1-1-2016

Objective Assessment of Physical Activity in Adults with Down Syndrome

Jasmine Symone Curtis

Objective assessment of physical activity in adults with Down syndrome

By

Jasmine Symone Curtis

A Thesis
Submitted to the Faculty of
Mississippi State University
in Partial Fulfillment of the Requirements
for the Degree of Master of Science
in Kinesiology
in the Department of Kinesiology

Mississippi State, Mississippi

May 2016

Objective assessment of physical activity in adults with Down syndrome

By

Jasmine Symone Curtis

Approved:

Stamatis Agiovlasitis
(Major Professor)

Ben Abadie
(Committee Member)

Daniel W. Wong
(Committee Member)

Marquell Johnson
(Committee Member)

Adam W. Love
(Graduate Coordinator)

Richard L. Blackbourn
Dean
College of Education

Name: Jasmine Symone Curtis

Date of Degree: May 6, 2016

Institution: Mississippi State University

Major Field: Kinesiology

Major Professor: Stamatis Agiovlasitis

Title of Study: Objective assessment of physical activity in adults with Down syndrome

Pages in Study 39

Candidate for Degree of Master of Science

The purpose of this study was to examine whether cut-points developed for the general population provide different estimates of physical activity (PA) levels in adults with Down syndrome (DS) compared to cut-points developed specifically in adults with DS. This study also attempted to objectively measure the PA levels of adults with DS and to determine if they meet the recommended amount of PA to obtain health benefits. Thirteen adults with DS wore an accelerometer to determine time spent in moderate, vigorous, and moderate-to-vigorous PA. Results indicated that different sets of cut-points responded differently in classifying moderate and vigorous PA levels, as well as in classifying whether participants met the recommended amount of PA for health benefits, as evidenced by the different estimates of moderate-to-vigorous PA in 10 minute bouts. Results also indicated that population specific cut-points should be used for assessment of PA levels in persons with DS.

DEDICATION

I would like to specifically dedicate this body of work to my mother, Virginia Lee, my father, Michael Curtis, and my best friends Phylece Johnson and Chassidy Watson, for their love, support, and prayers throughout this journey. My success would have not been possible without you four people.

ACKNOWLEDGEMENTS

First, I would like to acknowledge my advisor, Dr. Stamatis Agiovlasitis, who saw something in me that I did not see in myself. Thank you for approaching me with this opportunity, guiding me along the way, and pushing me to my highest potential. You are greatly appreciated. Second, I would like to acknowledge my research partner, Benjamin Carlson, for his hard work and efforts towards this project. It was a pleasure to work with you and I wish you all the best in your future endeavors. Third, I would like to acknowledge all my committee members, Dr. Ben Abadie, Dr. Daniel Wong, and Dr. Marquell Johnson, for their support and collaboration with this project. Your knowledge, inputs, and expertise have certainly been beneficial to this process. Fourth, I would like to thank Fabio Bertapelli for his contributions and support. I wish you well in your future endeavors. Lastly, I would like to acknowledge all the participants, and their parents, who took part in making this project happen. It would have not been possible without you.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

Down Syndrome (DS) is the most common form of chromosomal disorder associated with intellectual and developmental disabilities in the United States (Stancliffe et al., 2012). One in every 691 live births results in an infant with DS (National Down Syndrome Society [NDSS], 2012). DS is associated with many health conditions, which may be partially managed with physical activity (PA). However, adults with DS appear to have low PA levels (Draheim, Williams, & McCubbin, 2002; Phillips & Holland, 2011). The PA levels of persons with DS are not fully understood because of methodological issues. Better understanding of the PA levels of persons with DS may lead to more appropriate interventions for improving their health.

Persons with DS can experience several health problems. The most common health problems associated with the condition are congenital heart defects, hearing and vision impairments, depression, orthopedic problems, diabetes mellitus, and increased risk for Alzheimer's disease (Roizen, 2012; Roizen & Patterson, 2003; Stancliffe et al., 2012). In addition, persons with DS have high rates of being overweight and obese (Stancliffe et al., 2012) and extremely low physical fitness and functional capacity levels (Baynard, Pitetti, Guerra, Unnithan, & Fernhall, 2008; Carmeli, Kessel, Bar-Chad, & Merrick, 2004; Horvat, Pitetti, & Croce, 1997). Many of these health conditions that persons with DS face may be alleviated with PA. Some evidence suggests that many adults with DS are not meeting the PA guidelines for improving health (Heller, T. P., Hsieh, K. P., & Rimmer, J. P., 2002; Nordstrom, Hansen, Paus, & Kolset, 2013; Phillips & Holland, 2011). However, this research is not conclusive because there are problems with PA assessments in adults with DS. Therefore, there is a need to better understand the PA levels of adults with DS.

Only few studies on the PA of persons with DS have been conducted, and most have methodological problems limiting the knowledge base on PA in this population. Previous research in persons with DS have used proxy questionnaires to measure PA (Draheim et al., 2002; Heller et al., 2002). Subjective assessments of PA (surveys, questionnaires, or interviews) are not as accurate as objective ones (heart rate monitors, pedometers, accelerometers) (Frey, Stanish, & Temple, 2008; Matthews et al., 2011; Pitetti, Baynard, & Agiovlasitis, 2013; Troiano, et al., 2007). Objective measurement of PA with accelerometers are preferred because these activity monitors are more reliable and accurate than subjective assessments of PA (Welk, G. J., 2002). However, even objective assessment with accelerometers has some methodological problems for adults with DS. Limited past research using accelerometers in adults with DS has assessed their levels of light, moderate, and vigorous activity using intensity cut-points that were developed in persons without DS (Phillips & Holland, 2011). However, some evidence suggests that these cut-points may not be applicable to adults with DS because they may underestimate the intensity of PA (Agiovlasitis et al., 2011; Agiovlasitis, Motl, Foley, & Fernhall, 2012), but this needs to be studied further. Most often, accelerometers are mounted at the hip of participants. Because of participants' intellectual disability, non-compliance is common as some persons with DS may forget to wear the accelerometer

(Esposito et al., 2012; Nordstrom et al., 2013). Furthermore, accelerometers mounted on the hip do not measure PA during upper-body and non-ambulatory activities (Agiovlasitis et al., 2011; Esposito et al., 2012; Nordstrom et al., 2013; Phillips & Holland, 2011). In contrast, wrist-worn accelerometers take into account upper-body movements (Agiovlasitis et al., 2012; Swartz et al., 2000). They may also be worn at all times if they are secured properly. Furthermore, previous research has developed cut-points for activity intensity from wrist accelerometer data specifically for adults with DS (Agiovlasitis et al., 2012). Whether these specific cut-points result in different estimates of moderate, vigorous, and moderate-to-vigorous activity for adults with DS compared to cut-points developed in the general population is not known.

The purpose of this study was to examine whether cut-points developed in the general population provide different estimates of PA levels in adults with DS compared to cut-points developed specifically in adults with DS. We hypothesized that different cut-points would produce different estimates of PA levels. This study also attempted to objectively measure with a wrist accelerometer the PA levels of adults with DS and to determine if they meet the 2008 PA Guidelines for Americans. We hypothesized that adults with DS would have low PA levels and most would not meet the recommended amount of PA.

Therefore, this study examined the following research questions:

Question 1: *Will cut-points developed for adults with DS yield different estimates of their PA than cut-points developed for adults without DS?*

We hypothesized that different cut-points will produce different estimates of PA in those with DS.

Question 2: *What are the PA levels of persons with DS?*

We hypothesized that PA levels of persons with DS are low.

Question 3: *Are adults with DS meeting the recommended amount of PA set forth by PA guidelines?*

We hypothesized that adults with DS are not meeting the recommended amount of PA.

CHAPTER II

REVIEW OF LITERATURE

Down syndrome is one of the most common forms of intellectual disability. This condition affects health to various degrees. Some of the health problems that persons with DS experience may be due to physical inactivity. However, the PA levels of persons with DS are not completely understood because of difficulties with PA assessments. The purpose of this paper is to review what is known about health and PA in persons with DS. Additionally, this review will present the problems that researchers face with PA assessments in persons with DS.

Down syndrome

Definition

Down syndrome is caused by an extra chromosome 21 in a person's DNA. This extra chromosome 21 alters the course of development for the fetus and ultimately causes health-related conditions. Three types of DS have been identified, and medical complications tend to be similar among all three (Roizen, 2012). Trisomy 21, which is the most common of the three, is a result of non-disjunction during meiosis I of cell division; it accounts for 95% of the cases. The other two types of Trisomy 21 are translocation and mosaicism. Translocation occurs when chromosome 21 transfers parts of its chromosome to another chromosome in the cell. Mosaicism occurs when nondisjunction defects some cells of the body, but not all (Roizen, 2012; Roizen & Patterson, 2003).

Prevalence

Resulting from their increased life expectancy, due to improvements in access to medical care and treatment for many of the associated conditions (Atz, et al., 2011; Yang, Rasmussen, & Friedman, 2002), persons with DS are living longer, more satisfying lives. As a result, they are more susceptible to developing age-related health conditions, which can affect their support needs, health care, and lifestyle (Stancliffe et al., 2012). Having a reliable estimate of the number of people in the U.S. living with DS is necessary to effectively conduct meaningful research with this population and to effectively plan medical care and services. Research showed that, in 2008, approximately 250,700 individuals were living with DS in the U.S., which corresponds with the U.S prevalence rate of 8.27 per 10,000 population (Presson et al., 2013). According to the NDSS, the prevalence of DS is similar across all races and economic backgrounds; however, women of increasing maternal age are at a greater risk of having a child diagnosed with DS (NDSS, 2012; Roizen, 2012; Roizen & Patterson, 2003).

Economic Impact

Infants born with DS often face many health conditions such as leukemia, gastrointestinal issues, sensory impairments, celiac disease, and thyroid disease. In addition, more than half of infants born with DS are born with a congenital heart defect. As a result, health care costs are significantly high. In a study conducted by Boulet, Molinari, Grosse, Honein, & Villasenor (2008), the researchers estimated health care use and expenditures from health care insurance claims data of a privately insured population in the U.S. by comparing infants and children 0 to 4 years of age with and without DS. The findings of this study indicate that the mean and median costs for children with DS were $36,384 and $11,164 and $3,037 and $841 for those without DS (Boulet et al., 2008). The average and median incremental (difference between costs for children with and without DS) costs for children with DS were $33,347 and $10,323, respectively (Boulet et al., 2008). The economic impact was 12 to 13 times higher than those without DS. As a result, the cost of health care and expenditures poses economic burdens on the family of the affected child (Boulet et al., 2008).

Health and Down syndrome

Mortality and morbidity

Individuals with DS are shown to have an increased risk for mortality and morbidity (Esbensen, Seltzer, & Greenberg, 2007; Phillips & Holland, 2011; Presson et al., 2013). The increased risk is due to the various health problems that accompany the condition. Associated conditions result naturally from DS and are non-preventable. Secondary conditions are preventable physical and psychosocial health problems that are not inherent in DS.

Studies show that the most common non-preventable associated conditions in DS are congenital heart defects, hearing and vision impairments, hyperthyroidism, and a higher risk of Alzheimer's disease compared to the general population (Roizen, 2012; Roizen & Patterson, 2003; Stancliffe et al., 2012). According to Roizen & Patterson (2003), all children with DS should be assessed for these conditions immediately after birth because of their high prevalence. Alzheimer's disease has been shown to increase at a much higher rate with age in those with DS, compared to those without DS (Stancliffe et al., 2012). This increased rate is due to neuropathological changes that are highly associated with Alzheimer's disease, such as frequent seizures, focal neurological signs, change in personality, apathy, and loss of conversational skills (Roizen & Patterson, 2003).

The most common secondary, preventable conditions are obesity, low fitness levels, diabetes, depression, periodontal disease, and a small number of friendships (Roizen, 2012; Roizen & Patterson, 2003). Some research suggests that the small number of friendships by persons with DS can be attributed to lack of fostered relationships outside of school (D'Haem, 2008; Dyke, Bourke, Llewellyn, & Leonard, 2013). Obesity and low fitness levels have been reported simultaneously in those with DS, which may be related to their lower metabolic rate and physical inactivity. An increase in PA alone will not prevent obesity; however, it can serve as a good starting point and reduce the risk of other major health problems seen in those with DS.

Aging

In studying the aging of the brain, useful techniques such as computed tomography (CT) and magnetic resonance (MR) have been proven useful. Magnetic resonance has confirmed and discovered new age-related changes in the brain, which include atrophy, white matter lesions, and T-2 hypointensity of the basal ganglia, and are now considered components of normal aging (Roth, Sun, Greensite, Lott, & Dietrich, 1996). Features of premature aging have been shown in persons with DS. Due to the associated medical conditions with DS, the need to determine other factors that may play a part in the aging process is necessary.

A study conducted by Roth et al., (1996) compared persons with DS to a control group to determine if MR imaging showed any differences in aging of the brain. The comparison of these two populations was based on the frequency and severity of atrophy, white matter lesions, and T-2 hypointensity of the basal ganglia (Roth et al., 1996). The results of this study showed that persons with DS have an increased prevalence as they age and that the severity of the aging of the brain, with respect to atrophy and white matter lesions, occurs at a much higher magnitude and intensity compared to the age-and-sex matched control subjects (Roth et al., 1996). In addition, researchers discovered that abnormality of T-2 hypointensity of the basal ganglia was often the most detectable of the three markers because it was seen in many of the younger patients. The finding was most likely due to the premature iron deposition (Roth et al., 1996). This evidence is of importance because it demonstrates the ability of the MR technique to identify key markers of aging in the brain related to DS and is seen in conjunction with several other diseases, such as Alzheimer's disease, Parkinson's disease, and multiple sclerosis. Evidence states that Alzheimer's disease is more likely to occur in persons with DS (Stancliffe et al., 2012), and as a result, it is suggested that they show signs of premature aging faster than the general population (Roth et al., 1996).

Physical activity and Down syndrome

Physical activity guidelines for Americans

The *Physical Activity Guidelines for Americans,* of the U.S. Department of Health and Human Services, recommends that a "minimum of 150 minutes a week of moderate-intensity aerobic activity, such as brisk walking, consistently reduces the risk of many chronic diseases and other adverse health outcomes" (U.S. Department of Health and

Human Services, 2008 [USDHHS]). The USDHHS also recommends this amount for persons with disabilities, if they are able, to meet these guidelines as well (USDHHS, 2008). Also, it has been recommended that children and adolescents accumulate 60 minutes or more of PA daily, with most of the time spent doing moderate or vigorous-intensity aerobic PA. Vigorous-intensity PA should be incorporated at least three days a week (USDHHS, 2008).

Few studies have examined the PA levels of those with intellectual disabilities, and those that have been conducted have found that most individuals with intellectual disabilities have low PA levels and are not meeting the recommended amount to meet the PA guidelines, especially among those with DS (Draheim et al., 2002; Heller et al., 2002; Hilgenkamp, Reis, Wijck, & Evenhuis, 2012; Nordstrom et al., 2013; Phillips & Holland, 2011). A study conducted by Phillips & Holland (2011) assessed the PA levels of a large sample of individuals with and without DS, to identify if they meet the PA requirements. The results of this study showed that individuals with intellectual disabilities were not accumulating the recommended amount of PA (Phillips & Holland, 2011). In correspondence to DS, the study found that age-related physiological factors, such as chronotropic incompetence, impaired autoimmune function, low muscular strength, and muscle hypotonia, play a role in the reduced PA levels, which may be due to mitochondrial dysfunction (Phillips & Holland, 2011). Research suggest that these findings may contribute to why this group has lower physical fitness and higher rates of obesity compared to those without DS.

Walking: predominant activity for Down syndrome

A study by Draheim et al. (2002) was conducted to determine the prevalence of PA and the recommended frequency of PA in those with intellectual disabilities living in community settings. One significant finding was the primary means by which persons with DS get PA is through walking, which was reported for both men and women at 54% and 56.8%, respectively (Draheim et. al., 2002). Supporting the findings of Draheim et al., (2002), Heller et al., (2002) found that the most common type of exercise in which adults with DS participated was walking (73% of the participants reported that they performed walking for exercise). Draheim et al. (2002) reports that some studies show adults with intellectual disabilities are less physically active than those without intellectual disabilities; however, those studies did not report the prevalence of recommended PA. In order to relate the risk of a chronic disease to individuals with intellectual disabilities, the prevalence of meeting recommended PA and inactivity needs to be determined in this population. Although walking is their main form of PA, adults with DS may face many factors that contribute to and/or hinder their exercise participation (Heller et al., 2002).

Barriers and facilitators of exercise participation

Heller et al. (2002) used a social-cognitive model of behavioral change to assess the determinants of exercise participation in those with DS, by focusing on the barriers to exercise participation and the attitudes of caregivers' towards exercise outcomes. The results indicated exercise participation in adults with DS were determined by the caregivers' perception of exercise outcomes and access barriers (Heller et al., 2002). The perceived outcome expectations of adults with DS differed in the individual items when compared to the caregivers'. Specifically, those with DS reported more benefits, including feeling good emotionally and looking better (89%), while the benefit reported more often by caregivers' included improving overall health (91%) (Heller et al., 2002). The most commonly reported cognitive-emotional barrier for those with DS and those perceived by the caregivers' were lack of energy (46%) and lack of interest (36%), respectively. (Heller et al., 2002) The most commonly reported access barrier to exercise for those with DS and those perceived by the caregivers' were unavailable transportation (50%) and cost-efficiency (39%), respectively (Heller et al., 2002). Based on a multiple regression analysis, the study found significant predictors of exercise to be the age of the subject, outcome expectations, and access barriers (Heller et al., 2002). Overall, this study showed that individuals with DS have low exercise participation which is influenced by many social-environmental factors.

A similar study conducted by Mahy, Shields, Taylor, & Dodd (2010) aimed to identify facilitators and barriers to PA for adults with DS. The results of this study identified three facilitators of PA for adults with DS: support from others, the perception that PA was fun and had an interesting purpose, and routine and familiarity (Mahy et al., 2010). The key findings of barriers of PA for adults with DS in this study were lack of support, not wanting to engage in PA, and medical and physiological factors (Mahy et al., 2010). Many of the barriers and supports found in this study were similar to those reported in other studies in persons without disabilities (Mahy et al., 2010).

Work from both Heller et al. (2002) and Mahy et al. (2010) suggests the need to identify specific barriers and facilitators to exercise participation in those with DS. According to these researchers, in order to increase PA in this population, the barriers of

PA need to be removed and the facilitators of PA need to be improved. The main finding of both studies were the support people were a key facilitator and barrier to exercise participation (Heller et al., 2002; Mahy et al., 2010). The more knowledgeable and educated the support people are about the health benefits of exercise, specific issues related to intellectual disabilities, and the importance of continued encouragement for those with DS, the more effective the chances of removing specific barriers to exercise.

Physical activity assessments and Down syndrome

Few studies have examined PA of those with intellectual disabilities, particularly in those with DS (Phillips & Holland, 2011). Because DS is one of the most common forms of intellectual disabilities, researchers in this area are interested in the extent of their PA participation, and the effects it has on their condition (Stancliffe et al., 2012; Roizen, 2012). Objectively assessing the PA levels of persons with DS allow researchers to have a better understanding of the relationship between PA and health in this population (Agiovlasitis, Motl, Foley, & Fernhall, 2012). Both subjective and objective measures have been used for PA assessment in the general population; however, objective PA measurements have been reported to be the most accurate measures of PA (Welk, G. J., 2005). The importance of discussing an overview of the subjective measures of PA will give justification as to why objective measures are more accurate in assessing PA.

Subjective measures of physical activity

Subjective measurement of assessing PA includes surveys, questionnaires, and interviews. Due to methodological weaknesses and limitations of the subjective measures, specifically questionnaires and/or proxy reports, the reliability and validity of this type of measure to accurately assess PA is questionable (Shephard, 2003). Research provides evidence of the lack of accuracy of subjective measurements in both persons with and without DS. In a review by Pitetti et al. (2013), the authors criticized the accuracy of the subjective PA assessment through parental or teacher proxy reports among children and adolescents with DS. They argued that training is required for accurate data collection and claimed the reports may not reflect actual behavior, but instead perceived behavior. In addition, when Troiano et al. (2007) conducted a study comparing objective and subjective measures of PA, they found that the objective data was consistent with findings in subjective data; however, certain variables from the objective measures provide a more accurate way of assessing PA. Therefore, more reliable and valid measurements of assessing PA have been implemented.

Objective measures of physical activity

Objective measures of PA have overcome many of the inherent limitations in subjective measures and for this reason they provide a greater advantage when assessing PA. Objective measures include pedometers, heart rate monitors, and accelerometers. Pedometers lack the ability to measure PA in all forms (Hilgenkamp et al., 2012). Although walking is the main form of PA, it is not the only activity in which persons with DS participate (Draheim et al., 2002). The use of accelerometers to assess PA has grown tremendously in the realm of research. This method allows for more feasible, valid, and reliable attainment of PA levels of certain populations (Agiovlasitis et al., 2009; Gomez et al., 2014; Mitchell et al., 2013; Nordstrom et al., 2013; Phillips & Holland, 2011; Pitetti et al., 2013; Troiano et al., 2007; Welk, G. J., 2005).

A study conducted by Agiovlasitis et al. (2012) examined the relationship between energy expenditure and activity count rate between persons with and without DS by wrist accelerometry. The researchers found that wrist accelerometry provided an adequate assessment of energy expenditure in persons with DS (Agiovlasitis et al., 2012). Furthermore, to provide an accurate assessment of PA, the validity of the accelerometer must be calibrated against measures of actual energy expenditure (Agiovlasitis et al., 2012). In a similar study that examined the relationship between energy expenditure and activity count rate by use of accelerometers, the authors found that the relationship between the two variables to be significant in those with DS (Agiovlasitis et al., 2011). The relationship between the two variables suggests that accelerometry-determined cut-points may be different for those with and without DS. Therefore, the need for specific intensity level cut-points for PA assessments in persons with DS is necessary in addressing physical inactivity in this population. Specific cut-points will allow researchers to be more confident in accurately assessing the PA in those with DS. As a result, the PA levels of those with DS can be identified and may lead to better interventions to improve overall health.

Physical activity assessments

Swartz et al. (2000) examined the estimation of energy expenditure by use of Computer Science and Applications (CSA), Inc accelerometers at the wrist and hip. Computer Science and Applications regression equations were developed to predict gross energy expenditure from wrist and hip accelerometer counts. The equations can be used to establish cut-points as well as predict the energy cost of most activities. A review by Matthews (2005) suggests various studies in assessing PA have produced different variations of prediction equations and cut-points to describe moderate and vigorous activity levels for adults and children. Most of the studies presented in the review by Matthews (2005) use the ActiGraph accelerometer to establish prediction equations and cut-points to describe PA levels of the general population. For a better understanding of the methods in determining specific cut-points for different activities, researchers in this study (Matthews, 2005) combined information from other studies and conducted a validation study of PA levels. The compared estimates of the time spent in moderate intensity activity were derived from three sets of cut-points (Matthews, 2005). The results suggests the need for further calibration studies to provide results that can assist researchers in the area of accurately assessing PA levels. The information presented is limited to certain populations, and specific cut-points should be established for PA assessments in that particular population.

Cut-points, physical activity, and Down syndrome

A study conducted by Agiovlasitis et al. (2011) examined whether the relationship of metabolic rate and accelerometer output (worn at the hip) during walking differed in people with and without DS. The results noted a difference in these variables between persons with and without DS. For those without DS, the cut-points for moderate and vigorous intensity were 1054 and 3302 counts per second, respectively. For individuals with DS, the reported values for moderate and vigorous intensity were 396 and 1702 counts per second, respectively. These cut-points were based primarily on walking and could potentially underestimate true values (Agiovlasitis et al., 2010). A similar study by Agiovlasitis et al. (2012) examined the relationship between energy expenditure and activity count rate between individuals with and without DS by use wrist accelerometry.

Based on their established equations, cut-points for moderate and vigorous PA for those with DS were 1,137 and 4,525 counts per min, respectively (Agiovlasitis et al. 2012). In addition, the researchers established cut-points for moderate intensity PA for those without DS to be 1,526 counts per min. Vigorous intensity cut-points could not be established due to MET values that were above the threshold (Agiovlasitis et al., 2012). Results suggest the importance of PA and health in people with DS; however, they also suggest that accelerometry-determined cut-points should not be estimated from PA intensity for people without DS (Agiovlasitis et al., 2012). Therefore, the present cut-points should be viewed with caution and emphasize the importance of examining the relationship between METs and wrist accelerometer output.

Based on results from both studies, the relationship between METs and activity count rates produce a different response in persons with DS when compared to persons without DS. The cut-points presented represent different intensity count rates for moderate and vigorous PA and should be used with caution for PA assessments in those with DS. Nevertheless, the answer is not known if different cut-points from previous research produce different estimates of moderate, vigorous and combined moderate-to-vigorous PA in persons with DS.

Conclusions

Persons with DS face many health problems. Some of these conditions may be due to physical inactivity. Problems in PA assessments do not allow us to state with confidence the PA levels of persons with DS. To better understand the PA levels of persons with DS, accurate assessments of PA must be implemented. The assessments can be improved by establishing specific cut-points for persons with DS. Identifying and establishing these differences in cut-points on PA assessments will allow for better accuracy and ultimately improve the understanding of the relationship between PA and health in persons with DS.

CHAPTER III

METHODOLOGY

Participant Recruitment

Recruitment of participants for this study took place in a rural area of the Southern United States. Participants were recruited through community-based residential and recreational programs, such as the Special Olympics and local group homes, as well as advocacy groups for individuals with disabilities, and contacts from previous research studies. An effort was made to recruit an equal number of men and women for this study. Inclusion criteria for participating in this study were: (a) a diagnosis of DS as confirmed by parent or direct caregiver; (b) being ambulatory without an assistive device; (c) being 18-65 years of age; and (d) ability to understand the testing procedures. Written informed consent was obtained from the participants themselves, as well as from their parents or legally authorized representatives prior to any data collection. The study was approved by the university's Institutional Human Subjects Review Board prior to conducting this research study.

Procedures

Participants attended one testing session which lasted a maximum of 30 minutes. In addition, participants wore an accelerometer for seven days. The testing session was conducted in a place of convenience for all participants. Such places included the residencies of persons with DS and our laboratory.

At the beginning of the session, a parent or primary caregiver of the participant completed a questionnaire on the health history of the participant. The purpose of the health questionnaire was to record the general health status and the PA habits of the participants. Anthropometric variables was measured thereafter. Finally, information was offered to participants and their parents or caregivers about the activity monitor that was to be worn by participants for a week.

Anthropometrics

Height, weight, and waist and hip circumferences of each participant was obtained after the completion of the health questionnaire. Height and weight was measured with the participants' shoes off. Height was measured with a portable stadiometer (Model CE 0123; Seca, Chino, CA) and weight was measured with a portable scale (Model CE 813 Seca, Chino, CA). Participants' body mass index (BMI) was calculated as $weight \cdot height^{-2}$(kg$\cdot m^{-2}$). The waist and hip circumferences were measured over light clothing with a Gulick tape measure. The waist circumference was taken at the narrowest part of the torso above the umbilicus and the hip circumference was taken at the greatest protrusion of the gluteal muscles. This allowed for calculation of the waist-to-hip ratio.

Physical Activity

Physical activity was accessed objectively using a tri-axial accelerometer (GT3X+, ActiGraph LLC, Pensacola, FL, USA). The GT3X+ accelerometer is a commonly used activity monitor in research and clinical practice, and provides objective measurements of human movement in three axes. For this study, we used the accelerometer data only from the vertical axis; this was done because previously-published cut-points for determining the intensity of activity are for vertical axis data. Acceleration data are sampled by a 12 bit analog to digital converter at rates ranging from 30 Hz to 100 Hz (user selectable) and stored in a raw, non-filtered/accumulated format in the units of gravitational acceleration (G's). For this study, we sampled the data at 80Hz, which was what the software suggested as a general sampling rate for data collection. The data are stored directly into non-volatile flash memory. The acceleration data are then converted with an algorithm into units of PA named activity counts. Activity counts are recorded as averages over given time periods known as epochs. We processed the PA data in 1s epochs. Unlike previous models, the GT3X+ is also water resistant and can be worn at all times, even during showering or swimming. Accelerometers are calibrated by the manufacturer, but we also tested for accuracy of the accelerometers before data collection by allowing individuals in the general population to wear them for at least 7 days.

During the single session, the accelerometer was secured on the right wrist of each participant with a hospital band, so that it could not be easily removed. Participants wore the accelerometer for 7 full days at all times. After completion of the seven days, the accelerometer was removed by a parent or primary caregiver, and was returned to researchers either in person or via regular mail.

The data from the accelerometers were then downloaded onto a computer and processed using the ActiLife 6.0 software (ActiGraph, Pensacola, FL). Through data processing, we determined for each participant the time spent in moderate and vigorous PA. We also determined the time in combined moderate-to-vigorous PA accumulated in bouts of 10 min (MVPA-10); this was done to evaluate whether participants met the 2008 PA Guideliness for Americans. Each of these variables were derived using three sets of cut-points, corresponding to moderate and vigorous intensity, respectively: (a) 1,137 and 4,525 counts/min (Agiovlasitis et al., 2012); (b) 1952 and 5725 counts/min (Freedson et al., 1998); and (c) 2020 and 5999 counts/min (Troiano et al., 2008). The cut-points by Agiovlasitis et al., 2012 were developed from wrist accelerometry, specifically for persons with DS. The cut-points developed by Freedson et al., 1998 and Troiano et al., 2008 were derived based on hip placement for the general population. In the present study, we applied these hip cut-points to wrist data by utilizing the "Worn on Wrist" option in the ActiLife 6.0 (ActiGraph, Pensacola, FL) software, that scaled the activity counts to equivalent counts as if they were derived specifically from the wrist placement.

Statistical Analyses

Statistical analyses were performed using SPSS Statistics 23.0 (IBM Corp., Armonk, NY). Statistical significance was determined with an alpha level of 0.05. We used descriptive statistics (means and standard deviations) for demographic and anthropometric variables. To evaluate if the three sets of cut-points responded differently in classifying moderate and vigorous PA levels in adults with DS, we used 3 × 2 (method by intensity) within-subjects Analysis of Variance (ANOVA). When warranted, follow-up one-way repeated-measures ANOVA for each activity level and Bonferroni tests between methods were used to identify differences between the three sets of cut-points. We also used one-way repeated-measures ANOVA and follow-up Bonferroni tests as warranted to examine if the three sets of cut-points differed in their estimates of MVPA-10. Finally, we descriptively evaluated whether the three sets of cut-points performed differently in classifying participants with DS as meeting the 2008 PA Guidelines for Americans. For all ANOVAs, the Greenhouse-Geisser adjustment was applied when the assumption of sphericity was violated as assessed by Mauchly's test.

CHAPTER IV

RESULTS

Participants

A total of 18 adults with DS agreed to participate in the study; however, five individuals did not complete the study for the following reasons: (a) incompliance (n=3); (b) not willing to continue to participate in the study (n=1); and (c) losing the device (n=1). The final sample included 13 adults with DS (8 women and 5 men). The mean age of participants was 31 ± 15 y. The mean weight was 72.5 ± 20.9 kg, mean height 148.7 ± 6.7 cm, mean waist to hip ratio was 0.87 ± 0.09, and mean BMI was 33.3 ± 9.1 $kg \cdot m^{-2}$. Based on BMI, 61.5% of the sample (n = 8) was classified as obese, 30.8% (n = 4) as overweight, and 7.7% (n = 1) as being of normal weight. Nine participants lived with their parents and 4 in group homes.

Comparison between Different Cut-points in PA levels

The three different sets of cut-points responded differently in classifying moderate and vigorous PA levels in adults with DS (Table 1). This was demonstrated by significant method by intensity interaction in the 3 × 2 within-subjects ANOVA ($p = 0.006$). Follow-up one-way repeated-measures ANOVA showed that there were no significant differences in moderate PA levels between the three methods ($p = 0.285$). However, there were differences in how the three methods classified vigorous PA as evidenced by a significant main effect in one-way repeated-measures ANOVA ($p < 0.001$). This main effect was further analyzed with Bonferroni tests which showed that vigorous PA was higher when estimated with the Agiovlasitis et al. equation than both the Freedson and Troiano equations ($p < 0.001$); there were no differences between the Freedson and Troiano methods, both of which estimated zero vigorous PA in participants with DS.

Table 1

Mean ± SD weekly levels of physical activity in adults with Down syndrome as estimated by three different sets of cut-points.

	Method		
	Agiovlasitis	Freedson	Troiano
Moderate PA (min·week^{-1})	1543 ± 267	1459 ± 484	1380 ± 472
Vigorous PA (min·week^{-1})	817 ± 327*	0 ± 0	0 ± 0
MVPA-10 (min·week^{-1})	314 ± 337*	57 ± 70†	47 ± 63
Meeting Guidelines (%)	38.6	15.4	7.7

Note: * = statistically significant difference ($p \leq 0.036$) from each of the other two methods; † = significantly higher than Troiano ($p = 0.02$); MVPA-10 = moderate-to-vigorous physical activity accumulated in bouts of 10 min in duration.

Furthermore, we found that the three methods differed in classifying whether participants with DS met the 2008 PA Guidelines for Americans (Table 1). First, the three methods differed in their estimates of moderate-to-vigorous PA as evidenced by significant main effect for method in one-way repeated-measures ANOVA ($p = 0.011$). Follow-up Bonferroni tests showed that (a) the method by Agiovlasitis et al. produced higher moderate-to-vigorous PA levels than each of the other two methods ($p \leq 0.036$); and (b) the method by Freedson estimated higher levels than that by Troiano ($p = 0.02$).

As a result, the method by Agiovlasitis et al. classified a greater proportion of participants with DS as meeting the 2008 PA Guidelines than the other two methods.

CHAPTER V

DISCUSSION

The purpose of this study was to examine the effect of different accelerometer-based cut-points in objectively assessing PA levels in adults with DS. The main findings were that three sets of cut-points responded differently in estimating PA levels. Population-specific cut-points estimated higher levels of vigorous PA and MVPA-10, but not moderate PA than cut-points for the general population. Furthermore, population specific cut-points estimated higher proportion of the participants with DS as meeting the 2008 PA Guidelines for Americans. Despite the cut-points used, the majority of participants did not meet the Guidelines. These results have implications for assessment and promotion of PA in adults with DS.

Explanations

We found that the three sets of cut-points estimated different levels of vigorous but not moderate PA in adults with DS. The cause of the higher estimate of vigorous PA by the Agiovlasitis et al cut-points compared to the other two equations are likely due to the way each set of cut-points were derived. The Agiovlasitis et al cut-points were developed specifically for adults with DS, whereas those by Freedson et al and Troiano et al were developed for persons without disabilities. Cut-points are developed based on the relationship between the rate of oxygen uptake—a measure of PA intensity—and accelerometer output. However, past research has shown that adults with DS have higher rate of oxygen uptake at a given accelerometer output than adults without DS, resulting in lower cut-points for adults with DS (Agiovlasitis et al., 2012). Noticeably, the Freedson et al. and the Troiano et al. cut-points estimated zero vigorous PA in adults with DS. Although this finding is possible, it is also possible that it might represent error because cut-points for vigorous PA developed for adults without disabilities may not be applicable to adults with DS. Furthermore, Crouter et al., (2006) has reported that previous equations developed from walking tend to underestimate the time spent in vigorous PA. In contrast, the estimation of moderate PA did not differ between the three sets of cut-points. It could therefore be argued that one can confidently estimate combined moderate-to-vigorous PA by applying a moderate intensity cut-point developed for adults without disabilities to those with DS. A different picture, however, arises when we consider PA that meets the requirements of the 2008 PA Guidelines of Americans; namely, MVPA-10 which was higher with the Agiovlasitis et al cut-points compared to the other two methods. Consequently, a greater proportion of participants were classified as meeting the Guidelines with the Agiovlasitis method. This is likely a direct consequence of the fact that the DS-specific cut-point for moderate PA by Agiovlasitis et al. is lower than the other two methods. The present results do not allow us to determine which set of cut-points is the most appropriate. Logically, population-specific cut-points are more relevant, but all existing cut-points should be used with caution. There is a need to improve objective PA assessment with accelerometers in adults with DS.

Notably, the total amounts of moderate PA estimated by all three sets of cut-points and vigorous PA when estimated by the DS-specific cut-points appeared high in comparison to previous research showing low levels of PA in adults with DS (Draheim et al., 2002; Frey, 2004; Phillips & Holland, 2011; Temple, Anderson, & Walkley, 2000). A first possible explanation for this is that the cut-points were developed with accelerometer calibration studies that only used walking. Although walking is the most common form of activity among adults with DS (Draheim et al., 2002; Heller, Hsieh, & Rimmer, 2003), it is still not reflective of the complete spectrum of activities that people perform. A second possible explanation might relate to accelerometer placement. We placed the accelerometer on the right wrist. This was in accordance with the Agiovlasitis et al. calibration study. The studies by Freedson et al and Troiano et al also placed the accelerometer on the right side of the body, but on the hip. For these two sets of cut-points, we applied the "Worn on Wrist" option of the ActiLife software as done in National Health and Nutrition Examination Survey (NHANES). Nevertheless, the right wrist may have been the dominant for most participants. The dominant wrist may be used at high rates for light intensity activities which may be misclassified as moderate by the three prediction methods that only used walking when developing the cut-points.

Implications

Our results have implications for objective PA assessment in adults with DS. They suggest the need to consider population specific cut-points when examining with accelerometers the PA levels of adults with DS. Furthermore, our results indicate the need for accelerometer calibration studies that employ many activities representative of the lifestyle of adults with DS and consider carefully the placement of the accelerometer. Improvements in objective PA assessment for adults with DS are needed.

The present results also have implications for PA promotion. Despite the method used, it appears that the majority of persons with DS do not meet the recommended amount of PA for improving health. Low health promoting PA could partially explain why adults with DS face health disparities (Baynard et al., 2008; Carmeli et al., 2004; Horvat et al., 1997; Roizen, 2012; Roizen & Patterson, 2003; Stancliffe et al., 2012). To promote PA and reduce health disparities, health care professionals should systematically address the barriers and facilitators to PA for adults with DS. Barriers and facilitators to PA may be within the person or within the environment (Agiovlasitis, 2013; Pitetti, Baynard, & Agiovlasitis, 2013). Barriers within the person include health problems, negative attitudes towards PA, and low knowledge on healthy lifestyle (Agiovlasitis, 2013; Heller et al., 2003; Mahy et al., 2010). Possible barriers in the environment include lack of transportation, lack of accessible programs and fitness centers, and lack of knowledgeable physical activity professionals (Agiovlasitis, 2013; Heller et al., 2003). Facilitators within the person include looking and feeling good physically and emotionally, and routine and familiarity (Heller et al., 2003; Mahy et al., 2010). Facilitators within the evironment are support from others, having the opportunity to socialize, and PA programs that are enjoyble and serve an interesting purpose (Heller et al., 2003; Mahy et al., 2010). By addressing these factors, PA professionals may effectively promote PA and improve the health of adults with DS.

Limitations and Strength

This study has some limitations that should be considered. First, the sample size was relatively small, which may limit the generalizability of the findings. Second, several of the participants who volunteered for this study participated in organized PA programs which may not reflect the general population of adults with DS. Third, for the cut-points by Freedson et al. and by Troiano et al., we applied the “Worn on Wrist” option which may have introduced error in estimating PA. However, this approach has been shown to provide meaningful PA data by the NHANES (Troiano et al., 2008). Fourth, the accelerometer was placed on the right wrist. As discussed above, it is possible that such placement may have inflated moderate PA estimates for participants with right hand dominance. It should be considered, however, that we used the placement employed in the calibration studies that developed the cut-points. There are strengths of the present study that should be mentioned. First, the present study is amongst the few that have measured PA objectively with an accelerometer in adults with DS. Second, most participants wore the accelerometer over seven days, likely resulting in a more accurate representation of their PA levels.

Future Research

Future research needs to focus on the development of cut-points based on many activities and placement on the non-dominant wrist for persons with DS. Continued research on the comparison of different cut-points to predict PA for persons with and without DS should be further examined. Cross-validation of the present equations used and cut-points would be beneficial before obtaining a definitive answer as to which method is correct in accurately assessing PA in persons with DS. Furthermore, longitudinal research is needed to examine the PA levels of adults with DS and what factors contribute to them. Finally, interventions for increasing PA in persons with DS should be developed.

Conclusions

In conclusion, different accelerometer cut-points for PA intensity produce different estimates of PA levels in adults with DS. Compared to cut-points for the general population, DS-specific cut-points estimate higher levels of vigorous PA and MVPA-10, and they classify a higher proportion of adults with DS as meeting the PA Guidelines for Americans. Clinicians and researchers should employ existing cut-points with caution when examining the PA levels of this population. There is a need to validate accelerometry as an objective method of PA assessment in adults with DS.

REFERENCES

ActiGraph, LLC. (2014). Retrieved from ActiGraph: http://www.actigraphcorp.com/.

Agiovlasitis, S., McCubbin, J. A., Yun, J., Mpitsos, G., & Pavol, M. J. (2009). Effects of Down syndrome on three-dimensional motion during walking at different speeds. *Gait and Posture, 30*, 345-350.

Agiovlasitis, S., Motl, R. W., Fahs, C. A., Ranadive, S. M., Yan, H., Echols, G. H., . . . Fernhall, B. (2011). Metabolic rate and accelerometer output during walking in people with Down syndrome. *Medicine & Science in Sports & Exercise, 43*(7), 1322-1327. doi:10.1249/MSS.0b013e31820936c4.

Agiovlasitis, S., Motl, R. W., Foley, J. T., & Fernhall, B. (2012). Prediction of energy expenditure from wrist accelerometry in people with and without Down syndrome. *Adapted Physical Activity Quarterly, 29*, 179-190.

Agiovlasitis, S. (2013). Disability: exploring health disparities. In S. P. Brown, *Fundamentals of Kinesiology* (pp. 33-46). Dubuque, IA: Kendal Hunt Publishing Company.

Atz, A. M., Hawkins, J. A., Lu, M., Cohen, M. S., Colan, S. D., Jaggers, J., . . . Minich, L. L. (2011). Surgical management of complete atrioventricular septal defect: Associations with surgical technique, age, and trisomy 21. *Journal of Thoracic and Cardiovascular Surgery, 141*(6), 1371-1379.

Baynard, T., Pitetti, K. H., Guerra, M., Unnithan, V. B., & Fernhall, B. (2008). Age related changes in aerobic capacity in individuals with mental retardation: A 20 yr review. *Medicine & Science in Sports & Exercise*, 1984-1989. doi:10.1249/MSS.0b013e31817fl9al.

Boulet, S. L., Molinari, N.-A., Grosse, S. D., Honein, M. A., & Villasenor, A. C. (2008). Health care expenditures for infants and young children with Down syndrome in a privately insured population. *The Journal of Pediatrics, 153*, 241246. doi:10.1016/j.jpeds.2008.02.046.

Carmeli, E., Kessel, S., Bar-Chad, S., & Merrick, J. (2004). A comparison between older persons with Down syndrome and a control group: Clinical characteristics, functional status and sensorimotor function. *Down Syndrome Research and Practice, 9*(1), 17-24.

Crouter, S. E., Churilla, J., & Bassett Jr, D. (2006). Estimating energy expenditure using accelerometers. *European Journal of Applied Physiology, 98*(6), 601-612.

D'Haem, J. (2008). Special at school but lonely at home: An alternative friendship group for adolescents with Down syndrome. *Down Syndrome Research and Practice, 12*(2), 107-111.

Draheim, C. C., Williams, D. P., & McCubbin, J. A. (2002). Prevalence of physical inactivity and recommended physical activity in community-based adults with mental retardation. *Mental Retardation, 40*(6), 436-444.

Dyke, P., Bourke, J., Llewellyn, G., & Leonard, H. (2013). The experience of mothers of young adults with an intellectual disability transitioning from secondary school to adult life. *Journal of Intellectual & Developmental Disability, 38*(2), 149-162.

Esbensen, A. J., Seltzer, M. M., & Greenberg, J. S. (2007). Factors predicting mortality in midlife adults with and without Down syndrome living with family. *Journal of Intellectual Disability Research, 51*(12), 1039-1050. doi:10.1111/j.1365-2788.2007.01006.x.

Esposito, P. E., MacDonald, M., Hornyak, J. E., & Ulrich, D. A. (2012). Physical activity patterns of youth with Down syndrome. *Intellectual and Developmental Disabilities, 50*(2), 109-119. doi:10.1352/1934-9556-50.2.109.

Freedson, P. S., Melanson, E., & Sirard, J. (1998). Calibration of the computer science and applications, Inc. acceleromterq. *Med Sci Sports Exerc, 30*(5), 777-781.

Frey, G., Stanish, H., & Temple, V. (2008). Physical activity of youth intellectual disability: review and research agenda. *Adapt Phys Activ Q 2008, 25*, 95-117.

Frey, G. (2004). Comparison of physical activity levels between adults with and without mental retardation. *J Phys Act Health, 1*, 235-245.

Gomez, R. I., Gomez, D. M., Acha, A., Veiga, O. L., Villagra, A., & Cueto, M. D. (2014). Objective assessment of sedentary time and physical activity throughout the week in adolescents with Down syndrome. The UP&DOWN study. *Research in Developmental Disabilities, 35*, 482-489. doi:10.1016/j.ridd.2013.11.026.

Heller, T. P., Hsieh, K. P., & Rimmer, J. P. (2002). Barriers and supports for exercise participation among adults with Down syndrome. *Journal of Gerontological Social Work, 38*(1-2), 161-178. doi:10.1300/J083v38n01_03.

Heller, T., Hsieh, K., & Rimmer, J. (2003). Barriers and supports for exercise participation among adults with Down Syndrome. *Journal of Gerontological Social Work, 38*(1-2), 161-178. doi:10.1300/J083v38n01_03

Hilgenkamp, T. I., Reis, D., Wijck, R. v., & Evenhuis, H. M. (2012). Physical activity levels in older adults with intellectual disabilities are extremely low. *Research in Developmental Disabilities, 33*, 477-483. doi:10.1016/j.ridd.2011.10.011.

Horvat, M., Pitetti, K. H., & Croce, R. (1997). Isokinetic torque, average power, and flexion/extension ratios in nondisabled adults and adults with mental retardation. *Journal of Orthopedic and Sports Physical Therapy, 25*(6), 395-399.

Mahy, J., Shields, N., Taylor, N., & Dodd, K. J. (2010). Identifying facilitators and barriers to physical activity for adults with Down syndrome. *Journal of Intellectual Disability Research, 54*(9), 795-805. doi:10.1111/j.13652788.2010.01308.x.

Matthews, C. E. (2005). Calibration of accelerometer output for adults. *Medicine & Science in Sports & Exercise, 37*(11), S512-S522. doi:10.1249/01.mss.0000185659.11982.3d.

Matthews, L., Hankey, C., Penpraze, V., Boyle, S., Macmillan, S., & Miller, S. e. (2011). Agreement of accelerometer and a physical activity questionnaire in adults with intellectual disabilities. *Prev Med 2011, 52*, 361-364.

Mitchell, F., Melville, C., Stalker, K., Matthews, L., McConnachie, A., Murray, H., . . . Mutrie, N. (2013). *Walk well: a randomised controlled trial of a walking intervention for adults with intellectual disabilities: study protocol.* doi:10.1186/1471-2458-13-620.

National Down Syndrome Society . (2012). *Down Syndrome*. Retrieved from National Down Syndrome Society: http://www.ndss.org/Down-Syndrome/.

Nordstrom, M., Hansen, B. H., Paus, B., & Kolset, S. O. (2013). Accelerometer determined physical activity and walking capacity in persons with Down syndrome, Williams syndrome and Prader-Willi syndrome. *Research in Developmental Disabilities, 34*, 4395-4403. doi:10.1016/j.ridd.2013.09.021.

Phillips, A. C., & Holland, A. J. (2011). Assessment of objectively measured physical activity levels in individuals with intellectual disabilities with and without Down's syndrome. *PLoS ONE, 6*(12), 1-7. doi:10.1371.

Pitetti, K., Baynard, T., & Agiovlasitis, S. (2013). Children and adolescents with Down syndrome, physical fitness, and physical activity. *Journal of Sport and Health Science* (2), 47-57. doi:10.1016/j.jshs.2012.10.004.

Presson, A. P., Partyka, G., Jensen, K. M., Devine, O. J., Rasmussen, S. A., McCabe, L. L., & McCabe, E. R. (2013). Current estimate of Down syndrome population prevalence in the United States. *The Journal of Pediatrics, 163*(4), 1163-1168. doi:10.1016/j.jpeds.2013.06.013.

Roizen, N. J. (2012). Down syndrome (Trisomy 21). *Children with disabilities*, 307-318.

Roizen, N. J., & Patterson, D. (2003). Down's syndrome. *The Lancet, 361*(9365), 1281-1289.

Roth, G. M., Sun, B., Greensite, F. S., Lott, I. T., & Dietrich, R. B. (1996). Premature aging in persons with Down syndrome: MR findings. *AJNR Am J Neuroradiol* (17), 1283-1289.

Shephard, R. J. (2003). Limits to the measurement of habitual physical activity by questionnaires. *British Journal of Sports Medicine* (37), 197-206.

Stancliffe, R. J., Lakin, K. C., Larson, S. A., Engler, J., Taub, S., Fortune, J., & Bershadsky, J. (2012). Demographic characteristics, health conditions, and residential service use in adults with Down syndrome in 25 U.S. states. *Intellectual and Developmental Disabilities, 50*(2), 92-108. doi:10.1352/19349556-50.2.92.

Swartz, A. M., Strath, S. J., Bassett JR, D. R., O'Brien, W. L., King, G. A., & Ainsworth, B. E. (2000). Estimation of energy expenditure using CSA accelerometers at hip and wrist sites. *Medicine & Science in Sports & Exercise, 32*(9), S450-S456.

Temple, V., Anderson, C., & Walkley, J. (2000). Physical activity levels of individuals living in a group home. *J Intellect Dev Disabil, 25*, 327-341.

Troiano, R. P., Berrigan, D., Dodd, K. W., Masse, L. C., Tilert, T., & McDowell, M. (2007). Physical activity in the United States measured by accelerometer. *Medicine & Science in Sports & Exercise, 40*(1), 181-188. doi:10.1249/mss.0b013e31815a51b3.

Troiano, R. P., Berrigan, D., Dodd, K. W., Masse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Med. Sci. Sports Exerc, 40*(1), 181-188.

U.S. Department of Health and Human Services, 2008 (USDHHS), (2008). *2008 Physical Activity Guidelines for Americans*. Retrieved from health.gov: http://www.health.gov/paguidelines/guidelines/.

Welk, G. J. (2002). *Use of accelerometry-based activity monitors to assess physical activity.* Physical Activity Assessments for Health Related Research: Champaign, IL: Human Kinetics 2002.

Welk, G. J. (2005). Principles of design and analyses for the calibration of accelerometry-based activity monitors. *Medicine & Science in Sports & Exercise*, S501-S511. doi:10.1249/01.mss.0000185660.38335.de.

Yang, Q., Rasmussen, S. A., & Friedman, J. (2002). Mortality associated with Down's syndrome in the US from 1983 to 1997: a population-based study. *The Lancet, 359*(9311), 1019-1025