

LOWER LIMB STRENGTH AND BALANCE IN ADULTS
WITH AND WITHOUT DOWN SYNDROME

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ABSTRACT

Individuals with Down Syndrome demonstrate deficits in many physiological attributes, including muscular strength and balance. The purpose of this study was to examine the relationship between lower limb strength and balance in adults with and without (typically developing, intellectual disability) Down Syndrome. This was investigated using performance production measures of the BTrackS force plate and Lafayette dynamometer. Voluntary participants (n = 64) with diagnoses of Down Syndrome, intellectual disability, or typical development who ranged in age from 18 to 50 years old participated in the study. Balance was quantified by having the individuals stand on the BTrackS force plate for four consecutive 20-second trials. The medial/lateral, anterior/posterior, and ellipse area measurements were analyzed. There was no significant correlation found between lower limb strength and balance, but the participants with Down Syndrome did confirm inherent performance deficits in regards to strength and balance. The results from this study suggest that additional factors may affect balance than solely lower limb strength.

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INTRODUCTION

Down Syndrome

Down Syndrome (DS), also known as Trisomy 21, is an aneuploid chromosomal disorder that results from the presence of a third partial or whole copy of chromosome 21. The third copy is due to abnormal cell division, or nondisjunction of the sex cells. There are three types of DS: Complete Trisomy 21, Mosaic Trisomy 21, and Translocation Trisomy 21. 95% of individuals with DS have Complete Trisomy 21, or an entire extra copy that failed to split up during meiosis (Sherman, Allen, Bean, & Freeman, 2007). The remaining 5% of cases are due to only some of the body's cells having aneuploidy, or all the cells having a partial third copy on chromosome 21. Although there has been no definite cause discovered to perpetuate these abnormalities, genetic research has recognized etiological factors that influence the likelihood and trends from past cases. According to Gauden (1992), not only do 95% of fetuses with DS get the extra chromosome from the mother's egg, but increasing maternal age, and therefore decreasing health of the eggs, is the primary influencer determining prevalence. There have also been trends in the prevalence of DS, with non-Hispanic white individuals having the highest pooled prevalence, and lower rates in females than males across the board (Shin, Besser, Kucik, Lu, Siffel, & Correa, 2009). According to Presson, Partyka, Jensen, Devine, Rasmussen, McCabe, & McCabe (2013), there are about 8.27 people with DS for every 10,000 United States residents. DS is the most common cause of chromosomal intellectual disability and continues to be the focus of research (Mégarbané, Ravel, Mircher, Sturtz, Grattau, Rethoré, ... et al. Mobley, 2009).

Multiple intellectual, physiological, and neurological deficits accompany a diagnosis of DS. Although there is considerable variability in severity and disability throughout the DS population's spectrum, there are features and symptoms characteristic of DS that the vast

majority of this demographic exhibits. The more apparent physical abnormalities include facial features such as upslanting “almond-shaped” eyes, flat bridge of the nose, a protruding tongue, and an overall, distinctive stature, characterized by shorter height and heavier set (Epstein, 2016). The more inapparent features of this genetic abnormality include low muscular fitness and decreased cardiovascular and respiratory capacity (Pitetti, Baynard, & Agiovlasis, 2013). Individuals with DS’ inability to efficiently circulate oxygen and blood flow to their bodies, paired with lower muscular strength and endurance, leads to low rates of sufficient physical activity, and consequently, higher rates of overweight and obesity (Pitetti et al., 2013). Their musculoskeletal deficits go beyond just weak muscles; they also have hypotonia, or low muscle tone, and ligamentous laxity, or loose ligaments. The low muscle tone leads to a decreased ability to resist passive stretching while relaxed. Individuals with DS also tend to hold deficits in balance (Seron, Modesto, Stanganelli, Carvalho, Emanuel Messias Oliveira de, & Greguol, 2017). This deficit can be problematic, and lead to accidents, injuries, and the inability to complete activities of daily living (ADLs) independently.

Muscular Strength

Strength, simply stated, is the force that a muscle can produce. Muscular strength can be measured via either a cable tensiometer, a hand-grip dynamometer (MMT), an isokinetic device, or with free-weights or exercise machines using a one- to three-repetition maximum test (Hurley, 1995). Although most ADLs are quick, simple, and do not require a person’s maximum muscular strength to complete, peak strength testing provides functional insights to a person’s individualized baseline and what they are capable of doing (Lesnak, Anderson, Farmer, Katsavelis, & Grindstaff, 2019). As previously mentioned, individuals with DS struggle with numerous musculoskeletal abnormalities, including less muscular volume and overall strength.

According to Shields and Taylor (2010), people with DS generate half as much upper and lower limb strength compared to typically developing people of identical chronological age. With the use of dual energy x-ray absorptiometry (DEXA), both males and females with DS comprehensively showed lower values of total muscle mass versus individuals without an intellectual disability (González-Agüero, Vicente-Rodríguez, Moreno, Guerra-Balic, Ara, & Casajús, 2010 & Baptista et al., 2005). Specifically looking at the lower limbs, the ratio of hamstring to quadricep volume is 20% lower in those with DS compared to their counterparts of typical development (TD), hinting at their inherent physiological deficit (Pitetti et al., 2013). Atypical muscle mass, volume, and strength in people with DS negatively affects their peak strength. Since strength is required to maintain an upright position in equilibrium, deficits in maximum contraction ability may affect balance.

Balance

Balance is the ability to maintain the line of gravity (vertical line from center of mass) of a body within the base of support with minimal postural sway. Maintaining balance requires coordination of input from musculoskeletal and sensory systems (Vernadakis, Derri, & Antoniou, 2014). A typically developing person can control their upright posture and limit movements during an act of balance, ultimately decreasing the amount of deviations of their center of pressure (CoP), (Wang, Long, & Liu, 2012). Adults with DS commonly present more postural sway which leads to a significantly greater deviated center of pressure (Gupta, Rao, & SD, 2011). Every time the body shifts outside of its CoP, the probability of a stumble, unrecoverable loss of balance, or injury due to excessive and inappropriate force or motion on joints increases. So, if adults with DS sway significantly more outside of their CoP, their probability of falls, stumbles, or injuries also increase. The implications of balance loss in the DS

population are much greater and serious than a typically developing adult due to their inherent physiological deficits. This deficit in balance persists throughout the entire lifespan and affects countless activities of daily living involving transfer and locomotion (Carter, & Horvat, 2016). Balance in both typically developing and those with disabilities can be measured and tested by laboratory-grade force plates, which are the gold standard for measuring balance performances from both dynamic and static (standing) points of view (Mengarelli, Verdini, Cardarelli, Nardo, Burattini, & Fioretti, 2018) and assessing the CoP displacement (Gil, Oliveira, Coelho, Carvalho, Teixeira, 2011).

Muscular Strength and Balance in Individuals with Down Syndrome

If balance is maintaining the body's orientation and center of gravity within the base of support, then balance may be directly influenced by the strength of the base of support (Schoneburg, Mancini, Horak, & Nutt, 2013). The base of support, connected through the lower limbs when standing, has a dynamic tone that allows a person to adjust their postural balance to subconsciously maintain equilibrium. Input from the musculoskeletal system is essential to the maintenance of balance (Vernadakis et al., 2014). Therefore, an individual with compromised or abnormal muscles in the lower body (low muscle volume, strength, and/or tone) inherently holds deficits in the inputs needed to maintain balance (Chougala, Ashwini, & Akhil, 2016). If a person with DS has hypotonia, then their base of support is compromised via less available muscular tension and strength. The hypotonia makes individuals with DS have a decreased ability to resist passive stretch, so when they are in quiet stance, any CoP perturbations are inherently more difficult to resist, recover, and correct.

Project Significance

Limited body strength within the DS population can prevent the ability of independent living and completion of tasks in the work environment and can also impede ADLs (Carter, & Horvat, 2016). The purpose of this study was to examine the role of lower limb strength on balance in individuals with and without (typically developing and intellectual disability) Down Syndrome. Comparing the strength of the base of support and its effect (if any) on balance, may clarify differences in mobility, stability, and overall ability between these groups. Results from this study will provide a crucial step in understanding if intervention, therapy, and guidance on strength-focused physical activity could improve overall balance, and in turn, ADLs and independence in the DS population.

Purpose and Hypothesis

The purpose of this study was to examine the relationship between lower limb strength and balance among adults with and without Down Syndrome. Lower limb strength, or isometric knee extension strength, was quantified using a Lafayette Hand-Held Dynamometer, or Manual Muscle Tester (MMT). Balance was quantified using a Balance Tracking Systems (BTrackS) portable force plate. It was hypothesized that there would be a strong, positive, significant relationship between lower limb strength and balance.

METHODS

Participants

A total of 64 participants were included in this study (21 of TD, 24 with an intellectual disability (ID), and 19 with DS), all within the ages of 18 to 50 years old. Descriptive statistics of the participant demographics are included in Table 1. Participants were recruited at Special

Olympics Texas events, by word-of-mouth, and via flyer and all individuals participated voluntarily. There was no attempt to include or exclude individuals based on distinction of mosaicism, translocation, or trisomy 21, as physiological characteristics in these populations are similar. Exclusion criteria included other comorbid conditions (i.e. cerebral palsy, muscular dystrophy, etc.), ankle-foot orthotics (AFOs) due to increased fall risk, and individuals that were immobile without assistive devices or were completely reliant on an assistive device. In addition, individuals were required to be able to stand independently in order to participate. To minimize risk and protect the participants, individuals who were unable to fully understand instructions were not allowed to participate in the study.

Table 1. Descriptive Statistics of Participants

	Typical Development	Intellectual Disability	Down Syndrome
Mean Age (yrs.)	34.1 ± 10.0	31.0 ± 9.3	25.9 ± 5.8
Mean Height (in.)	67.1 ± 4.1	64.7 ± 5.0	59.5 ± 3.7
Mean Weight (lbs.)	156.7 ± 24.3	174.3 ± 50.2	172.6 ± 28.7
Mean BMI	24.5 ± 3.6	29.1 ± 7.4	34.5 ± 6.1

Instruments

BTrackS Portable Force Plate

The Balance Testing Protocol consists of four consecutive 20-second trials (1 practice trial, 3 recorded trials). The BtrackS portable force plate measured center of pressure at a rate of 25Hz. Center of pressure (CoP) data produced measures of total sway, anterior-posterior sway, medial-lateral sway, and sway velocity. BTrackS detects disruptions in balance via CoP data and

generates a fall risk assessment and postural sway analysis. The results are calculated by the BtrackS™ Assess Balance Software (Goble, Manyak, Abdenour, Rauh, & Baweja, 2016).

Lafayette Hand-Held Dynamometer

The Lower Limb Strength Testing Protocol consists of three consecutive 5-second trials of isometric maximum knee extension. Hand-held dynamometers, or Manual Muscle Testers (MMT) objectively and consistently measure force output produced by one or more muscles, or the absolute strength of a muscle (group).

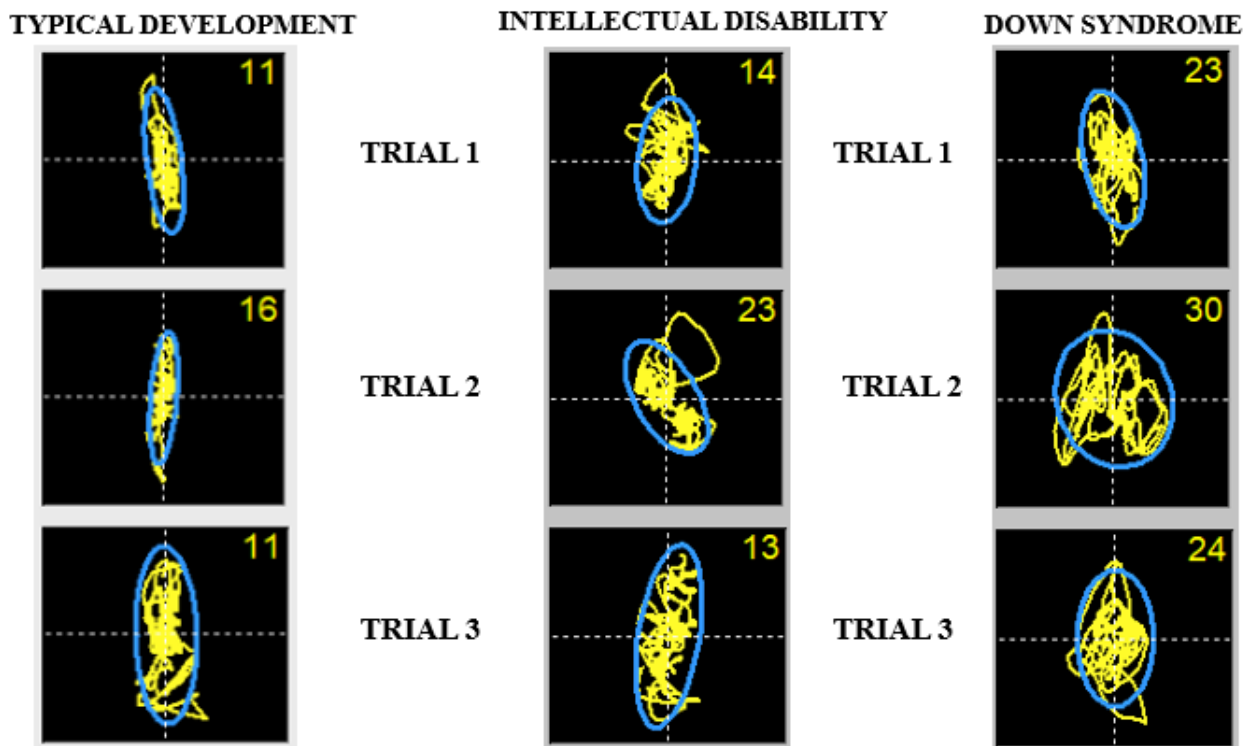
Procedures

Balance Measurements

After the Departmental Review Board (DRB) gave approval for the study, procedures were explained, and consent was given, all participants were instructed to remove their shoes. Height was measured using a portable height stadiometer, and weight was measured using a standard scale. Both were measured to the nearest 0.1 inch and 0.1 pound respectively.

The BtrackS portable force plate measured center of pressure at a rate of 25Hz. Center of pressure data produced measures of total sway, anterior-posterior sway, medial-lateral sway, and sway velocity. Participants were instructed to stand quietly and feet shoulder-width apart, hands on hips, and eyes closed for the duration of the four consecutive 20-second trials. The researcher gave verbal commands such as “go” and “okay, you may open your eyes” when the trials started and stopped. Through these measurements of distribution of center of pressure in both medial-lateral and anterior-posterior dimensions, an ellipsis was created. Samples of BTrackS ellipses for each participant group is included in Figure 1. The number in the top right corner of each trial’s postural sway ellipse indicated the number of perturbations in balance.

Figure 1. Sample of BTrackS Ellipses



Lower Limb Strength Measurements

Following the balance testing protocol, all participants were instructed to sit on either a chair or counter, whichever was easily assessable and deemed safe for the participant. If the participant was sitting in a chair with a back on it, they were instructed to sit up straight (with no back support) and avoid utilizing the back of the chair as leverage during the test. Regardless of where the participant sat, it was imperative that their feet could not touch the ground from that position to ensure they did not slide their feet along the ground for added traction during the trials. After a verbal cue (“go”) from the researcher, participants provided maximum force (“kicked out”) in a seated position against the MMT for three, 5-second intervals. The MMT was placed on the distal anterior shank 3 inches above the ankle, approximately 3 inches from the bottom of the shin. The procedure was then repeated on the other limb. The MMT reported the

participants' force output in pounds after the force was held for at least five seconds, sounding with a beep once the adequate time had been surpassed. If a participant did not provide maximum force in one of the three trials, a fourth trial was conducted.

Statistical Analysis

Once collection was completed, data from the BtrackS Force Plate was downloaded and coded using the BtrackS Assess Balance Software (Goble, Manyak, Abdenour, Rauh, & Baweja, 2016). An average was taken from the three most similar strength trials. If four trials were conducted, the three most similar trials were selected before averaging them. Balance and strength data were analyzed using SPSS statistical package. One-way ANOVA was used to determine significant differences amongst the groups in regards to strength and balance (Table 3). The Scheffe Test (post-hoc) allowed for identification of which pairs of means were significant. Significance was determined at the 0.05 alpha level for all completed tests.

RESULTS

Group statistics were expressed with means and standard deviations as shown in Table 2. Participants of TD displayed significantly less ($p < 0.01$) balance disruptions compared to their peers with ID and DS. Participants with DS displayed the greatest amount of balance disruptions compared to those with TD and ID. There were no significant differences between participants with DS and ID. In terms of mean velocity differences, there was a significance of 0.000 between TD and DS, a significance of 0.004 between ID and DS, but no significance between TD and ID.

TD participants were significantly stronger than peers with ID ($p < 0.01$) and DS ($p < 0.01$). Furthermore, participants with ID were significantly stronger than their peers with DS ($p < 0.01$). Overall, there is a weak relationship between lower limb strength and balance.

Correlations between lower limb strength and 95% Ellipse area are all weak and not significant ($r = 0.072$).

Table 2. Mean Performance Descriptives

	Typical Development	Intellectual Disability	Down Syndrome
95% Ellipse Area	0.84 ± 0.44	1.23 ± 0.83	1.31 ± 0.63
Mean Velocity (cm/s)	1.00 ± 0.23	1.21 ± 0.50	1.90 ± 0.92
Mean Distance (cm)	0.38 ± 0.10	0.46 ± 0.13	0.44 ± 0.14
Mean Root Mean Square Medial - Lateral (cm)	0.13 ± 0.05	0.20 ± 0.13	0.21 ± 0.09
Mean Root Mean Square Anterior - Posterior (cm)	0.44 ± 0.13	0.47 ± 0.15	0.48 ± 0.14
Total Strength (lbs.)	71.71 ± 16.91	38.96 ± 19.82	19.28 ± 8.99

Table 3. ANOVA

	95% Ellipse Area	Mean Velocity	Mean Distance	Mean RMS Medial-Lateral	Mean RMS Anterior-Posterior	Total Strength
Significance (r)	0.072	0.000	0.108	0.051	0.725	0.000

DISCUSSION

The purpose of this study was to examine the role of lower limb strength on balance in individuals with and without (typically developing and intellectual disability) Down Syndrome. The results of this study suggest that although lower limb strength may play a role in healthy balance in an individual, strength is not the primary and sole input to balance. There was no

correlation between lower limb strength and balance, but there were significant differences between the three demographics in regards to strength, amount of perturbations in balance, and mean velocity of perturbations.

As shown in Table 2, individuals with Down Syndrome sway not only anteriorly and posteriorly, but also more laterally and medially. On top of this, they significantly differ in their mean velocity during center of pressure changes compared to adults of typical development. They also show significantly less total strength during the isometric knee extension test. All of these deficits combine and lead to individuals with Down Syndrome, while inherently weaker in their lower limb muscles, swaying faster and with less precision. This significantly impacts their ability to correct any trips during ambulation or uneven stances, putting them at a high risk of falls.

The findings from this study coincide and support past research stating that individuals with Down Syndrome significantly differ in their strength and balance performance in comparison to others of typical development or with intellectual disabilities. Past studies have also attempted to find the main contributor to healthy balance in individuals, but to no avail. These results may help to advance the ever-growing list of factors that are helpful, yet not the sole input to balance. This study may offer insight on other variables that should be researched in depth instead, such as core strength.

Practical Implications

Balance is necessary for a sense of independence and activities of daily living. When individuals with Down Syndrome (who already inherently lack overall muscular strength) cannot safely navigate their environment due to deficits in postural control, opportunities to live a healthy life dwindle. Healthcare professionals such as physical and occupational therapists

should focus on improving lower limb strength from an early age which may lead to increased postural stability, better balance due to less general weakness and deficits, and a lower fall risk. This improvement in major aspects of one's independence could foster beneficial growth in individuals with Down Syndrome's mental health, physical health, and promote a longer life with fewer complications.

Limitations

A limitation of this study was the generalization of findings due to the narrow scope of research. We only focused on lower limb strength and its influence on balance, which may have eliminated other contributing factors such as core strength. In this study, participants tended to vary in (perceived) level of overall fitness, height of foot arches, length of the subject's leg in proportion to the rest of their body, understanding of instructions, and dedication to giving maximum effort during each trial.

Future Directions

In the future, it will be important for researchers to further analyze additional factors that may influence balance in individuals with Down Syndrome, intellectual disabilities, and of typical development. Additional factors may include amount of physical activity, moment arm ratio of femur to tibia, and degree of arch support, as individuals with DS are known to have extremely flat feet. Larger sample sizes are needed in order to observe statistical significance and to make recommendations regarding effective interventions for this population.

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