COMPARING ANKLE RANGE OF MOTION IN TYPICALLY DEVELOPING, DOWN SYNDROME, AND INTELLECTUALLY DISABLED POPULATIONS

by

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Submitted in partial fulfillment of the

requirements for Departmental Honors in

the Department of Kinesiology

Texas Christian University

Fort Worth, Texas

May 7, 2018

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ABSTRACT

The purpose of this study was to identify differences in ankle range of motion (ROM) between individuals with typical development (TD), Down syndrome (DS), and intellectual disabilities (ID). This is the first step in obtaining an understanding of the role ankle ROM and instability have on balance. Fifty-one individuals (ages 20-50, 16 TD, 14 DS, and 21 ID) voluntarily participated. Ankle ROM (active eversion, inversion, plantarflexion, dorsiflexion) was measured using a goniometer. Descriptive statistics (means and standard deviations) were used to analyze the data. All means for DS and ID fell below the reported Center for Disease Control and Prevention reference values. A one-way Analysis of Variance (ANOVA) determined group differences, and a Scheffe post-hoc determined significance levels ($p < 0.05$ & 0.01). Results showed statistical differences of $p < 0.05$ for: TD and ID left ankle eversion, TD and DS left/right plantarflexion. Results showed differences of $p < 0.01$ for: TD and ID left/right inversion and left/right plantarflexion, ID and DS left plantarflexion. Statistical significance was observed for all movements between at least two populations, but no statistical significance was observed for dorsiflexion among any population. Individuals with DS and ID have cognitive deficits, while only individuals with DS have physical/motor deficits. Results showed that DS and ID were statistically similar, which indicates a cognitive effect as opposed to motor/phenotypic. The motor/phenotypic effect would be observed if ID and TD were statistically similar, since both groups do not have motor deficits. Future research should investigate ankle ROM alongside strength and balance to determine which factors to target during balance intervention.

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INTRODUCTION

A disability is in part classified by differences in ability among people, meaning there are deficits in his or her ability to complete activities of daily living. Balance is a skill that is important for daily life. Balance differs in individuals with a disability, and many factors, known and unknown, contribute to these deficits. One of the factors, range of motion (ROM), has yet to be widely discussed in populations with disabilities that affect balance.

Intellectual Disability

The first population to be discussed includes individuals with intellectual disabilities (ID). The average intelligence score (IQ) for a typically developing individual is 90-100, with 95% of the population falling between 70 and 130 (Harris, 2005). These values are two standard deviations away from the mean. Individuals with intellectual disabilities have IQ scores below 70, less than two standard deviations away from the mean. Intellectual disability can be further classified based on specific IQ ranges: mild (55-69), moderate (40-54), severe (25-39), and profound (< 25) (Harris, 2005). The majority of individuals with intellectual disabilities fall into the mild and moderate ranges.

Intellectual disability is not only identified by sub-70 IQs, but also deficits in at least two adaptive behaviors. Adaptive behaviors include conceptual skills, social skills, or practical skills (Schalock, et al., 2010). Conceptual skills include literacy and money management; social skills involve difficulty with interpersonal interaction; and practical stills include activities of daily living (ADLs) and routine. These deficits, in both IQ and adaptive behaviors, must be observed before the age of 18 in order for an official

intellectual disability diagnosis to be confirmed. One of the most common mild-moderate intellectual disabilities is Down syndrome.

Down Syndrome

Down syndrome (DS) is caused by a specific genotypic defect, which results in various phenotypic manifestations. This genotypic defect is known as trisomy twenty-one (Bull, 2011). Each parent contains two copies of each chromosome, making a pair. Every individual possess twenty-three pairs of chromosome, or forty-six in total. During gamete (egg and sperm) formation, these parental pairs split. After fertilization, the resulting embryo receives a copy of each chromosome from each parent, forming his or her own set of twenty-three pairs. Occasionally genetic mutations will prevent the parental chromosome pairs from splitting during gamete formation. This results in the transfer of two copies of a chromosome from one parent, and one from another. The embryo will then obtain three copies of the chromosome, which is known as trisomy. Down syndrome results specifically from trisomy of the twenty-first chromosome.

This genetic mutation manifests itself via widely identified phenotypic characteristics (Lyle et al., 2008). These include delays in language and motor development, characteristic facial features, and short stature (Delabar, et al. 1993). Individuals with Down syndrome have the same weight gain as those with typical development, but this weight is distributed over a smaller frame. This often causes individuals with Down syndrome to be overweight or obese. Additionally, “hypotonia, ligament laxity and motor alterations are characteristics observed among individuals with Down syndrome (DS)” (Galli et al., 2008). Ligaments are connective tissue structures that connect bone to bone. In the ankle joint specifically, the talus bone of the foot

articulates with the tibia and fibula of the lower leg. This joint contains ligaments that maintain the integrity at the joint. Ligament laxity results in looser connections between the bones, and has implications on joint stability.

Hypotonia is decreased muscle tone. Muscle tone is resistance to passive stretch. Hypotonia involves decrease resistance to movement and as well may cause muscle weakness (Lackie, 2010). Hypotonia results in below baseline resistance to stretch, and therefore muscles have a decreased ability to generate force. Individuals with Down syndrome display higher levels of relaxed muscle fibers, which have implications on strength at the joint. Latash and colleagues (2008) propose that this deeper relaxation is observed via reduced active muscle force during passive joint motion. Overall, those with excessive ligament laxity and poor muscle tone, such as individuals with Down syndrome, may experience a decrease in strength due to the viscoelastic properties associated with the diagnosis (Latash, Wood, & Ulrich, 2008).

Muscle strength plays an important role in both balance and the ability to complete ADLs (Sharav & Bowman, 1992). Muscle strength not only impacts DS exercise capacity, but is also important for the completion of daily tasks (Gonca & Eren 2017). Muscle strength of individuals with DS has also been reported as important "for the preservation of dynamic balance skills, for their functional independence, and for increasing their quality of life" (Carmeli et al., 2002). Decreased muscle tone and ligament laxity also have implications on balance.

Static Balance and ID/DS

Balance can be classified as either static or dynamic. Static balance refers to balance when the center of gravity is directly over the base of support. This can be

examined when standing. Previous Texas Christian University departmental research tested static balance between DS and ID populations. The researchers used BtracksS, which is a force plate that tracks shifts in an individual's base of support, monitoring natural sway while standing. Natural sway is an effective way to quantify static balance ability. They found that individuals with DS had an overall greater unpredictability in standing balance, which directly correlates to increased instability. This departmental research corroborated a study published to the *Journal of Gait & Posture* (Cabeza-Ruiz et al., 2011). These researchers used a force plate similar to BtrackS, but instead compared DS to typically developing (TD) populations. Cabeza-Ruiz et al. found that individuals with Down syndrome have "poorer static equilibrium control" compared to the control group (TD), which again refers to static balance.

Static Balance and Fall Risk

Although previous research has examined static balance in isolation, it is also important to consider that tasks requiring static balance are performed throughout the day. While performing these tasks, the base of support is stationary, but the center of gravity may shift outside. Examples of such tasks include reaching for a plate in the cupboard, or the stance phase of walking. Static balance deficits are of concern in these populations, because they are related to increased fall risk. Igler et al., 2016 evaluated fall risk in ID populations and found an increased fall risk associated, as compared to TD populations. Increased falls have obvious implications on both an individual's quality of life and ability to complete activities of daily living. Again, we know that decreased stability and balance, and therefore fall risk, can be attributed to loose ligaments and

decreased muscle tone in individuals with DS, but there is less research on the role of ankle range of motion (ROM).

Range of Motion

Flexibility is the capacity of a joint to move through its complete ROM. Range of motion is important for mobility, which influences functional independence and the ability to complete activities of daily living (Riebe, et al., 2018). ROM also determines how efficient and powerful movements are (Moltubakk et al., 2016). A daily, simple example of this importance can be observed in walking. An individual needs sufficient ROM to ensure heel strike and adequate push-off to generate the sufficient amount of force to take a step, which is known as the step phase of walking. At the same time, an individual does not want too much ROM, which would decrease stability around the ankle joint. This instability would lead to problems with static balance, impacting the stance phase of walking. A decreased ability to perform efficient and powerful movements, due to diminished or excessive ROM, reduces the ability of an individual with ID or DS to complete adaptive behaviors, or ADLs.

Ankle Range of Motion and Down syndrome

The specific phenotypic characteristics associated with DS have implications on this ability to perform efficient and powerful movements. Ligament laxity implies decreased stability at the joint, which has implications on balance. Additionally, hypotonia reduces the strength of the muscles around the joint, decreasing joint control. Both cause an increase in ROM, which is again problematic for the completion of ADLs. Ankle foot orthotics is an example of a currently used intervention to help improve the integrity at the ankle joint. These ankle foot orthotics are often used to help increase

control and stability at the ankle joint (Ptitetti & Wondra, 2005). These devices provide external rigidity to help increase the integrity of the joint. The purpose of physical therapy and medicine is to develop devices such as these, as well as develop proper interventions, to counteract these physical disparities.

Project Significance

This study analyzed individuals with typical development, Down syndrome, and intellectual disability. These populations are ideal since typically developing individuals are cognitively and physically intact; individuals with ID have cognitive deficits but are physically intact; and individuals with DS have deficits both cognitively and physically. This provides an ideal comparison and allows the results to be further identified as having a motor effect, which is anticipated due to predicted ROM differences or a cognitive effect (due to IQ deficits).

Additionally, the number of deficits in adaptive behaviors is directly correlated to an individual's level of disability. By alleviating the problems associated with these phenotypic characteristics, healthcare professionals can decrease balance deficits, decrease fall risk, and decrease his or her overall level of disability, while increasing an individual's ability to perform ADLs.

Purpose

The primary purpose of this study was to examine ankle ROM in TD, DS, and ID populations to determine if there are statistical differences between the three groups. By examining ankle ROM in these groups, I will take the first step in obtaining a better understanding of the potential role ankle ROM and instability have on balance. If in future research, concrete connections are established that show ankle ROM is identified

as a significant contributor to balance deficits, there are direct implications on balance intervention in special populations as well as a greater explanation for increase fall risk.

METHODS

Participants

Participants for this study were recruited via several mechanisms. Individuals with ID and DS were recruited from Special Olympics Texas events as part of the Healthy Athlete Screenings, North Crowley High School, the Intellectual & Developmental Needs Council of Tarrant County, and the Mental Health-Mental Retardation Council of Tarrant County. Typically developing individuals were primarily recruited via word of mouth. Participants ages 20-50 years were recruited, with the mean age being 27.0 ± 8.91 years. Our participant population included 22 females and 29 males. The 51 total participants consisted of 16 TD, 21 ID, and 14 DS.

Instruments/Procedure

In order to measure ankle ROM, a goniometer was used to measure ankle eversion, inversion, plantarflexion, and dorsiflexion. Measurements were taken once on each foot. The movements were demonstrated for each individual, and active ankle movements were measured. Angles were measured from neutral, which is measured as 0°.

For ankle eversion and inversion measurements, the axis of the goniometer was placed on the front of the ankle at the mid-point between the medial and lateral malleoli. The stationary arm was placed along the tibial crest, which can be identified as the prominent line of bone that runs along the shin. For both eversion and inversion, the

moveable arm is placed in line with the second metatarsal. This procedure was replicated on both the left and right foot. The reference value for normal eversion, according to a 2014 Range of Joint Motion Evaluation Chart provided by the Washington State Department of Social & Health Services, is 25 degrees. The same publication stated that the reference value for inversion is 30 degrees.

In order to measure plantarflexion and dorsiflexion, the axis of the goniometer was aligned with the lateral malleolus. The stationary arm of the goniometer was aligned with the head of the fibula. Upon plantarflexion and dorsiflexion, the angle will be measured by aligning the moveable arm parallel to the shaft of the fifth metatarsal. Again, these measurements were taken for both the left and the right foot. The Center for Disease Control and Prevention also released a Normal Joint Range of Motion Study in 2010, which states that the reference value for plantarflexion is about 50 degrees and about 20 degrees for dorsiflexion, when averaging values for men and women.

Statistical Analysis

Data analysis included descriptive statistics such as means and standard deviations to evaluate the ankle measurements. Group differences were determined using a One-way Analysis of Variance (ANOVA). A Scheffe post-hoc was used to determine significance levels ($p < 0.05$).

RESULTS

Intellectual Disability (n = 21)

Group statistics were expressed with means and standard deviations as shown in Table 1. Individuals with ID's average measurement fell below the reference value for

eversion (25°), with the mean being 23.4°±10.6 for the right foot, and 16.0°±9.1 for the left foot. A statistical difference of p=0.011 was observed between ID and TD for left eversion (Figure 1). The measurements for inversion also fell below the reference value (30°), 10.3°±9.7 right and 13.4°±7.6 left. Statistical differences were also observed for right inversion (p=0.05) and left inversion (p=0.02) between ID and TD (Figure 2).

ID means also fell below the references values for plantarflexion (50°) and dorsiflexion (20°). Right plantarflexion measured at 37.0°±14.4 and left plantarflexion measured 36.2°±11.2 (Table 2). Statistical differences were observed for right plantarflexion between ID and TD (p=0.00), and left plantarflexion between ID and TD (p=0.00) and between ID and DS (p=0.03) (Figure 3). The mean for right dorsiflexion was 9.1°±6.7 and left dorsiflexion was 12.7°±6.5 (Table 2). No statistical significance was observed between ID and either population for dorsiflexion (Figure 4).

Down Syndrome (n = 14)

Individuals with DS also exhibited means below the reference values for eversion and inversion ankle measurements. Right eversion measured 21.3°±12.7 and left eversion measured 19.0°±3.6 (Table 1). No statistical significance was observed for DS eversion or inversion (Figures 1 and 2).

DS right and left plantarflexion means were within the normal reference value ranges, with the right being 46.1°±14.2 and the left being 49.3°±11.5 (Table 2). Statistical significance was measured for right plantarflexion between DS and TD (p=0.028). Left plantarflexion was also statistically different between DS and TD (p=0.048) and DS and ID (see above) (Figure 3). Averages for right and left dorsiflexion were below the reference value. Right dorsiflexion measured 11.4°±8.2, and left dorsiflexion measured

8.4°±8.0 (Table 2). No statistical significance was measured between differences in DS and either population for dorsiflexion (Figure 4).

Typical Development (n = 16)

TD eversion means were 29.1°±10.7 for the right foot, and 24.7°±7.2 for the left. Inversion measurements were recorded as 22.1°±11.0 for the right foot, and 25.3°±10.7 for the left foot (Table 1). Plantarflexion means were observed at 60.0°±12.4 for right, and 59.1°±8.4 for the left. Dorsiflexion measured at 8.4°±3.5 for the right foot, and 11.7°±5.4 for the left (Table 2). With the exception of dorsiflexion, which fell below, the other three TD measurements met or exceeded the references values for the respective movement. For statistical differences, see above.

DISCUSSION

The purpose of this study was to determine if there were statistical differences in ankle ROM between individuals with ID, DS, and TD. The results of this study do show statistical differences, but the specific values observed differed from my initial prediction: that DS would show greater ankle range of motion due to phenotypic characteristics. The two possible explanations for this observation are a cognitive effect and a greater role of muscle tone on ROM performance.

Cognitive Effect

Motor/phenotypic deficits such as ligament laxity and hypotonia are characteristic of DS (Galli et al., 2008). Thus, I expected these individuals to display greater ankle ROM, and individuals with TD and ID would measure at, or around, the reference values. If my initial prediction were to be confirmed, I would have observed more statistical significance between individuals with ID and TD. This is due to the lack of

phenotypic/motor deficits within these groups. Since both groups are physically intact, we would expect similar results, averaging at the reference values. The opposite was observed. Individuals with DS and ID reported angles below the reference values for all four ankle measurements. Additionally, individuals with DS and ID displayed results that were more statistically similar and as well collectively statistically different from TD individuals. This potentially indicates a more dominant cognitive effect, as opposed to predicted motor/phenotypic effect. Individuals with ID may be physically intact, but they do exhibit cognitive deficits (Harris, 2005). Individual's with DS have been found to have cognitive deficits when compared to chronological TD peers, and specifically they have deficits in cognitive functions such as working memory (Ringenbach et al., 2016). Since these two groups (DS and ID) reported similar results, the cognitive deficits may have played a greater role. Assisted cycling therapy (ACT), in which an individual's feet are physically moved through the cycling motion at a pre-determined cadence, has been shown to result in improvements in reaction time in individuals with DS, when compared to voluntary cycling (Ringenbach et al., 2016). These results imply that cognitive deficits play a role on the ability to complete a task. When this cognitive effect is essentially removed (ACT), performance increases and results/benefits of the task do as well.

The measured ankle movements were active, and, despite being demonstrated, individuals with ID and DS may not have fully understood the instructions. This can be likened to the deficits observed in adaptive behaviors (Schalock et al., 2010). Additionally, ID and DS may have thought to evert, invert, plantarflex, and dorsiflex, but not to their full range of motion. The second predicted explanation is a greater role of motor systems on ankle ROM.

Role of Motor Systems

Additionally, we predicted ligament laxity to result in a greater ankle ROM for individuals with DS. Since this was not observed, an initial exploratory explanation involves hypotonia. The measurements recorded were active ankle movements. Participants were instructed and observed, but their joint was not physically manipulated through its full ROM. Active ankle movements also require significant amounts of muscle activation, and individuals with DS have reduced strength due to the viscoelastic properties associated with the disorder (Latash et al., 2008). Individuals with DS have also been found to perform slow and/or ineffective contractions as a result of associated hypotonia (Ribeiro et al., 2017). If decreased muscle tone causes reduced ability to generate force, individuals with DS may not have been able to flex their ankle joint to its full range of motion.

Additionally, low muscle tone is strongly associated with decreased muscle strength (Priosti, et al., 2013), and individuals with DS have reported lower scores for lower extremity strength (Gonca & Eren, 2017). Low leg strength values for individuals with DS may have negative effects on their ability to complete activities of daily living (Sharav & Bowman, 1992). The role of muscle tone on the ability to complete movements can be observed by the results of this study. There are documented motor deficits associated with the disorder, and individuals with DS should work to improve their physical function through muscle strength- targeted fitness programs (Gonca & Eren, 2017).

Co-contraction is a muscle contraction mechanism observed in individuals with DS. Co-contraction is the simultaneous contraction of agonists (muscles used for

movement) and antagonists (muscles opposing the movement). This contractions strategy can be viewed as an adaptive movement that reflects a tendency to trade efficacy for stability (Aruin et al., 2006). Along with decreased muscle tone and strength, co-contraction may have impacted the individuals' coordination, altering their ability to complete the ankle movements. This is in line with Galli et al.'s 2008 study, which concluded that DS results in joint laxity and muscle hypotonia, which causes functional weakness. Galli et al. also observed decreased joint stiffness at the ankle compared to the hip, and concluded that despite hypotonia and ligament laxity being hallmarks of DS, these characteristics may not be observed at every joint under every condition.

Limitations

Limitations to this study include the role of the cognitive effect and a narrow study scope. Additional measures could have taken to reduce the cognitive effect such as additional practice, longer side-by-side demonstrations, and a quieter, distraction free testing environment. In order to more effectively test the effect of ankle ROM, components of both strength and balance should have been included. The addition of these factors would have accounted for the role of motor systems and given more comprehensive results.

Implications and Future Directions

The results of the study confirm that ankle ROM may impact balance, but that muscle tone and strength do as well. Future research should examine balance, ankle ROM, and strength in the same individuals to provide a more direct conclusion. These more concrete connections can be used to determine what factors are more significantly contributing to balance deficits in DS populations. If these factors can be identified, there

are direct implications on balance intervention in special populations, as well as a greater explanation for increased fall risk. If healthcare professionals can better target balance deficits, they will more efficiently and effectively decrease measured balance deficits. A decrease in balance deficits will decrease the reported incidences of falls, increase ADL performance, and overall reduce the level of disability.

FIGURES AND TABLES

Table 1.

Group		Eversion (R)	Eversion (L)	Inversion (R)	Inversion (L)
DS	(n= 14)	21.3 ± 12.7	19.0 ± 3.6	8.3 ± 3.8	11.7 ± 15.3
ID	(n= 21)	23.4 ± 10.6	16.0 ± 9.1	10.3 ± 9.7	13.4 ± 7.6
TD	(n= 16)	29.1 ± 10.7	24.7 ± 7.2	22.1 ± 11.0	25.3 ± 10.7

Figure 1.

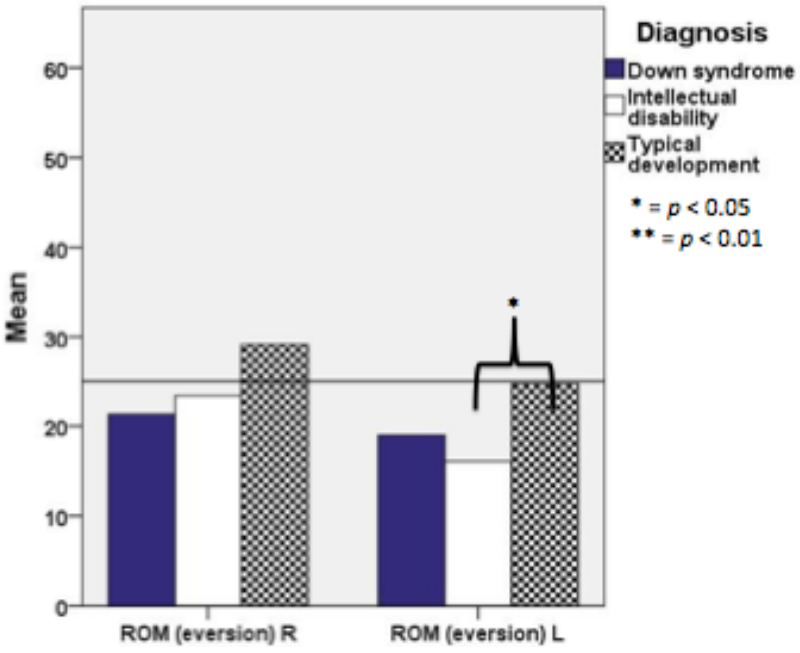


Figure 2.

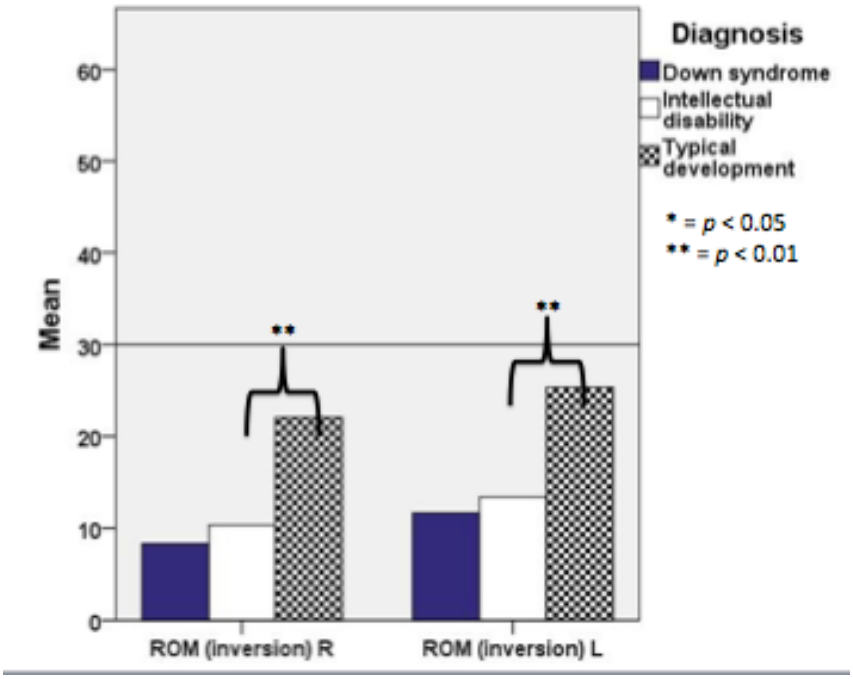


Table 2.

Group	Plantar-flexion (R)	Plantar-flexion (L)	Dorsiflexion (R)	Dorsiflexion (L)
DS (n= 14)	46.1 ± 14.2	49.3 ± 11.5	11.4 ± 8.2	8.4 ± 8.0
ID (n= 21)	37.0 ± 14.4	36.2 ± 11.2	9.1 ± 6.7	12.7 ± 6.5
TD (n= 16)	60.0 ± 12.4	59.1 ± 8.4	8.4 ± 3.5	11.7 ± 5.4

Figure 3.

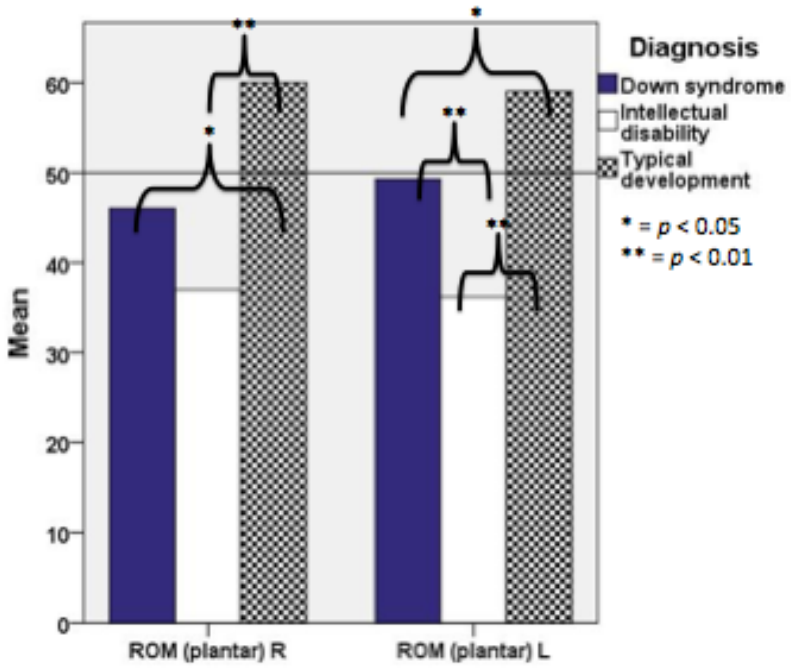
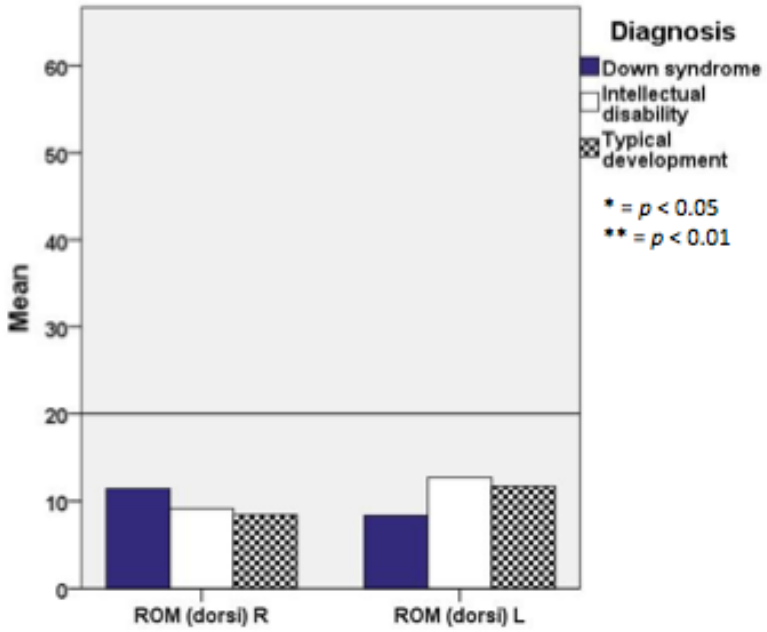


Figure 4.



REFERENCES

Aruin, A. S., Almeida, G. L., & Latash, M. L. (1996). Organization of a Simple Two-Joint Synergy in Individuals With Down Syndrome. *American Journal on Mental Retardation, 101*(3), 256.

Bull, M. J., MD. (2011). Clinical Report—Health Supervision for Children With Down Syndrome. *American Academy of Pediatrics*. Retrieved October 1, 2017.

Cabeza-Ruiz, R., Garcia-Masso, X., Centeno-Prada, R., Beas-Jimenez, J., Colado, J., & Gonzalez, L. (2011). Time and frequency analysis of the static balance in young adults with Down syndrome. *Gait & Posture,* 33(1), 23-28.

Carmeli, E., Kessel, S., Coleman, R., & Ayalon, M. (2002). Effects of a Treadmill Walking Program on Muscle Strength and Balance in Elderly People with Down Syndrome. *The Journals of Gerontology, 57*(2), a, M106-M110.

Charaśna-Blachucik, J., & Blachucik, J. (2016). Somatic Development and Physical Fitness of Schoolgirls with Mild Intellectual Disabilities - A Comparative Study. *Journal Of Physical Education & Health Social Perspective*, *5*(8), 35-48.

Delabar, J. M., Theophile, D., Rahmani, Z., Chettouh, Z., Blouin, J. L., Prieur, M., & Sinet, P. M. (1993). Molecular mapping of twenty-four features of Down syndrome on chromosome 21. *European Journal Of Human Genetics: EJHG*, *1*(2), 114-124.

Enkelaar, L., Smulders, E., van Schrojenstein Lantman-de Valk, H., Weerdesteyn, V., & Geurts, A. C. (2013). Prospective study on risk factors for falling in elderly persons with mild to moderate intellectual disabilities. *Research in Developmental Disabilities, 34* (11), 3754-3765.

Finlayson, J., Morrison, J., Jackson, A., Mantry, D., & Cooper, S.A. (2010). Injuries, falls and accidents among adults with intellectual disabilities. Prospective cohort study. *Journal of Intellectual Disability Research, 54* (11), 966-980.

Galli, M., Rigoldi, C., Brunner, R., Virji-Babul, N., & Giorgio, A. (2008). Joint stiffness and gait pattern evaluation in children with Down syndrome. *Gait & Posture. 28*(3), 502-506.

Gonca, I., & Eren, U. (2017). Comparison of Lower and Upper Extremity Strength of Individuals with Down Syndrome in Terms of Age Groups and Gender. *Gymnasium: Scientific Journal Of Education, Sports & Health*, *18*(1), 56-66.

Harris MD, J.C. (2005). *Intellectual Disability: Understanding Its Development, Causes, Classification, Evaluation, and Treatment.* Oxford University Press.

Lackie, J. (2010). *A Dictionary of Biomedicine.* Oxford University Press.

Latash, M., Wood, W., & Ulrich, D.. What Is Currently Known about Hypotonia, Motor Skill Development, and Physical Activity in Down Syndrome. *What Is Currently Known about Hypotonia, Motor Skill Development, and Physical Activity in Down Syndrome*. Down Syndrome Education International, 11 Nov. 2008. Web. 01 Dec. 2016.

Lyle, R., Béna, F., Gagos, S., Gehrig, C., Lopez, G., Schinzel, A., & Antonarakis, S. E. (2009). Genotype-phenotype correlations in Down syndrome identified by array CGH in 30 cases of partial trisomy and partial monosomy chromosome 21. *European Journal Of Human Genetics: EJHG*, *17*(4), 454-466. doi:10.1038/ejhg.2008.214

Moltubakk, M. M., Eriksrud, O., Paulsen, G., Seynnes, O. R., & Bojsen-Møller, J. (2016). Hamstrings functional properties in athletes with high musculo-skeletal flexibility. *Scandinavian Journal Of Medicine & Science In Sports*, *26*(6), 659-665.

Pitetti, K. H., & Wondra, V. C. (2005). Dynamic Foot Orthosis and Motor Skills of Delayed Children. *Journal Of Prosthetics & Orthotics (JPO)*, *17*(1), 21-24.

Priosti, P.A., Blascovi-Assis, S.M., Cymrot, R., Vianna, D.L., & Caromano, F.A. (2013). Grip strength and manual dexterity in Down syndrome children, *Fisioterapia e Pesquisa*, *20(3)*, 278-285.

Riebe, D., Ehrman, J. K., Liguori, G., & Magal, M. (2018). *ACSM's Guidelines for Exercise Testing and Prescription* (Tenth ed.). Philadelphia, PA: Wolters Kluwer.

Ringenbach, S. D. R., Holzapfel, S. D., Mulvey, G. M., Jimenez, A., Benson, A., & Richter, M. (2016). The effects of assisted cycling therapy (ACT) and voluntary cycling on reaction time and measures of executive function in adolescents with down syndrome. *Journal of Intellectual Disability Research,* 60*(11),* 1073-1085.

Schalock, R. L., Borthwick-Duffy, S. A., Bradley, V. J., Buntinx, W. H., Coulter, D. L., Craig, E. M., Yeager, M. H. (2010). *Intellectual disability: Definition, classification, and systems of supports* (11th ed.). Washington, DC: American Association on Intellectual and Developmental Disabilities.

Sharav, T., & Bowman, T. (1992). Dietary practices, physical activity, and body-mass index in a selected population of Down syndrome children and their siblings, *Clinical Pediatrics*, *31(6)*, 341-344;

Shetreat-Klein, M., Shlomo, S., & Rapin, I. Abnormalities of joint mobility and gait in children with autism spectrum disorders. *Official Journal of the Japanese Society of Child Neurology*. 26(2), 91-96.

Soucie, J.M., Wang, C., Forsyth, A., Funk, S., Denney, M., Roach, K.E., Boone, D., and the Hemophilia Treatment Center Network (2010). Range of motion measurements: reference values and a database for comparison studies. *Center for Disease Control and Prevention,* Hemophilia, e-pub November 11, 2010.