THE EFFECT OF TAEKWONDO TRAINING ON STRENGTH AND BALANCE OF YOUNG ADULTS WITH DOWN SYNDROME

by

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(Under the Direction of Michael Horvat)

ABSTRACT

According to the National Down Syndrome Society (NDSS, 2012) 1 in every 691 babies born in the United States is born with Down syndrome (DS). In addition, life expectancy for people with DS has increased dramatically. With advances in medical care the number of individuals with DS living into older adulthood will continue to increase, with typical consequences of aging such as decreased strength and balance becoming more pronounced in this population. Individuals with Down syndrome (DS) are born with lower levels of strength than typically developing (TD) infants as well as having delayed development of balance. The lower levels of strength and balance continues throughout their entire lifespan. This study provided taekwondo training 2 times per week for 10 weeks to 22 young adults with DS as a different method of improving strength and balance. A control group of 22 young adults with DS was used for comparison. Lower body strength was measured utilizing hand held dynamometry (HHD), static balance was measured using the modified Clinical Test for Sensory Integration and Balance (mCTSIB) in the eyes open and eyes closed conditions and dynamic balance was measured utilizing limits of stability (LOS). Lower body strength was significantly improved in the taekwondo group at each assessment over time while the control groups' strength levels remained unchanged. The taekwondo training group did not significantly improve static balance in either eyes open or eyes closed condition or improve dynamic balance ability. The lack of improvement may be due to lack of proper assessment orientation in some of the participants or the intervention was not of significant length to elicit physiological changes. No injuries or adverse incidents occurred due to training which may indicate taekwondo is an activity that is feasible and fun for this population.

INDEX WORDS: Down syndrome, Taekwondo, Martial Arts, Strength, Balance

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CHAPTER 1

INTRODUCTION

According to the National Down Syndrome Society (NDSS, 2012) 1 in every 691 babies born in the United States is born with Down syndrome (DS). From 1979 through 2003, the prevalence of DS births increased by 31.1% (Shin et al., 2009) with currently more than 400,000 people in the United States living with DS (NDSS, 2012). At the same time, life expectancy for people with DS has increased dramatically, from 9 years of age in 1929 (Gonzalez-Aguero et al., 2010) to 25 years of age in 1983, to 60 years old today (NDSS, 2012). With advances in medical care the number of individuals with DS living into later adulthood will continue to increase, with typical consequences of aging such as decreased strength and impaired balance becoming more pronounced in this population at earlier ages than in the typically developing (TD) population. This chapter will provide an introduction to motor development and the development of strength and balance across the lifespan of individuals with DS.

Beginning at birth, limitations in physical and motor functioning are apparent in infants with DS. Biological factors such as growth rate, sensory processing, flexibility, and strength progress over time. Since biological maturation and learning of motor skills go hand in hand mastering of functional skills cannot occur until the physical system is ready to learn. Motor development is sequential with each functional skill learned used again in a slightly different way to achieve something else. Although the rate of motor development may vary from individual to individual the sequence in which skills are developed is the same (Cech & Martin, 2012). Infants with Down Syndrome (DS) follow the same sequences of motor development

(Connolly & Michael, 1986; Sacks & Buckley, 2003; Vicari, 2006) although achievement of these motor milestones may be delayed. Decreased rate of development does not proclude advances in functioning but are characterized by less precision and appear uncoordinated and clumsy (Sacks & Buckley, 2003). Also children with DS require more opportunities to practice so they can develop and improve their motor skills, although these opportunities are not readily available to them. When provided with similar opportunities, it is apparent that children with DS will achieve a level of functional ability that is concurrent with their peer group (Horvat & Croce, 1995; Sacks & Buckley, 2003). For example, a child with DS may learn to run, but the speed will be slower and their gait will be wider than that of a TD child.

The pattern of delays in achieving functional movement in infants and children with DS continues through adolescence and into adult life (Carmeli, Ariav, Bar-Yossef, Levy & Imam, 2012; Carmeli, Kessel, Coleman & Ayalon, 2002; Cioni, Cocilovo & Di Pasquale, 1994; Mendonca, Pereira & Fernhall, 2011). This may be partly due to the development of their adolescent growth spurt at a later age than TD adolescents and ultimately not achieving the same level of strength as their TD peers (Gupta, Rao & Kumaran, 2011). Decreased levels of strength and balance continues to be evident in young adults with DS when compared to TD age matched adults (Pitetti, Climstein, Mays, & Barrett 1992) and older adults with DS continue this pattern (Angelopoulou et al., 2000; Rimmer, Heller, Wang & Valerio, 2004; Tsimaras & Fotiadou, 2004).

As adults with DS age lack of function in strength and balance may lead to declines in functional abilities in a population that is traditionally inactive and generally lower in their physical performance (Horvat & Croce, 1995). These functional declines associated with aging may manifest themselves as decreased mobility, decreased coordination, impaired balance, increased risk of falls, and inability to complete activities of daily living (ADLs) (Carmeli, Bar-Chad, Lenger & Coleman, 2002; Lifshitz, Merrick & Morad, 2008; Maaskant, et al., 1996; Smith & Ulrich, 2008; Temple, Fey & Stanish, 2006). Functional declines have been found to occur at younger ages in adults with intellectual disabilities (ID) when compared to TD adults and occur at even younger ages in adults with DS (Lifshitz et al., 2008; Nakamura & Tanaka, 1998; Smith & Ulrich, 2008; Temple et al., 2006). This indicates that physical activity should be emphasized from early childhood in order to counter this loss of functioning.

Muscular strength is an important component of motor function starting with learning to sit, stand, and support body weight, continuing into walking and running. Muscular strength, especially lower extremity strength of individuals with DS, is of fundamental importance to their overall health and wellbeing (Gupta et al., 2011; Holm, 2008; Horvat, Croce, Roswal & Seagraves, 1995; Pitetti et al., 1992; Winders, 1997). Muscle weakness in adults with DS can impact their ability to perform activities of daily living (ADL) or perform tasks in the work environment (Cowley et al., 2010; Shields, Taylor & Dodd, 2008). In adulthood, individuals with DS typically have jobs that emphasize physical rather than cognitive skills and decreased strength can have a negative impact on their vocational opportunities (Cowley et al., 2010; Horvat, Pitetti & Croce, 1997; Shields & Dodd, 2004; Smail & Horvat, 2009) by compromising how long they can physically stay on the job and perform repetitive activities (Smail & Horvat, 2009) such as stacking boxes or carrying equipment.

A growing body of literature suggests that increasing strength may lead to improvements in functional ability of adults with DS (Shields & Dodd, 2004; Smail & Horvat, 2006) and is an important component when trying to increase independence and self reliance. Children with DS have demonstrated the ability to increase their muscle strength after participation in many physical activities (Horvat & Croce, 1995; Murphy & Carbone 2008; Smail & Horvat, 2009; Smith, Kubo, Black, Holt & Ulrich, 2007). Tsimaras & Fotiadou (2005) showed significant improvements in terms of isokinetic peak torque of the lower extremities in adults with DS after 12 weeks of plyometric exercise three times per week, while Rimmer et al., (2004) showed improvements in lower body strength of adults with DS (mean age 39.4 yrs.) with a programmed resistance training program of the same length and frequency training sessions. This was also supported by Smail & Horvat (2009), Carmeli, Zinger-Vaknin, Morad & Merrick (2005) and Gupta et al., (2011) who reported significant functional changes following strength training. In each study it becomes more apparent that low levels of muscular strength can be improved in individuals with DS.

Another component that is essential for functional development is balance. Balance allows the body to keep its center of gravity over its base of support and is necessary for performance of most activities of daily living (Humphriss, Hall, May & Macleod, 2011. Balance is composed of two components, static and dynamic. Static balance is the ability to sustain the body in stationary equilibrium or within its base of support (DiStefano, Clark & Padua, 2009) while dynamic balance requires the ability to perform a movement task while maintaining a stable position (Ricotti, 2011). In addition, the development of balance considerably influences learning and implementation of new skills and is a reliable predicting factor regarding the development of basic motor skills such as walking, running, and throwing (Tsimaras, Giamouridou, Kokaridas, Sidiropaulou & Patsiaouras, 2012).

Dynamic balance is not only influenced by strength, but also somatosensory (proprioceptive, cutaneous, and joints), visual and vestibular information (Grigg 1994; Nasher, Black & Wall, 1982; Palmieri, Ingersoll, Stone & Krause, 2002; Vuillerme, Marin & Debu,

2001) by requiring individuals to have the ability to integrate sensory, muscular, and neurological systems. A common problem associated with ID is the lack of ability or misuse of sensory information to establish stability and initiate movement (Horvat, Croce & Zagrodnik, 2010; Smail & Horvat, 2006; Tsimaras and Fotiadou, 2004). This may impede their ability to monitor and adjust sensory feedback in order to maintain stability leading to lower dynamic balance.

Static and dynamic balance is important for all individuals to provide a base for movement control and achievement of physical independence (Villamonte et al., 2010). Impairments in balance and postural control may limit a persons' participation in sports and physical activities, and hinder motor skill development and maintenance by increasing risk of falls and decreasing performance of sports skills (Fong & Tsang, 2012). For a population with limitations in motor skill development, balance is a critical element of performance and is generally lower in individuals with DS (Connolly & Michael, 1986; Tsimaras & Fotiadou, 2004).

The lack of balance and postural control limit motor development and may create a greater risk of falls and decreased independence (Carmeli, Bar-chad et al., 2002). As indicated in the development of strength, balance can be improved with training. For example, Smail and Horvat's (2009) research showed increased function and work performance with a strength and balance training program designed to mimic work activities. They were also able to eliminate asymmetries of strength and balance in left and right extremities that compromise overall functioning, (Smail & Horvat, 2009). Recent investigations have also reported significant static and dynamic balance improvements in adults with intellectual disabilities (ID) after a rhythmic gymnastics program (Neofotistou, 2006) and after various exercise programs (Smail & Horvat, 2009; Tsimaras, Angelopoulou, Rsorbatzoudis, Abatzidis & Mandroukas, 2000). All of these activities utilize lower body strength, as well as shifting a participants' body weight beyond their normal limits of stability.

Taekwondo is a sport that primarily utilizes lower body muscle groups and requires participants to actively shift their weight between the lower extremities, reach beyond their limits of stability and also balance on one foot during kicking movements. With the emphasis on precise movements and increased performance, taekwondo utilizes both static and dynamic balance routinely. Training in taekwondo has been able to bring about many physiological benefits for TD individuals including increased lower body muscular strength (Kim, Stebbins, Chai & Song, 2011; Probst, Fletcher & Seelig, 2007; Toskovic, Blessing & Williford, 2004) and balance (Cromwell, Meyers, P.M., Meyers, P.E., Newton, 2007; Douris et al., 2004; Leong, Fu, Ng & Tsang, 2011). In addition, Leong et al., (2011) showed young adults aged 18-30 years who have been training in taekwondo for 1-3 years performed better on static balance tests than age matched sedentary controls. Taekwondo has also been shown to improve strength and balance of TD older adults (Cromwell et al., 2007) and children with developmental coordination disorder (Fong, Tsang & Ng, 2012). Although there are several articles on the effects of taekwondo training on individuals with DS they are all anecdotal. These articles written by taekwondo schools for their websites indicate it is possible that participation in taekwondo training may increase strength, static and dynamic balance in adults with DS. Therefore, the purpose of this study is to determine the effects of taekwondo training on the lower body strength and balance of young adults with DS.

Statement of the Problem

It is apparent that adults with DS have lower levels of strength and balance that may compromise their functional ability. Deficiencies can be improved upon by increased physical activity and/or sports training interventions. Taekwondo has been shown to increase strength and balance in TD individuals but the effect of taekwondo training on individuals with DS has not been explored. This study hypothesizes there will be a significant improvement in lower body strength, static balance and dynamic balance in young adults with DS after a 10 week taekwondo training intervention.

Purpose of the Study

The purpose of this study is to determine if a 10 week taekwondo training program can significantly improve lower body strength, static balance and dynamic balance in young adults with DS. Taekwondo has been used in TD populations and may be a useful training intervention for individuals with DS.

Hypotheses

This study is designed to investigate the effect of a 10 week taekwondo training program on the lower body strength, static and dynamic balance of young adults with DS.

Hypothesis 1: It is hypothesized that lower body muscular strength will significantly increase in young adults with DS following a10 week, twice weekly taekwondo training intervention.

Hypotheses 2: It is hypothesized there will be a significant decrease in the amount of sway over center of pressure (COP) indicating an improvement in static balance in the eyes closed (EC) and eyes open (EO) conditions in young adults with DS following a 10 week, twice weekly taekwondo training intervention.

Hypotheses 3: It is hypothesized there will be an increase in time on target in limits of stability (LOS) indicating an improvement in dynamic balance in young adults with DS following a 10 week, twice weekly taekwondo training intervention.

Justification of the Study

Balance and strength play a part in how well a person interacts with their environment and how well they perform activities of daily living. Increases in either of these parameters have the possibility of improving an individual's quality of life. Establishment of the effect of taekwondo training on these parameters may encourage parents/guardians to enroll their family members with DS in classes that have the ability to improve their level of independence and overall quality of life.

Significance of the Study

Taekwondo is a physical activity that may be beneficial for young adults with DS. Since taekwondo is an individual sport, students' progress at their own pace and learn movements with specific, individualized instructor feedback. For example, all drills can be modified for every student depending on their level of competence with a particular technique being practiced. Belt ranking depends on achieving certain physical skills and mental progression and not on comparison to other students. Despite the individual nature of the sport, students are taught in a group setting with student to student interaction being not only acceptable, but encouraged, providing a chance to interact with peers and develop social relationships. In addition, all students are taught respect for everyone giving students with DS an environment of inclusion despite their differences. The effect of martial arts training on strength and balance has been studied in typically developing populations, but not in populations with DS.

Delimitations

This study will be delimited to:

1. Individuals with Down syndrome who are 21-30 years of age
2. Individuals who are able to understand simple verbal instructions

3. Individuals with DS who have not been participating in other organized sports or physical activities in the past three months
4. Individuals with no martial arts training within the past two years
5. Individuals who are not currently taking any medication that could affect their physiological responses to exercise
6. Individuals who are free of neurologic, orthopedic (including atlantoaxial instability), or cardiovascular problems likely to prevent them from successfully participating in a taekwondo training program.

Limitations

The following are limitations to this study:

1. Findings from this study will only be generalizable to adult individuals with DS.
2. Findings from this study will only be generalizable to studies utilizing martial arts as a training intervention.

Definition of Terms

Balance, dynamic – ability to perform a task while maintaining a stable position (Ricotti, 2011)

Balance, static – body's ability to keep its center of gravity over its base of support (DiStefano et al., 2009; Humphriss et al., 2011)

Break test – examiner holding a dynamometer and exerting force against the participants limb segment until the participant's effort is overcome, and the limb segment gives or breaks. (Horvat, Block & Kelly, 2007, p. 114).

Fixation - firmness or stability of the body or body part, which is necessary to insure an accurate test of a muscle or muscle group (Kendall, McCreary, Provance, Rodgers & Romani, 2005, pg. 14)

Hypotonia – abnormally low intrinsic resting tension (i.e., low tone in muscles) (Taber's Cyclopedic Medical Dictionary, 2009)

Intellectual Disability – disability characterized by significant limitations both in intellectual functioning and in adaptive behavior as expressed in conceptual, social, and practical adaptive skills with onset before age 18. (American Association of Intellectual and Developmental Disabilities, 2002).

Isokinetic – moving at a constant rate of speed (Powers & Howley, 2012, p. 473).

Isometric – increase in tension without change in muscle length (Kendall, McCreary, Provance, Rodgers & Romani, 2005, p. G-2

Make test - involves the examiner holding the dynamometer stationary while the participant exerts a maximum effort against the device (Horvat, Block & Kelly, 2007, p. 114).

Motor Development – change in motor behavior experienced over time (Cech & Martin, 2012)

Percent on Time Target - percent of time the participant is within the target zone (CSMi HUMAC Balance System User's Guide, 2012)

Stability index - average difference between the participants' angle and a vertical position (CSMi HUMAC Balance System User's Guide, 2012)

CHAPTER II

LITERATURE REVIEW

Down syndrome (DS) is a genetic condition that affects the development of 1 in every 691 infants born in the United States (National Down Syndrome Society, 2012). These individuals commonly exhibit physical and developmental limitations, such as hypotonia and short stature that contribute to delays in motor development and achievement of typical motor patterns. Physical characteristics include hypotonia, ligament laxity, and lower levels of strength that is present at birth and continues throughout the lifespan (NDSS, 2012). Further, the presence of lower levels of lower body strength compromise the ability to develop a sufficient level of stability and balance that remain at levels lower than typically developing (TD) individuals and contributes to lower levels of functional ability (Gupta et al., 2011).

This chapter examines the relevant literature related to the development of muscular strength and balance abilities of individuals with DS, as well as methodology utilized in the research, and training programs that have been implemented to improve functions in these individuals. This chapter will also review literature in regards to martial arts, specifically taekwondo, and its effect on strength and balance of TD individuals and individuals with DS. The following categories will be outlined: muscular strength of individuals with DS, measurement methodologies used including reliability and validity with TD and DS populations, training programs utilized and results achieved, individuals with DS ability to balance both statically and dynamically compared to TD peers, measurement methodologies for static and dynamic balance, training programs utilized to improve balance and results achieved with these training methods, and finally, martial arts training effect on TD individuals as well as individuals with DS.

Muscular Strength of Individuals with Down Syndrome

The development of muscular strength in individuals with intellectual disability (ID) is lower when compared to TD peers. Individuals with ID due to DS demonstrate lower strength levels than individuals with other forms of ID as well as TD individuals and these levels remain lower at all stages of life (Angelopoulou et al., 2000; Carmeli & Kessel et al. 2002; Cioni et al., 1994; Cowley et al., 2011; Gupta et al., 2011; Horvat & Croce, 1995; Shields, Dodd & Abblitt, 2009). The following section will review strength levels of individuals with DS in comparison to other individuals with and without intellectual disability (ID). In addition, the various training methods that were used to increase muscular strength of individuals with DS will be reported.

Assessment of Strength. Several methods of assessment have been used to quantify strength in individuals with ID. These measures include isometric (hand held dynamometry, HHD), isokinetic (cybex or biodex machines), one repetition maximal lift (1 RM), and field tests.

HHD consists of a small device equipped with an internal transducer that measures muscular force at a particular muscle length (Verschuren, et al. 2008) and is held in one hand by a researcher. The MicroFet2 is a common brand of HHD whose accuracy has been tested by Hoggan Health Systems and is stated to be accurate within 2%. Horvat and colleagues (Horvat & Croce, 1995; Horvat, Croce & Roswal, 1993) investigated several aspects of assessing strength of individuals with ID utilizing HHD. Magnitude and reliability were assessed across 3 and 6 trials on dominant and nondominant flexor and extensor muscle groups in 17 individuals with ID. Intraclass correlations ranged from 0.96 to 0.98 for six and three trials respectively. This indicates individuals with ID can achieve sufficient magnitude of strength to ensure reliability with three trials (Horvat & Croce, 1995; Horvat et al., 1993). Test-retest intraclass correlation coefficients of 0.83 to 0.86 (Horvat, Croce & Roswal, 1994) indicate HHD is reliable and appropriate for documenting isometric muscular strength in individuals with ID (Horvat & Croce, 1995; Wuang, Chang, Wang & Lin, 2013).

HHD has been used in a multitude of studies to assess isometric strength. Equipment is portable, tests are simple to perform and reproduce, and test conditions (participant's posture, joint positions, etc.) are well defined. Other studies have found similar test-retest results of lower extremity strength values being obtained during single sessions (Pitetti, Climstein, Mays & Barrett, 1992; Wang, Olson & Protas, 2002) and multiple sessions performed over two days (Angelopoulou, Tsimaras, Christoulas, Kokaridas & Mandroukas, 1999; Cioni et al., 1994; Horvat, Croce & Roswal, 1993). HHD have been shown to be both statistically reliable and valid under various conditions with many populations including individuals with cerebral palsy (Verschuren et al., 2008), Huntington's disease (Busse, Hughes, Wiles & Rosser, 2008), and individuals with ID (Croce & Horvat, 1992; Gupta et al., 2011; Horvat & Croce, 1995; Seagraves, Horvat, Franklin & Jones, 2004; Suomi, Surburg & Lecius, 1993). Intertester reliability of HHD with individuals with ID has also been found to be reliable (Croce & Horvat, 1992).

In contrast, isokinetic measurement is laboratory based and used to measure muscular force generated throughout a controlled movement at a set speed. This allows measurement of muscle strength through a specified range of motion. Since the majority of activities of daily living (ADLs) utilize a full or partial range of motion, isokinetic measurements are considered advantageous over isometric measurements (Verschuren et al., 2008). However, isokinetic equipment must be set up in a permanent location with participants being transported to that location. They must be secured into position per manufacturer's instructions with set joint angles and then participants must move through specific motions at preset speeds of contraction. Isokinetic testing equipment (Cybex and Biodex) have been used successfully with individuals with ID and individuals with DS (Carmeli, Bar-chad et al, 2002; Carmeli, Kessel et al., 2002; Carmeli, Zinger-Vaknin 2005; Cowley et al., 2011; Horvat, Croce, Pitetti & Fernhall, 1999; Horvat, Pitetti & Croce, 1997; Pitetti et al., 1992; Suomi et al., 1993; Tsimaras & Fontiadou, 2004). Two or three trials completed at each joint angle and movement speed appear to produce data with the best effort from participants (Carmeli, Bar-chad et al., 2002; Carmeli, Kessel et al., 2002; Carmeli et al., 2005; Cowley et al., 2011; Tsimaras & Fontiadou, 2004).

Other field methods used to measure strength in TD individuals, individuals with ID and individuals with DS are the chair stand test (Terblanche & Boer, 2012), sit up and push up tests (Guidetti, Franciosi, Gallotta, Emerenziani & Baldari, 2010), 1 RM utilizing leg press (Rimmer et al., 2004; Shields et al., 2008; Toskovic et al., 2004), 12 RM utilizing leg and chest press, leg extension and lower back extension (Mendonca et al., 2011). All of these testing methods have been validated on many populations of varying ages and health status but their use has not been validated in individuals with DS.

Lower Muscular Strength of Individuals with DS. Individuals with DS demonstrate lower levels of strength than TD individuals and also demonstrate lower levels of strength than individuals with other forms of ID at all stages of life (Angelopoulou et al., 2000; Carmeli, Bar-chad et al. 2002; Cioni et al., 1994; Cowley et al., 2011; Gupta et al., 2011; Horvat & Croce, 1995; Shields et al., 2009). Pitetti, Baynard & Agiovlasitis (2012) stated for individuals with DS it is apparent that lower extremity strength may be a limiting factor in both work performance and aerobic capacity. Gupta et al., (2011) stated the male adolescent growth spurt that normally occurs by 14 years of age for TD adolescents occurs later for individuals with DS and they do not demonstrate a physiological increase in muscle strength as part of this growth spurt placing their strength levels further behind their age matched peers (Cioni et al., 2001).

Stemmons-Mercer & Lewis, (2001) used HHD to measure peak isometric force of right hip abductor and right knee extensor muscles in 17 children with DS ages 7-15 years and compared them to 17 age matched TD children. Children with DS produced lower values on all measurements compared to age matched controls for both right hip abduction ($t= -3.21$; $df=32$; $p<0.025$) and right knee extension ($t=-4.79$; $df=32$; $p<0.025$).

Also utilizing HHD Seagraves et al., (2004) measured peak-isometric strength on elbow flexion, elbow extension and shoulder abduction on individuals with DS ages 14-18 years. The treatment group participated in a resistance training program 2 times/week for 10 weeks, while a control group participated in group and individual games. The author noted a 24.3% and 25.7% increase in upper left and upper right sides of the body, respectively.

Mendonca et al., (2010) compared muscular strength of 25 individuals with DS (age 36.5±5.5 years) to strength of 12 TD individuals (age 38.7±8.3 years) utilizing 12 RM protocol for leg press and leg extension. Participants with DS showed lower muscular strength than TD individuals in all exercises (group main effect, $F=15.3$; $p<.05$).

Looking at isokinetic equipment, Carmeli et al., (2012) compared leg strength of young adults with DS (means age 30.0±4.5 years) to older adults with DS (mean age 57.3±3.4 years) and two control groups of age matched TD individuals (mean age 32.0±3.2 years and 55.0±4.2 years). They found individuals with DS were consistently lower in leg strength than their TD peers and older individuals with DS were lower in leg strength than their age matched peers as well as young adults with DS.

In an earlier study Pitetti et al., (1992) found similar results measuring isokinetic leg strength. This study utilized a Cybex II to measure knee extension and knee flexion strength in adults with DS, adults with ID nonDS related, and TD adults (18 in each group). The authors concluded that individuals with DS were not only deficient in their lower body strength compared to TD individuals', they were also lower in leg strength than individuals with ID nonDS.

Similar results were reported by Angelopoulou et al., (1999) who assessed peak isokinetic knee muscle strength at 60°, 120° and 300°/s for 7 adolescents with DS (mean age 19 ±4), 8 adolescents with ID not related to DS (mean age 20.3±2.4), and 12 sedentary TD individuals (mean age 23.9±5.7) were compared. Similar to earlier research, sedentary adults produced higher strength values than either individuals with ID or individuals with DS for hamstring and quadriceps strength.

In addition, Cioni et al., (1994) compared isokinetic strength of both knee extensor muscles at 30°/s. Participants were 25 children and adolescents with DS, 40 TD individuals, and 30 individuals with ID of unknown origin. Results indicated that both children and adolescents with DS performed at lower levels than the TD control group and the group with ID nonDS.

Carmeli et al., (2002) measured dynamic torque of knee extensors and knee flexors utilizing Biodex dynamometer on 9 subjects with DS (mean age 61 years) and 16 subjects with ID without DS (mean age 63 years). Results indicated in knee extension and knee flexion isokinetic power for the ID non DS group showed significantly higher scores than the DS group ($p<0.01$). This study indicates decreased levels of strength in individuals with DS continues through older age groups. As individuals with DS live longer lower strength levels may lead to decreased functional ability, decreased independence and lower quality of life.

Angelopoulou et al., (2000) tested 8 individuals with DS ages (23.9±4.2 years), 8 individuals with intellectual disabilities nonDS related (ages 23.5±3.6 years) and 10 healthy sedentary university students (ages 25.9±2.9 years) on the Cybex II to measure isokinetic muscular strength of the right quadriceps and right hamstring muscles. Combining the two groups with ID there was a significant difference when the combined groups were compared with the TD student group. The ID nonDS group was stronger in the quadriceps at 300°/s ($p<0.01$), in quadriceps at 120° and 60°/s ($p<0.05$) and hamstrings at 300°/s ($p<0.05$) than the DS group. These studies indicate the lower level of muscle strength in individuals with DS continues into young adulthood.

Many functional and work related tasks individuals with DS perform require upper body strength which was the focus of studies by Horvat and colleagues. Horvat et al., (1997) measured upper body strength utilizing the Cybex 340. Isokinetic torque, average power, and elbow flexion/extension ratios were obtained for a control group of 13 TD individuals (mean age 24.2±3.4 years), 13 individuals with ID non DS related (mean age 24.1±3.6 years), and 9 individuals with DS (mean age 25.9±4.3 years). Individuals in the TD group displayed significantly greater isokinetic peak torque ($p<0.01$) and average power for elbow flexion and extension than individuals with ID non DS and DS groups at speeds of 60° and 90°/s. The DS and ID non DS groups were similar to each other on all measures.

Smail & Horvat, (2006) measured knee flexion and extension of ten high school students with mild ID prior to participating in a strength training program 3 times per week for 12 weeks. Individuals were randomly assigned to a treatment or control groups. Measurements were taken pretraining, at midpoint (6 weeks), and post training (12 weeks), and again after a retention period (18 weeks). Significant differences were evident for treatment group in dominant lower body, $F(1,4)=8.74$, $p<.02$; and nondominant lower body $F(1,4)=8.73$, $p<.02$.

It is evident from the above research that TD individuals have greater upper body strength than individuals with ID nonDS, and individuals with DS while individuals with DS and those with ID non DS have similar upper body strength levels. When lower body strength is measured results are highest for TD individuals, followed by individuals with ID without DS, and individuals with DS having the lowest level of lower body strength.

Training Individuals with DS to Increase Muscle Strength. Although muscular strength is diminished, individuals with DS have demonstrated the ability to increase muscle strength and work capacity after participation in physical exercise (Horvat & Croce, 1995; Murphy & Carbone, 2008; Smail & Horvat, 2009; Smith et al., 2007). The majority of research reviewed utilized progressive resistance training (PRT) to increase strength in individuals with DS, but other training protocols used include plyometric exercises (Tsimaras & Fotiadou, 2004), treadmill walking (Carmeli, Bar-chad et al., 2002), and sport specific training (Guidetti et al., 2010).

Progressive resistance training protocols varied in number of days per week and number of weeks of training. Several studies reported training two times per week while others utilized three workouts per week (Carmeli et al., 2005; Gupta et al., 2011; Rimmer et al., 2004; Smail & Horvat, 2009). In other types of studies, Tsimaras & Fotiadou (2004) performed plyometric training 3 times per week, Carmeli et al., (2005) had participants walk on a treadmill 3 times per week, and Guidetti et al., (2010) practiced specific sports (basketball, track and field) 3 times per week.

Length of training protocols for PRT varied from 6 weeks (Gupta et al., 2011) to 6 months (Carmeli et al., 2005). Majority of resistance studies were 10 weeks (Cowley et al., 2011; Seagraves et al., 2004; Shields et al., 2008) or 12 weeks in length (Mendonca et al., 2011; Rimmer et al., 2004; Smail & Horvat, 2009). Tismaras & Fotiadou (2004) conducted plyometric training for 12 weeks, Carmeli et al., (2005) trained on a treadmill for 25 weeks, and Guidetti et al., (2010) conducted sport specific practice for 9 months.

A variety of exercises were used during progressive resistance training. Smail & Horvat (2009) performed heel raises, sit ups, squats, lunges and leg extensions. Cowley et al., (2011), Shields et al., (2008), and Rimmer et al., (2004) performed leg press with Cowley et al., (2011) and Shields et al., (2007) also performing leg extensions and Rimmer et al., (2004) performing leg curls. All studies indicated an improvement in strength except Shields et al., (2008) who found no significant change in lower body strength performing seated leg press, knee extension and seated calf raise.

Each participant completed 2 sets of 10 repetitions (reps) with weights increased when 10 reps could be completed without fatigue. Gupta et al., (2011) examined the effect of PRT on 12 children with DS ages 7-15 years. A control group of 11 children with DS continued with their normal activities. A HHD was used to measure hip flexors, hip extensors, hip abductors, knee flexors, knee extensors, and ankle plantar flexors bilaterally. A 6 week PRT program was held 3 times per week for 6 weeks based on an individuals’ 1 repetition maximum lift (1 RM). All participants in the intervention group successfully completed the exercise program. Strength measurements for all muscles tested increased in the intervention group with no change in the control group ($p<0.05$).

Smail & Horvat, (2009) utilized a PRT program with individuals with ID ages 15-19 years, 3 times per week for 12 weeks. Strength of the dominant side of the lower body increased 12% ($p=.037$) and nondominant lower body strength increased 15% ($p=.037$) between training weeks 0 and 6. Strength continued to increase from 6 weeks to 12 weeks of the study with dominant lower body increasing 20%, ($p=.006$) and nondominant lower body strength increasing 28% ($p=.003$).

Shields et al., (2008) completed a study where young adults with DS (mean age 26.8±7.8 years) participated in a PRT program 2 times/week for 10 weeks. No significant difference was found between the control group which received no exercise intervention and the progressive resistance training group (Shields, et al., 2008). The authors felt it could have been the training program did not have sufficient frequency or intensity to elicit improvements.

Utilizing a different method, Tsimaras and Fotiadou (2004) used physical training including plyometric exercises such as the two foot ankle hop, single foot side to side ankle hop, tuck jump with knees up, etc. with 15 men with DS (24.5 ±3.9 yrs.) in a intervention group. Ten individuals with DS (mean age 24.7±2.7) served as a control group and continued with their normal daily activity. Peak torque was measured on all individuals on the anterior and posterior femoral muscles utilizing a Cybex II. Isokinetic endurance of quadriceps muscles was measured after 25 repeated maximum efforts at an angular velocity of 180°/second and was defined by the percentage of decline from the peak torque. The intervention group participated in 12 weeks of training, 3 times/week for 30-35 minutes each session. No individual in the intervention group was absent for more than 2 days. Significant improvements were made in peak torque of both anterior (300, 180, 120°/s; $p<0.001$; 60°/s; $p<0.01$) and posterior (300, 180, 120, 60°/s; $p<0.01$) femoral muscles and isokinetic endurance of anterior femoral muscles at angular velocity 180°/s (p<0.01) by the intervention group with no change in the control group. This study indicates individuals with DS can improve muscular strength participating in an exercise program that does not utilize weight or strength training equipment.

Cowley et al., (2011) tested 30 individuals with DS (ages 27-29 years) for bilateral isometric and isokinetic knee extensor and knee flexor strength on the Biodex System 3 dynamometer at joint angles of 45°, 60°, and 75°. Nineteen of these individuals were placed in an intervention group which participated in progressive resistance training 2 times per week for 10 weeks while 11 individuals were assigned to a control group which continued to do their normal daily activities. Strength training consisted of 3 sets of 8-10 reps on leg extension, knee flexion, and leg press. Isometric strength of the intervention group improved in measures for absolute change in knee extensor peak torque at joint angles of 45° (p=0.01), 60° (p=0.00) and 75° (p=0.00) when compared to the control group. Measures for knee flexor peak torque at 45° (p=.87), 60° (p=0.93), and 75° (p=0.79) were not significantly different from the control group.

Mendonca et al., (2011) combined aerobic training 3 days per week for 30 minutes at 65%-85% peak oxygen consumption and resistance training 2 days per week, 2 sets of 12 reps for each exercise. Thirteen individuals with DS (mean age 36.5±5.5 years) and 12 TD individuals (mean age 38.7±8.3 years) were measured pre-exercise and after 12 weeks of training. Although participants with DS improved their muscle strength (p<.05) the level of improvement was similar to improvement made by the TD participants (F=15.3, p<.05). Therefore, muscle strength for individuals with DS was lower than TD individuals and remained lower even though their overall strength improved.

In a study with a similar age group, Rimmer et al., (2004) implemented a PRT with 30 individuals with DS (mean age 38.6±6.2 years) 3 days/week for 12 weeks while 22 individuals with DS (mean age 40.6±6.5 years) continued with their normal activities and served as controls. Strength was assessed utilizing seated leg press machines to determine 1 RM. Participants performed 30-45 minutes of cardiovascular (CV) training and 15-20 minutes of strength training 3 times/week for 12 weeks. The PRT group improved in strength ($p<.0001$) as compared to the control group.

Carmeli et al., (2005) assigned older adults with ID (ages 54-66 years) to a general exercise program or a progressive resistance program progressive resistance training 3 days per week for 45 minutes. The general exercise group had improvement in knee muscle strength only while the PRT group significantly improved all strength measures. This study indicates individuals with ID can improve strength by exercising, but that specific strength training can improve strength to a larger degree.

Taken together these studies indicate adults with DS are able to increase muscular strength. This increase in muscle strength may lead to increases in functional capacity and possibly increase their employability. Work tasks for individuals with DS tend to be more physical in nature and maintaining or increasing muscle strength will assist in keeping individuals integrated into community work environments. Increased strength may also allow individuals with DS to remain independent by maintaining performance of ADLs.

Balance Ability of Individuals with Down Syndrome

Balance is defined as the ability of the body to maintain its center of gravity (COG) within its limits of stability (LOS) as determined by the base of support (Palmieri et al., 2002). Balance is an essential prerequisite to performance of most activities of daily living (ADLs) (Humphriss et al., 2011) and can be categorized as either static or dynamic balance. Static balance is the ability to sustain the body in stationary equilibrium (DiStefano et al., 2009) and is important for posture and upright motions. Dynamic balance requires the ability to perform a movement task while maintaining a stable position (Ricotti, 2011). Both static and dynamic balance requires integration of visual, vestibular and proprioceptive input as well as adequate lower body strength (Grigg, 1994; Nasher et al., 1982; Palmieri et al., 2002). Development of balance can influence learning and implementation of new motor skills and is a reliable predicting factor regarding the development of basic motor skills such as walking, running, and throwing (Tsimaras et al., 2012). Static and dynamic balance are also important for the development of functional tasks such as walking upstairs, lifting objects and the ability to participate in recreation, exercise, social activities and independent living (Villamonte et al., 2010). Individuals with DS have a significant delay in balance and motor skill development (Connolly & Michael, 1986; Spano et al., 1999; Villamonte et al., 2010; Wang & Huei, 2002). They tend to rank lower on balance performance than TD individuals or individuals with ID that is nonDS related (Connolly & Michael, 1986; Tsimaras & Fontiadou, 2004).

The following section will discuss methods used to measure both static and dynamic balance, reliability and validity of these methods with the DS population, review levels of balance in individuals with DS compared to TD individuals and individuals with ID nonDS related, and discuss training methods utilized in various studies in attempts to increase balance of individuals with DS.

Assessment of Balance. Methods utilized in measuring static balance include Bruininks Oseretsky Test of Motor Proficiency (BOTMP), Berg Balance Scale (BBS), Flamingo Balance Assessment (FBA), Single Leg Stance (SLS), Balance Error Scoring System (BESS), and modified Clinical Test of Sensory Integration and Balance (mCTSIB). BOTMP is an individually administered norm-referenced test that assesses motor functioning of children 4 to

21 years of age (Horvat et al., 2006). Balance is one of 8 subsets of assessments made up of 9 items including walking forward on a line, standing on one foot on the floor and standing on one foot on a balance beam. Reliability for test scores has been established through studies on interrater reliability (r=.9-.98) and test-retest reliability (r=.86-.89) (Bruininks, 1978). BOTMP has been used successfully with children with DS (Connolly & Michael, 1986; Gupta et al., 2011; Wang & Huei, 2002)

Berg Balance Scale is a performance based measure of balance consisting of 14 observational tasks (Enkelaar, Smulders, Lantman-de Walk, Geurts & Weerdesteyn, 2013). Items are scored as 0-4 with 0 representing an inability to perform the task and 4 as being able to complete the tasks without deviations. Tasks include standing, turning around 360º, and picking up an object from the ground. Reliability and validity have been established with several populations including healthy individuals and older adults at risk for falls (Hale, Miller, Skinner & Gray, 2009; Smith & Ulrich, 2008).

Flamingo Balance Assessment, Single Leg Stance, and Balance Error Scoring System work on similar protocols. Flamingo Balance Assessment counts the number of trials needed for an individual to achieve a total duration of 30 seconds of balance on their preferred foot on a flat, firm surface (Guidetti et al., 2010; Van de Vliet et al., 2006). Single Leg Stance measures the length of time a participant stands on their dominant leg up to 30 seconds (Fong et al., 2012; Terblanche et al., 2012). SLS correlates with dynamic measures of walking and indicates risk of falls in older adults with DS (Ringsberg, Gerdhem, Johansson & Obrant, 1999). This method has been used successfully with individuals with development coordination disorder (Fong, Fu & Ng, 2011). BESS measures the number of times a participant loses their balance in 20 seconds while standing on stable and unstable surfaces in three stances, double leg stance with feet together, SLS, and tandem stance (toe of one foot placed against the heel of the other foot) (Bressel, Yonker, Kras & Heath, 2007).

mCTSIB measures the amount, velocity, and direction a person sways while standing erect and as still as possible on a force plate. Relative absence of sway indicates greater stability while greater amounts of sway indicates less stability. This allows the mCTSIB to quantify postural sway velocity and stability with participants standing quietly on the force plate. mCTSIB has been shown to have excellent interrater and test-retest reliability and has been validated with sensory organization posturography for vestibular patients (Horak, 1997; Horak, Jones-Rycewica, Black & Shumway-Cook, 1992). Center of Gravity (COG) sway tests have been shown to be reliable when used with individuals with DS (Villamonte et al., 2010). This static balance test has been used with judoists (Paillard, Costes-Salon, LaFont & Dupui, 2012), ballet dancers (Gerbino, Griffin & Zurakowski, 2007; Perrin, Deviterne, Hugel & Perrot, 2002), and soccer players (Gerbino et al., 2007).

Dynamic balance is measured using functional reach (FR) and limits of stability (LOS) performed on a force plate. Both tests force the participant to lean as far as possible without losing their balance. Functional reach measures how far an individual can reach forward, measured in centimeters, while maintaining both feet flat on the floor. Test-retest and interrater reliability have been established with healthy persons (Duncan, Weiner, Chandler & Studenski, 1990) and elderly at risk for falls (Duncan, Studenski, Chandler & Prescott, 1992). FR tests have been used successfully with individuals with ID (Carmeli et al., 2005; Hale, Bray & Littmann, 2007). To perform LOS, participants lean as quickly and as accurately as possible attempting to move a cursor to land on targets displayed on a computer screen. The goal is to move the cursor, which coincides with the participants COP, to highlighted targets (Computer Sports Medicine, 2012).

Balance Ability of Individuals with DS. Individuals with DS have a significant delay in balance development (Connolly & Michael, 1986; Spano et al., 1999; Villamonte et al., 2010; Wang & Huei, 2002). They rank lower on balance performance than TD individuals or individuals with ID that is nonDS related throughout their entire lifespan (Connolly & Michael, 1986; Tsimaras & Fontiadou, 2004).

Connolly & Michael (1986) used the BOTMP test to measure physical performance of children with ID in motor proficiency tasks. Twelve children with DS and 12 TD children (age 7.6-11years) participated in the study. There was a significant group difference in balance with TD children scoring higher than children with DS. The difference in scores between girls and boys was not significant for either group.

Force plates and balance boards have both been utilized to measure static and dynamic balance in different populations. Balance boards use transducers similar to those found in force plates to measure force distribution and center of pressure (COP) (Clark et al., 2010).

Vuillerme et al., (2001) investigated static postural control in teenagers with DS utilizing a force plate to measure displacement of the center of foot pressure (COP). Participants stood barefoot on a platform and were asked to stand very quietly and not to move for the duration of the trial. Thirteen adolescents with DS (mean age 16 years 8 months) were compared with 11 TD individuals (mean age 15 years 10 months) in four conditions; solid support eyes open, solid support eyes closed, foam support eyes open, and foam support eyes closed. Three trials of 40 seconds each were measured. Teenagers with DS had greater sway under all conditions ($p<0.05$) with no difference between males and females. Villarroya et al., (2012) performed a similar study with 32 children and adolescents with DS (ages 10-19 years) and 33 age matched TD controls. Participants stood bipedal, barefoot on a solid force platform with eyes open and eyes closed, and also stood on a foam pad with eyes open and closed. No differences between genders were found. Results showed adolescents with DS had greater sway in all conditions in both anteroposterior and medial-lateral directions ($p<0.05$). Even though they presented with lower static balance scores than their peers without DS the group with DS showed similar postural control patterns to the TD control group (Villarroya et al., 2012).

While investigating postural control of young adults with DS Cabeza-Ruiz et al., (2011) measured bipedal static balance on a force plate. Twenty seven individuals with DS (mean age 27.44±1.6 years) were compared to 27 college students without DS (mean age 23.38±1.25 years) for mean velocity (MV, mm/s), mean frequency (MF, Hz), and sway (SA, mm^2/s). Participants stood barefoot on a force plate with arms unfolded by their sides. All participants were asked to stand for 50 seconds with eyes open and another 50 seconds with eyes closed. Participants with DS showed greater sway than the TD control group on all measures ($p<.001$).

Galli et al., (2008) performed the same tests as the studies reviewed above by Villarroya et al., (2012) and Vuillerme et al., (2001) but measured COP in a time series in anterior/poster (A/P) and medial/lateral (M/L) directions and also measured frequency of movements. Sixty individuals with DS (means age 18.7 years) and a control group of 10 TD individuals (mean age 22.3 years) were asked to stand on a force plate bipedal and barefoot for 30 seconds with eyes open and eyes closed. The results of this study showed individuals with DS had increased frequency of oscillations ($p<.05$) in both anterorposterior and medial-lateral directions thus giving less control over postural behavior.

The above studies indicate individuals with DS have poorer static balance abilities on firm and soft surfaces with eyes open and eyes closed than TD individuals. These results are the same for groups of children, adolescents, and young adults with DS. There appears to be no gender difference in balance ability in individuals with DS.

Training individuals with DS to improve static and dynamic balance. There appears to be a small amount of research on whether training can improve static and dynamic balance in individuals with DS. Gupta et al., (2011) measured 23 children with DS (ages 7-15 years) using the balance subscale of the BOTMP. Children were divided into an intervention group (n=12) and a control group (n=11) with the intervention group participating in a PRT program 3 times/week for 6 weeks with 2 sets of 10 repetitions being performed on each of 5 exercises at each session. The intervention groups balance improved from scores of 10.5 (8.00-15.50) to 19.5 (16.25-24.00) in the experimental group with an overall statistically significant difference (p=0.007) in overall final scores between the two groups.

Tsimaras and Fotiadou, (2004) measured dynamic balance using a balance board with measurements in number of seconds the subject could remain standing on the platform in durations of 30, 45, and 60 second intervals. An experimental group of 15 individuals with DS participated in a 12 week, 3 sessions per week, 30-35 minutes per session training utilizing plyometric and balance exercises, such as walking on a line, standing on 1 foot, walking across a balance beam, etc. Ten individuals with DS were assigned to the control group which continued with normal activities. All participants had a mean age of 24.5±3.9 years. Post hoc analysis showed that dynamic balance ability improved for the experimental group (30s, $p<.01$; 45s, $p<.001$; 60s, $p<.001$) with no significant changes occurring with the control group.

Can increasing muscular strength and balance improve physical functioning? Using functional tests Carmeli et al., (2005) tested 17 individuals with ID (ages 50-67 years) and 12 individuals with ID on "timed up and go" (TUAG) test (seconds), a full turn test (seconds and number of steps), a functional reach test (cm), a sit to stand test (number of times per 20 seconds), and a 1 legged stand test (seconds). The intervention group participated in six months of ball exercises and walking on a treadmill. Training was held 5 days/week for 27 weeks; 3 days per week walking on a treadmill and 2 days per week performing ball exercises. Treadmill walking started at 5 minutes at 0% grade and increased to 30 minutes at 2-3% grade. Fifteen of the 17 participants in the intervention group completed the training. The training program positively influenced all 5 tests but was only statistically significant for forward reach (18% improvement) and sit to stand tests (9.5% improvement).

Taekwondo and Its Effect on Strength and Balance

Because of the difficulties in developing and maintaining functional strength and stability it is essential to utilize an activity that will incorporate activities that facilitate improvement in each area. Martial arts are ancient forms of combat that have been modified for sport, self-defense and recreation (Woodward, 2009). The differences between various martial arts are defined by the unique ways in which they use and/or combine one or more basic techniques (Tedeschi, 2003). Taekwondo is a defensive art that primarily utilizes foot techniques for self-defense. Bouncing on the balls of the feet, and quickly sliding (in all directions) helps to keep opponents at a distance. It also necessitates stabilizing the body while extremities are kicking or punching. Forms (choreographed movements) practice requires moving between long and/or wide stances causing participants to move beyond their base of support (Cromwell, 2007). Taekwondo does not frequently use upper body techniques that cause opponents to be close together. Upper body is primarily used for blocking, but only recently were punches to the body considered “scoring” in taekwondo competitions.

Martial Arts and Muscular Strength. In general, experienced martial arts participants tend to have strong lower bodies, high levels of flexibility and excellent balance. Only one study compared martial artists to active controls. This study by Probst et al., (2007) measured quadriceps and hamstring muscle strength, muscle endurance and flexibility in 9 karate athletes (age 24.3±6.7 years) and 15 non-karate age matched active controls (age 22.1±3.2 years). The karate group showed greater muscular strength and flexibility than controls, with no difference in muscular endurance between the two groups. Karate matches tend to be of shorter duration, more anaerobic in nature. This would explain the lack of difference between the groups in muscular endurance.

With eighty percent of taekwondo skills related to kicking techniques it was hypothesized that muscles of the lower limbs would be particularly affected by training. Lower limb muscle strength is crucial in explosive kicking, jumping, maintaining stances, and stance stability. Toskovic et al., (2004) compared the muscle strength between black belt practitioners and beginners and found that black belt practitioners possessed greater strength in the lower body than the beginners, regardless of gender. A literature review by Fong and Ng, (2011) indicated that despite the variations in assessment techniques and training regimes, it is possible that the more time one spends in taekwondo training the greater the muscle strength a person could gain (Fong & Ng, 2011).

This was supported by Kim, Dattilo & Heo, (2011) who measured 31 female adolescents ages 15-16 years for explosive strength using standing long jump, and isokinetic strength of knee extensors and flexors of each leg using an isokinetic dynamometer (Cybex 770) at angular velocities of 60°/second and 180°/second. After completion of two 50 minute taekwondo training sessions per week for 12 weeks. It was evident taekwondo enhanced explosive muscle strength ($p<.05$), isokinetic muscle strength flexion at 60° and 180°/s ($p<.05$) and extension at 60°/s ($p<.05$), but had no effect on upper body muscle endurance. In this context, taekwondo primarily utilizes weight bearing muscles so stimulus to the upper body was not adequate to produce an improvement in upper body muscle endurance.

Another study by Toskovic et al., (2004) compared profiles of recreational taekwondo practitioners with experienced taekwondo practitioners. The experienced group consisted of men and women who reported 3 years or more of active, regular participation in taekwondo and who train at least two days per week for 1 hour each session. Everyone in the experienced group had reached the rank of black belt. Novice recreational participants were taking 75 minute beginning taekwondo classes, 2 days/week, for 8 weeks and were classified as white belt students. Lower body strength was measured using a maximum leg press utilizing Hammer Strength machines. Lower extremity explosive power was measured using the vertical jump and reach protocol. Experienced subjects scored higher for lower body strength ($p<0.05$) compared to novice subjects, and experienced males scoring higher than experienced females ($p<0.05$). There was no significant difference between novice and experienced practitioners on the explosive power test.

Martial Arts and Balance. Training in many sports have been reported to improve balance and postural control in TD and individuals with ID. Studies have shown dancers (Gerbino et al., 2007; Schmidt & Smith, 2007; Simmons, 2005), gymnasts (Aydin, Yildiz, Y., Yildiz, C. & Kaylon, 2002; Bressel et al., 2007), and judo specialists (Gerbino et al., 2007, Paillard et al., 2002; Perrin et al., 2002) have better balance performance than people without sports training (Leong et al. 2011). Taekwondo, with its frequent jumping, weight shifting, and foot work has been thought to stimulate sensory systems and enhance postural control (Leong et al., 2011).

Leong et al., (2011) compared 11 taekwondo practitioners (mean age 20.9 years±1.5 years) who had been training in taekwondo for approximately 4 hours per week for 1-3 years with a control group comprised of 11 untrained individuals (mean age 24.0±3.8 years) on sensory organization test (SOT) and drop test. A SOT test measures the person's ability to integrate information from the somatosensory, visual and vestibular systems for maintaining balance. In the drop test the subject is suspended by an electromagnet in a neutral vertical position with arms by their side and feet flexed 30 cm above a force platform, blindfolded and wearing a bicycle helmet. A verbal signal was given between 5 to 20 s before the electromagnet was disconnected so exact moment of drop could not be predicted. Subjects were asked to maintain balance as quickly as possible with the least amount of sway after each fall and remain stable for 10 seconds. It was observed that people with taekwondo training had better balance during stance with eyes closed on a fixed support than untrained subject (p=0.011) and shorter time to stability (TTS) after vertical drops (p=0.018). Their findings indicate taekwondo practitioners with greater than one year experience rely more on somatosensory and vestibular inputs to maintain their balance control (Leong et al., 2011).

Age related decline in balance is a major risk factor for falls in older adults causing adaptations such as shorter step length and decreased walking velocity (Cromwell et al., 2007). Taekwondo's emphasis on shifting weight with the lower extremities while moving the upper extremities requires participants to spend more time in SLS as they lengthen strides to achieve necessary stances. Forty participants took part in a study by Cromwell et al., (2007) in which 20 individuals (17 women and 3 men aged 72.7±6.1 years) agreed to enroll in a taekwondo exercise class. Twenty community dwelling (13 women and 7 men aged 73.8±7 years) served as controls. All participants were measured in SLS, multidirectional reach test (participants reached as far forward, backward right and left with arm parallel to floor, MDRT), and timed up and go test (TUG). The intervention group participated in one hour taekwondo classes twice per week for 11 weeks, with an adherence rate of 70.6%. Groups were similar at pretest on all measures except TUG. Comparison of pre and posttest scores for control group demonstrated no significant differences. The taekwondo group showed significant improvement for MDRT in back, right and left directions ($p<0.05$). Reach increased at least 4.0 cm in each of these directions. Forward reach improved 3.6 cm but was not statistically significant. Times for SLS increased an average of 10.2 seconds and TUG also improved but neither result was statistically significant. Results show taekwondo can be an alternative exercise to improve balance in older adults.

Physical Activity, Taekwondo and Down Syndrome

Temple et al., (2006) reviewed research articles on physical activity levels of adults with ID. The proportion of participants that accrued at least 30 minutes of moderate intensity physical activity per day was 17.5% to 33%. Walking for transportation was the primary physical activity noted and the level of physical activity of adults with DS compared to the level of activity demonstrated by sedentary TD adults. Physical activity for sport or recreation made less of a contribution to overall physical activity levels. Dancing, swimming and bowling were noted more frequently than other sports or recreational activities (Temple et al., 2006). Taekwondo was chosen for this study due to the group nature of the activity (for socialization) and the individualization of the training.

Research specifically on taekwondo training for individuals with ID is limited to a study by Fong & Ng, (2011) on providing taekwondo training to children with developmental coordination disorder (DCD). This is important to the current study since the majority of children with DCD have balance problems that impair postural control and hinder motor skill development similar to children with DS. Fong, et al., (2012) studied 44 children with DCD (mean age 7.6±1.3 years) and 18 TD children (mean age 7.2±1 years) on the SOT and SLS which yielded significant differences in the pretest measurements of vestibular ratio ($p=0.012$) and COP sway velocity ($p=0.003$) among the three groups. The DCD group with taekwondo training had significant improvement (increased by 25.6%, $p<0.001$) after 3 months of training. No change was evident in the control groups. The intervention group also showed significant improvement (71.9%, $p<0.001$) in vestibular ratio after 3 months of taekwondo training with the DCD-taekwondo group average vestibular ratio after training was 61.8% higher than the DCD control group and comparable to the TD control group ($p>0.01$). Because of the similar characteristics of the DCD group with DS, it is evidence that taekwondo training may provide a viable activity to improve the muscular strength and balance of individuals with DS.

The above literature review has given evidence that taekwondo training can improve strength and balance in various populations of all ages. TD individuals as well as individuals with special needs have improved various parameters with participation in a taekwondo program. It is the intent of this study to determine whether taekwondo training will have an effect on the lower body strength and balance of young adults with DS.

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CHAPTER III

THE EFFECT OF TAEKWONDO TRAINING ON LOWER BODY STRENGTH IN YOUNG ADULTS WITH DOWN SYNDROME

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Abstract

This study evaluated the effect of taekwondo training on lower body strength in young adults with Down syndrome (DS). Forty four young adults with DS aged 21-30 years of age were assigned to a control group (n=22) or a training group (n=22) based on whether they were available for prescheduled taekwondo classes. The training group participated in 60 minute taekwondo classes 2 days per week for 10 weeks while the control group continued with their regular activities. Each class consisted of a 10 minute warm up, 30 minutes of taekwondo drills, 10 minutes of calisthenics or forms practice, and a 10 minute cool down. Average class attendance was 73.4% (approximately 15 of 20 possible classes) with attendance ranging from 55.6% to 100% (approximately 11-20 classes). Lower body strength was measured in pounds utilizing a hand held dynamometer prior to training, after 5 weeks of training, and 10 weeks of training and after a 5 week detraining period. At the completion of training, significant lower body strength gains were evident in the taekwondo group with a significant ($p < .05$) mean increase of 44% after 5 weeks of training and an additional 25% increase during the last 5 weeks of training. A significant ($p < .05$) decrease of 30% was shown during the 5 week detraining period. Strength measures for the control group remained unchanged throughout the study. Results indicate taekwondo training can increase lower body strength in young adults with DS. Additional research is needed to determine if these strength changes would translate into benefits related to physical function. The detraining effect indicates that physical activity must be ongoing in order for strength gains to be maintained.

Introduction

According to the National Down Syndrome Society (NDSS, 2012) 1 in every 691 babies born in the United States is born with Down syndrome (DS). From 1979 through 2003, the prevalence of DS births increased by 31.1% (Shin et al., 2009). At the same time, life expectancy for people with DS has increased dramatically, from 9 years of age in 1929 (Gonzalez-Aguero et al., 2010) to 25 years of age in 1983, to 60 years old today (NDSS, 2012). Individuals with DS demonstrate lower levels of strength than age matched TD individuals at all stages of life (Angelopoulou et al., 2000; Carmeli, Bar-chad et al., 2002; Cioni et al., 1994; Cowley et al., 2011; Gupta, Rao & Kumoran, 2011; Horvat & Croce, 1995; Shields, Taylor & Dodd, 2008). Pitetti, Baynard & Agiovlasitis (2012) stated that for individuals with DS lower extremity strength may be a limiting factor in both work performance and aerobic capacity impacting their ability to perform activities of daily living (ADL) or perform tasks in the work environment (Cowley et al., 2010; Horvat, Croce & Roswal, 1993; Shields, Taylor & Dodd, 2008). The decreased strength levels may also limit opportunities to participate in physical activity or organized sports contributing to the sedentary lifestyle of this population (Horvat, Pitetti & Croce, 1997; Smail & Horvat, 2009).

Although muscular strength is diminished, individuals with DS have demonstrated an ability to increase muscle strength and work capacity after participation in physical exercise programs (Horvat & Croce, 1995; Murphy & Carbone, 2008; Smail & Horvat, 2009; Seagraves, Horvat, Franklin & Jones, 2004). The majority of research has utilized progressive resistance training (Carmeli, Zinger-Baknin, Morad & Merrick, 2005; Cowley et al., 2011; Gupta et al., 2011, Mendonca, Pereira & Fernhall, 2011; Seagraves et al., 2004; Shields et al., 2008; Smail & Horvat, 2009) but other physical interventions have included plyometric exercises (Tsimaras & Fotiadou, 2004), and sport specific training (Guidetti, Franciosi, Gallotta, Emerenziani & Baldari, 2010). A growing body of literature suggests that increasing strength, particularly lower body strength, may lead to improvements in the functional abilities of adults with DS (Shields &

Dodd, 2004; Smail & Horvat, 2006) and is an important component in potentially increasing independence and self-reliance. This finding is further supported by Carmeli et al., (2005) and Gupta et al., (2011) who reported significant functional improvements in individuals with DS following physical training, especially training emphasizing the lower extremities. Furthermore, Smail and Horvat (2006) demonstrated specific improvement in knee flexion and extension of high school students with mild intellectual disability (ID) after participation in a strength training program 3 times per week for 12 weeks. It is becoming apparent that low levels of muscular strength can be improved with activity in individuals with DS although gains appear to be diminished when intervention is not sustained.

One approach that has successfully increased lower body muscular strength in typically developing (TD) individuals of all ages is taekwondo training (Cromwell, Meyers, P.M., Meyers, P.E. & Newton, 2007; Fong & Ng, 2011; Kim, Stebbins, Chai & Song, 2011, Toskovic, Blessing & Williford, 2004). In general, experienced martial arts participants have been shown to have increased lower extremity strength when compared to active controls due to low stances and primarily lower body techniques. Probst et al., (2007) measured quadriceps and hamstring muscle strength in 9 karate trained athletes (age 24.3±6.7 years) and 15 non-karate age matched active controls (age 22.1±3.2 years) with the karate group showing greater muscular strength than controls. Toskovic et al., (2004) compared black belt practitioners with beginning taekwondo students and found that individuals at black belt level had greater strength in the lower body even though they were older indicating the longer one trains the greater the strength gains. A literature review of the physical effects of taekwondo training by Fong and Ng (2011) indicated that despite variations in assessment techniques and training regimes, it is possible that the more time one spends in taekwondo training the greater the muscle strength a person could gain (Fong & Ng, 2011).

Taekwondo is a sport that primarily utilizes lower body muscle groups. With a large part of taekwondo skills related to explosive movements such as kicking and jumping as well as utilizing long stances during forms (choreographed movements) it is thought that muscles of the lower limbs would be particularly affected by training. Lower limb muscle strength is crucial in kicking, maintaining stances, and stance stability so improvements in lower body strength would be expected. Therefore, the purpose of this study was to determine if a 10 week, twice weekly, taekwondo training program could significantly improve lower body strength in young adults with DS. The hypothesis is there will be a significant increase in lower body strength of young adults with DS following ten weeks of taekwondo training.

Methodology

Participants. Participants were recruited from an adult education program for individuals with DS, and a continuing education program for individuals with intellectual disabilities (ID). Individuals with DS and their parents/guardians were invited to attend informational meetings where individuals indicated their interest in taekwondo training by completing a pre-participation questionnaire. This questionnaire reviewed medical history, physical activity history and medications. Individuals were chosen for participation in the study if they were 21-30 years of age, able to understand verbal instructions as evidenced by performance of requested tasks during informational meetings, were not currently participating in any other organized sport or physical activity, had no background in martial arts participation during the previous 2 years, and were free of neurologic, orthopedic (including atlantoaxial instability), or cardiovascular problems that would prevent them from successfully participating in a taekwondo program.

Program administrators and parents/guardians confirmed all individuals with DS were in the mild to moderate range of intellectual functioning. Participant's signed assent forms and parent/guardians signed consent forms. This study was reviewed and approved by the University Institutional Review Board.

Physical Assessments. Assessments were completed in a private area to maintain an individual's privacy and to minimize distractions. The same researcher completed assessments during each testing period to decrease participant anxiety and to maintain consistency. Height was measured to the nearest ¼ inch on a wall mounted measuring tape with shoes removed. Weight was measured to the nearest ½ pound with shoes and excess clothing (jackets, extra shirts, etc.) removed on the Humac balance board digital scale. Age on the first day of taekwondo classes was calculated in years.

An individual orientation session for each participant was conducted no more than one week prior to pretest assessments. Each participant was put into proper position and guided through each assessment verbally and physically until participants were able to perform the muscle testing protocol on cue (Horvat, Croce & Roswal, 1994). Prior to each assessment participants were asked to perform the required movement without the hand held dynamometer (HHD) to assure understanding. Words of encouragement and prompting were scripted in a manner used by Hislop and Montgomery (2007) and repeated as necessary. Physical assessments were completed no more than one week prior to the start of taekwondo training, the 5 week training assessments were completed no more than five days after the final taekwondo class (after 5 weeks of training), while ten week training assessments were completed no more than five days after the last taekwondo class. The detraining interval assessment was completed 5 weeks after the final taekwondo class.

Strength Assessment. Lower body strength was measured using a MicroFet2 (Hoggan Health Systems, Draper, Utah) hand held dynamometer (HHD). Accuracy of MicroFet2 has been tested by Hoggan Health Systems and stated to be within ±2%. Validity and reliability of the use of HHD with individuals with ID has been established in several investigations by Croce & Horvat (1992), Seagraves et al., (2004), Smail & Horvat (2006) and with DS adults specifically by Wuang, Chang, Wang & Lin (2013). Assessments were completed using a "make test" which involves the examiner holding a HHD stationary while the participant exerts a maximal effort against the device (Horvat, Block & Kelly, 2006, p.114). Six muscle groups were assessed on both dominant and non-dominant sides in the following order to minimize changes in body position: ankle plantar flexors, knee flexors, hip extensors, hip abductors, knee extensors, and hip flexors with dominant side being measured first. Both sides were used to provide a lower body composite score per recommendation in previous studies to reflect lower extremity strength. (Horvat et al., 1994; Horvat et al., 2006; Smail & Horvat, 2006; Smail & Horvat, 2009). Dominant side was determined by asking a participant to kick a ball 3 times. The leg used to kick the majority of the time was considered the dominant side. Testing protocol included position of participant and investigator, directions for stabilizing muscle groups, and scripted instructions to give to participants. These protocols were standardized according to guidelines recommended by Horvat et al., (2006), Hislop & Montgomery (2007), and Kendall, McCreary, Provance, Rogers, & Romani (2005). The majority of studies reviewed utilizing HHD used the mean of three trials as their method of measurement (Busse, Hughes, Wiles & Rosser, 2008; Gupta et al., 2011; Seagraves et al., 2004; Smail & Horvat, 2006, 2009; Verschuren et al., 2008). Horvat & Croce (1995) found that three trials of each muscle measured were adequate to determine whether an individual with ID gave their full effort without being overly exhaustive for participants. Mean scores of each muscle tested were summated to create a lower body composite score (Horvat et al., 1994; Horvat et al., 2006).

Intervention. Taekwondo classes were taught at each program's facility in 60 minute sessions, 2 sessions per week for 10 weeks. All classes were taught by a 4th degree Black belt with nine years taekwondo teaching experience and classes followed the standard curriculum of the American Taekwondo Foundation. Assistants were available to help hold pads and encourage participants throughout the training session. Each training session consisted of a 10 minute warm up (light aerobic activities, stretching), 30 minutes of taekwondo drills (punching, blocking, basic kicking), 10 minutes of calisthenics (sit ups, pushups, plank, etc.) one day per week and poomse (form) practice one day per week, 10 minutes of cool down and stretching. Forms are set patterns of movements beginning with basic stances, kicks, and punches with each successive form increasing in number of movements, changes in direction, and level of difficulty. This gradual progression continually challenges participants both mentally and physically. The control group continued their daily activities and did not participate in any organized sports or physical activities for the duration of the study. Individuals in the control group were provided with ten weeks of free taekwondo classes after the study was completed for their participation in the testing and compliance.

Statistics. All statistics were completed using SPSS 21 and all effects were reported as statistically significant at $p<.05$. Means and standard deviations were calculated on demographic data. A two-way repeated measures ANOVA was utilized with the independent variable being taekwondo training and the dependent variable being lower body strength (composite score in pounds) over time (pretest, 5 weeks, 10 weeks, and 5 weeks post), using Greenhouse-Geisser adjustment to correct for sphericity. Post hoc analyses were conducted using t-tests for each time period between mean strength scores by group. Percentage change was calculated for the taekwondo group at each time interval.

Results

Participants. Forty four individuals were accepted for participation and divided into taekwondo training and control groups based on their availability to consistently attend taekwondo classes at prescheduled days and times. Twenty two (22) individuals were assigned to the treatment group with 22 individuals assigned to the control group. The control group agreed to not participate in any organized sport or physical activity and to continue with their current daily activities for the duration of the study. Prior to beginning the intervention, taekwondo and control groups were compared for height, weight, BMI and age (Table 1). No significant differences were found.

Intervention. Each participant in the taekwondo group was eligible to attend 20 classes. Average attendance was 73.4% (approximately 15 classes) with attendance ranging from 55.6% to 100% (11-20 classes). Reasons given for not attending all classes were lack of transportation and school events. To assure compliance to the teaching protocol fifty percent of classes were observed by an independent observer with times of each section of the session recorded to determine instructor compliance to teaching protocol. Compliance to teaching protocol was 100% for session time ± 2 minutes of protocol.

Physical assessments. Prior to beginning assessments, inter-tester reliability was measured by Intraclass Correlation Coefficient at .766. Fifty percent of assessments from each assessment period were observed by an independent observer to assure compliance to assessment protocols with 100% of assessments observed completed accurately.

Strength measures. Within group comparisons of mean pretest scores of females vs. males, and dominant side vs. nondominant side strength were completed and found to be nonsignificant allowing all scores to be grouped together during analysis. Groups were compared over time using two way repeated measures ANOVA with taekwondo training as the independent variable and strength as the dependent variable. There was a significant main effect between subjects by group on strength, $F(1,42)=12.33$, $p<.001$, $\eta^2=.227$. This indicated there were overall differences between groups based on strength measurements. Using Greenhouse-Geisser adjustment there was a significant within subjects effect of time on strength, $F(3,126)=25.494$, $p<.001$, $\eta^2=.016$, indicating strength values changed over the four time points. There was also a significant interaction effect between time and group on strength, $F(3,126)=22.37$, $p<.001$, $\eta^2=.116$ indicating performance over the four time points depended on group assignment. In order to determine at which time point differences occurred, t-tests were computed for each time point using mean strength scores by group. There was no significant difference between groups at pretest ($t=.85$, $p=.399$) revealing both groups began the study with similar levels of strength. Progressing over time there were significant differences between groups at 5 weeks training ($t=3.68$, $p=.001$), 10 weeks training ($t=5.049$, $p<.001$), and 5 weeks post training ($t=3.08$, $p=.004$). Together these tests indicate that taekwondo training significantly increased lower body strength measures of young adults with DS. Trend analysis over the first three time points for the taekwondo group show that strength gains increased in a linear fashion, $F(1,21)=48.0$, $p<.001$. Overall percentage of change was calculated for the taekwondo group showing a 44% increase from pretest to 5 weeks training, then an additional 25% increase from 5 weeks to 10 weeks of training. A t-test was used to compare post-test results for the taekwondo group with results from the taekwondo group retention assessments and this was significant (t=6.465, p<.001) indicating a significant change in strength. A percentage change of -30% was seen from 10 weeks training to 5 weeks post training indicating a decrease in strength levels, however lower body strength after 5 weeks of detraining continued to be higher than pre-training levels.

Discussion

The purpose of this study was to determine the effect of 10 weeks of taekwondo training on the lower body strength of young adults with DS. The main finding was that young adults with DS were able to increase their lower body muscular strength by participation in a taekwondo training program. These results are in agreement with previous studies that indicate individuals with DS were able to increase muscular strength with physical training (Carmeli et al., 2002; Guidetti et al., 2010; Horvat & Croce, 1995; Murphy & Carbone, 2008; Smail & Horvat, 2009; Smith, Kubo, Black, Holt & Ulrich, 2007; Tsimaras & Fotiadou, 2004). Several studies have also reported taekwondo training improved muscular strength in TD individuals (Heller et al., 1998; Toskovic et al., 2004).

In this study, lower body strength increased in the taekwondo group 44% from pretest to 5 weeks of training and an additional 25% increase from 5 weeks to 10 weeks of training. The larger increase in strength during the first 5 weeks of training could be due to neural system adaptation including increased motor unit recruitment and synchronization (Taaffe & Marcus, 1997) increased neural activation, increased α motor neuron excitability and decreased Golgi tendon organ inhibition (Staron et al., 1994). Giagazoglou et al., (2013) utilizing EMG found individuals with intellectual disabilities (ID) improved motor unit recruitment and activation following a 14 week hippotherapy program. During the hippotherapy program children with ID had to constantly adjust to the horses' movements, just as taekwondo practitioners must constantly adjust to movements of their training partners and opponents.

These increases in performance were mitigated by the rapid decline of muscular strength during the detraining period. This decline is in agreement with Winters and Snow (2000) who found that muscle strength decreased significantly toward baseline in premenopausal women following a detraining period. Also, Elliott, Sale and Cable (2013) found significant detraining effects in postmenopausal women, and Lemmer et al., (2000) produced the same results in TD participants 20-30 years of age and 65-75 year of age after 9 weeks of strength training and 31 weeks of detraining. In this study strength decreased 30% in 5 weeks of detraining. Although still above the pretest strength levels it is possible all strength gained from training would have been eliminated if the time period of detraining was longer. The percentage of strength lost in this study was greater than Volaklis, Douda, Kokkinos & Tokmakidis, (2006) who noted a decrease of 10-16% after 3 months of detraining in participants with coronary artery disease (CAD) and more than a study by Staron et al., (1991) where 15 college aged women lost 13-32% of strength following a 6 month detraining period after an intensive 20 week strength training program. The percentage of strength lost was equivalent to that seen by Taaffe & Marcus (1997) who measured a 30% loss in lower body strength in 11 elderly individuals after 12 weeks of detraining. We have no mechanism in the current study to determine if detraining affected muscle fiber type in addition to neural adaptations. Mujika and Padilla (2000) found that both muscle atrophy and diminished neural activation were responsible for the decline in maximal force in trained athletes following 12 weeks of inactivity however, since no muscle hypertrophy was seen in this study it is felt there would be no change in muscle fiber size with detraining. The large decreases in strength after the detraining phase in this study confirm the positive effect of taekwondo training and the need for continued activity to maintain strength gains in young adults with DS.

Group sports training can assist in developing physical fitness (muscular strength, balance, etc.), improving the ability to perform activities of daily living, and also promotes socialization and self-confidence. The opportunity to interact with others and develop friendships is an important component in facilitating continued active participation. Jones, Mackay & Peters, (2006) reported that friendship was one of the main factors that influenced continued participation in martial arts. Increasing motivation of individuals with DS to participate in routine exercise programs can be a challenge. This study used the novel intervention of taekwondo training to provide positive social support while attempting to increase lower body strength. All participants in the study stated that they enjoyed taekwondo and none withdrew from the study. Participants were able to learn motor tasks without injuries or other adverse events resulting from training indicating that taekwondo training is safe for young adults with DS and may be beneficial in increasing lower extremity strength as well as increasing participation in a community activity. Because young adults with DS lack opportunities for activities in the community setting, taekwondo programs can be valuable and should be recommended.

Conclusions. Results of this study indicate taekwondo can increase lower body muscular strength of young adults with DS. This increase in strength may allow these individuals to maintain their independence longer, provide an activity in which they can successfully participate, and possibly improve independent functioning and their quality of life. Although strength gains are usually associated with resistance training, taekwondo training also resulted in lower extremity strength gains.

A limitation of this study is the taekwondo instructor knew which parameters were being measured. This could have led to a teaching bias and using more strength related drills than would normally be taught. Another limitation is the lack of a TD training group. The addition of a TD group would have given a reference point as to whether young adults with DS increase strength at the same rate as age matched peers would.

Future research should determine whether adolescents and younger children would benefit from participation in taekwondo training. Another aspect to explore would be whether increased participation (3 days/week vs. 2 days/week) would increase the amount of strength gained over the same time period. It is also important to determine if a longer training period (i.e. 6 months or more) can continue gains in strength or whether neural adaptation plateaus without further change in muscular adaptations.

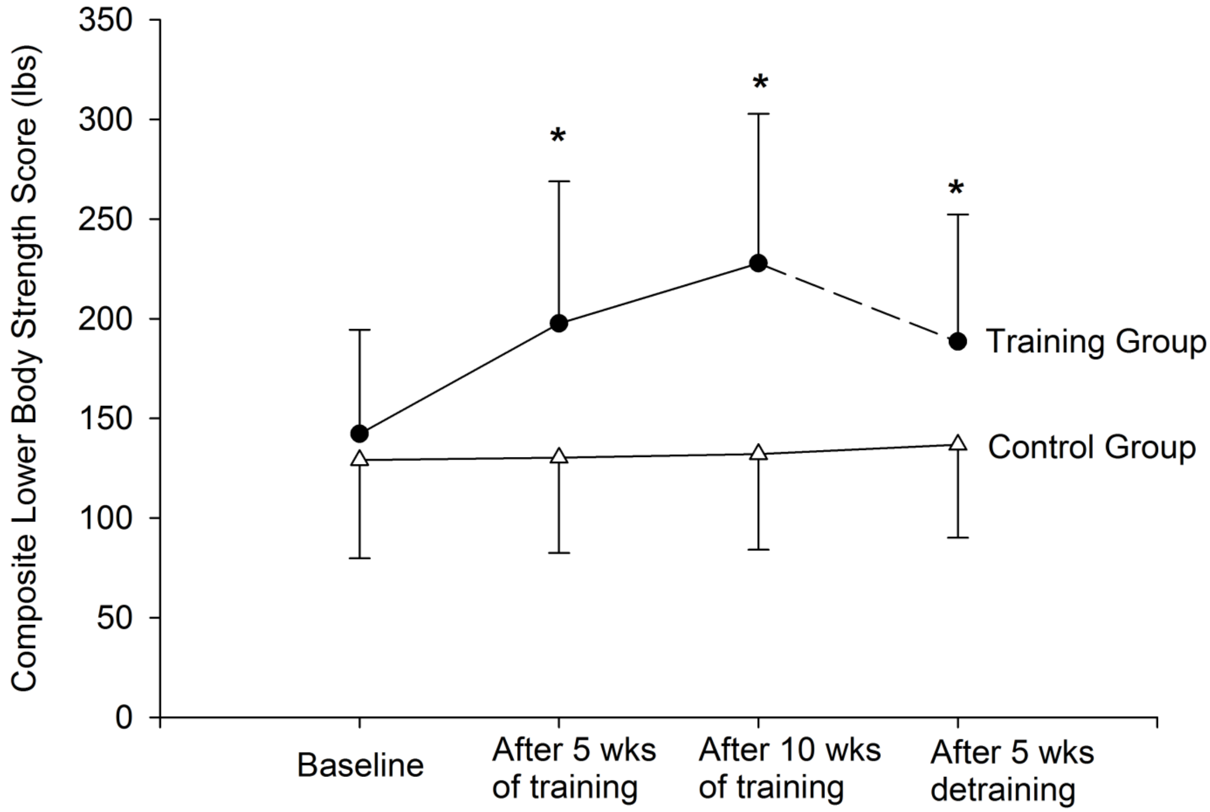
Table 3.1

DEMOGRAPHIC INFORMATION FOR TAEKWOND AND CONTROL GROUPS

Taekwondo group, n = 22; Control group, n = 22; SD – standard deviation; p values for t tests between groups, significance <.05.

	Taekwondo	SD	Control	SD	p=
Age (yrs.)	24.25	±3.19	25.90	±3.33	.507
Height (in.)	60.98	±3.49	59.93	±2.06	.233
Weight (lbs.)	147.8	±32.38	151.55	±33.50	.706
BMI	24.42	±6.28	25.67	±5.53	.491
Gender	Female	10	10		
	Male	12	12		
Race	Caucasian	22	20		
	African Am.	0	2		

Figure 3.1



MEANS OF STRENGTH MEASURES OVER FIVE WEEK INTERVALS

* indicates significant between group differences. Significance <.05.

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CHAPTER IV

THE EFFECT OF TAEKWONDO TRAINING ON STATIC AND DYNAMIC BALANCE IN YOUNG ADULTS WITH DOWN SYNDROME

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Abstract

The purpose of this study was to determine if taekwondo training 2 times per week for 10 weeks would improve static and dynamic balance abilities of young adults with DS. Forty four young adults with DS (21-30 yrs.) were assigned to either a taekwondo training group or a control group based on ability to attend prescheduled classes. The training group participated in 60 minute taekwondo classes, 2 days per week for 10 weeks while the control group continued with their regular activities. Each class consisted of a 10 minutes warm up, 30 minutes of taekwondo drills, 10 minutes of calisthenics, and a 10 minute cool down. Average attendance was 73.4% (approximately 15 classes) with attendance ranging from 55.6% to 100% (11-20 classes). Balance tests utilized the Humac Balance board (Computer Sports Medicine, Inc., Stoughton, MA). Static balance was measured using the modified clinical test for sensory integration and balance (mCTSIB) on a solid surface with eyes open (EO) and eyes closed (EC) while dynamic balance was measured utilizing the limits of stability (LOS) test. Results: A repeated measures ANOVA was utilized to determine differences between groups over time for each of the 3 assessments. There were no significant differences seen between groups in static balance, EO or EC, or dynamic balance. Both groups improved in all areas measured.

Introduction

Balance is defined as the ability of the body to maintain its center of gravity (COG) within its limits of stability (LOS) as determined by the base of support (Palmieri, Ingersoll, Stone & Krause, 2002). It is an essential prerequisite to performance of most activities of daily living (ADLs) (Humphriss, Hall, May and Macleod, 2011) and can be categorized as either static or dynamic. Static balance is the ability to sustain the body in stationary equilibrium (DiStefano, Clark & Padua, 2009) and is important for posture and upright motions. Dynamic balance requires the ability to perform a movement task while maintaining a stable position (Ricotti, 2011). Balance requires integration of visual, vestibular and somatosensory input as well as adequate lower body strength (Grigg, 1994; Nasher, Black & Wall, 1982; Palmieri et al., 2002). Development of balance is a reliable predicting factor regarding the development of basic motor skills and influences learning and implementation of new motor skills and (Tsimaras, Giamouridou, Kokaridas, Sidiropoulou & Patsiaouras, 2012). Static and dynamic balance are also important for the development of functional tasks such as walking upstairs, lifting objects and the ability to participate in exercise, social activities and independent living (Villamonte et al., 2010). Individuals with DS have a significant delay in balance and motor skill development (Connolly & Michael, 1986; Spano et al., 1999; Villamonte et al., 2010; Wang & Huei, 2002). They tend to rank lower on balance performance than TD individuals or individuals with ID that is nonDS related (Connolly & Michael, 1986; Tsimaras & Fontiadou, 2004). The lower level of balance abilities in individuals with DS have been demonstrated throughout the entire lifespan (Carmeli, Bar-chad, Lenger & Coleman, 2002; Connelly & Michael, 1986; Spano et al., 1999; Tsimaras & Fontiadou, 2004; Villamonte et al., 2010; Wang & Huei, 2002) and for this population who have limitations in motor skill development, balance is a critical element of independent functioning.

There is a limited amount of research on whether physical training can improve static and/or dynamic balance in individuals with DS. Gupta, Rao & Kumaran, (2011) measured 23 children with DS (ages 7-15 years) using the balance subscale of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP). The intervention group participated in a progressive resistance training (PRT) program 3 times/week for 6 weeks and improved balance score from 10.5 to 19.5. Tsimaras and Fotiadou (2004) utilized plyometric and balance exercises for 12 weeks with participants improving balance measures at 30, 45 and 60 second time intervals. Smail & Horvat's (2009) research showed increased physical function and work performance with a strength and balance training program designed to mimic work activities. Other investigations have also reported significant static and dynamic balance improvements in adults with intellectual disabilities (ID) after exercise programs (Tsimaras, Angelopoulou, Rsorbatzoudis, Abatzidis & Mandroukas, 2000), a rhythmic gymnastics program (Neofotistou, 2006) and resistance exercise programs (Sayadinezhad et al., 2013; Tsimaras et al., 2000).

Because of the difficulties individuals with DS have in developing and maintaining functional stability it is essential to utilize an activity that will incorporate activities that facilitate improvement while being fun for the participants. Training in many sports have been reported to improve balance and postural control in TD individuals as well as individuals with ID. Dancers (Gerbino, Griffin & Zurakowski, 2007; Schmidt & Smith, 2007; Simmons, 2005), gymnasts (Aydin, Yildiz, Y., Yildiz, C. & Kaylon, 2002; Bressel, Yonker, Kras &Heath, 2007), and judo specialists (Paillard, Costes-Salon, Lafont & Dupui, 2002; Perrin, Deviterne, Hugel & Perrot, 2002) have all shown better balance performance than people without sports training (Leong, Fu, Ng & Tsang, 2011). Taekwondo is an activity that primarily utilizes foot techniques, bouncing on the balls of the feet, quickly sliding in all directions to avoid opponents, and balancing on one foot during kicking techniques. Training in taekwondo has been able to bring about many physiological benefits for TD individuals including increased static and dynamic balance (Cromwell, Meyers, P.M., Meyers, P.E., Newton, 2007; Douris et al., 2004; Leong et al., 2011). Leong et al., (2011) showed TD young adults aged 18-30 years who trained in taekwondo for 1-3 years performed better on static balance tests than age matched sedentary controls. This study also showed that taekwondo practitioners rely more on somatosensory and vestibular inputs to maintain their balance (Leong et al., 2011). Taekwondo has also been shown to improve balance of TD older adults with mean age of 73 years (Cromwell et al., 2007) and children with developmental coordination disorder (Fong & Tsang, 2012).

Taekwondo is typically taught in group settings which encourage peer interaction and promote socialization. This social interaction is essential for motivating a sedentary population to continue with physical activity and maintain physical functioning. For this population it is important to encourage activities that promote balance as well as providing social outlets to encourage active participation and independence. Therefore, the purpose of this study was to determine if a 10 week, twice weekly, taekwondo training program would significantly improve static and dynamic balance in young adults with DS.

Methodology

Recruitment. Participants were recruited from an adult education program for individuals with DS and a continuing education program for individuals with ID. Individuals with DS and their parents/guardians were invited to attend an informational meeting where individuals indicated their interest in taekwondo training by completing a pre-participation questionnaire. This questionnaire reviewed medical history, physical activity history and medications. Individuals were chosen for participation if they were 21-30 years of age, able to understand verbal instructions, were not currently participating in any other organized sport or physical activity, had no background in martial arts participation during the previous 2 years, and were free of neurologic, orthopedic (including atlantoaxial instability), or cardiovascular problems that would prevent them from successfully participating in a taekwondo program. Program administrators and parents/guardians confirmed all individuals with DS were in the mild to moderate range of mental functioning. Participant's signed asset forms and parent/guardians signed consent forms. This study was reviewed and approved by the University Institutional Review Board of the university.

Physical Assessments. Physical assessments were completed no more than one week prior to the start of taekwondo training. Five week assessments were completed no more than five days after the final taekwondo class at the end of the 5th week of training. Ten week assessments were completed no more than five days after completion of the last taekwondo class. A detraining assessment was completed 5 weeks after the final taekwondo class.

Static and dynamic balance were assessed by computerized dynamic posturography performed on the Humac Balance board (Computer Sports Medicine, Inc., Stoughton, MA) which utilizes transducers located in a force platform which measures vertical and horizontal forces that are produced by the body's movement around a fixed base of support (Guskiewicz, 2001; Guskiewicz, Riemann, Perrin & Nasher, 1997). Static balance was determined using the modified Clinical Test of Sensory Interaction on Balance (mCTSIB) which measures the amount, velocity and direction a person sways while standing erect as still as possible on a force plate. "Stability" is defined as relative absence of sway (CSMI, 2012). Relative absence of sway indicates greater stability, while greater amounts of sway indicate less stability. The mCTSIB has been shown to have excellent inter-rater and test-retest reliability and has been validated with sensory organization posturography for vestibular patients as well as individuals with DS (Horak, 1997; Horak, Jones-Rycewica, Black & Shumway-Cook, 1992; Villamonte et al., 2010). To perform the Limits of Stability test (LOS), participants lean as quickly and as accurately as possible attempting to move a cursor to land on targets displayed on a computer screen. The goal is to move the cursor, which coincides with the participants' center of pressure, to highlighted targets (Computer Sports Medicine, 2012). Force plates have been successfully used with individuals with DS (Cabeza-Ruiz et al., 2011; Galli et al., 2008; Villarroya et al., 2012; Vuillerme, Marin, & Debu, 2001).

Static balance. Testing followed the protocol developed by CSMI for the mCTSIB (CSMI, 2012). The balance board was placed 3 feet from a wall with the participant facing the wall and the researcher standing to one side. During the mCTSIB test participants were instructed to maintain an upright standing position on the balance board, barefoot with arms hanging by their sides and feet positioned in a natural position (Villarroya et al., 2012). A small black target, adjustable in height according to the eye level of each participant was placed on the wall in front of the balance board (Villarroya et al., 2012). Standardized verbal cues to “look at the black dot”, “stand as still as possible”, and “just a few more seconds” were given to each participant per the standardized protocol. Each participant performed three trials with eyes open (EO) and three trials with eyes closed (EC). The order of trials with EO or EC was randomized to control for effects associated with repeated testing. Each trial lasted 30 seconds with a 15 second rest period in between trials. Overall stability index (average difference between the participant’s tilt angle and a vertical position) was recorded with the lowest of three trials used for mCTSIB data analysis.

Dynamic balance. For dynamic balance the Limits of Stability (LOS) test was utilized. Participants stood on the balance board with the location of the participant’s center of gravity displayed on-screen as a cursor which provided visual feedback (Figure 1). The participant was indicated on the computer screen by a small cursor and the test began with the participants’ cursor in the center red circle. When a circle turned yellow, the participant moved the cursor by leaning/weight shifting. When the participants’ cursor was kept on the yellow circle for 1 second the yellow circle turned grey and the participant brought their cursor back to the center.

Highlighting of circles was randomized by the Humac computer program. The LOS test consisted of eight directional movements performed in random order; forward, forward-right, right, backward-right, backward, backward-left, left, forward-left. Each participant completed 3 trials with a 15 second rest period between trials. Results were measured as percentage of overall time on target with the highest of the tree trials used for data analysis.

Intervention. Taekwondo classes were taught at each program's facility in 60 minute sessions, 2 sessions per week for 10 weeks. All classes were taught by a 4^{th} degree Black Belt with 9 years of taekwondo teaching experience. Assistants were available to hold pads, encourage participants, etc. Each training session consisted of a 10 minute warm up (light aerobic activities, stretching, etc.), 30 minutes of taekwondo drills (punching, blocking, basic kicking), 10 minutes of calisthenics (sit ups, push-ups, plank, etc.) 1 day per week and form (choreographed movements) practice 1 day per week, 10 minutes of cool down and stretching. Fifty percent of assessments were observed by an independent observer to assure compliance to assessment protocols. One hundred percent of assessments observed were completed according to protocol.

The control group continued with their daily activities and agreed to not participate in any organized sports or physical activity programs during the duration of the study. Individuals assigned to the control group received 10 weeks of free taekwondo classes after final assessments were completed.

Statistics. Data was analyzed using SPSS 21 with significance level set at $p<.05$. Means and standard deviations were calculated on demographic data. A t-test was conducted on pretest data to determine whether differences existed between groups prior to training. Two way repeated measures analysis of variance (ANOVA) was utilized with the independent variable being taekwondo training. Dependent variables were static balance eyes open (overall stability index), static balance eyes closed (overall stability index) and dynamic balance (percent time on target) over time (pretest, 5 week, 10 week, and 5 week post). Greenhouse-Geisser adjustment was used to evaluate observed within-group F ratios. Post hoc t-tests were calculated for each time period between mean balance scores by group. Analysis of Covariance (ANCOVA) was performed on static balance eyes open (EO) to adjust for lower overall stability index in the control group.

Results

Participants. Forty four individuals were accepted for participation and divided into taekwondo training and control groups based on their availability to consistently attend taekwondo classes at prescheduled days and times. Twenty two individuals were assigned to the training group with 22 individuals assigned to the control group. There were no significant differences between the control and taekwondo group in height, weight, BMI or age (Table 1). Group by time by gender was determined to be nonsignificant in both static balance EO and EC conditions and dynamic balance allowing all participants to be grouped together.

Intervention. Each participant in the taekwondo group was eligible to attend 20 classes. Average attendance was 73.4% (approximately 15 classes) with attendance ranging from 55.6% to 100% (11 to 20 classes). Reasons given for not attending all classes were lack of transportation and school events. Fifty percent of classes were observed by an independent observer with times of each section of the session recorded to determine instructor compliance to the teaching protocol. Compliance to the teaching protocol was 100% for session time ± 2 minutes of protocol.

Static balance, eyes open. Overall stability index was determined by the Humac Balance Board measuring each deviation from center and averaging the total sway movements to calculate average distance of sway. There was a significant difference between groups for pretest measurements in the EO condition ($t = 2.367$, $p = .023$) with the control group showing more stability (less sway) when compared with the taekwondo group. Between subjects main effect was nonsignificant, $F(1,42)=0.7$, $p=.407$. Utilizing the Greenhouse-Geisser adjustment there was a significant within subjects effect of time, $F(2.011, 84.55)=27.68$, $p<.001$ indicating a change in static balance in the EO condition for participants over time. Time by group within subjects effect was also significant, $F(2.01,84.55)=5.36$, $p=.006$. Post hoc t-tests between groups resulted in nonsignificant results at 5 weeks ($t=.22$, $p=.824$), 10 weeks ($t= -.564$ $p=.59$) and 5 weeks post ($t=.634$, $p=.529$). Taken together, these results indicate there were no significant differences between groups and both groups improved their overall static balance scores over time in the EO condition. It may be the lack of orientation to the assessment process for all participants may have allowed a learning effect. Not all participants completed an assessment orientation thus, it may also be that taekwondo at the beginner level does not provide an adequate amount of stimulation to induce changes in static balance with EO.

Due to the significant difference in pretest scores between groups an ANCOVA was calculated utilizing pretest scores as a covariate. The between subjects effect was non-significant, $F(1,41)=2.238$, $p=.142$. Within subjects effects were also non-significant for time, $F(1.068, 62.389)=.702$, $p=.48$, and for time by group, $F(1.733,71.048)=2.054$, $p=.142$. This indicates that even when correcting data for significantly different pretest scores, no significant change was seen in either group in the overall stability index in the EO condition.

Static balance, eyes closed. Pretest comparison of groups for overall stability was non-significant ($t=1.933$, $p=.06$) indicating groups had similar balance scores prior to taekwondo training. The between subjects main effect was non-significant, $F(1,42)=1.225$, $p=.275$. The within subjects effect over time was significant, $F(1.61,126)=15.502$, $p<.001$ indicating there were changes occurring over the four time points. When looking at time by group the results indicate there were no differences between the groups over time, $F(1.61,126)=3.146$, $p=.06$. Together, these indicate that both the taekwondo group and control group changed in static balance in the EC condition over time. T-tests performed on group means at 5 weeks ($t=.513$, $p=.611$), 10 weeks ($t= -.788$, $p=.441$) and 5 weeks post ($t=.764$, $p=.449$) were all non-significant and confirm the result previous result.

Dynamic balance. The taekwondo and control groups were not significantly different for LOS (overall percentage of time on target, TOT) prior to intervention, ($t= -1.75$, $p=.087$). A between subjects main effect by group was non-significant, $F(1,42)=.875$, $p=.355$ indicating no difference between the groups. Within subjects effect of time was significant, $F(2.441,126)=9.957$, $p<.001$, indicating there were significant changes over time. Within subjects effect of time by group was non-significant, $F(2.441,126)=2.651$, $p=.553$. This indicates both groups static balance ability changed over time in the EC condition. T-tests performed on group means substantiate these results with 5 weeks ($t= -.059$, $p=.953$), 10 weeks ($t=.81$, $p=.422$) and 5 weeks post ($t= -.966$, $p=.34$) all being non-significant.

Discussion

Balance and control of posture requires the integration of somatosensory, visual and vestibular inputs. It is an integral part of daily living and if balance is impaired it is difficult for anyone to perform functional movements and/or participate in activities of daily living (ADL).

Individuals with DS have lower balance abilities, both static and dynamic (Connolly & Michael, 1986; Spano et al., 1999; Villamonte, et al., 2010; Wang & Huei, 2002) than TD individuals throughout their entire lifespan (Connolly & Michael, 1986; Tsimaras & Fontiadou, 2004). This impairment in postural control can increase risk of falls and may limit a person's participation in physical activities and sports.

Training in various sports is often utilized to assist children with motor development. Sports may also be activities that children enjoy more than traditional physical training and would be more willing to pursue long term. However, there is specificity of training and practicing a static balance sports, such as judo may lead to better static balance than participating in a dynamic balance sport such as dance (Negahban, Aryan, Mazaheri, Norasteh & Sanjara, 2012). Taekwondo is considered a dynamic sport that provides opportunity to practice single leg stances during kicking motions (Pieter, 2009) and also perform ballistic movements when keeping away from opponents making it a sport for both static and dynamic balance.

Research regarding taekwondo and static balance is inconclusive. Negahban et al., (2012) utilized center of pressure sway to compare postural control of experienced taekwondo practitioners with that of expert shooters. Taekwondo experts displayed significantly more sway in bilateral stance than expert shooters or untrained controls. Other "dynamic" balance sports found similar results. Surfers (Chapman, Needham, Allison, Lay & Edwards, 2008), dancers (Perrin et al., 2002; Schmit, Regis & Riley, 2005) and rhythmic gymnasts (Calavalle at al., 2008) have reported increased sway when compared to less skilled practitioners or inactive controls. In contrast, other studies have shown that dancers (Gerbino et al., 2007) and gymnasts (Aydin et al., 2002; Bressel et al., 2007) have better static balance performance than people without training (Leong et al., 2011). Fong et al., (2012) trained children with Developmental Coordination

Disorder in taekwondo 3 days per week for 12 weeks and those children had less body sway than children without training. However, the protocol used by Fong et al., (2012) included many movements that were similar to vestibular exercises commonly used in sensory integration therapy. This protocol may have provided movements which may not normally have been included in a beginning taekwondo program or provided more repetitions of these movements than would normally be completed at this level.

The current study did not show improvement in static balance in either EO or EC conditions. Beginning taekwondo classes focus on technique by using midlevel kicks to waist height. Fong and Ng (2012) suggested the superior unilateral stance stability in long term taekwondo practitioners may have resulted from repeated practice of high kicks, up to head level of their opponent. Head level kicks score more points in taekwondo competition. It is possible the midlevel kicking did not elicit enough of a vestibular response to improve static balance for beginning taekwondo practitioners and should be studied further.

Dynamic balance is an area where individuals with DS are deficient and may benefit from taekwondo training. As taekwondo practitioners become more proficient with kicking techniques their movements become more ballistic thus requiring more dynamic balance. Cromwell et al., (2007) noted significant improvement in a multidirectional reach test performed by older adults (61-80 years) following 11 weeks of taekwondo training. Looking specifically at adults with DS, Fontiadou et al., (2009) had ten adults with DS (age 22-35 years) participate in a rhythmic gymnastics program while 8 individuals with DS of comparable age served as controls. The group that participated in the rhythmic gymnastics program significantly improved their dynamic balance scores at each time interval. Tsimaras & Fotiadou (2004) showed improved dynamic balance following 12 weeks of dynamic balance and plyometric exercises in subjects with DS.

The current study did not show significant improvement in dynamic balance scores after 10 weeks of taekwondo training. At each of the 4 time points, participants performed three trials of an LOS assessment shifting their weight to move a cursor on a computer screen. Single trials took over 1½ minutes to complete, and in some instances, over three minutes per trial. A 15 second rest period was given between trials. In contrast, participants in the studies by Fontiadou et al., (2009) and Tsimaras & Fontiadou (2004) were given 3-5 minutes rest between trials on the stabiliometer with trials lasting 30-, 45-, and 60-seconds.. It was observed during this study that participants became tired and distracted during the third trial. It could be that fatigue and/or lack of motivation produced poorer results. It is also thought that individuals with DS need more practice to fully understand and execute a task (Gomes & Barela, 2007). More than one orientation session may be required for participants to fully understand the task.

A limitation of the current study is the taekwondo classes were self contained with only individuals with DS participating. It is possible that inclusion of TD individuals in the class would allow for pairing of TD participants with participants with DS for partner drills thus promoting more physical activity and active engagement during each class. This may also provide for greater role modeling of techniques. No studies with inclusive taekwondo classes were found. Another limitation was taekwondo participants from the community adult education program often attended other programs at the facility on the same days as individuals in the control group. Even though the individuals in the control group did not participate in taekwondo classes they may have been learning movements and “practicing” with their friends on days when taekwondo was not offered.

Future research should explore whether inclusive classes would bring about different results due to modeling behaviors and increased activity during classes. Also, development of balance is delayed in children with DS and it may be beneficial to determine if taekwondo training would improve balance in this age group.

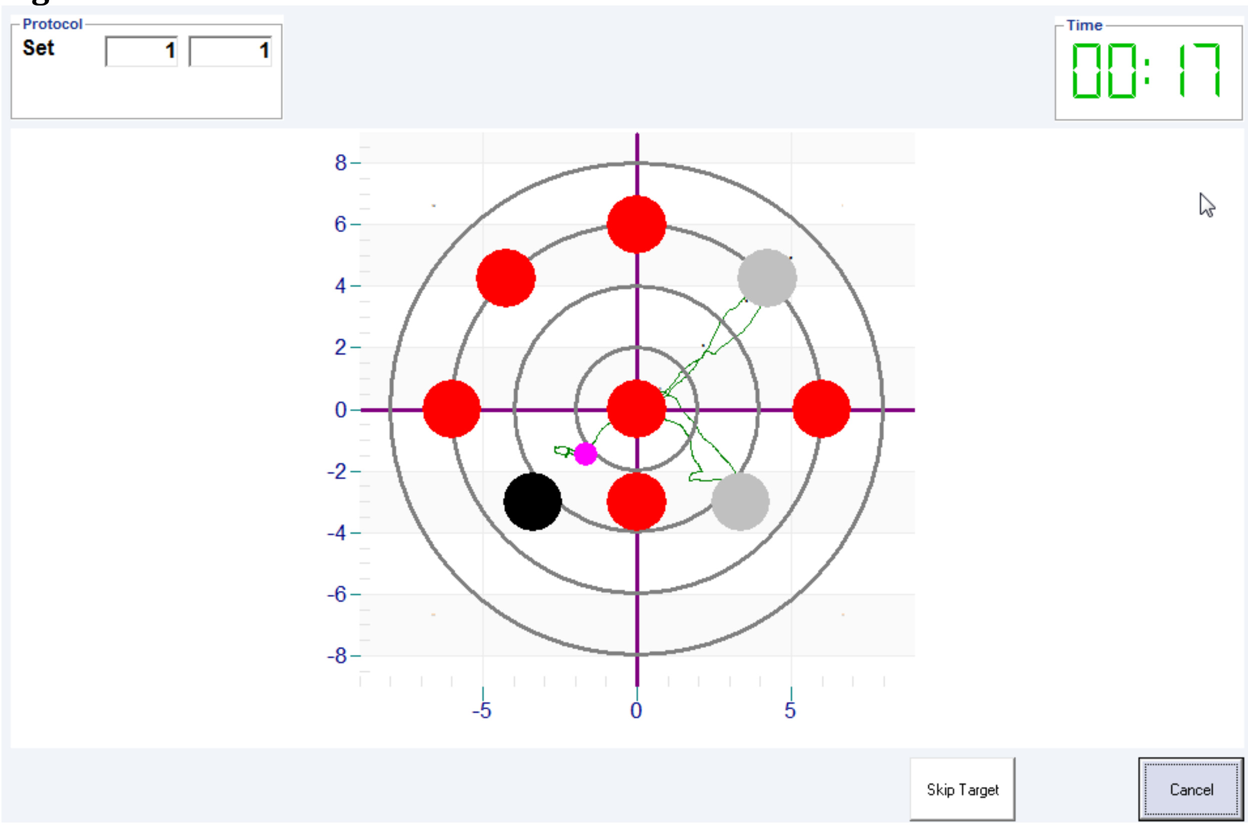
Table 4.1

DEMOGRAPHIC INFORMATION FOR TAEKWOND AND CONTROL GROUPS

Taekwondo n = 22; Control n = 22; SD – standard deviation; p values for t tests significance <.05.

	Taekwondo	SD	Control	SD	p=
Age (yrs.)	24.25	±3.19	25.90	±3.33	.507
Height (in.)	60.98	±3.49	59.93	±2.06	.233
Weight (lbs.)	147.8	±32.38	151.55	±33.50	.706
BMI	24.42	±6.28	25.67	±5.53	.491
Gender	Female	10	10		
	Male	12	12		
Race	Caucasian	22	20		
	African Am.	0	2		

Figure 4.1



Feedback Display: Limits of Stability

The Limits of Stability Display measures the patient's ability to lean toward points around their center of pressure. The goal is for the patient to move the round cursor (their COP) to the highlighted target. After the patient remains in the target for 1.0 seconds, the system turns the target to gray and moves to the next target. The patient moves between the center target and each surrounding target in a random order.

(Humac Balance Board Users Manual, 2012)

Table 4.2

BALANCE MEASURES AT FIVE WEEK INTERVALS

Eyes Open and Eyes Closed measure overall stability index which is the average difference between the participant's tile angle and a vertical position. Dynamic balance measured percentage time on target. M = mean; SD = standard deviation.

	Eyes Open				Eyes Closed				Dynamic			
	TKD		Control		TKD		Control		TKD		Control	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Pretest	5.6	±2.5	4.0	±1.7	6.0	±3.7	4.3	±2.0	14.2	±8.9	19.2	±10.1
5 weeks	3.4	±1.3	3.5	±1.8	3.8	±1.7	3.5	±1.8	23.9	±18.1	24.2	±11.9
10 weeks	2.7	±1.5	3.0	±1.8	2.7	±1.5	3.1	±1.9	22.2	±15.9	25.7	±12.9
5 wk post	3.0	±1.5	2.7	±1.5	3.3	±1.5	2.9	±1.6	16.5	±9.9	19.3	±9.2

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CHAPTER 5

DISCUSSION

This chapter presents the results of the current study in the context of possible physiological causes for decreased strength and balance in young adults with DS along with possible mechanisms for improved these parameters with physical activity.

Strength. Individuals with Down syndrome (DS) demonstrate lower strength levels than individuals with other forms of ID or TD individuals. These levels remain lower at all stages of life (Angelopoulou et al., 2000; Carmeli & Kessel et al., 2002; Cioni, Cocilovo & DiPasquale, 1994; Cowley et al., 2011; Gupta, Rao & Kumaran, 2011; Horvat & Croce, 1995; Shields, Dodd & Abblitt, 2009). Several mechanisms for decreased strength levels in these individuals have been proposed. Cioni et al., (1994) sugested that a general "hypofunctioning" of the neuromuscular system may be responsible for decreased strength in children with DS. Cioni et al., (1994) determined that children with DS did not show typical strength gains at puberty despite typically increasing hormone levels leading them to suggest that individuals with DS may exhibit a basic defect of the pyramidal system, which would impact descending signals to the muscles. It has also been proposed that there is a dysfunction of the muscle itself which causes decreased strength (Rothermal, Vega, Yang, Bassel-Duby & Williams, 2000). Individuals with DS appear to have a gene, CSCR-1, which encodes myocyte-enriched calcineuron interacting protein (MCIP1). The interaction between MCIP1 and calcineuron appears to alter calcineuron dependent pathways. It is believed the calcineurin dependent pathways are responsible for hypertrophy in skeletal muscle, thus if altered would decrease contractility and thus muscular strength (Tiernan, 2012).

Muscular strength, particularly leg strength, has been shown to be a significant predictor of functional performance in adults with DS (Terblanche & Boer, 2012) and increasing strength may lead to improvements in functional ability (Shields & Dodd, 2004; Smail & Horvat, 2006) and possibly help maintain independence. Individuals with DS have demonstrated the ability to increase their lower body muscular strength after participation in various physical activities (Horvat & Croce, 1995; Murphy & Carbone 2008; Smail & Horvat, 2009; Smith, Kubo, Black, Holt & Ulrich, 2007), especially progressive resistance training. The use of taekwondo as a means of improving lower body muscular strength of young adults with DS was unique. The majority of taekwondo skills are kicking techniques and lower body strength is crucial to explosive kicking, jumping and stance stability. Machado, Osorio, Silva & Magini, (2010) analyzed kicking motions in taekwondo and kickboxing athletes and the analysis showed better results in muscle recruitment in athletes with more experience in both sports. Black belt martial art practitioners have routinely shown greater lower body strength than beginning taekwondo students (Fong & Ng, 2011; Probst, Fletcher & Selig, 2007; Toskovic, Blessing & Williford, 2004). Kim, Dattilo & Heo (2011) improved lower body muscle strength of 15-16 year old females by participation in taekwondo training. Although increased lower body strength is correlated with length of taekwondo training, it was thought that use of taekwondo as an intervention would possibly increase strength in young adults with DS.

One of the main finding of this study was that young adults with DS were able to increase their lower body muscular strength with 10 weeks of taekwondo training. These results are in agreement with previous studies that indicate individuals with DS are able to increase muscular strength with physical training when given the opportunity to do so (Carmeli, Bar-Chad, Lenger & Coleman, 2002; Guidetti, Franciosi, Gallotta, Emerenziani & Baldari, 2010; Horvat & Croce, 1995; Murphy & Carbone, 2008; Smail & Horvat, 2009; Smith, et al. 2007; Tsimaras & Fotiadou, 2004) and also in agreement with studies indicating taekwondo improves muscular strength in other populations (Kim, Stebbins, Chai & Song, 2011; Probst, Fletcher & Seelig, 2007; Toskovic, Blessing & Williford, 2004). Two major adaptations occur which contribute to increased muscular strength; hypertrophy and neural adaptations. In the current study, participants trained for 10 weeks, since increased muscle fiber size generally requires a minimum of 12 weeks training (Gupta et al., 2011) there was most likely an insufficient amount of time to elicit significant changes in muscle cross sectional area which implies neural changes would make the most significant contribution to increased strength. Increased neural activation, more efficient motor unit recruitment, improved motor unit synchronization and decreased Golgi tendon organ inhibition may all contribute to increased muscular strength (Staron et al., 1994). Also, individuals with DS frequently demonstrate a pattern of co-activation, increasing activity of both agonist and antagonist muscles, especially when faced with an unfamiliar movement pattern or perturbation (Latash, 2008). With consistent practice over the 10 weeks, it may be the participants of this study were able to better coordinate the activation of relevant muscles and to more fully activate the prime movers in specific movements. This improved coordination would lead to a greater force produced within that movement (Sale, 1988).

A concern from this study’s findings is the loss of muscular strength after completion of the training period. This decline is in agreement with Winters and Snow (2000) who found that muscle strength decreased significantly toward baseline in premenopausal women following a detraining period. Also, Elliott, Sale and Cable (2013) found similar significant detraining effects in postmenopausal women, and Lemmer et al., (2000) produced the same results in TD participants 20-30 years of age and 65-75 year of age after 9 weeks of strength training and 31 weeks of detraining. In the current study strength decreased 30% after 5 weeks of detraining. Although still above the pretest strength levels it is possible all strength gained from training would have been eliminated if the time period of detraining was longer. The percentage of strength lost in this study was greater than Volaklis, Douda, Kokkinos & Tokmakidis, (2006) who noted a decrease of 10-16% after 3 months of detraining in participants with coronary artery disease and greater than a study by Staron et al., (1991) where 15 college aged women lost 13-32% of strength following a 6 month detraining period after an intensive 20 week strength training program. The percentage of strength lost was equivalent to a 30% loss in strength seen in 11 elderly individuals after 12 weeks of detraining (Taaffe & Marcus, 1997). It is believed that individuals with DS develop aging related physical changes earlier than TD individuals, which may lead to a greater detraining effect in this population. We have no mechanism in the current study to determine if detraining affected muscle fiber type or neural adaptations however, Mujika and Padilla (2000) found that both muscle atrophy and diminished neural activation were responsible for the decline in maximal force in trained athletes following 12 weeks of inactivity. The large decreases in strength after the detraining phase in this study confirm the positive effect of taekwondo training and the need for continued activity to maintain strength gains in young adults with DS. The rapid loss of strength may also indicate these individuals do not have the opportunity or motivation to participate in physical activity on their own. Extra effort may be required on the part of parents/caretakers to schedule physical activity in order to promote fitness and health.

Balance. Infants with DS are typically born with a normal sized brain, however brain development diminishes by up to 24% during early childhood, with the cerebellum and brainstem being particularly affected (Anson, 1992; Costa, Walsh & Davisson, 1999; Tsimaras & Fontiadou, 2004, Vicari, 2006). There is poor myelination of descending tracts and brainstem neurons, with decreased neural connection in the motor cortex, basal ganglia, cerebellum, and brainstem (Becker, Mito, Takashima & Onoderak, 1991; Shumway-Cooke & Woolacott, 1985). Balance ability depends on the CNS selecting and integrating sensory inputs from visual, vestibular and somatosensory systems (Fong & Ng, 2012) however, the relationship between brain structural abnormalities and balance ability is unclear. Studies which have attempted to facilitate normal motor development through a variety of stimulation techniques have shown mixed results (Uyanik, Brumn & Kayihan, 2003). Children with DS have a significant delay in development of balance and motor skills (Connolly & Michael, 1986; Spano et al., 1999; Villamonte et al., 2010; Wang & Huei, 2002) tending to rank lower on balance performance than TD individuals or individuals with ID that is nonDS related (Connolly & Michael, 1986; Tsimaras & Fontiadou, 2004).

Possible causes for balance difficulties in individuals with DS could be how sensory information coming from visual, vestibular and somatosensory inputs are integrated and properly used to control motor systems. Lack of integration or deficiency in one sensory system creates a need for compensation from the other systems. Individuals with ID have difficulty processing visual information and so muscle groups co-activate toward the termination of movement patterns. For example, tensing muscles around a joint increases stretch sensitivity of muscle spindles and enhances proprioception at that joint. This co-activation is more pronounced in individuals with DS (Horvat, Croce & Zagronik, 2010). Individuals with DS also demonstrate longer long-loop reflexes (Anson, 1992) leading to longer reaction times, which may create increased postural sway velocity (Shumway-Cook & Woollacott, 1985; Webber, Virji-Babul & Edwards, 2004) and slower responses to postural perturbations (Hale, Miller, Barach, Skinner & Gray, 2009). The later onset of latencies of muscular response and irregular muscle activation around joints during movement can possibly create difficulty in reacting to environmental changes. It has been suggested that individuals with DS utilize muscular co-contraction as a cautionary strategy against unpredictable changes in the environment (Rigoldi, Galli & Albertini, 2011; Vuillerme, Marin & Debu, 2001; Webber et al., 2004). The consequence of this compensatory mechanism is that active movements may be executed with decreased speed, and while mechanically suboptimal it does provide better control (Rigoldi et al., 2011; Webber et al., 2004). In general, research shows individuals with DS have greater sway in both the EO and EC conditions than TD age matched peers (Galli et al., 2008; Villarroya et al., 2012; Vuillerme et al., 2001) with no physical training. Gomes and Barela (2007) examined the effects of visual and somatosensory information on body sway in adults with DS. When these adults with DS were allowed to place their index finger on a stationary surface the amount of sway decreased to levels equal to TD adults in both eyes open and eyes closed conditions suggesting individuals with DS may require enhanced sensory input to optimize sensory information and improve postural control (Gomes & Barela, 2007). Adults with DS and TD adults both had greater postural sway in the eyes closed conditions

There is a limited research on improving balance in individuals with DS. Gupta et al., (2011) successfully utilized a progressive resistance training program to increase lower body strength and therefore increase balance. Tsimaras and Fotiadou (2004) improved balance of individuals with DS by using plyometric and balance exercises. Negahban, Aryan, Mazaheri, Norasteh & Sanjari, (2012) proposed practicing a “static balance” sport, such as judo, may lead to lesser body sway. Perrin, Deviterne, Hugel & Perrot (2002) also suggested practicing a specific sport may improve both static and dynamic balance but training over a long period of time may be necessary for the appropriate learning to occur.

Fong and Ng (2012) have indicated taekwondo practitioners do not have superior standing balance when compared to judo practitioners and assessed bilaterally and. Taekwondo tends to be a “dynamic” sport which requires stabilizing on one supporting leg in order to perform kicking techniques with the other leg. Young taekwondo practitioners show superior unilateral stance when compared to age matched TD controls. This may result from repeated practice of high kicks during training (Fong & Ng, 2012). Studies have found reduced reflex excitability in athletes trained in sports with high postural demand. Suppression of the reflexes would reduce muscle spindle activation and enhance postural control (Cheung). Tsimaras and Fotiadou (2004) indicated the vestibular system is important for development of posture and balance. They have reported the adaptations of the central nervous system and the stimulation of the vestibular system that exercise evokes may result in improving the balance of people with ID. Possible improvements in balance can be explained by the nature of the movements practiced during taekwondo training. Spinning motions performed during taekwondo may stimulate the vestibular system and possibly increase its sensitivity (Fong & Ng, 2012). Stances encourage longer step length; more time is spent in single leg support while coordinating arm movements improving the ability to perform multiple tasks while standing and walking; spinning motions emphasize orientation with respect to space and location (Cromwell, Meyers, P.M., Meyers, P.E. & Newton, 2007). Together these may improve quality of gait and efficiency of performance of daily activities, thus improving quality of life (Jankowicz-Szymanslca, Mikolajczyk, Wojtanowski, 2012).

In this study, neither static balance in both EO and EC conditions nor dynamic balance improved with 10 weeks of taekwondo training. It could be since not all participants participated in assessment orientation sessions the learning effect masked any changes in bilateral static balance. Also, bilateral static balance has been shown not to improve with taekwondo training however, unilateral stance has shown improvements. Because of the dynamic nature of the sport, taekwondo may not improve bilateral static balance (Fong, Tsang & Ng, 2012) which was the measure utilized in this study. Taekwondo practitioners tend to rely on visual and vestibular inputs to maintain standing balance. It may be that 10 weeks of training was not sufficient enough to significantly improve participants' ability to rely on somatosensory input for balance (Fong et al., 2012).

Sports training may be a viable and enjoyable way of improving balance. After completion of this study, all participants requested they be permitted to attend taekwondo classes being held for the control group indicating they enjoyed the classes and may possibly wish to continue training long term. No injuries or other adverse events resulting from training occurred indicating taekwondo training is achievable and safe for young adults with DS to participate in. This may alleviate concerns of parents/caretakers that taekwondo may cause injury to or promote aggressive action from participants.

Conclusions. Taekwondo can increase muscular strength of young adults with DS. This increase in strength may allow these individuals to maintain their independence longer, provide a sport in which they can continually and successfully participate, and possibly improve their quality of life. Many studies have shown improvement in strength of individuals with DS utilizing progressive resistance training. It can be difficult for highly motivated TD individuals to continue a progressive resistance training program even when they do not have the transportation issues, the need for supervision, and access issues individuals with DS come up against. A taekwondo training program may provide a fun, social atmosphere that will assist in keeping individuals with DS motivated to continue training, therefore keeping their levels of strength higher.

Limitations. A limitation of this study is not all participants were fully oriented to the balance equipment and tests prior to initial testing. This may have created a learning curve which skewed the data. There also was no monitoring of control group participants to assure they were not participating in any organized sports or programs and were not "practicing" with their friends who were in the taekwondo class while they were at their facility.

Another limitation of this study is the assessor knew which individuals were in the control and taekwondo groups introducing a possible bias. It would be advisable to have researchers doing assessments who would be blind as to group affiliation. Although assessment directions and encouragement statements were scripted it is still possible for a researcher to introduce a bias based on which group the participant was assigned to.

Classes were held at program sites with only individuals with DS participating. Individuals with DS tend to learn by visually seeing a demonstration of the movement and also being lead through the movement kinesthetically. Having integrated classes may provide a greater number of practitioners for individuals with DS to visually observe and follow. Also, overall pace of the classes may have been higher if the classes had been integrated providing more drills during the session and possibly providing greater opportunity for improvement.

Future research. Future research should investigate whether teaching adolescents and/or young children taekwondo would increase the rate at which they develop strength and balance. Would it be possible to increase these abilities to the same level as age matched TD peers, would this improve their ability to participate in sports and other recreational activities, and would it improve balance ability as they reach young adulthood?

Another area of possible research would be utilizing a longer training period (i.e. 6 months or more). A longer training period may help determine if maximal lower body strength can be reached and if balance would increase with more exposure to the sport.

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APPENDIX

Participant Preparticipation Medical History and Demographic Questionnaire

Participant name: ____

Address: ______________________________ Phone Number: ______________

______________________________ Cell Number: ______________

Email: ______________________________ Date of Birth: ______________

Gender (circle): Male Female

Ethnicity (circle): Caucasian African American Hispanic Asian Other

Parental contact name and number: ______________________________

____

Please answer the following questions:

1. Is the participant able to follow simple verbal instructions? Y N
2. Does the participant currently participant in organized sports? Y N

If yes, what sports?____

3. Has the participant ever received any martial arts training? Y N

If yes, when?____

4. Does the participant have any neurological challenges? Y N

If "yes", please explain.____

5. Does the participant have any orthopedic challenges? Y N

   If "yes", please explain. ____

6. Has the participant ever been diagnosed with atlantoaxial instability? Y N

7. Does the participant have any cardiac challenges? Y N

   If "yes", please explain. ____

8. What type of physical activities does the participant engage in on a daily basis?

   Please list: ____

9. What type of recreational activities does the participant enjoy?

   Please list: ____

10. Is there any reason why the participant should not participate in martial arts training?

    Please explain: ____

____

Signature Date

Relationship to participant: ____

Height: to nearest ¼ inch:______________________________

Weight: to nearest ½ pound: ______________________________

Age at beginning of study: years and months:____________________

For IRB Approval Stamp

SUBJECT INFORMED CONSENT DOCUMENT

THE EFFECT OF TAEKWONDO TRAINING ON BALANCE AND STRENGTH IN ADULTS WITH DOWN SYNDROME

IRB number:
Principle investigator: Kathy Carter MS, RD
Study sites: Down Syndrome of Louisville, Louisville Metro Parks, Browns Taekwondo
If you have questions call: 502-852-8352

You or your adult child with Down syndrome (hereafter referred to as "You") are invited to participate in a research study. The study is being conducted by Kathy Carter MS, RD. The study is sponsored by the University of Louisville, Department of Health and Human Performance. The study will take place at Down Syndrome of Louisville, Metro Parks and Recreation, Brown's Traditional Taekwondo.

Purpose
The purpose of this study is to determine if participating in a taekwondo training program will improve the static balance, dynamic balance, and/or lower body strength of adults with Down syndrome.

Procedures
Approximately 60 subjects will be invited to participate. Participants will be "randomized" into groups. This means each participant will be assigned to either a taekwondo training group or a control (do their normal activities) group using a method like flipping a coin. Those participants assigned to the control group will be able to participate in taekwondo free for 10 weeks after the initial 15 weeks of the study. This will be provided as our "thank you" for agreeing to be in the control group.

In this study you will be asked to stand on a balance board with your eyes open and eyes closed; stand on the balance board and try to move a cursor on a computer screen by leaning forward, backward and side to side; lie and sit on a table contracting various muscles against a hand held dynamometer. Physical testing will take approximately 45 minutes. The testing will be completed four (4) times during the study: prior to starting taekwondo training, after five (5) weeks of taekwondo training, after 10 weeks of taekwondo training, and five (5) weeks after the end of taekwondo training. This study will continue for fifteen (15) weeks. You may refuse to complete any test that makes you feel uncomfortable. All tests will be conducted by the same person each time.

Each taekwondo training session will last 60 minutes. These sessions will consist of a warm up period, pad drills, forms training (individual movements taught in a specific order), conditioning exercises (push ups, sit ups, etc.), cool down, and stretching.

Potential Risks
No risk is expected but participation in the study may lead to muscle soreness and fatigue. Muscle soreness may result from the use of muscles that have not been previously exercised. Training is structured so exercise will start slowly and progress in intensity to minimize both muscle soreness and fatigue. All training will be closely monitored by the lead researcher, taekwondo instructors, and assistant instructors to reduce the risk of accidents. In addition, each person will be given instruction in proper techniques and pacing of exercise.

Benefits
Individuals who take part in this study may improve their static balance, dynamic balance and/or lower body strength. In addition, information gained may provide for improved future programming for children with Down syndrome.

Compensation
You will not be compensated for your time, inconvenience, or expenses while you are in this study. However, you will receive free instruction in taekwondo for a period of ten (10) weeks.

Study Related Physical Injury
If you are injured by participating in this study treatment is available. The study site, or the investigator has not set aside money to pay for treatment of any injury. You and your insurance will be billed for the treatment of these injuries. Before you agree to take part in this study you should find out whether your insurance will cover an injury in this kind of study. You should talk to the investigator or staff about this. If you are injured, there is no money set aside for discomfort, disability, etc. You do not give up your legal rights by signing this form. If you think you have a study related injury, please call the investigator.

Confidentiality
Total privacy cannot be guaranteed. Information collected about me will be kept confidential unless otherwise required by law. If the results from this study are published, your name will not be made public. My identity will be coded and all data will be kept in a secure, password protected computer. While unlikely, the following may look at the study records:

University of Louisville Institutional Review Board, Human Subjects Protection Program Office

People who are responsible for research oversight at Down Syndrome of Louisville and/or Metro Parks Recreation

Office of Human Research Protections

Voluntary Participation
Your participation is voluntary. You can refuse to participate or stop taking part at any time without giving any reason, and without penalty or loss of benefits to which you are otherwise entitled. You will be told about any changes that may affect your decision to continue in the study. You can ask to have all information related to yourself be returned to you, removed from the research records, or destroyed.

Research Subject’s Rights, Questions, Concerns, and Complaints

If you have any concerns or complaints about the study or the study staff, you have three options:

You may contact the principal investigator at 502-852-8352 or 502-709-2791.

If you have any questions about your rights as a study subject, questions, concerns or complaints, you may call the Human Subjects Protection Program Office (HSPPO) at 502-852-5188. You may discuss any questions about your rights as a subject, in secret, with a member of the Institutional Review Board (IRB) or the HSPPO staff. The IRB is an independent committee composed of members of the University community, staff of the institutions, as well as lay members of the community not connected with these institutions. The IRB has reviewed this study.

If you wish to speak to a person outside the University, you may call 1-877-852-1167. You will be given a chance to talk about questions, concerns or complaints in secret. This is a 24 hour hot line answered by people who do not work at the University of Louisville.

This paper tells you what will happen during the study if you choose to take part. Your signature means that this study has been discussed with you, that your questions have been answered, and that you will take part in the study. This informed consent document is not a contract. You are not giving up any legal rights by signing this informed consent document. You will be given a signed copy of this paper to keep for your records.

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Name of Subject/Legal Representative   Signature of Subject/Legal Representative Date Signed

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Name of Person Explaining Consent Form   Signature   Date Signed
(if other than investigator)

____

Name of Researcher   Signature of Researcher   Date Signed

Telephone number: 502-709-2791   Email: kapick01@louisville.edu

Please sign both copies, keep one and return one to the researcher.

LIST OF INVESTIGATORS	PHONE NUMBERS
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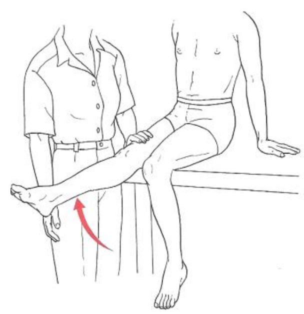
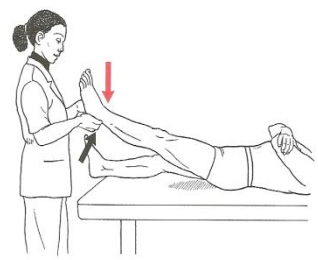
Direction for Hand Held Dynamometry Assessment

Test	**Position of Participant**	**Position of Researcher**	**Instructions to Participant**	**Picture**
Foot Plantar flexion	Prone with feet off end of table.	Standing at the end of the table in front of the foot to be tested. One hand is contoured under and around the test leg just above the ankle. HHD is placed against the plantar surface at the level of the metatarsal heads.	"Point your toes like a ballet dancer."	
Knee Flexors	Prone with limbs straight, toes hanging over edge of table. Test is started at 45° knee flexion.	Standing next to limb to be tested. HHD placed on posterior surface of the leg just above the ankle. Other hand is placed over hamstring tendons on posterior this to assist stabilization.	"Bend your knee. Bring it all the way to your behind."	
Knee Extensors	Sitting on edge of table, knees slightly out from the edge of the table, knees bent to 90°, feet relaxed. Participant may lean slightly back to relieve hamstring muscle tension. Test is started in 45° knee flexion.	Standing at side of limb to be tested. HHD placed over anterior surface of the distal leg just above the ankle. Other hand may be placed on top of quadriceps muscle just above the knee to assist in stabilization.	"Straighten your knee. Bring it all the way up."	

Hip Flexors	Short sitting with thighs fully supported on table and legs hanging over edge. Participant may use arms to provide trunk stability by grasping table edge or with hands on table at each side.	Standing next to limb to be tested. HHD placed over distal thigh just proximal to knee joint.	"Lift your leg off the table. Keep knee bent."	
Hip Extension	Participant lies prone on table. Arms may be overhead or abducted to hold side of table.	Standing at side of limb to be tested at level of pelvis. HHD is placed on posterior leg just above the ankle. Opposite hand may be used to stabilize or maintain pelvis alignment. MMT may be placed on posterior thigh just above the knee for a less demanding test.	"Lift your leg off the table as high as you can without bending your knee."	
Hip Abductor	Patient is side-lying with test leg uppermost. Start test with limb slightly extended beyond the midline and the pelvis rotated slightly forward. Lowermost leg is flexed for stability.	Standing behind participant. HHD placed across the lateral surface of the knee. HHD may be placed at the ankle giving a longer lever and requiring greater strength	"Lift your leg up in the air as high as you can. Don't move your hips."	

Adapted from Muscle Testing, Techniques of Manual Examination, 8th edition. Hislop and Montgomery, Elsevier, 2007.

There are several things that participants may do/not do that could interfere with the accuracy of the tests.

1. There may be variation in their "true" effort expended. It is important to try to motivate the participants to give their best effort.
2. They may not be willing to endure discomfort. Try to make the tests as comfortable as possible for participants both in their position on the table and in the placement of the HHD.
3. They may have difficulty understanding the requirements of the test. Provide a practice run (or several if necessary) on each position prior to starting testing. This can be done by asking the participant to show you the motion they are to make before you put the HHD into place.

If you have difficulties that you feel may affect the results, please make notes on the back of the results sheet.

Tests need to be done in the following order to limit the number of times participants must change position; ankle plantar flexors, knee flexors, hip extensors, hip abductors, knee extensors, hip flexors. Test the dominant side first, then nondominant side, then ask the participant to change to the next position.

In order to keep things as consistent as possible, it is important to give each participant the same instructions prior to each test and to give them the same "encouragement" during each test. Read each tests directions prior to administering the test. Give the standardized directions for the test and then state, "when I say go push as hard as you can. Ready? 3 – 2 – 1 GO. Push. Push. Push. Push. Push. Relax." Each push should be given on the second so at the end of 5 "pushes" they have held the position for 5 seconds.

Use a stop watch or watch with a second hand to count off a 30 second rest period then test the muscle again. Each muscle will be tested a total of 3 times. Once the dominant side has been tested, test the nondominant side before asking the participant to change positions.