ABBREVIATED MODELS FOR PREDICTING FALL RISK
IN ADULTS WITH INTELLECTUAL DISABILITIES

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 2, 2016
ABBREVIATED MODELS FOR PREDICTING FALL RISK
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ABSTRACT

The purpose of this study is threefold: first, to describe anthropometric measures in individuals with Down syndrome (DS) and those with other intellectual disabilities (ID); second, to generate abbreviated methods for predicting fall risk in each population; and third, to assess the validity of these abbreviated models. Body mass index (BMI), Timed Up and Go (TUG), and Berg Balance Scale (BBS) scores from participants (n=49 (12 DS, 37 ID); ages 18-44) recruited at the 2015 Special Olympics Fall Classic in Bryan, Texas were used in stepwise linear regression analyses to produce three equations predicting fall risk: one for those specifically with DS, one for those with any other ID, and one combining the two subgroups. BBS item “standing on one foot” explained a majority of the variance in total BBS scores for both ID (R²=0.677) and DS (R²=.816) subgroups, as well as in the overall participant group (R²=.709). BMI (R² = 0.14) and TUG (R² = 0.27), however, only accounted for a small fraction of the variance. Validity was assessed on a separate group of participants (n=41 (9 DS, 32 ID); ages 18-45) recruited from the 2016 Special Olympics Winter Games in Austin, Texas. Using predictive equations based on “standing on one foot”, minimal difference was found between actual and predicted BBS in the ID (mean diff = -0.74%), DS (mean diff = -4.51%), and combined (mean diff = -1.38%) models. Results suggest these models are valid alternatives to more extensive fall risk assessments typically used in clinical settings.
ACKNOWLEDGEMENTS

First off, we would like to thank Norm Arias and Special Olympics Texas for allowing us to conduct our research during the 2015 Fall Classic and 2016 Winter Games. We would also like to extend our gratitude to the athletes who participated in this study. Your involvement provided us with invaluable experiences and made this research possible.

We would also like to recognize our research committee members, Dr. Mitchell and Mrs. Crenshaw. Thank you for your support, not only during this process, but throughout our entire time as TCU students. Your encouragement was crucial to the success of our project and the maintenance of our sanity.

Above all, we would like to express our immense gratitude for Dr. Esposito and his unyielding dedication to this project. Thank you for your guidance and support (and at times, sarcasm), as they were all equally essential for completing our research. Your commitment to your students, inside and outside the classroom, and the wisdom you share with us is appreciated more than you could ever know. Good work outta you.

#HonorsBrainTrust
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INTRODUCTION

Balance and Fall Risk

Community safety and reducing risk of injury are high priorities for individuals, their families, and members in the healthcare profession. The primary indicator of lack of safety while ambulating in the community is the incidence of falls. A fall is “an event that results in a person coming to rest inadvertently on the ground or other level, other than as a consequence of lost consciousness, a violent blow, stroke, or epileptic seizure,” (O’Neill, Marsden, Adams, & Silman, 1996). Falls pose high risk of injury, as falling is the third most common cause of accidental death and the primary cause of unintentional injuries (Askham et al., 1990).

Fall risk is integrally dependent on balance abilities. Balance refers to the act of “maintaining the position and momentum of the body’s center of mass within the base of support without falling,” (Cherng, Lee, & Su, 2003). Balance is a highly integrative system, involving visual, somatosensory, vestibular, and musculoskeletal systems, and is essential for upright posture and successfully performing activities of daily living (Pereira, Maia, & de Azevedo Silva, 2012). Many studies indicate poor balance capabilities as a well-established risk factor for falls, particularly in older adults (American Geriatrics Society, British Geriatrics Society, & American Academy of Orthopaedic Surgeons Panel on Falls Prevention, 2001; Close, Lord, Menz, & Sherrington, 2005; Deandrea et al., 2010; Muraki et al., 2013; Quach et al., 2011; Stenhagen, Ekstrom, Nordell, & Elmstahl, 2013; Tinetti & Kumar, 2010).

Another key component of fall risk is mobility. Mobility can be defined as the “human activity of moving from place to place” and is dependent upon a person’s body
functions, structures, and capacities (Bussmann & Stam, 1998; World Health Organization, 2001). In addition to poor balance, mobility impairments have been found to contribute fall risk (Bartlo & Klein, 2011). In fact, mobility problems have been identified as the most important risk factor for falls, especially in the elderly population (Speechley, 2011; Tinetti, Speechley, & Ginter, 1988; Verghese, Holtzer, Lipton, & Wang, 2009).

**Balance and Fall Risk in Intellectual Disabilities**

Intellectual disability (ID), formerly known as mental retardation, is a disability characterized by “significant limitations in both intellectual functioning and adaptive behavior” (American Association of Intellectual and Developmental Disabilities [AAIDD], 2013). According to the AAIDD (2013), a person has an ID if he or she meets three criteria: IQ is below 70-75, there are significant deficits in adaptive functioning areas (e.g. conceptual skills, social skills, and practical skills), and the condition originates before the age of 18. Common causes of intellectual disabilities include genetic conditions (e.g. Down syndrome, Fragile X syndrome), problems during pregnancy (e.g. Fetal Alcohol Spectrum Disorder), birth complications, childhood injuries or diseases, toxic exposure (e.g. lead or mercury poisoning), and environmental factors (e.g. pollution, poverty) (AAIDD, 2013). Approximately 1% of the global population has an ID, with 85%, 10%, 4%, and 3% of these individuals having an ID classified as mild, moderate, severe, and profound, respectively (Maulik, Mascarenhas, Mathers, Dua, & Saxena, 2010; King, Toth, Hodapp, & Dykens, 2009).

Falls and related injuries are a frequent and serious concern for individuals with ID (Bray et al., 2002; Cox, Clemson, Stancliffe, Durvasula, & Sherrington, 2010;...
Enkelaar, Smulders, van Schrojenstein Lantman-de Valk, Weerdesteyn, & Geurts, 2013; Hale, Bray, & Littmann, 2007; Hsieh, Rimmer, & Heller, 2012; Sherrard, Tonge, & Ozanne-Smith, 2001). Not only do individuals with ID experience a higher rate of falls compared to the general population, but falling leads more often to injury and hospitalization than in age-matched controls (D. Wang, McDermott, & Sease, 2002; Finlayson, Morrison, Jackson, Mantry, & Cooper, 2010; Sherrard et al., 2001). Possible risk factors for falling in people with ID include visual impairments, concurrent medical problems, medication, impaired mobility, high rates of inactivity, and physical declines in balance and strength (Hale et al., 2007; Haveman et al., 2011; Hsieh et al., 2012; Smulders, Enkelaar, Weerdesteyn, Geurts, & van Schrojenstein Lantman-de Valk, 2013; Wagemans & Cluitmans, 2006; Wilgoss et al., 2010). Severity of ID may also play a role in fall risk. Van Dijk, Meulenberg, Van De Sande, & Habbema (1996) found that people with moderate and profound ID may be at a higher risk of falling than those with mild or severe ID.

Similarly to the general population, the risk of falling in individuals with ID increases with advancing age (Cox et al., 2010; Hsieh, Heller, & Miller, 2001; Wagemans & Cluitmans, 2006; Willgoss, Yohannes, & Mitchell, 2010). Adults with ID over the ages of 50 and 70 are reported to have a 2.5 and 10.6 times higher fall risk, respectively, compared to their younger counterparts (Chiba et al., 2009; Hsieh et al., 2001). In addition, the risk of falling for older adults with cognitive impairments is two times greater (at a 60% annual incidence of falls) than cognitively normal older adults (Jensen, Nyberg, Gustafson, & Lundin-Olsson, 2003; Tinetti et al., 1988). Unlike the general population, however, an increased fall risk for individuals with ID is not exclusive to
older adults, but is present across the lifespan (Sherrard et al., 2001). Australian children with ID are admitted to hospitals at double the rate and with more severe injuries than children without ID, with approximately 32% of the hospitalizations being due to falls (Sherrard et al., 2001). In addition, this study found that the high rate of injuries and falls seen in children with ID aged 5-14 persists into young adult life, in contrast to the general population (Sherrard et al., 2001).

Research suggests that the balance deficits may contribute to fall risk in individuals with ID (Hale et al., 2007). Adolescents with ID have poorer postural balance than age-matched controls (Blomqvist, Olsson, Wallin, Wester, & Rehn, 2013). In addition, adults with ID have larger mean body sway and delayed responses to postural perturbations than non-ID controls (Dellevia, Pallavera, Orlando, and Sforza, 2009; Hale, Miller, Barach, Skinner, and Gray, 2009; Suomi & Koceja, 1994). A longitudinal study by Lahtinen, Rintala, and Malin (2007) suggests that physical performance, including balance, in individuals with ID increases from early to late adolescence and declines during adulthood. This is a pattern similar to that found in previously published normative data for the general Finnish population but to a greater extent (Lahtinen, 1975; Lahtinen 1986; Heliovaara & Aromaa, 1980; Laatikainen et al., 2003). This trend becomes exacerbated in the elderly population. Oppewal, Hilgenkamp, van Wijckm, and Evenhuis (2013) suggest that older adults with ID have poor balance capacities similar to adults in the general population who are approximately 20 years older.

Balance deficits and poor gait capacities are two key factors underlying mobility impairments common in the ID population (Bartlo & Klein, 2011; Enkelaar, Smulders, van Schrojenstein Lantman de-Valk, Weerdesteyn, & Geurts, 2012). Adolescents with
mild ID performed significantly worse on the Extended Timed Up and Go Test than individuals without ID (Blomqvist et al., 2013). In addition, elderly individuals with mild ID performed 6 seconds slower than non-ID individuals on the same test (Carmeli, Bar-Chad, Lotan, & Coleman, 2003). Mobility has been identified as the most important risk factor for falls in the general population, suggesting these mobility impairments may contribute to falls in the ID population as well (Tinetti et al., 1988; Lord, Ward, Williams, & Anstey, 1994; Verghese et al., 2009; Speechley, 2011).

**Balance and Fall Risk in Down Syndrome**

One subgroup classified under intellectual disabilities includes individuals with Down syndrome (DS), a genetic disorder caused by a mutation of the 21st chromosome (King, Mulligan, & Stansfield, 2013). Approximately 1 out of every 691 babies in the United States are born with DS, making it the most common genetic condition in the country (National Down Syndrome Society [NDSS], 2012; Parker et al., 2010). The most frequent type of DS is Trisomy 21, in which there is an extra copy of the 21st chromosome, but other forms of DS include Mosaicism and Translocation (NDSS, 2012).

In addition to an intellectual disability ranging from mild to moderate severity, common characteristics of individuals with DS include developmental delays, distinct physical features (e.g. flattened facial features, small body stature, upward slanting eyes), increased risk of medical complications (e.g. heart defects, Alzheimer’s, hypothyroidism, obesity), hypotonia, muscle weakness, and high ligamentous laxity (Carmeli, Avalon, Barchad. Sheklow, & Reznick, 2002; Fernall et al., 1998; Pitetti, Rimmer, & Fernhall, 1993). Many dynamic motor dysfunctions, including slower movements, longer reaction times, and co-contraction of agonist and antagonist muscle pairs, are also present in
individuals with DS (Galli et al., 2008). Though exact neuropathological causes are still uncertain, these motor dysfunctions are likely due to cerebellar dysfunction, delayed myelination, and vestibular and proprioception deficits (Galli et al., 2008). Since DS affects multiple bodily functions apart from the intellectual disability, previous studies have argued to treat DS and ID as distinct populations in regards to physical activity and separate participants by these specific diagnoses (Cervantes & Poretta, 2010; Frey, Stanish, & Temple, 2008; Phillips & Holland, 2011; Roberts, 2007).

However, balance deficits are a concern for individuals with DS, similarly to those with other ID. Many studies indicate children with DS have delayed development of postural control and significant deficits in maintaining static standing balance (Block, 1991; Butterworth & Cichetti, 1978; Galli et al., 2008; Henderson, Morris, & Frith, 1981; Villarroya, Gonzalez-Aguero, Moros-Garcia, & Marin, 2012; Woollacott & Schumway-Cook, 1986). Adolescents with DS also have worse balance with both open and closed eyes than their age-matched peers without DS (Rigoldi, Galli, Mainardi, Crivellini, & Albertini, 2011; Vuillerme et al., 2001). Similar trends in decreased postural control and balance impairments have been found in adults with DS, especially when visual information is manipulated (Cabeza-Ruiz et al., 2011; Galli et al., 2008).

One hypothesized reason for these balance deficits is that individuals with DS have sensory dysfunctions, most likely caused by limited sensory experience due to a lack of normal motor control (Uyanik, Burnin, & Kayihan, 2003). Another reason is that when tested under dual task conditions, individuals with DS use significantly different temporal and spatial patterns compared to typically developing individuals (Horvat, Croce, Tomporowski, & Barna, 2013). As a result these individuals have less efficient
and functional movements when an additional task is encountered during walking (Horvat et al., 2013).

Balance impairments also play an important role in fall risk for individuals with DS. However, research is inconclusive about how balance and fall risk compare between those with DS and those with other ID. A longitudinal study by Lahtinen et al. (2007) found that participants without DS displayed significantly worse static balance than those with DS throughout childhood, adolescence, and adulthood. On the contrary, Dellavia et al. (2009) found that young adults with DS have greater mean body sway than that non-DS controls, but significantly less sway than those with other ID. In addition, a study by Finlayson et al. (2010) shows that individuals with ID have a higher fall risk when they do not have DS. One proposed theory for why DS have less number of falls than those with other ID is due to the stability-enhancing gait pattern of people with DS, which may suggest an effective strategy (Oppewal, Hilgenkamp, Wijck, Schoufour, & Evenhuis, 2014).

**Clinical Assessments**

**Body Mass Index**

Body mass index (BMI) is calculated by dividing weight (kg) by height squared (m²). This quick and inexpensive tool is widely used to classify individuals as underweight (<18.5), normal weight (18.5-24.9), overweight (25.0-29.9), and obese (>30.0) (World Health Organization, 2000). BMI indirectly assess body fat, and the accumulation of adipose tissue (and thus, increased BMI) has been determined to be a major contributing factor contributing to falls, particularly in conjunction with low muscle mass (Greve, Alonzo, Bordini, & Camanho, 2007). The positive correlation found
between BMI and postural instability is likely due to the need to initiate greater shifts in a greater mass to keep postural balance (Greve et al., 2007). Mirroring these findings, BMI has been shown to play a significant role in performance on the both Timed Up and Go Test and the Berg Balance Scale, which indicate fall risk (Enkelaar et al., 2012).

Within the ID population, the high rate of obesity is widely documented and is considered a key indicator of health in this population (Temple, Foley, and Lloyd, 2014). A large study consisting of 11,643 Special Olympics athletes with ID found that 5.5% were underweight, 36.1% were normal weight, 24.7% were overweight, and 32.1% were obese (Temple et al., 2014). When considering the DS population and the associated physical characteristics, questions have been raised about the validity of the BMI estimation of body fat for this population. It has been found that BMI calculations often misidentify some individuals with DS as overweight that do not have excess body fatness (Bandini, Fleming, Scampini, Gleason, & Must, 2013).

**Timed Up and Go Test**

The Timed Up and Go test (TUG) is a common assessment of mobility that predicts fall risk. This assessment measures the amount of time it takes an individual to stand up from a seated position in a chair, walk 3 meters, return to the chair, and return to the seated position. There is a generalized cutoff of 13.5-14 seconds for typically developing, community-dwelling older adults and a longer time to complete the task indicates high fall risk (Enkelaar et al. 2012).

These critical values indicating fall risk have not been validated for the ID population, but average times were typically higher, indicating the ID population is at higher risk of falls (Enkelaar et al., 2012). Children and adolescents with Down syndrome
typically have statistically significant higher TUG scores than age-, weight-, and sex-matched typically developing individuals (Nicolini-Panisson & Donadio, 2013). Reliability of the TUG for the DS population was studied among children and adolescents with DS, and it was found to have high same-day reliability (Nicolini-Panisson & Donadio, 2013). The feasibility of the TUG for older adults with ID has been considered high, with several studies reporting 100% completion (Enkelaar et al., 2012).

**Berg Balance Scale**

The Berg Balance Scale (BBS) is a widely used clinical tool to assess balance and fall risk. This test analyzes functional performance in static and dynamics balance tasks. It takes about 25 minutes to complete, and includes 14 items, each of which are ranked on an ordinal scale of 0-4 according to performance parameters. BBS scores are used to predict fall risk, with a cut-off score of 45 or below (out of 56 total points) typically used to categorize high fall risk (Oppewal et al., 2013). Studies examining the fall risk prediction based on BBS scoring found that in the general elderly population living in assisted living facilities, a score below 45 was correlated with a 2.8 times greater risk to fall for the next year than those with a score above 45 (Oppewal et al., 2013).

While initially designed for the typical elderly population, this assessment has been proven valid for the ID elderly population and demonstrates significant correlations with score of other balance scales, such as the TUG and Tinetti Balance subscale (Oppewal et al., 2013). Further, the BBS has been proposed as the most applicable instrument to evaluate balance capacities and fall risk in older adults with ID (Hilgenkamp, van Wijck, & Evenhuis, 2010). Yet, validity of the BBS has yet to be established for the ID and DS populations (Oppewal et al., 2013). The use of the 45 point
score cutoff based on typical population norms is likely not suitable to the ID population. Norms for the BBS based on the typically developing elderly assume balance capabilities are primarily impacted by age-related declines and decrease in cognitive functioning; however, the ID population experiences age-related changes differently, as they have lifelong cognitive and motor function impairments and, thus, may exhibit different compensation strategies (Oppewal et al., 2013). Research literature describes BBS as having excellent feasibility for borderline and mild impairment, good feasibility for moderate impairment, and low feasibility for severe and profound levels of ID (Hilgenkamp, van Wijck, and Evenhuis, 2013). The BBS is not a feasible measure for those with severe to profound ID or those who rely on wheelchairs, as they have completion rates of the assessment below 25% (Hilgenkamp et al., 2013). In one study, 392 of 900 participants did not complete all 14 items of the original BBS, with the primary reasons for dropout being difficulties understanding the task and physical limitations (Oppewal et al., 2013). Older persons with ID have the greatest difficulty understanding the tandem stance item of the BBS (Enkelaar et al., 2012). Providing familiarization and practice sessions greatly improved the completion rate for the ID population (Oppewal et al., 2013).

**Project Significance**

It is critical that health professionals monitor balance and fall risk, particularly for individuals with intellectual disability, in order to identify those in need of intervention. However, not all instruments are feasible to use with the ID population due to limitations in cognitive ability, as well as various comorbidities associated with these conditions (Bruckner & Herge, 2003; Carmeli et al., 2003; Hale et al., 2007; Sackley et al., 2005;
Oppewal et al., 2013). Many individuals with ID have trouble completing balance assessments with the primary reasons for drop-outs being difficulty understanding task instructions, lack of motivation, concentration problems, and anxiety (Oppewal et al., 2013). In addition, these cognitive barriers could interfere with the accuracy of evaluations and may be exacerbated by the time-consuming nature of these tests (Oppewal et al., 2013). An assessment that would decrease time and equipment requirements, yet accurately predict fall risk for these populations, would be highly valuable in clinical settings.

**Purpose and Hypothesis**

The purpose of this study is threefold: first, to explore anthropometric differences between individuals with Down syndrome (DS) and those with other intellectual disabilities (ID); second, to generate abbreviated methods for predicting fall risk in each population; and third, to assess the validity of these techniques. As BMI, TUG, and the BBS have all been associated with fall risk measurements, it is hypothesized that all three factors will be included in the abbreviated testing equation.

**METHODS**

**Participants**

Out of the initial 98 potential participants, 8 dropped out of the study for various reasons including time constraints and lack of motivation. This resulted in a total of 90 adults with intellectual disabilities (21 DS, 69 ID) between the ages of 18 and 45 participating in this study. 47 participants were males and 43 were females. There were four repeating participants, whose data for the model validation were excluded. Diagnosis was self-reported and the use of hearing and visual aids was permitted during testing.
Individuals who utilize Ankle-Foot orthotics or assistive mobility devices, such as canes or walkers, were required to complete all tests without the use of these aids. Individuals who are completely reliant on such assistive devices and immobile without the use of them, including individuals who use wheelchairs, were not allowed to participate.

49 of the total participants (12 DS, 37 ID, aged 30.1 ± 7.0) were recruited at the Special Olympics Texas Fall Classic in Bryan, Texas. The 41 remaining participants (9 DS, 32 ID, aged 26.9 ± 8.3) were recruited at the Special Olympics Texas Winter Games in Austin, Texas. Study procedures were thoroughly explained to participants, who then signed a consent form. If participants were unable to complete a signature, a verbal “yes” or “no” sufficed. For nonverbal individuals, we accepted a head nod or hand sign for yes and no, along with a caregiver’s signed permission.

**Instruments**

**Body Mass Index**

Body Mass Index (BMI) is an inexpensive method for classifying obesity levels that is relatively easy to use. While BMI is typically calculated by dividing a person’s weight in kilograms by height in inches squared, it can also be calculated using imperial units with the following equation: \( \text{BMI} = \left[ \frac{\text{weight (lbs)}}{\text{height (in)}^2} \right] \times 703 \). BMI ranges are used to classify adults into standard weight status categories: underweight (<18.5), normal weight (18.5-24.9), overweight (25-29.9), obese (30-39.9) or extremely obese (>40). In this study, height was measured in inches using a seca 0123 stadiometer and weight was measured in pounds using a seca 869 scale.
**Timed Up and Go Test**

The Timed Up and Go Test (TUG) is a measurement of functional mobility. The test begins with participants sitting in an armed chair with their hips positioned at the back of the seat. Participants wear their regular footwear, and a piece of tape is placed on the floor 3 meters away from the front legs of the chair. Participants are instructed to stand up, walk to the line, turn around, walk back to the chair and sit down again. Participants should walk at their normal pace and can use the arm rests when standing and sitting. A stopwatch is used to measure the time from the word “go” to when the participant’s buttocks touch the seat again.

**Berg Balance Scale**

The Berg Balance Scale (BBS) is a 14-item test that assesses static and dynamic balance capabilities based on performance of functional tasks. Test items include sitting to standing, standing unsupported, sitting unsupported, standing to sitting, transfers, standing with eyes closed, standing with feet together, reaching forward with outstretched arm, retrieving object from floor, turning to look behind, turning 360 degrees, placing alternate foot on stool, standing with one foot in front, and standing on one foot. Each item is individually scored 0-4 based on standard performance criteria (Appendix). Each item’s score is summed and the total score is used to predict fall risk according to population-specific ranges. For the purpose of this study, total scores of 41-56 were considered low risk, scores of 21-40 were considered moderate risk, and scores of 0-20 were considered high risk. Equipment used included a stopwatch, a ruler, tape, chairs at a standard height and an 8-in. step stool.
**Procedure**

**Model Creation**

After signing consent forms, participants recruited at the Special Olympics Texas Fall Classic completed BMI, TUG, and BBS assessments. Height and weight were measured to the nearest 0.1 inch and 0.1 pound respectively. BMI was calculated using the imperial equation: $\text{BMI} = \left[\frac{\text{weight (lbs)}}{\text{height (in)}}\right]^2 \times 703$. According to standardized BMI ranges, participants were classified as underweight, normal, overweight, obese, or extremely overweight.

Participants then completed the TUG test. First, investigators provided the participants with verbal instructions and a brief demonstration of the task. It was emphasized that participants should walk at their regular, controlled pace, and participants were allowed to use the arm rests when standing and sitting. Participants completed a practice trial before being timed to the 0.01 second.

Lastly, participants completed the BBS assessment. This test was implemented and scored according to the standardized protocol (Appendix) with the exception of “standing unsupported one foot in front.” For this task, tape was utilized as a visual aid to assist with comprehension of instructions. A long piece of tape through two “X”-shaped pieces was placed on the floor to achieve the proper alignment and positioning of feet. Prior to evaluating each task, investigators provided verbal instructions and a brief demonstration. When necessary, participants were given the opportunity to complete a second trial for any particular task to ensure instructions were fully understood.
Data from these participants were used to generate three predictive models: one for those specifically with DS, one for those with any other ID, and one combining the two subgroups.

**Model Validation**

Participants at the Special Olympics Texas Winter Games followed the same procedure as the Fall Classic group. Data from these participants were used to validate the predictive equations. Individuals whose data contributed to the model creation group were excluded from participating again in the model validation group.

**Statistical Analysis**

Descriptive statistics and independent samples t-test measures were used to discern if any significant differences existed between the model creation and model validation participant populations regarding age, height, weight, BMI, TUG, and BBS. Predictive models were created based on a theoretical framework using variables (BMI, TUG, and tasks from the BBS) believed to be important. Then, stepwise linear regression was used with model creation data to confirm which variables best explained the variance in total BBS scores. Descriptive statistics were used to compare predicted and actual BBS scores within the model validation group.

**RESULTS**

Descriptive statistics and independent sample t-tests were used to compare the model creation and model validation groups. Overall group statistics with means and standard deviations are shown in Table 1. No significant differences were found between the model creation and model validation groups regarding age, height, weight, BMI, TUG, or BBS scores. In addition, these statistical analyses were used to examine
differences between the ID and DS subgroups within the model creation and model validation groups. Results are shown in Table 2. Between ID and DS participants of the model creation group, significant differences were found in height (p=0.000), and BMI (p=0.001). In the model validation group, significant differences between ID and DS were found in height (p=0.002), BMI (p=0.007), TUG (p=0.000), and BBS (p=0.002).

Stepwise linear regression analyses were used to produce predictive equations based on variables identified as best explaining the variance in overall BBS scores (Table 3). Participants’ diagnosis (DS or ID) and BBS item “standing on one foot” accounted for a majority of this variance (R² = 0.709). BMI (R² = 0.14) and TUG (R² = 0.27) only accounted for a small fraction of the variance. Using these variables, an equation was produced to predict overall BBS scores in all individuals with intellectual disabilities (DS and ID combined): Predicted BBS = 43.980 + 2.804(Standing on one foot) - 1.345(Diagnosis). If participants have DS, a 1 is inputted for diagnosis, whereas a 0 should be used for participants with any other type of intellectual disability. Two additional models were created to predict BBS scores in each specific diagnosis subgroup: DS and ID. “Standing on one foot” explained most of the variance in DS participants (R² = .816) resulting in the predictive equation: Predicted BBS = 39.821 + 3.571(Standing on one foot). In ID participants, “standing on one foot” accounted for approximately two-thirds of the variance (R²=0.677) resulting in the equation: Predicted BBS = 44.629 + 2.618(Standing on one foot).

Descriptive statistics were used to compare the predicted and actual BBS scores for the model validation group. For the combined model, the mean percent difference was calculated to be -1.38%, with a standard deviation of 2.69%. This model at most
underestimated the BBS score by 9.40% and overestimated by 4.06% (Figure 1). The mean percent difference for the DS-specific model was -4.51% with a standard deviation of 3.65%. The DS model underestimated BBS score between 1.65 and 12.08% (Figure 2). The ID-specific model yielded a mean percent difference of -0.74% and a standard deviation of 1.85%. The greatest underestimation of BBS score was by 6.10% with the largest overestimation at 3.89% (Figure 3).

DISCUSSION

When running descriptive statistics, a significant difference was found between ID and DS in regard to height and BMI in both the model creation and model validation groups. The difference in height is to be expected, as short stature is a prominent component in the DS phenotype. There was not a significant difference in weight between the ID and DS; therefore, the significant difference in BMI can be contributed to the height distinctions between these two populations (Bandini, Fleming, Scampini, Gleason, & Must, 2013).

Within the model creation group, no significant difference was found for TUG and BBS between ID and DS; however, there was a significant difference for those two measures between ID and DS in the model validation group. Many uncontrolled variables may account for this discrepancy between events. Environmental differences between the two events, such as noise and visual distractions, might have altered performance on the TUG and BBS. Individuals with ID and DS may have different challenges processing extraneous stimuli, which could have affected performance. Several studies have indicated, particularly in the DS population, that deficits in sensory processing impede movement performance by lengthening reaction time and decreasing balance (Horvat,
2003; Smail & Horvat, 2006; Welsh & Elliott, 2001). Furthermore, according to Welsh and Elliott (2001), the most challenging type of sensory processing for those with DS is auditory integration, and this was likely exacerbated by the persistent karaoke and other background noise present at the model validation event while verbal instructions for the TUG and BBS were given. Secondly, there was nearly a significant difference in age between model creation and model validation groups (p=0.05). When comparing within diagnosis groups between the two participant populations, we found that there was a significant difference in age between model creation and model validation in ID (p=0.032) but not DS (p=0.935). The ID participants for the model validation was younger than the ID for model creation. Though there was a greater level of distracting stimuli at the model validation facility, the ID population was younger, suggesting these environmental factors may not have impacted the ID population as much as those with DS. This supports previous research literature that suggests that aging increases deficits in selective attention and sensory processing (Guerrerio, Murphy, & van Gerven, 2010). These factors may have contributed individually or interactively to the significant difference in TUG and BMI for the model validation group.

The first predictive model created applies to all individuals with intellectual disabilities. Considering the emphatic support of research literature about the need to differentiate DS from the rest of ID when considering physical activity, we then split our combined model into two population-specific equations (Cervantes & Poretta, 2010; Frey, Stanish, & Temple, 2008; Phillips & Holland, 2011; Roberts, 2007). When comparing the equations’ y-intercepts, we see that the ID model has the highest (44.62), DS has the lowest (39.82), and the combined model falls in the middle (43.98). This
represents the fact that DS scored lower on total BBS on average compared to ID. The combined model falls in between as it considers both groups. When analyzing the differences in coefficients of “standing on one foot”, we find that this factor is more heavily weighted in DS (3.57) than combined (2.80) or ID (2.62) models. This reflects the finding that “standing on one foot” explained more of the variance of total BBS score in the DS group ($R^2=0.816$) than for ID ($R^2=0.677$) or for both diagnoses combined ($R^2=0.709$). Research literature describes TUG and BMI as key indicators of fall risk (Enkelaar et al., 2012; Greve, Alonzo, Bordini, & Camanho, 2007); in our study, however, these measures only accounted for 14% and 27% of the variance in BBS scores, respectively. These findings did not support our hypothesis that BMI and TUG would be included as influential factors in predicting fall risk.

For the combined predictive model, high predictive accuracy was demonstrated by the mean percent difference of -1.38%. In relation to BBS scoring, this would equate to an underestimation of 0.77 BBS points compared to participants’ actual scores. For the ID predictive model, the mean percent difference was -0.74%, proportional to about -0.41 BBS points. For the DS model, on average there was an underestimation of 4.51%, which is equivalent to 2.52 BBS points. The BBS indicates a minimum of an 8-point difference for clinical significance. When considering our mean percent differences in regard to this standard, our models were highly accurate.

**Practical Implications**

The models established in this study are highly valuable to clinical settings. The amount of time required for assessing fall risk is greatly reduced (less than 30 seconds compared to the 25 minute full BBS assessment). With insurance providing coverage for
a limited number of physical therapy appointments, it is important that assessments require less time to complete so that more time can be dedicated towards treatment. Cost for this fall risk assessment is minimal, with a stopwatch as the only required equipment. The decreased cost and equipment necessary to complete this assessment allows for a wide use of this tool in health outreach settings.

This abbreviated model also alleviates many of the cognitive barriers seen in individuals with ID and DS while performing various balance assessments (Bruckner & Herge, 2003; Carmeli et al., 2003; Hale et al., 2007; Sackley et al., 2005; Oppewal et al., 2013). The time required to complete the test is greatly diminished, which reduces the difficulty for these populations to maintain focus and effort throughout entire assessments. This model includes only one task, which has simple instructions. Therefore, the risk of patients misunderstanding instructions, which may lead to misrepresentation of balance capabilities, is greatly reduced. Decreased time and complexity involved in this assessment also reduces the potential anxiety a patient may experience.

**Limitations**

One limitation to this study is that all participants were athletes involved with Special Olympics. This may have caused a floor effect where all participants had some level of physical activity that is greater than the ID and DS populations at large. In addition, our participants’ ages and severity levels (i.e. mild to moderate) may not have completely represented the whole ID and DS populations.

Secondly, assessments were performed by students with no professional training. This may have led to increased risk of scoring errors in assessment scoring.
Future Directions

Further research should be performed to assess the validity of these models for a wider population within ID and DS. First, these models should be tested with children, adolescents, and older adults to establish its validity throughout the lifespan. Secondly, these predictive equations should be studied across all severity levels, including those with mild, moderate, severe, and profound intellectual disabilities. Lastly, these models should be verified for individuals with ID and DS that engage in various levels of physical activity.

Currently, no normative data has been established for BBS scores in the ID and DS populations. Consequently, BBS score ranges associated with fall risk have not been validated in these specific populations. Research is needed to establish cutoff scores indicating low, medium, and high fall risk for ID and DS patients.
Table 1

*Group Demographics – Model Creation vs. Model Validation*

<table>
<thead>
<tr>
<th></th>
<th>Model Creation (N=49)</th>
<th>Model Validation (N=41)</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>30.1 ± 7.0</td>
<td>26.9 ± 8.3</td>
<td>.050</td>
</tr>
<tr>
<td>Height (in.)</td>
<td>62.9 ± 4.4</td>
<td>62.9 ± 4.2</td>
<td>.990</td>
</tr>
<tr>
<td>Weight (lbs.)</td>
<td>186.5 ± 54.3</td>
<td>175.2 ± 44.3</td>
<td>.288</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td>33.2 ± 9.1</td>
<td>31.2 ± 7.4</td>
<td>.252</td>
</tr>
<tr>
<td>TUG (sec)</td>
<td>9.2 ± 3.5</td>
<td>8.7 ± 2.5</td>
<td>.401</td>
</tr>
<tr>
<td>BBS Score</td>
<td>53.6 ± 2.4</td>
<td>53.3 ± 2.3</td>
<td>.675</td>
</tr>
</tbody>
</table>
Table 2

*Group Demographics – Down syndrome vs. Other Intellectual Disabilities*

<table>
<thead>
<tr>
<th></th>
<th>Model Creation</th>
<th></th>
<th>Model Validation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DS (N=12)</td>
<td>ID (N=37)</td>
<td>p-value(^a)</td>
<td>DS (N=9)</td>
</tr>
<tr>
<td>Age (years)</td>
<td>30.5 ± 6.7</td>
<td>29.9 ± 7.2</td>
<td>.816</td>
<td>30.2 ± 8.7</td>
</tr>
<tr>
<td>Height (in.)</td>
<td>59.0 ± 3.1</td>
<td>64.1 ± 4.0</td>
<td>.000*</td>
<td>59.1 ± 3.8</td>
</tr>
<tr>
<td>Weight (lbs.)</td>
<td>201.9 ± 54.4</td>
<td>181.5 ± 54.0</td>
<td>.263</td>
<td>184.4 ± 28.9</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td>40.3 ± 7.6</td>
<td>30.9 ± 8.5</td>
<td>.001*</td>
<td>36.9 ± 2.9</td>
</tr>
<tr>
<td>TUG (sec)</td>
<td>9.8 ± 3.2</td>
<td>9.0 ± 3.6</td>
<td>.521</td>
<td>11.1 ± 2.2</td>
</tr>
<tr>
<td>BBS Score</td>
<td>52.9 ± 2.6</td>
<td>53.8 ± 2.3</td>
<td>.296</td>
<td>51.3 ± 2.5</td>
</tr>
</tbody>
</table>

\(^a\) p-values are comparing DS to ID.
Table 3

*Predictive Models for Estimating Berg Balance Scores*

<table>
<thead>
<tr>
<th>Model</th>
<th>Predictive Equation</th>
<th>$R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined</td>
<td>$43.980 + 2.804(Standing on one foot) - 1.345(Diagnosis^a)$</td>
<td>.709</td>
</tr>
<tr>
<td>DS</td>
<td>$39.821 + 3.571(Standing on one foot)$</td>
<td>.816</td>
</tr>
<tr>
<td>ID</td>
<td>$44.629 + 2.618(Standing on one foot)$</td>
<td>.677</td>
</tr>
</tbody>
</table>

*Note.* Predictive equations were generated using stepwise linear regression. $R^2$ refers to the amount of variance in total BBS scores that is explained by the variables in each predictive model.

^a Diagnosis: ID = 0, DS = 1
Figure 1

Percent Difference between Actual and Predicted BBS Scores – Combined Model

Diagnosis
- Gray: Intellectual disability
- Purple: Down syndrome
Figure 2

Percent Difference between Actual and Predicted BBS Scores – DS Model
Figure 3

Percent Difference between Actual and Predicted BBS Scores – ID Model


APPENDIX

**Berg Balance Scale**

The Berg Balance Scale (BBS) was developed to measure balance among older people with impairment in balance function by assessing the performance of functional tasks. It is a valid instrument used for evaluation of the effectiveness of interventions and for quantitative descriptions of function in clinical practice and research. The BBS has been evaluated in several reliability studies. A recent study of the BBS, which was completed in Finland, indicates that a change of eight (8) BBS points is required to reveal a genuine change in function between two assessments among older people who are dependent in ADL and living in residential care facilities.

**Description:**
14-item scale designed to measure balance of the older adult in a clinical setting.

**Equipment needed:** Ruler, two standard chairs (one with arm rests, one without), footstool or step, stopwatch or wristwatch, 15 ft. walkway

**Completion:**
- **Time:** 15-20 minutes
- **Scoring:** A five-point scale, ranging from 0-4. “0” indicates the lowest level of function and “4” the highest level of function. Total Score = 56

**Interpretation:**
- 41-56 = low fall risk
- 21-40 = medium fall risk
- 0–20 = high fall risk

A change of 8 points is required to reveal a genuine change in function between 2 assessments.
## Berg Balance Scale

Name: ________________________________ Date: __________________

Location: ________________________________ Rater: __________________

<table>
<thead>
<tr>
<th>ITEM DESCRIPTION</th>
<th>SCORE (0-4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sitting to standing</td>
<td></td>
</tr>
<tr>
<td>Standing unsupported</td>
<td></td>
</tr>
<tr>
<td>Sitting unsupported</td>
<td></td>
</tr>
<tr>
<td>Standing to sitting</td>
<td></td>
</tr>
<tr>
<td>Transfers</td>
<td></td>
</tr>
<tr>
<td>Standing with eyes closed</td>
<td></td>
</tr>
<tr>
<td>Standing with feet together</td>
<td></td>
</tr>
<tr>
<td>Reaching forward with outstretched arm</td>
<td></td>
</tr>
<tr>
<td>Retrieving object from floor</td>
<td></td>
</tr>
<tr>
<td>Turning to look behind</td>
<td></td>
</tr>
<tr>
<td>Turning 360 degrees</td>
<td></td>
</tr>
<tr>
<td>Placing alternate foot on stool</td>
<td></td>
</tr>
<tr>
<td>Standing with one foot in front</td>
<td></td>
</tr>
<tr>
<td>Standing on one foot</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
</tbody>
</table>

**GENERAL INSTRUCTIONS**

Please document each task and/or give instructions as written. When scoring, please record the lowest response category that applies for each item.

In most items, the subject is asked to maintain a given position for a specific time. Progressively more points are deducted if:

- the time or distance requirements are not met
- the subject’s performance warrants supervision
- the subject touches an external support or receives assistance from the examiner

Subject should understand that they must maintain their balance while attempting the tasks. The choices of which leg to stand on or how far to reach are left to the subject. Poor judgment will adversely influence the performance and the scoring.

Equipment required for testing is a stopwatch or watch with a second hand, and a ruler or other indicator of 2, 5, and 10 inches. Chairs used during testing should be a reasonable height. Either a step or a stool of average step height may be used for item # 12.
**Berg Balance Scale**

**SITTING TO STANDING**
INSTRUCTIONS: Please stand up. Try not to use your hand for support.
( ) 4 able to stand without using hands and stabilize independently
( ) 3 able to stand independently using hands
( ) 2 able to stand using hands after several tries
( ) 1 needs minimal aid to stand or stabilize
( ) 0 needs moderate or maximal assist to stand

**STANDING UNSUPPORTED**
INSTRUCTIONS: Please stand for two minutes without holding on.
( ) 4 able to stand safely for 2 minutes
( ) 3 able to stand 2 minutes with supervision
( ) 2 able to stand 30 seconds unsupported
( ) 1 needs several tries to stand 30 seconds unsupported
( ) 0 unable to stand 30 seconds unsupported

If a subject is able to stand 2 minutes unsupported, score full points for sitting unsupported. Proceed to item #4.

**SITTING WITH BACK UNSUPPORTED BUT FEET SUPPORTED ON FLOOR OR ON A STOOL**
INSTRUCTIONS: Please sit with arms folded for 2 minutes.
( ) 4 able to sit safely and securely for 2 minutes
( ) 3 able to sit 2 minutes under supervision
( ) 2 able to sit 30 seconds
( ) 1 able to sit 10 seconds
( ) 0 unable to sit without support 10 seconds

**STANDING TO SITTING**
INSTRUCTIONS: Please sit down.
( ) 4 sits safely with minimal use of hands
( ) 3 controls descent by using hands
( ) 2 uses back of legs against chair to control descent
( ) 1 sits independently but has uncontrolled descent
( ) 0 needs assist to sit

**TRANSFERS**
INSTRUCTIONS: Arrange chair(s) for pivot transfer. Ask subject to transfer one way toward a seat with armrests and one way toward a seat without armrests. You may use two chairs (one with and one without armrests) or a bed and a chair.
( ) 4 able to transfer safely with minor use of hands
( ) 3 able to transfer safely definite need of hands
( ) 2 able to transfer with verbal cuing and/or supervision
( ) 1 needs one person to assist
( ) 0 needs two people to assist or supervise to be safe

**STANDING UNSUPPORTED WITH EYES CLOSED**
INSTRUCTIONS: Please close your eyes and stand still for 10 seconds.
( ) 4 able to stand 10 seconds safely
( ) 3 able to stand 10 seconds with supervision
( ) 2 able to stand 3 seconds
( ) 1 unable to keep eyes closed 3 seconds but stays safely
( ) 0 needs help to keep from falling

**STANDING UNSUPPORTED WITH FEET TOGETHER**
INSTRUCTIONS: Place your feet together and stand without holding on.
( ) 4 able to place feet together independently and stand 1 minute safely
( ) 3 able to place feet together independently and stand 1 minute with supervision
( ) 2 able to place feet together independently but unable to hold for 30 seconds
( ) 1 needs help to attain position but able to stand 15 seconds feet together
( ) 0 needs help to attain position and unable to hold for 15 seconds
Berg Balance Scale continued...

REACHING FORWARD WITH OUTSTRETCHED ARM WHILE STANDING
INSTRUCTIONS: Lift arm to 90 degrees. Stretch out your fingers and reach forward as far as you can. (Examiner places a ruler at the end of fingertips when arm is at 90 degrees. Fingers should not touch the ruler while reaching forward. The recorded measure is the distance forward that the fingers reach while the subject is in the most forward lean position. When possible, ask subject to use both arms when reaching to avoid rotation of the trunk.)
( ) 4  can reach forward confidently 25 cm (10 inches)
( ) 3  can reach forward 12 cm (5 inches)
( ) 2  can reach forward 5 cm (2 inches)
( ) 1  reaches forward but needs supervision
( ) 0  loses balance while trying/requires external support

PICK UP OBJECT FROM THE FLOOR FROM A STANDING POSITION
INSTRUCTIONS: Pick up the shoe/slipper, which is in front of your feet.
( ) 4  able to pick up slipper safely and easily
( ) 3  able to pick up slipper but needs supervision
( ) 2  unable to pick up but reaches 2-5 cm (1-2 inches) from slipper and keeps balance independently
( ) 1  unable to pick up and needs supervision while trying
( ) 0  unable to try/needs assist to keep from losing balance or falling

TURNING TO LOOK BEHIND OVER LEFT AND RIGHT SHOULDERS WHILE STANDING
INSTRUCTIONS: Turn to look directly behind you over toward the left shoulder. Repeat to the right. (Examiner may pick an object to look at directly behind the subject to encourage a better twist turn.)
( ) 4  looks behind from both sides and weight shifts well
( ) 3  looks behind one side only other side shows less weight shift
( ) 2  turns sideways only but maintains balance
( ) 1  needs supervision when turning
( ) 0  needs assist to keep from losing balance or falling

TURN 360 DEGREES
INSTRUCTIONS: Turn completely around in a full circle. Pause. Then turn a full circle in the other direction.
( ) 4  able to turn 360 degrees safely in 4 seconds or less
( ) 3  able to turn 360 degrees safely one side only 4 seconds or less
( ) 2  able to turn 360 degrees safely but slowly
( ) 1  needs close supervision or verbal cuing
( ) 0  needs assistance while turning

PLACE ALTERNATE FOOT ON STEP OR STOOL WHILE STANDING UNSUPPORTED
INSTRUCTIONS: Place each foot alternately on the step/stool. Continue until each foot has touched the step/stool four times.
( ) 4  able to stand independently and safely and complete 8 steps in 20 seconds
( ) 3  able to stand independently and complete 8 steps in > 20 seconds
( ) 2  able to complete 4 steps without aid with supervision
( ) 1  able to complete > 2 steps needs minimal assist
( ) 0  needs assistance to keep from falling/unable to try

STANDING UNSUPPORTED ONE FOOT IN FRONT
INSTRUCTIONS: (DEMONSTRATE TO SUBJECT) Place one foot directly in front of the other. If you feel that you cannot place your foot directly in front, try to step far enough ahead that the heel of your forward foot is ahead of the toes of the other foot. (To score 3 points, the length of the step should exceed the length of the other foot and the width of the stance should approximate the subject’s normal stride width.)
( ) 4  able to place foot tandem independently and hold 30 seconds
( ) 3  able to place foot ahead independently and hold 30 seconds
( ) 2  able to take small step independently and hold 30 seconds
( ) 1  needs help to step but can hold 15 seconds
( ) 0  loses balance while stepping or standing

STANDING ON ONE LEG
INSTRUCTIONS: Stand on one leg as long as you can without holding on.
( ) 4  able to lift leg independently and hold > 10 seconds
( ) 3  able to lift leg independently and hold 5-10 seconds
( ) 2  able to lift leg independently and hold ≥ 3 seconds
( ) 1  tries to lift leg unable to hold 3 seconds but remains standing independently.
( ) 0  unable to try of needs assist to prevent fall

( )  TOTAL SCORE (Maximum = 56)
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