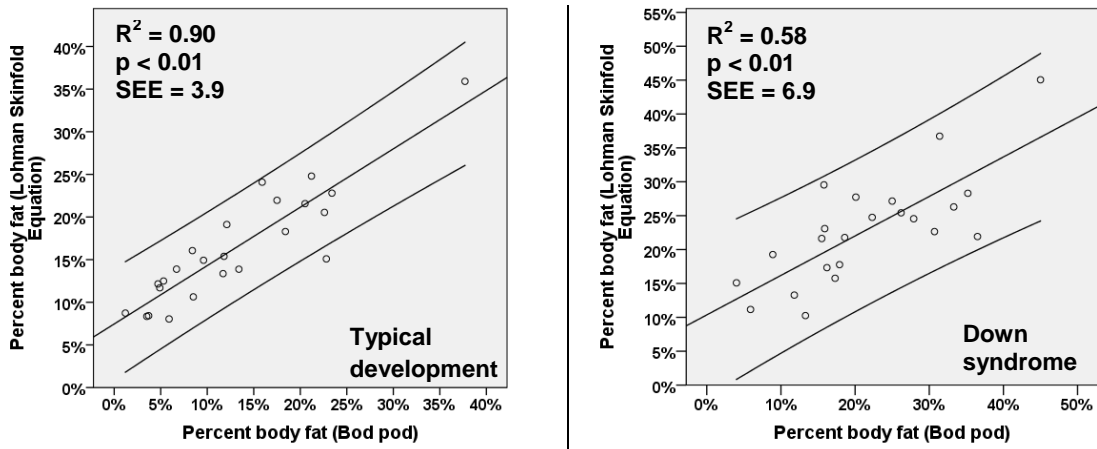


Figure 4.2. Comparing predicted body composition (Lohman, 1987 equation) to criterion body composition (Bod Pod)

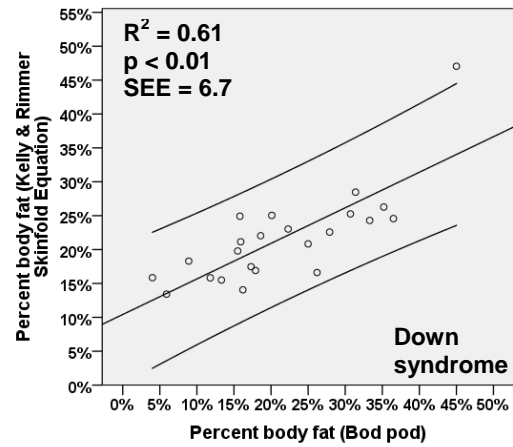
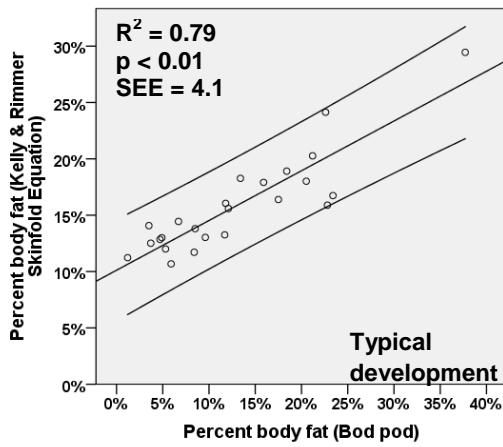


Figure 4.3. Comparing predicted body composition (Kelly & Rimmer, 1987) to criterion body composition (Bod Pod)

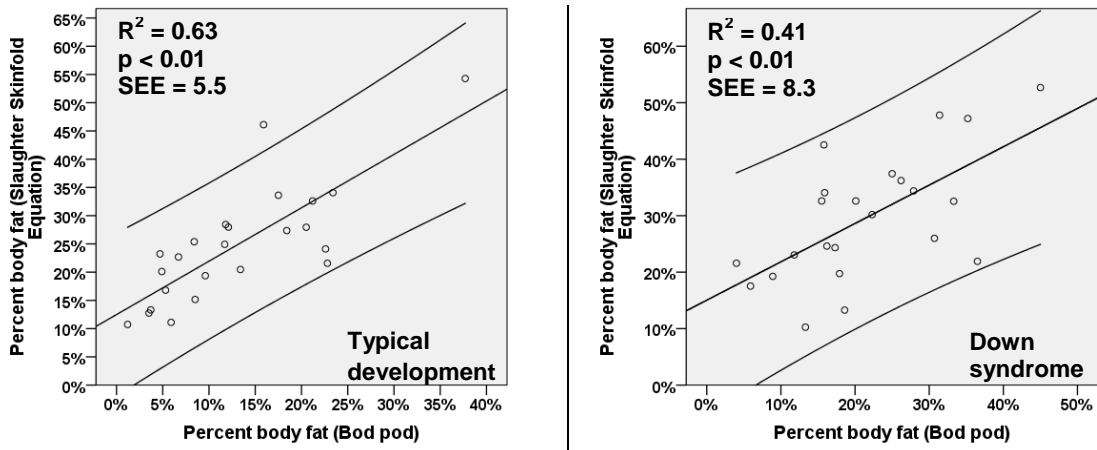


Figure 4.4. Comparing predicted body composition (Slaughter et al., 1988) to criterion body composition (Bod Pod)

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CHAPTER 5

SUMMARY AND CONCLUSIONS

In recent years the promotion of physical activity has become an important health priority. This is evidenced by recent publications and position statements by leading public health authorities outlining recommendations for physical activity as well as highlighting its many health benefits for individuals of all ages (U.S. Department of Health and Human Services, 2008, 2010a), including individuals with disabilities (WHO, 2011). One of these benefits is the role physical activity plays in maintaining a healthy body weight (U.S. Department of Health and Human Services, 2008). With an increased focus on physical activity and its associated health outcomes, there exists a need for valid and reliable tools of measurement.

The purpose of this dissertation was to a) examine the pattern of physical activity in youth with DS, b) examine the validity of the Actical accelerometer for measuring physical activity of youth with Down syndrome (DS), and c) examine the validity of using common skinfold equations used to estimate body fat in a sample of youth with DS.

Based on the results of our first study it appeared youth with DS spent a vast majority of their time in sedentary activities and spent little time in moderate and vigorous activities. Many of these children were already classified as being overweight and obese at a young age. There was also no relationship between

physical activity (sedentary or moderate-to-vigorous) and body composition (BMI and percent body fat). It is with these results in mind we sought to evaluate the validity of our methods of measurement and assessment. Many of the methods used to measure and evaluate physical activity and body composition have been created and validated in healthy populations. These methods often do not consider the unique constraints present in atypical populations.

Given these concerns, two primary research questions appeared to be important if we want to continue to accurately measure physical activity and body composition in the DS population. More importantly, we want our assessments of our measurements to be precise and truly reflect the DS population. The first research question was, are methods of measuring physical activity and body composition valid among youth with DS? Second, does consideration of the unique phenotypic characteristics among individuals with DS greatly improve measurement accuracy?

Accelerometers are commonly used to give researchers the ability to objectively measure a variety of activities with a high amount of precision. Of particular interest to many researchers is the best method to quantify the intensity of an activity and how much time was spent in that activity. These two variables (i.e., intensity and duration) are important areas of study and necessary if researchers and health professionals want to understand the dose-response relationship between physical activity and health. Researchers have calibrated and validated several cut-points and coupled these with physical activity data counts produced by accelerometers to estimate physical activity intensity

(Corder, Brage, Wareham, & Ekelund, 2005; Pfeiffer, et al., 2006; Puyau, et al., 2002). These cut-points serve to provide threshold values to identify various levels of physical activity intensity. However, these cut-points have been established almost exclusively with individuals without disabilities, without consideration for the unique constraints that exist among some populations. In order to have the most precise information, researchers need to consider the unique differences in various populations.

Individuals with DS present with a variety of unique constraints making the measurement and interpretation of physical activity increasingly more difficult. In particular individuals with DS have lower fitness levels compared to their peers without DS (Fernhall, et al., 1996; Fernhall, Tymeson, Millar, & Burkett, 1989; Varela, Sardinha, & Pitetti, 2001). These lower fitness levels can be attributed to lower aerobic capacities and lower maximal heart rates (Fernhall, et al., 1996). In addition, children (neonates through 11 years of age) with DS also have decreased resting metabolic rates (Luke, et al., 1994; Murray & Ryan-Krause, 2010). These decreased metabolic rates result in decreased energy expenditure.

Collectively these factors greatly impact how researchers assign meaning to the data counts produced by accelerometers. In order to make meaningful interpretations of accelerometer data, the cut-point thresholds need to accurately reflect the physical responses associated with the intensity of the physical activity being performed. One purpose of this dissertation was to examine the validity of the Actical accelerometer for measuring physical activity in youth with Down syndrome. To do this, 53 individuals (27 with DS; 26 without DS) aged 9-18

years wore an Actical accelerometer and had their heart rate, expired gases, and oxygen consumption measured while performing a submaximal, graded treadmill protocol. In addition to determining validity of the Actical accelerometer for measuring physical activity in youth with DS, a secondary purpose was to determine if current cut-points used to establish levels of physical activity intensity accurately reflected the actual intensity experienced in a sample of youth with and without Down syndrome.

The Actical accelerometer is a valid device for quantifying both the amount and intensity of physical activity in youth without disabilities (Corder, Ekelund, Steele, Wareham, & Brage, 2008; Pfeiffer, et al., 2006; Puyau, et al., 2004). Results from this dissertation suggest the use of cut-points that have been developed for typically developing children, without DS, result in biased estimates of physical activity intensity. These cut-points fail to consider the unique physiological responses to physical activity found among individuals with DS (Baynard, et al., 2008; Fernhall, 2008; Fernhall & Unnithan, 2002; Millar, et al., 1993; Pitetti, et al., 2000; Pitetti, et al., 2001). Considering these unique characteristics are important and practical issues to be addressed in order to collect and interpret valid and reliable information pertaining to physical activity participation.

Few researchers have tested the validity and calibrated the Actical accelerometer in youth. The first study to calibrate the Actical accelerometer was completed by Puyau and colleagues (2004). This study on healthy children without DS between the ages of 7 and 18 years included unstructured, free-living

activities and some treadmill walking and running. This study created cut-points designed to predict energy expenditure. Cut-points from the Puyau (2004) study were 1500 data counts per minute for moderate activities and 6500 data counts per minute for vigorous activities. Pfeiffer and colleagues (2006) used free-living activities and a portable metabolic system to develop cut-points in pre-school aged children without DS. These cut-points were 2860 and 5644 data counts per minute for moderate and vigorous activity respectively. Another study used 39 healthy children without disabilities and measured energy expenditure in a structured laboratory setting (Corder, et al., 2005). For this study participants completed a graded exercise test on a treadmill. This test required participants to walk on the treadmill for 3.2 km/h at 0% grade and continued walking for 15 minutes as speed and grade gradually increased to 5.8 km/h at 10.2% grade. This study resulted in cut-points to predict energy expenditure. Collectively these studies found data counts produced by the Actical explain between 67-81% of the variance in energy expenditure.

At this time only one study has examined the Actical accelerometer for individuals with DS (Agiovlasitis, Motl, Fahs, et al., 2011). This study examined the relationship between metabolic rate and data counts produced by the Actical accelerometer in adults with DS. This study also examined the differences between individuals with DS and without DS during over ground walking. Results from this study showed adults with DS had an altered relationship between data counts and metabolic rate during over ground walking. The authors noted

activity counts were less predictive of metabolic rate in adults with DS as compared to their peers without DS.

Presently there is no research on the validity of the Actical accelerometer for use in youth with DS. Laboratory data from this dissertation demonstrated when presented with identical workloads, the Actical produced similar data counts for both individuals with and without Down syndrome. These results are encouraging considering the atypical gait patterns of individuals with DS (Agiouvasitis, Motl, Fahs, et al., 2011; Mendonça, Pereira, Morato, & Fernhall, 2010; Smith, et al., 2007). When attaching biological meaning to these data counts, the two groups had similar absolute heart rates. When absolute heart rates were converted to a percent of age predicted maximum heart rates to approximate level of physical activity intensity the groups were similar. Considering and adjusting for the lower maximal heart rates found in the DS population, the DS group was found to be working at a much greater percent of their predicted maximum heart rate.

In addition to the above differences the DS group also exhibited lower $\dot{V}O_2$ values than their peers without DS. When controlling for lean body mass, the DS group demonstrated consistently lower $\dot{V}O_2$'s as compared to their peers without DS. These results are similar to previous research regarding cardiovascular function in youth with DS (Fernhall, et al., 2000; Fernhall & Pitetti, 2000; Fernhall, et al., 1997; Pitetti & Fernhall, 1997). Although the tasks in this study were designed to be submaximal in nature, respiratory exchange ratios (RER) in the DS group were found to be giving near maximal effort (RER values greater than

one) (Howley, Bassett, & Welch, 1995). These results again suggest for an identical workload, the DS participants are exerting themselves more than their peers without DS. These results suggest there are some underlying differences to consider when selecting tools of measurement or at the very least exercising caution when interpreting results. From a practical perspective, individuals with DS appear to exert themselves more to complete the same amount of work as their peers without DS.

The Actical accelerometer is designed to measure accelerations and researchers use these acceleration values to quantify physical activity intensity. The accuracy of the physical activity intensity estimates are influenced by the cut-points selected. A practical issue to consider is if meaningful differences exist between cut-points and physical activity thresholds. When comparing previous cut-points developed for typically developed children to metabolic and heart rate data collected in Chapter two of this dissertation they were found to consistently underestimate physical activity by as much as 12% in light activities and 15% in vigorous activities (Pfeiffer, et al., 2006; Puyau, et al., 2004). It should be recognized absolute cut-points will not perform equally across groups. Individual group cut-points have been created to increase the amount of precision associated with cut-points and their associated levels of physical activity intensity.

Limitations specific to Chapter two are related to the treadmill protocol and its applicability to transfer to additional activities. The biomechanics of movement differ from structured treadmill activities and free-living activities. As a

result, task transfer could be an issue (Freedson, et al., 2005). Selecting a calibration protocol is important in developing and applying threshold values. Accelerometers have been validated and calibrated using continuous, graded walking, treadmill tests (Corder, et al., 2005). Treadmill tests allow researchers to control the pace. This is important since it allows researchers the ability to individualize a protocol or adjust the level of intensity (by altering speed or grade). For this study we deemed a graded treadmill exercise protocol to be the most appropriate to answer our research questions.

While on the treadmill, heart rate was measured. Although heart rate is not a true, direct measure of physical activity intensity, it is a measure of relative stress placed on the cardiovascular system by a given activity (Rowlands & Eston, 2007). Using heart rate as a measure of physical activity is not without its limitations. A number of factors can influence heart rate (fitness, hydration, humidity, room temperature, stress, and anxiety). These factors can particularly influence heart rates at lower levels of activity intensity (Freedson, et al., 1998). In addition, heart rate lag can be problematic but for sustained bouts of activity engagement, heart rate monitoring provides valid and reliable data (Troiano, 2005; Trost, et al., 2002). Specific to individuals with DS, increased body fat could increase cardiovascular stress, resulting in increased heart rates (Rowlands, Eston, & Ingledew, 1999).

An alternative approach to heart rate is the use of indirect calorimetry and free-living activities to determine energy expenditure. Activity counts have been found to be moderately to highly correlated with energy expenditure (Rowlands &

Eston, 2007). Energy expenditure in the DS population can be problematic. Energy expenditure studies would assume individuals with DS expend the same amount of energy for a given activity as their peers without DS. Previous literature suggests children with DS have lower resting metabolic rates (Allison, et al., 1995; Andriolo, El Dib, Ramos, Atallah, & da Silva, 2005; Luke, et al., 1994). Further complicating the relationship between energy expenditure and physical activity is hypothyroidism being present in approximately half of youth and adolescents with DS (Barnhart & Connolly, 2007; Murray & Ryan-Krause, 2010; Roizen & Patterson, 2003). Untreated hypothyroidism places children with DS at-risk for deceleration of growth. It is also a factor in decreased metabolic rate resulting in decreased energy expenditure and increased weight gain. Although one method is not vastly superior to another; understanding these differences are important in selecting a protocol.

This dissertation study represents an initial step in producing quality information regarding physical activity in youth with DS. With very limited research in this area, this study provided strong evidence regarding error inherent in using cut-points without considering the unique features found among individuals with DS. Results from this study will help to improve precision associated with physical activity measurement and allow for interpretations more reflective of the work being performed. This methodology also provides a more solid base for researchers studying physical activity in individuals with DS.

Overall the Actical accelerometer is a valid device for measuring physical activity. However, adjustments are required for the interpretation of the data

produced by these devices. These adjustments need to better reflect the actual physiological responses to activity found in the DS population. Future research should continue to examine these differences and systematically identify impairments and constraints associated with DS. Understanding and controlling for these might allow for more accurate and meaningful interpretation of the data.

The second aim of this dissertation study was to assess the validity of current skinfold equations against a criterion measure. In this study, the criterion measure was air-displacement plethysmography (commercially known as the Bod Pod). The skinfold regression equations were developed by Lohman (1987), Kelly and Rimmer (1988) and Slaughter and colleagues (1988). In our sample, the Kelly and Rimmer (1987) anthropometric skinfold equation performed the best. It had the highest correlation to the criterion measure and it displayed the least amount of error. This particular equation considers some of the unique body proportions found in the DS population such as circumferences at the waist and forearm as well as using height and body mass.

Considering these unique distributions are important. Previous researchers using dual-energy X-ray absorptiometry have found individuals with DS distribute their mass differently from individuals without DS (Baptista, et al., 2005; Guijarro, et al., 2008). Of additional importance is where individuals with DS carry their fat mass. In general, females with DS were found to have greater concentrations of fat mass in their trunk and smaller amounts of fat mass in their lower limbs when compared to female peers without DS (González-Agüero, Ara, et al., 2011a).

Young males with DS were found to have more fat mass in their whole body and upper limbs and decreased amounts of fat mass in their lower limbs (González-Agüero, Ara, et al., 2011a). With these unique distributions in mind, some of the errors from these measures are likely to be caused by individuals with DS distributing their lean and fatty tissue differently than their peers without DS. If individuals with DS are distributing a majority of their fat in their upper body and upper limbs, regression equations need to be sensitive to this and adjust body site specific coefficients accordingly.

For example, in our sample, both the Lohman (1987) and Slaughter et al. (1988) equations were found to be less valid measures of estimating body composition in youth with DS. Although correlation coefficients were statistically significant and moderately high, there was a significant amount of error when compared to the criterion measure (Bod Pod). Looking at each equation individually, the Slaughter et al. (1988) equation uses only two skinfold locations (calf and triceps). Considering how individuals with DS distribute their mass these two sites do not accurately reflect where individuals are carrying their fat mass.

The Lohman (1987) equation performed slightly better than the Slaughter et al. (1988) equation. The Lohman equation utilizes three skinfold locations. In males the locations are the chest, abdomen, and thigh. Locations for females are the triceps, suprailiac, and thigh. These equations provide better estimates of body composition as compared to the Slaughter et al. (1988) equation

because they use more sites and choose sites more representative of where individuals with DS distribute their mass.

The equations by Slaughter and colleagues (1988) and Lohman (1987) demonstrated better validity when applied to individuals without DS. In general they performed well on individuals with DS who were leaner or displayed body proportions more similar to their peers without DS. The one equation specifically developed for adults with intellectual disabilities, including individuals with DS is the Kelly and Rimmer (1987) anthropometric equation. This equation considers this population's reduced stature as well as recognizing this group carries a majority of their mass in their torso and abdomen region.

Although the Kelly and Rimmer (1987) equation was derived in adults it performed well in this sample of youth with DS. One reason for the positive transfer could be young people with DS show increased amounts of body fat in their torso as well as decreased amounts of lean mass in their lower extremities. These distributions of tissue have been previously identified in adults with DS (Baptista, et al., 2005; Guijarro, et al., 2008).

Results from this dissertation study demonstrate a strong need for considering population specific characteristics. This study is consistent with previous research on anthropometric equations and DS (González-Agüero, Ara, et al., 2011a; Usera, et al., 2005). The better performance of the Kelly and Rimmer (1987) equation highlights a need for more population derived methods of measurement. In this instance considering the unique features of this

population yielded a more accurate measurement compared to the criterion measure.

In general our sample of youth with DS was representative of the DS population at large with respect to the percent that are overweight and obese as defined by BMI. The control sample of youth without DS was similar to the population at large with the exception of a few individuals meeting criteria for being 'underweight'. These individuals could have served to exaggerate the differences between the two groups. Additional limitations include difficulty in isolating the differences between methods. Of specific interest is identifying if differences are a function of measurement error, error inherent in the equations themselves, or from sampling. There is likely to be some variability and error due to the prediction equations being derived from populations with known differences in body mass distribution and body proportions uniquely different from those of individuals with DS (Bronks & Parker, 1985; Usera, et al., 2005; Wade, et al., 2000). Skinfolds also require a high degree of tester skill and results can be greatly influenced tester error. Another advantage to the Kelly and Rimmer (1987) method is taking waist and forearm circumferences require less skill than taking skinfolds.

Future calibration studies should focus on regional analyses (trunk, upper and lower limbs) of fat and lean masses using highly accurate DEXA scans. These studies will help us better understand where individuals with DS are distributing their body mass and allow researchers to develop anthropometric measures to more accurately reflect the unique body proportions found in this

population. In addition, researchers and allied health professionals could potentially identify alternative measures other than BMI for assessing cardiovascular risks such as waist circumference (Moreno, et al., 2002)

Summary

Population based surveillance of overweight and obesity status is an important area of public health concern (CDC, 2002, 2009; U.S. Department of Health and Human Services, 2010b; WHO, 2011; World Health Organization, 2003). With increased focus on specific populations designed to better understand specific groups of people there is a need for more specific methods for measuring body composition. There is a need for methods reflective of the populations they are designed to measure. Most epidemiological and public health studies use anthropometric measurements, specifically BMI or other anthropometric measures to estimate body composition. These methods are practical and when used correctly can provide valid estimations of body composition.

A recent CDC publication has noted BMI and some anthropometric measures are not valid measures in certain populations, specifically those with disabilities (CDC, 2011a). The same publication recommends developing newer, more objective methods of measuring body composition. Understanding obesity and having accurate tools to measure obesity is important considering its relationship to chronic health conditions. By developing more precise measures of body composition, specific to certain populations, researchers can gain a more complete understanding of body composition and its relationship to health.

Accurate tools will also improve the design and testing of intervention programs by reducing error inherent in measurement.

One goal of this dissertation was to examine some common skinfold equations used to estimate body composition in youth with DS. It is generally well recognized individuals with DS are shorter in stature and typically overweight (Pitetti & Fernhall, 1997). As a result these individuals have unique body shapes and proportions atypical from most populations and samples from which skinfold equations were derived. It is from this frame work Kelly and Rimmer (1987) developed an anthropometric equation to estimate body fat in adults with intellectual disabilities, including individuals with DS. Results from this dissertation found the population specific Kelly and Rimmer (1987) anthropometric equation provided the best estimates of body fat when compared to other common skinfold equations used in youth without DS.

Although there is likely no universal or perfect method of measurement, researchers and health professionals should consider the unique traits of individuals with DS when considering tools of measurement or assigning value or judgment based on measurements. This study provided some initial steps to considering these unique traits with respect to measuring physical activity and body composition. Additional research is needed to continue to validate and further develop measurement tools for this population.

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