UNDERSTANDING THE EFFECT OF ANKLE-FOOT ORTHOTICS IN INTELLECTUAL DEVELOPMENTAL DISABILITIES

by

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ABSTRACT

Ankle foot orthoses (AFOs) are frequently prescribed to improve balance in individuals with a variety of disabilities. However, the role of AFOs in balance control is not completely understood in individuals with intellectual developmental disabilities (IDDs). The aim and purpose of the study was to evaluate the effectiveness of AFOs on balance in individuals with Down syndrome, Autism Spectrum Disorder (ASD), and other diagnosed intellectual disorders.. The study included 15 individuals with intellectual disabilities who were assessed on balance using a portable force plate and a static AFO. The subjects performed a total of six balance tests on the force plate, three without the AFO and three with the AFO. Using data collected from the force plate, participants were measured and compared to themselves with and without the AFO. The results generally demonstrated an improvement in balance and individual balance variables when wearing the AFO. Specifically, 95% ellipse area, mean distance, anterior-posterior sway, and medio-lateral sway each decreased across the 15 participants. The balance variable of mean velocity was the only outlier in this trend. Further research in the field could improve on the method of this study as well as investigate other types of orthotics or how AFOs can be used in conjunction with other interventions.

INTRODUCTION

Balance is a fundamental skill required for many activities of daily living, limiting the likelihood of falls, and promoting overall well being (Blankevoort et al., 2010; Kelsey et al., 2010). Balance is broadly defined as the state of equilibrium that occurs when there are net zero forces acting on the individual (Pollock et al., 2000; Ragnarsdottir, 1996). This means that an individual is able to stay stable in equilibrium despite the force of gravity acting upon the individual (Yim-Chiplis & Talbot, 2000). Usually, when balancing, one considers an individual's ability to stay upright. Therefore, to be balanced would mean that the individual is not experiencing any forces to in any direction that would cause them to fall as a result of gravity (Pollock et al., 2000; Ragnarsdottir, 1996; Yim Chiplis & Talbot, 2000).

Furthermore, to fully comprehend balance, one must understand the concept of center of mass (COM). Center of mass is a complicated physical phenomenon but can be best thought of as the point where forces are centered on the body (Lafond et al., 2004; Tesio & Rota, 2019). While many factors can have an effect on balance, the base of support of the individual is of great importance (Winter et al., 2019).

The size of one's base of support is directly proportional with how stable one will be (Trimble & Koceja, 2001; Lott, 2019). The wider the base of support, the more stable an individual is. Vice versa, the more narrow a base of support is, the less stable the individual will be.The greater the line of displacement (the distance from the COM) without the individual losing balance or falling is known as stability (Pollock, A. et al., 2000). The line of displacement constantly changes in everyday tasks including ambulation. Being able to maintain balance throughout the changing line of displacement by enhancing stability contributes to improved functioning. Balance as a whole plays a vital role in many ADLs (Blankevoort et al., 2010). ADLs are activities that individuals do to support homeostasis and foster independence every day (Edemekong et al., 2021). Activities such as general ambulation and personal care are great indicators of an individual's functional status and require some degree of balance to sustain activity (Khan & Andersen, 2022; Spector et al., 1987).

Balance is a complex skill that is accomplished by the integration of both motor and sensory systems (Gill-Body et al., 2000; Sturnieks et al., 2008). Balance impairment can be caused by any of a number of motor and sensory deficits, many of which are often encountered in clinical practice. These impairments can be found in several disabilities and chronic conditions such as Down syndrome and Autism Spectrum Disorder (ASD). One area of impairment involves vestibular dysfunction (Marchetti et al., 2011). Vestibular dysfunction is relatively common in individuals with ASD and occurs from some type of damage to the inner ear, vestibular nerves, or brain (Van Hecke et al., 2019; Marchetti et al., 2011). Other balance impairments stem from joint or muscle irregularities (Zemková & Hamar, 2014; Rinalduzzi et al., 2015). This is the case, for example, in Down syndrome patients who experience extensive ankle joint laxity and hypotonia, affecting balance and overall stability (Cabez-Ruiz et al., 2011). Other individuals experience nerve damage that can affect balance such as in cases of neuropathy (Wang et al., 2017). Other disruptions in proprioceptive feedback as well as vision problems can also contribute to balance difficulties (Rozzi et al., 1999; Hammami et al., 2014). Both neuropathy and proprioceptive disruptions are common in individuals with Down syndrome (Wang et al., 2017; Rozzi et al., 1999). Regardless of the specific impairment that contributes to balance issues, the effects can be extensive and can significantly alter one's quality of life, particularly through falls, and importantly, their level of independence (Claxton et al., 2006).

Achievement or maintenance of balance is a common goal in various types of therapy for a variety of different patient populations including anyone from outpatient surgery patients to patients with lifelong disabilities. Balance is after all part of almost all, if not all, ADLs (Kim & Park, 2014). Therefore, the importance of balance cannot be overstated. In therapy settings, dynamic balance (balance when an individual is actively performing a task) is what is often being tested because while the individual might have deficits in static balance (balance when standing still), dynamic deficits are often more observable and can be more functionally relevant (Wikstrom. et al., 2005; Rendon et al., 2012).

However, static balance is more often studied experimentally. It is important to understand some of the more common balance tests to see how balance can be assessed in a multitude of therapeutic interventions. Some common balance tests include the heel-toe test for dynamic balance, the stork test for static balance, the Gross Motor Function Measure test, and measuring balance on a force plate pre- and post-intervention (Gutiérrez-Vilahú, 2016; Ghobadi, 2019; Rahmayanti et al., 2022; Ansari et al., 2021). A force plate is a piece of technology that records measurements of COM, center of pressure (CoP), and postural sway (Karlsson & Frykberg, 2000; Chen et al., 2011). It is the method with which this study will measure the balance of participants. Force plates have been studied and found to be a reliable source with which to test balance (Beckham et al., 2014; Alsalaheen et al., 2015). Furthermore, using a 95% confidence interval, force plates have been proven to detect underlying causes of balance deficits in healthy adults with no history of falls (Harro & Garascia, 2019).

Balance tests have long been used as a measurement of the effectiveness of various interventions and therapies in improving balance in those with disabilities (Hrysomallis, 2007). Some examples of these interventions that have been used to help individuals with disabilities include things like various physical training programs (Gross Motor Function Measure test), dance programs (pre-and-post trials on a force plate), active videogame programs (heel-toe tests and stork tests of balance), and aquatic training programs (again the heel-toe tests and stork tests of balance) (Gutiérrez-Vilahú, 2016; Ghobadi, 2019; Rahmayanti et al., 2022; Ansari et al., 2021). Beyond these, however, are ankle-foot orthotics (AFOs). They are among the best known and most effective interventions for balance. AFOs function by stabilizing the ankle joint to assist in balance, limiting the motion of the ankle joint in one or more planes (see Figure 1)(Panwalkar & Aruin, 2013). They have been demonstrated to help with the management of various pathological conditions and disabilities by decreasing sway while standing. Improvements in balance with the use of AFOs can be assessed using pre- and post-intervention force plate balance tests as was performed in this study.

Ankle foot orthotics are very commonly used to assist in the improvement of balance in many cases (Cattaneo et al., 2002). There is undeniable evidence that these devices are a great contributor to balance, allowing many individuals to live a better day-to-day life by assisting them with balance deficits (Nevisipour & Honeycutt, 2020). AFOs have been linked to improvements mostly in static balance, but in dynamic balance as well (Abe, 2006; Chern et al., 2013; Wang et al., 2005). These changes are usually instantaneous and happen promptly after an individual has time to acclimate to the new device attached to their extremities (Yalla et al., 2014). There is variation in the specific design and materials of AFOs with some allowing for either greater or lesser mobility of the ankle joint (Tyson & Kent, 2013; Daryabor et al., 2018; Mulroy et al., 2010; Cattaneo et al., 2002).

AFOs specifically are helpful in assisting in foot clearance, correcting foot eversion, and increasing plantarflexor activity (Neptune & Vistamehr, 2019). Furthermore, postural sway, ankle sway, and COM have all improved in clinical studies when an AFO was introduced (Neptune & Vistamehr, 2019). Specifically, it has been found that ankle sway decreased by 60.8% and COM differences decreased by 49% after an AFO was worn by the subject (Neptune & Vistamehr, 2019). The extensive evidence of AFOs improving balance explains why such devices could be expected to effectively increase balance in individuals with a variety of disabilities where balance is impaired. While there are a multitude of interventions that are possible to increase balance for various disabilities, AFOs are consistently utilized and are among the most effective in the existing literature due to the significant gains in balance that it allows (Harris et al., 1986). Stability of individuals when wearing AFOs dramatically increases when compared to individuals wearing shoes with no AFO device. AFOs contribute to changes in muscle activation patterns, allowing individuals to have increased stability indexes across the board in many different scenarios (Lee et al., 2014).

Specifically, the AFO works in stabilizing the ankle joint of the individual, increasing proprioceptive reception which aids in balance (Wang et al., 2018; Smalley et al., 2018). Because of joint laxity in individuals with Down syndrome for example, it is expected that the support provided by the AFO will effectively increase stability. Positive gains in balance can similarly result in improved gait mechanics, gait speed, and self-confidence in one's own mobility. Arguably one of the greatest benefits of AFO intervention in populations with disabilities is that this increase in balance and gait mechanics contributes to a decreased chance of falls which are often responsible for significant negative health outcomes and setbacks (Cakar et al., 2010). Therefore, these improvements to balance through AFO use will allow for better performance of activities of daily living, greater functionality, greater independence, and ultimately an increased quality of life for those whose disability results in some kind of mobility and balance impairment

(Carmeli et al., 2002).

The aim of the study was to investigate the effect of the AFOs on the static balance of individuals with ASD, Down syndrome, and other forms of ID. Looking to advance the growing research on AFOs, it was hypothesized that individuals with each of these conditions would experience improvements in balance with the AFO on. However, due to the mechanisms behind how AFOs are known to improve balance and the cause of balance impairments in individuals with Down syndrome, it was expected that individuals with Down syndrome would see the greatest improvement in balance with the AFOs on in comparison to individuals with ASD or other forms of ID.

METHODS

Participants

The study included fifteen subjects, including one individual with Down syndrome, seven individuals with Autism Spectrum Disorder (ASD), and seven individuals with other diagnosed intellectual disabilities that are not Down syndrome or ASD. Inclusion criteria included individuals between the ages of 18 and 40 of either sex. The fifteen subjects were recruited at the Special Olympics of Texas Fall Classic in College Station, Texas. Individuals were both recruited and the study was performed on site. Exclusion criteria for the study was any individual who had a history of orthopedic issues that would interfere with completion of the six balance tests. All subjects were provided with a consent form approved by the university's Institutional Review Board detailing the procedure of the study before taking part in the study.

Procedure

This cross sectional study was conducted during Health Promotions screenings at the Special Olympics Texas 2023 Fall Classic to explore the effect of ankle-foot orthotics on balance. The study was approved by the Texas Christian University Institutional Review Board. The subjects were only required to visit the "lab" (the Health Promotions tent) once for this study where they performed a total of 6 balance tests: three with a static AFO and three where they did not have this orthotic. Whether subjects conducted the AFO or non-AFO balance tests first was determined through randomization (a random number generator) and recorded. Subjects wore whatever comfortable shoes that they chose as long as they permitted use of the AFO device.

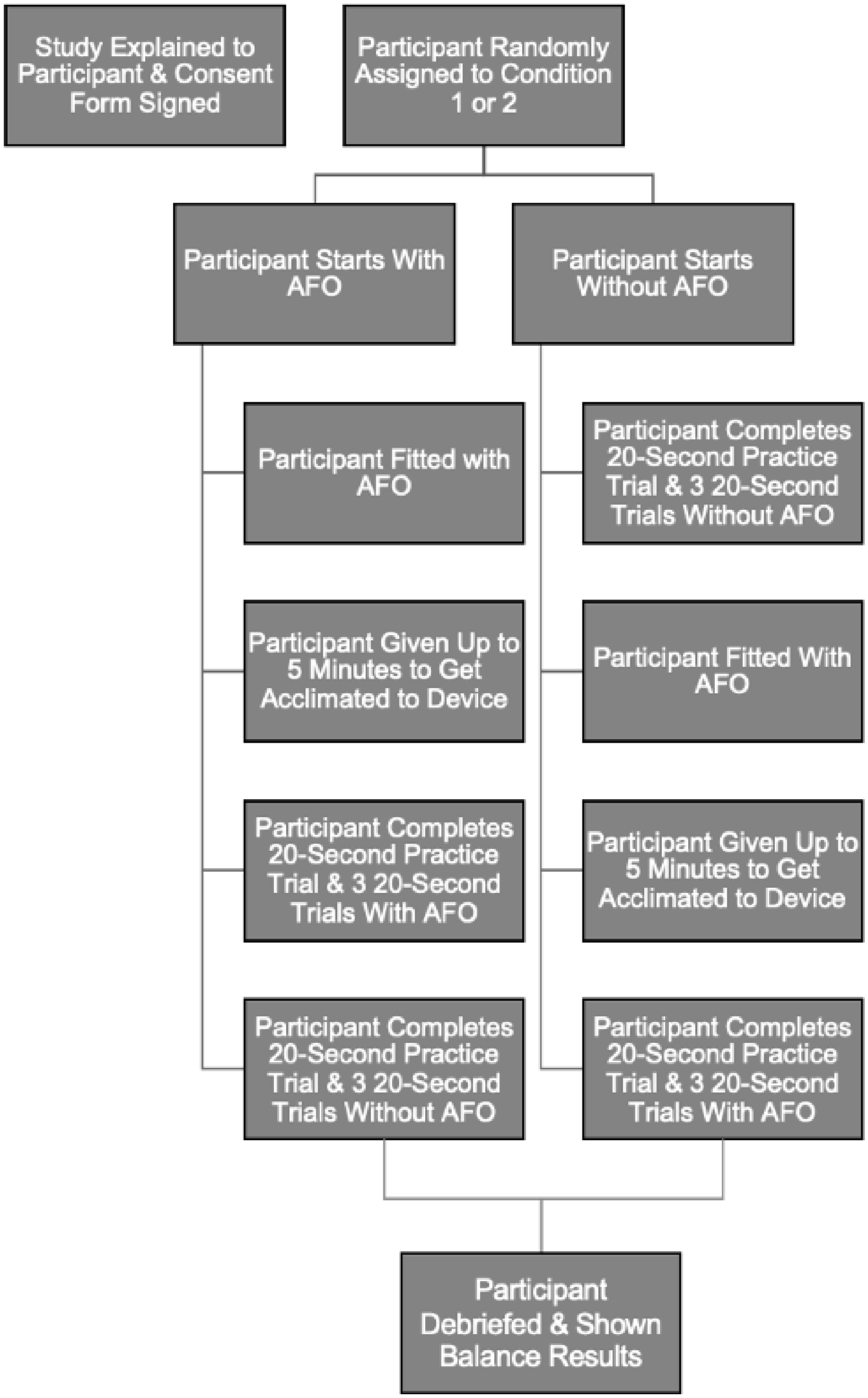
Figure 1

(The London Orthotic Consultancy, n.d.)

To conduct a balance test, subjects were instructed to stand on the force plate comfortably with their feet no more than hip width apart, with their hands on their hips, and with their eyes closed. Subjects were instructed to remain in this position for the entirety of each balance test. Once on the force plate, subjects balanced for 20 seconds as a practice round where the data were not recorded. After the practice round, the subject stood and balanced on the force plate for the three tests of the given condition (AFO or non-AFO) with breaks in between the tests at the discretion of the participant. Each trial was begun at the direction of the participant and participants were given a five-second countdown to the conclusion of each trial.

After completing these three tests, the subject then conducted their next three balance tests with or without the AFO depending on their randomized order. When the subject was preparing for the AFO balance tests, they were first outfitted with a static AFO that was adjusted by lab personnel to optimize comfort and utility. The subject was then given up to 5 minutes to get acclimated to the device before beginning their first balance test. During the 5 minute acclimation period, participants were free to perform any activity of their choice to get comfortable with the device. They were also able to terminate the acclimation period at their discretion to begin the first balance test with the AFO. The entire procedure lasted approximately 10 minutes for each subject. The subjects' data was then recorded with the three balance tests of each condition averaged to create mean AFO balance test data values and mean non-AFO balance test data values.

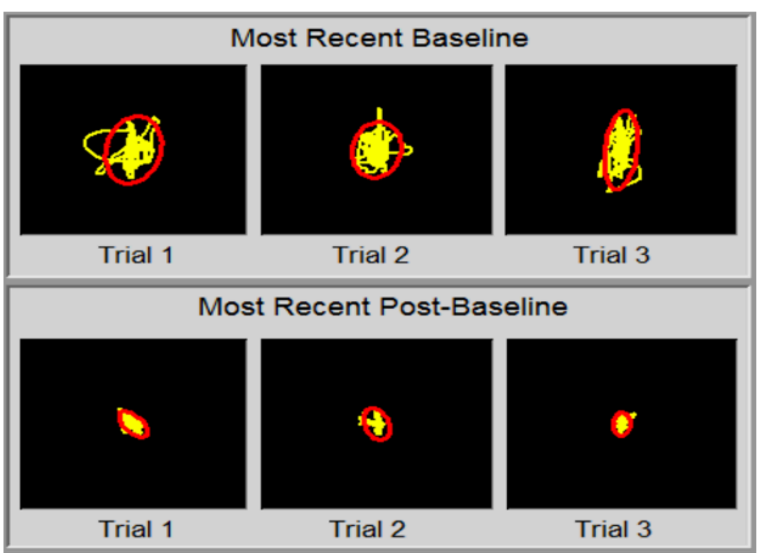
Figure 2


Study Explained to Participant & Consent Form Signed
Participant Randomly Assigned to Condition 1 or 2
Participant Starts With AFO
Participant Starts Without AFO
Participant Fitted with AFO
Participant Completes 20-Second Practice Trial & 3 20-Second Trials Without AFO
Participant Given Up to 5 Minutes to Get Acclimated to Device
Participant Fitted With AFO
Participant Completes 20-Second Practice Trial & 3 20-Second Trials With AFO
Participant Given Up to 5 Minutes to Get Acclimated to Device
Participant Completes 20-Second Practice Trial & 3 20-Second Trials Without AFO
Participant Completes 20-Second Practice Trial & 3 20-Second Trials With AFO
Participant Debriefed & Shown Balance Results

Measures

The study used a force plate to record data in reference to changes in the subject's CoP throughout each 30 second trial. The force plate will be set with a sampling frequency of 100 Hz prior to beginning the trial. An example of the output generated by the force plate is included below (Figure 3). This quantified measurement of CoP allowed for generation of data regarding 95% ellipse area, mean distance, mean velocity, anterior-posterior sway, and medio-lateral sway. 95% ellipse area calculated the area of the ellipse, in square centimeters, that encompassed 95% of all CoP measurements throughout the balance test trial. Mean distance, measured in centimeters, averages how many centimeters each individual CoP data value was from the averaged CoP across the entirety of the trial. Mean velocity measured the average velocity of the CoP movement across the span of the trial. This data can further be broken down into anterior-posterior or medial-lateral sway with anterior-posterior sway referring to how much the individual moved forward-to-back and medio-lateral sway referring to how much the individual moved side-to-side.

Figure 3



Statistical Analysis

Each subject's data output was statistically analyzed using dependent *t* tests through IBM's SPSS software to test for significant differences (using p = 0.05) and Cohen's d effect sizes, when applicable, in each of the measured balance criteria when they were wearing the AFO and when they were not. The results for each subject were then compared to that of other subjects of different disabilities to determine the degree to which AFOs affect static balance across individuals of different intellectual disabilities.

RESULTS

Using the aforementioned dependent t-test statistical analysis, quantitative variables of 95% ellipse, mean distance, mean velocity, medio-lateral sway, and anterior-posterior sway were compared pre- and post-AFO intervention through dependent *t*-test analysis. None of the variables achieved statistical significance (p = 0.05) likely due in part to the small sample sizes used. For this reason, Cohen's d-effect sizes were included in the statistical analysis of the data to better understand how the data differed between the two conditions.

Figure 4

	Mean	n	Std. Deviation	Std. Error Mean	One-Sided p value	Cohen's d effect size
95% Ellipse w/o AFO	2.353	15	1.8383	0.4746		
95% Ellipse w/ AFO	2.207	15	2.1774	0.5622	0.345	0.404
Mean Distance w/o AFO	0.593	15	0.2374	0.0613		
Mean Distance w/ AFO	0.527	15	0.2658	0.0686	0.104	0.185

Mean Velocity w/o AFO	1.387	15	0.7063	0.1824		
Mean Velocity w/ AFO	1.480	15	0.5890	0.1521	0.134	0.811
Medio-Lateral Sway w/o AFO	0.367	15	0.2274	0.0587		
Medio-Lateral Sway w/ AFO	0.320	15	0.3792	0.0979	0.266	0.347
Anterior-Posterior Sway w/o AFO	0.547	15	0.2052	0.0530		
Anterior-Posterior Sway w/ AFO	0.527	15	0.1552	0.0401	0.283	0.360

Effect sizes ranged from as low as low as 0.185 for Mean Distance and as high as 0.811 for Mean Velocity. Other effect sizes fit more modestly around 0.3 - 0.4. Furthermore, trends specific to each condition were able to be analyzed to understand how each of these variables are affected depending on disability or condition. Looking individually at the data for ID (Figure 5), DS (Figure 6), and ASD (Figure 7) participants allows for better understanding of how each variable is affected with respect to possible impairments or deficits characteristic of the diagnosis or condition.

Figure 5

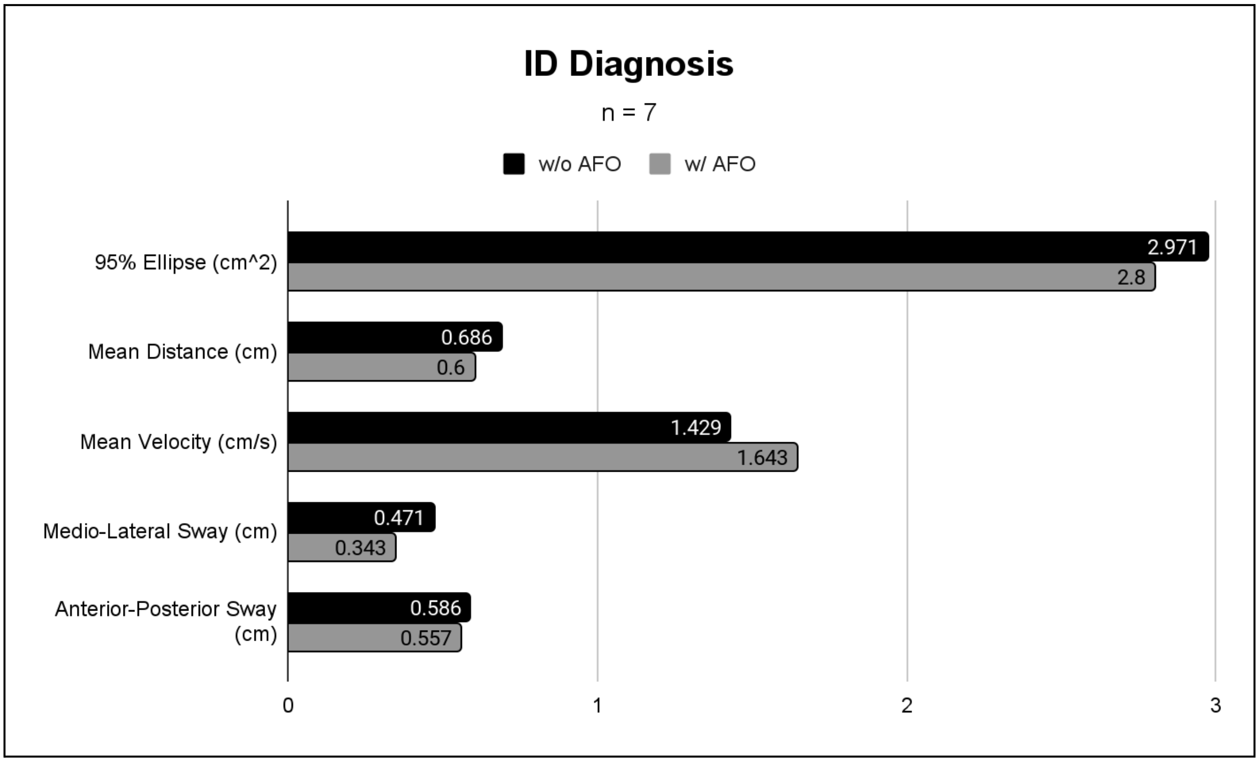


Figure 6

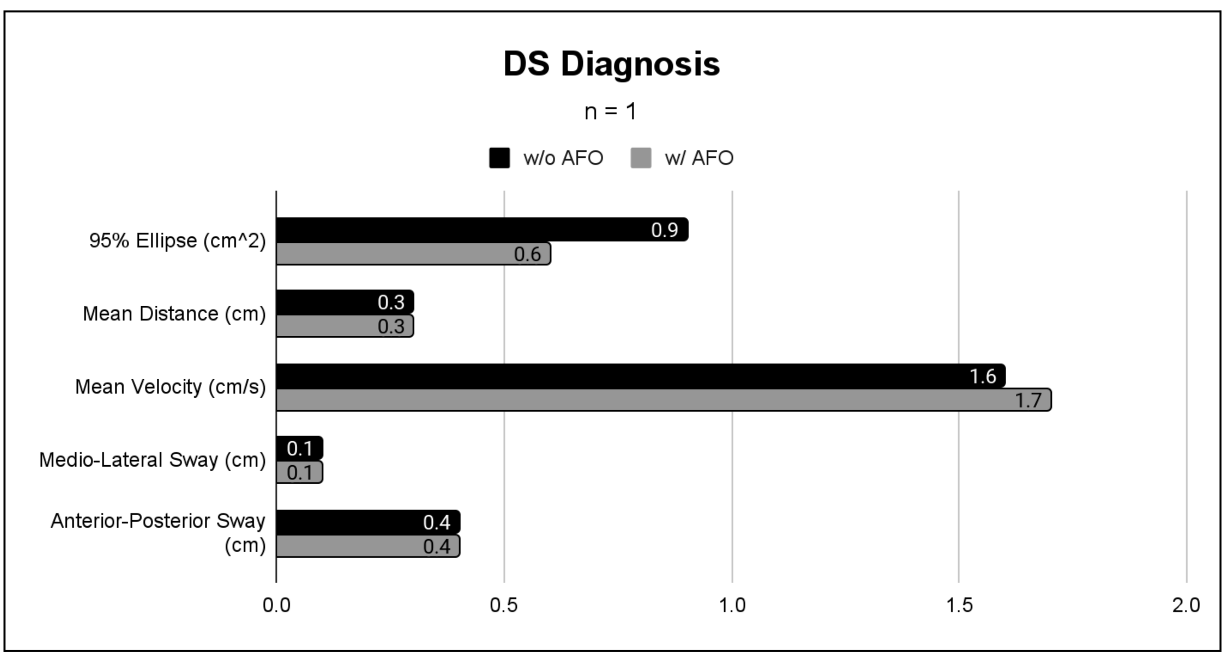
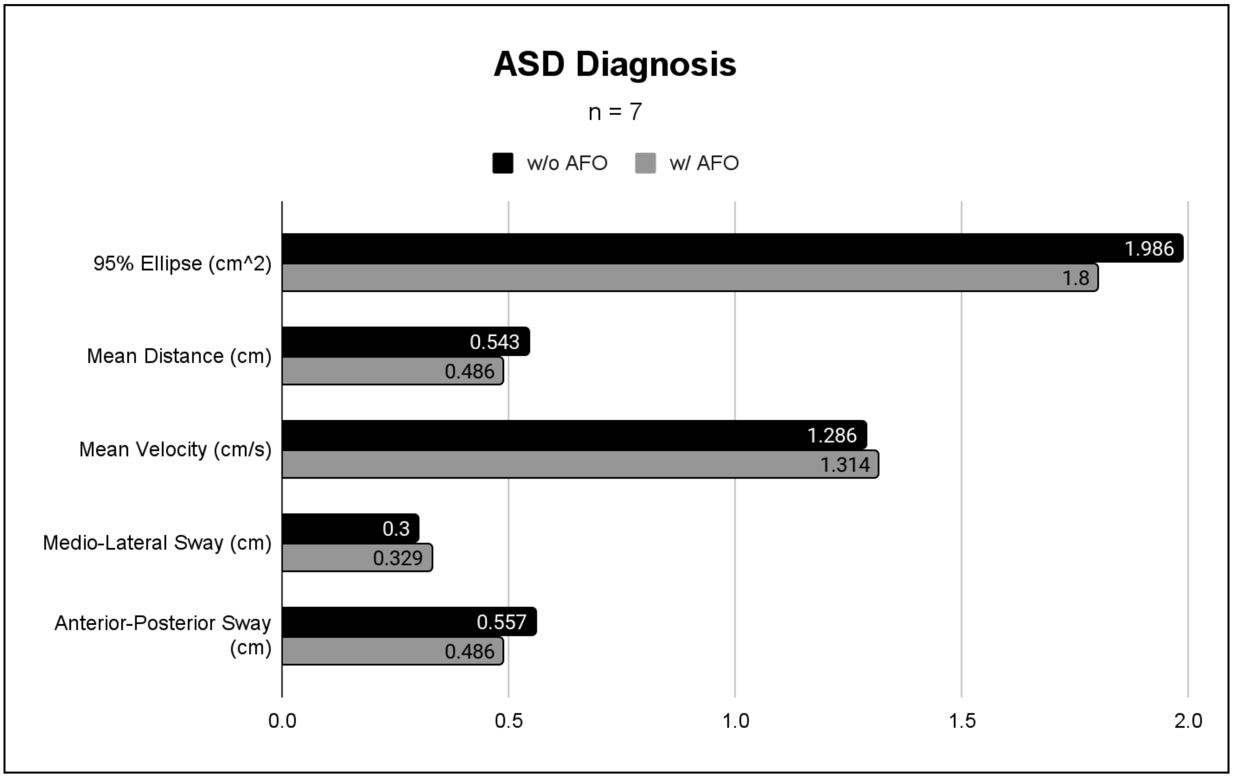


Figure 7



DISCUSSION

Overall, the results of individuals across the board indicate general improvements in individual variables when the AFOs were worn versus when they were not. This is congruent with existing research in the field (Yalla et al., 2014; Lee et al., 2014). Each individual variable decreased with the exception of mean velocity and in the ASD participant subsection specifically, medio-lateral sway. With the fixing of the joint and decreased laxity, the expectation is that the participant's balance would improve and each of the variables analyzed would decrease. These results mostly fall in line with that original hypothesis as well as existing literature in the field (Yalla et al., 2014; Burtner et al., 1999). One possible explanation for why the mean velocity increased in each individual group and when the results were analyzed as a whole is that the AFO works to stabilize the joint which makes the movement and sway that does occur more jerky and sudden. Therefore, despite there being less movement on the whole as seen with the remainder of the results, the movement that did occur likely happened more quickly and was jerkier than before, explaining why this variable that was expected to decrease actually increased with the intervention. The only other variable that did not decrease was medio-lateral sway in the ASD sample exclusively. One reason why medio-lateral sway may have increased contrary to expectations was that the specific type of static AFO used in this study primarily restricts anterior-posterior movement, strapping across the anterior side of the lower extremity and across the top of the foot. Restricting anterior-posterior movement may have meant that when individuals were using proprioception to find their balance, they had to rely more significantly on medio-lateral movements (not a plane limited by the specific AFO used), increasing medio-lateral sway in some individuals within the ASD group.

Due to the small sample sizes and specifically there only being one individual with DS included in the study, it could not be determined which disability group benefited the most from the intervention. It should be noted that no group as a whole had negative results. Furthermore, there were only two instances where individuals responded negatively to the intervention. Both individuals whose balance worsened with the implementation of the intervention were individuals with ID (not Down syndrome or ASD). Similarly, both of these individuals were randomly assigned to the condition in which they did the trials without the AFO first followed second by the trials with the AFO. Therefore, participants could have been potentially fatigued from the non-AFO trials depending on how much the prior tests fatigued them mentally or physically and how much break they allowed themselves in between trials as well as conditions. Other possible explanations could include participants not using an adequate portion of the acclimation period before completing trials meaning they had not yet gotten used to the device. Providing participants with a specific warm-up activity or mandated warm-up period could help to mitigate discrepancies across participants. Finally, they could have experienced discomfort with AFO which could explain why their balance decreased against expectations and that no matter what, they may always respond poorly to this intervention.

AFOs are certainly not a miracle intervention and their effectiveness will of course vary from individual to individual. Some individuals, as seen with this study, will respond more strongly to the intervention than others. However, the intervention is accessible and minimally invasive. Non-custom orthotics can be purchased from a plethora of retailers and are relatively inexpensive. Therefore, it may be worth implementing the intervention for anyone with the aforementioned disabilities to see if their balance could improve as indicated by the early findings of this research. Furthermore, the intervention can be utilized in combination with other long-term interventions for balance improvement (Blankevoort et al., 2010). This could help to complement the improvements enabled by other interventions and could be an asset to the individual in the long term.

Some other areas for future research based on the results of this study include trying different styles of AFOs (Daryabor et al., 2018; Abe, 2006). As previously mentioned, the AFO used in this study primarily restricted anterior-posterior movement. There are many different types of AFOs, both static and dynamic, on the market and further research could replicate this study's design with other types of AFOs to compare how balance is impacted when individuals use different styles of AFOs. Another avenue for future research would be to look at how balance is affected with other interventions, particularly long-term interventions. Looking at how balance is improved when individuals undergo a certain period of physical therapy in combination with using the AFO could be interesting and of value.

Some important limitations to note in regard to this study include primarily the small sample size. The sample only included a sample size of 15 individuals overall and the size of the Down syndrome group was only 1 individual. This led to less generalizable results and despite significant effect sizes, there were no significant results. Greater sample sizes could produce significant results or at the very least, better inform how the AFOs contribute to the balance of individuals with IDD.

Another limitation of the study was the setting. Recruitment and data collection took place at the Health Promotions tent at the Special Olympics of Texas Fall Classic. The study was one of many activities happening in the tent with many people in attendance. Therefore, the environment that data collection took place in was busy and loud. This could have led to some vestibular system interruption and also just served as a general distraction. Future research would likely benefit from a more controlled space for data collection such as a traditional lab or a device to cover the ears such as earplugs. Similarly, motivation levels and general feelings toward AFOs could affect results across the board. Many individuals with IDDs have utilized AFOs at some point so if anyone had any aversion to the device or decreased motivation levels going in, that could have impacted their results.

A final limitation of the study was that all participants were given up to 5 minutes as an acclimation period before beginning their trials with the AFO on. However, participants varied in how much of that acclimation period they actually used and what they did during that time. Future research could benefit by standardizing the time before data collection and creating a regimented warm-up for all participants to better equate balance performance improvements or declines across participants.

The overall implications of this study demonstrate that AFOs are an effective means of improving balance, particularly for individuals with the conditions investigated in this study. This study confirmed the previously ascertained mechanism of AFOs functioning to decrease postural sway by limiting movement in certain planes. This was particularly beneficial in the one individual with Down syndrome, a condition characterized by impaired proprioception and muscle irregularities. As a result, the role of AFOs should be taken into consideration when completing balance interventions and in the daily life of individuals with balance impairments.

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