BODY COMPOSITION ASSESSMENT IN

ADULTS WITH DOWN SYNDROME

by

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ABSTRACT

Individuals with Down syndrome (DS) have a high prevalence of obesity and low bone mineral density (BMD), but body composition assessment needs additional study in DS. Three studies examined the agreement between body fat percentage (BF%) from air displacement plethysmography (ADP) and dual-energy x-ray absorptiometry (DXA), BF% from a four-compartment (4C) model and skinfolds (SF) and bioelectrical impedance analysis (BIA), and bone mineral content (BMC) from DXA and BIA. Sixty-six adults participated (33 DS, 33 control). In the first study, DXA provided higher BF% than ADP in both DS ($t = 5.252$, $df = 32$, $p < .000$) and controls ($t = 7.714$, $df = 32$, $p < .000$). In the second study, BF% from four BIA equations was not significantly different from 4CBF% in DS ($p > .01$), but these had a standard error of estimate (SEE) from 4.8 to 6.0 and wide limits of agreement (± 9.5% to ± 11.6%). Two BIA equations were not significantly different than 4CBF% in controls ($p < .01$), but these had SEE's of 7.2 and 7.8 and wide limits of agreement (± 24.6% and ± 22.9%). Two SF equations were not significantly different from 4CBF% in DS ($p < .007$). Two of the SF equations were significantly different from 4CBF% in controls ($p < .008$). In the third study, BMC from DXA was significantly lower than BIA in DS ($t = -5.237$, $df = 20$, $p < .000$). DXA was significantly higher in controls ($t = 3.110$, $df = 20$, $p = .006$). There was no significant difference in DS males ($t = -1.116$, $df = 7$, $p = .301$) or control females ($t = -7.978$, $df = 12$, $p = .000$). DXA was significantly higher in control males ($t = 5.641$, $df = 7$, $p = .001$) and significantly lower in females with DS ($t = -7.978$, $df = 12$, $p = .000$). In conclusion, many methods of BF%

assessment may be acceptable for adults with DS, but only appropriate equations should be selected. BIA should not currently be used to assess BMC in DS.

DEDICATION

Dedicated to all of the people who have supported me throughout graduate school.

LIST OF ABBREVIATIONS

4CBF%	four-compartment model body fat percentage
ABAS-3	Adaptive Behavior Assessment System, Third Edition
ADP	air displacement plethysmography
BD	body density
BF%	body fat percentage
BIA	bioelectrical impedance analysis
BIACH	Chumlea et al. (2002) BIA equation
BIADE	Deurenberg et al. (1991) BIA equation
BIAK	Kyle et al. (2001) BIA equation
BIALO	Lohman (1992) BIA equation
BIASU	Sun et al. (2003) BIA equation
BM	body mass
BMC	bone mineral content
BMD	bone mineral density
BMI	body mass index
BV	body volume
DS	Down syndrome
DXA	dual-energy x-ray absorptiometry
ES	effect size

FFM	fat-free mass
FM	fat mass
Ht	height (cm)
P12BIA	Patil et al. (2012) BIA equation for BMC
R	resistance
SEE	standard error of estimate
SF	skinfold
SFDW	Durnin & Womersly (1974) skinfold equation
SFJ	Jackson & Pollock (1978) and Jackson et al. (1980) skinfold equation
SFKR	Kelly & Rimmer (1987) skinfold equation
SFLE	Leahy et al. (2013) skinfold equation
SFLO	Lohman (1981) skinfold equation
SFO10	O'Connor et al. (2010) skinfold equation
SFOBMI	O'Connor et al. (2010) skinfold with BMI equation
SFRO	Rossato et al. (2016) skinfold equation
TBBM	total body bone mass
TBW	total body water
TGV	thoracic gas volume
TLAS	total leisure activity score
USG	urine specific gravity
UWW	underwater weighing
Wt	weight (kg)
Xc	reactance

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CHAPTER 1

INTRODUCTION

Down syndrome (DS) affects around one to three in 1,000 births [Covelli et al., 2016], and results in intellectual disability and distinct physical characteristics including short legs and arms in relation to torso, hypotonia, joint hypermobility, congenital defects of the heart and respiratory systems, poor balance, poor vision, hearing loss, and perceptual difficulties [Fegan, 2011; Fernhall et al., 2013; Heward, 2013]. Although life expectancy for individuals with DS was only 9 years in the 1920's, individuals with DS now live to age 60 and beyond [Glasson et al., 2002]. However, despite this increase in life expectancy, DS results in premature aging and development of adverse health conditions associated with old age [Covelli et al., 2016]. Further contributing to their risk of disease, individuals with DS commonly lead sedentary lifestyles [Hilgenkamp et al., 2012; Shields et al., 2013] and exhibit a high rate of obesity [Izquierdo-Gomez et al., 2014; Izquierdo-Gomez et al., 2015; Nickerson et al., 2015; Oviedo et al., 2014], increasing their risk of developing conditions such as coronary heart disease [Laaka & Laaksonen, 2007], Type 2 diabetes [Kota et al., 2013], hypertension, stroke, certain cancers, and the metabolic syndrome [Rizvi, 2010]. Also associated with obesity, low grade systemic inflammation is commonly observed in individuals with DS [de Winter et al., 2011; Magge et al., 2008; Ordonez et al., 2014; Rosety-Rodriguez et al., 2013; Rosety-Rodriguez et al., 2014] as early as childhood [Nateghi et al., 2012]. Consequently, managing obesity and maintaining an appropriate body fat percentage (BF%) is critical to the health of individuals with DS.

Individuals with DS also display lower bone mineral density (BMD) compared to individuals in the general population and individuals with intellectual disability who do not have DS [Geijer et al., 2014; Guijarro et al., 2008; Srikanth et al., 2011] even during childhood [González-Agüero et al., 2011c]. While diagnosis of DS is considered to be an independent risk factor for osteopenia, people with DS also frequently present with comorbid conditions such as epilepsy, hypotonia, hypothyroidism, [van Schrojenstein Lantman-de Valk, Haveman, & Crebolder, 1996] and early menopause [Ejskjaer, Uldbjerg, & Goldstein, 2006] that are also considered risk factors for poor BMD [Srikanth et al., 2011]. Thus, a high prevalence of osteoporosis in adults with DS [Van Allen et al., 1999] coupled with an increasing lifespan in these individuals underscores the importance of providing BMD assessments to individuals with DS for early detection and treatment of low BMD.

Laboratory Techniques

Laboratory measures such as dual-energy x-ray absorptiometry (DXA) can provide highly accurate measures of BF% across many populations [Casey, 2013] and can also assess BMD [Lowry & Tomiyama, 2015]. However, DXA is expensive and must be performed in a medical or laboratory setting, and therefore is impractical and often unavailable [Casey, 2013; Esco et al., 2016; González-Agüero et al., 2011b]. DXA also involves exposure to radiation and requires subjects to remain motionless for several minutes, which may be difficult and even anxiety-provoking for individuals with DS [González-Agüero, 2017; Määttä et al., 2006]. Therefore, alternatives to DXA such as air displacement plethysmography (ADP) are sometimes used to assess body composition.

Although still considered a laboratory technique, ADP is faster and less expensive than DXA and does not involve exposure to radiation [Lowry & Tomiyama, 2015]. However, unlike

DXA, which takes into account fat mass (FM), bone tissue, and fat-free mass (FFM), ADP is a two-compartment method for assessing body composition that only considers FM and FFM, providing a slightly less precise measurement [Fields et al., 2002; Lowry & Tomiyama, 2015]. When using this method, accuracy depends on the assumption that an individual's FFM is comprised of about 73% water and has a density of 1.100 kg/L, even though the density of FFM can vary from one individual to the next [Withers et al., 1999]. An additional consideration is the finding by Lowry and Tomiyama (2015) that ADP may provide less accurate measures of BF% for individuals whose body mass index (BMI) falls outside of the normal range. This finding has relevance for individuals with DS, who are commonly obese [Fegan, 2011] and may therefore obtain inaccurate results from ADP.

Individuals with DS also display different physical characteristics compared to the general population, including short stature and short limbs relative to the length of the torso [Fegan, 2011] and reduced FFM and bone mass [González-Agüero et al., 2011a; McKelvey et al., 2013]. Compared to the general population, these individuals have also been shown to have lower FFM in the legs and to distribute body FM differently, with females with DS displaying higher body FM and FFM in the trunk compared to females without DS and males with DS displaying greater FM in the arms compared to males without DS [González-Agüero, 2011a; González-Agüero, 2017; Usera et al., 2005]. Individuals with DS also more frequently experience abdominal obesity [Real de Asua et al., 2014]. Although ADP has been validated for use in adults in the general population without disabilities [Fields et al., 2002], agreement between ADP and other laboratory methods has not yet been demonstrated specifically in individuals with DS. Therefore, further research is needed to investigate the agreement of different laboratory methods in this population.

Anthropometry

In contrast to ADP and DXA, anthropometric measures such as skinfold (SF) and circumference measurements can be used across many settings outside of the laboratory, and are relatively inexpensive and non-invasive [Rossato et al., 2016]. Although multiple prediction equations have been developed to estimate BF% from anthropometric measures, very few have been developed using subjects with DS, whose body type differs from that of the general population [González-Agüero et al., 2011a; Rossato et al., 2016]. Nevertheless, BF% estimated from SF techniques developed on the general population has been reported for individuals with DS in the literature [Izquierdo-Gomez et al., 2015; Ordonez et al., 2006; Oviedo et al., 2014] despite the fact that BF% obtained from prediction equations is accurate only for individuals in the population from which the equations were developed [Usera et al., 2005]. Furthermore, multiple studies have found that many common SF equations, BMI-based equations, and the body adiposity index, which compares hip circumference and height, are inaccurate for people with DS [Esco et al., 2016; Nickerson et al., 2015; Rossato et al., 2016; Usera et al., 2005]. Therefore, further study is warranted to determine the most accurate field methods of BF% assessment in individuals with DS so that appropriate models can be developed for use in DS.

Recently, anthropometry-based BF% prediction models for individuals with DS have been developed for both adolescents [González-Agüero et al., 2017] and adults [Rossato et al., 2016]. However, both González-Agüero et al. (2017) and Rossato et al. (2016) reported small sample sizes as a limitation. Therefore, examining the accuracy of these equations in other groups of individuals with DS is warranted. Another potential limitation to these two studies is the use of ADP as the reference method for developing the model [Rossato et al., 2016]. As discussed previously, the accuracy of ADP for individuals with DS needs further examination,

and ADP also has the limitation of being only a two-compartment model. Consequently, comparison of the recently-developed equations with a four-compartment method could provide valuable information regarding the accuracy of these equations for predicting BF% in individuals with DS.

Bioelectrical Impedance Analysis

One promising field measure of BF% for individuals with DS is bioelectrical impedance analysis (BIA) [Loveday et al., 2012]. BIA offers an inexpensive and simple alternative to laboratory methods for assessing BF% and can also provide estimates of FFM [Macfarlane, 2016]. However, BF% obtained from BIA can be influenced by a person's fat distribution as well as the particular equation used [Nickerson et al., 2017]. Additionally, research suggests that BIA may provide less accurate measures of FFM in obese individuals compared to individuals with a normal BMI even when using equations developed for obese populations [Hofsteenge et al., 2015]. However, BIA has been validated for use for a wide variety of subjects in the general population [Sun et al., 2003; Wu et al., 2015], and Loveday et al. (2012) found good agreement between BIA and DXA in children and adolescents with DS. However, even though BF% values obtained from BIA have been reported for subjects with DS in the literature [Calders et al., 2011; Mendonca et al., 2011], further study of the accuracy of BIA in measuring BF% specifically in adults with DS is needed. Esco et al. (2017) recently found that compared to DXA, single-frequency BIA significantly underestimates BF% and overestimates FFM in adults with DS, although the sample size included in the study was small and only the manufacturer's equation was tested. Therefore, further study examining additional equations with larger sample sizes is warranted to determine the accuracy of estimating BF% and FFM in this population.

In addition to providing measures of BF% and FFM, BIA can also be used to provide estimates of bone mineral content (BMC) [Macfarlane et al., 2016]. Because of the limited availability of DXA and the increased risk of osteoporosis in DS, having a simple field measure to assess bone health would be valuable for individuals with DS. While BIA prediction equations have been validated for use in healthy adults [Patil et al., 2012], these equations have not been evaluated in individuals with DS. Furthermore, Rom et al. (2015) found poor agreement between BMC values obtained from BIA versus DXA in adult smokers, whose body composition differs from that of the general population, with increased abdominal obesity and decreased fat-free mass and BMC. As people with DS are also more likely than the general population to display abdominal obesity [Real de Asua et al., 2014], low lean mass [González-Agüero et al., 2011a], and low BMC [McKelvey et al., 2013], further study is merited before BIA-based prediction equations can be considered valid for use in assessing BMC in DS.

Conclusion

Providing accurate measures of body composition to individuals with DS can assist them in achieving and maintaining good health throughout their lives. As there is a high prevalence of obesity [Usera et al., 2005] and low BMD from an early age in the DS population [González-Agüero et al., 2011c], as well as a tendency toward premature aging [Covelli et al., 2016], valid and accessible methods for assessing body composition are critical to the healthcare of people with DS. Unfortunately, however, many methods of body composition assessment have not been validated for use in this population. Nonetheless, different methods of BF% measurement not developed specifically for DS are applied in research settings, which may explain inconclusive findings regarding the effectiveness of weight management interventions in individuals with DS [Casey & Rasmussen, 2013]. Therefore, in order to provide individuals with DS accurate and

meaningful body composition assessment, as well as to develop effective interventions to achieve healthy BF% and BMD in this population, further study of both laboratory and field techniques for body composition assessment in DS is warranted.

The purpose of this dissertation was to examine the agreement between different methods of assessing BF% and BMC in adults with DS. The following are the specific aims of each study:

Study 1: The purpose of this study was to evaluate the agreement of ADP and DXA for measuring BF% in adults with DS. It was hypothesized that the agreement between ADP and DXA would be worse for adults with DS compared to healthy adult controls.

Study 2: The first purpose of this study was to compare BF% from selected anthropometric prediction equations for adult men and women with DS to a four-compartment model (4CBF%). The second purpose of this study was to examine the agreement between selected BIA equations and 4CBF% in measuring BF% in adults with DS. It was hypothesized that the agreement between 4CBF% and anthropometric and BIA equations developed on the general population would be worse than agreement between 4CBF% and equations developed specifically for DS. It was further hypothesized that control subjects would have better agreement between 4CBF% and each equation developed for the general population compared to subjects with DS.

Study 3: The purpose of this study was to examine the agreement of BMC in adults with DS between DXA and multi-frequency BIA using the equation developed by Patil et al. (2012) (P12BIA). It was hypothesized that P12BIA would show greater agreement with DXA in controls compared to subjects with DS.

REFERENCES

1. Calders, P., Elmahgoub, S., de Mettelinge, T.R., Vandenbroeck, C., Dewandele, I., Rombaut, L., Vandevelde, A., & Cambier, D. (2011). Effect of combined exercise training on physical and metabolic fitness in adults with intellectual disability: a controlled trial. *Clinical Rehabilitation, 25(12),* 1097-1108.

2. Casey, A.F. (2013). Measuring body composition in individuals with intellectual disability: a scoping review. *Journal of Obesity, 3,* 28428.

3. Casey, A.F., & Rasmussen, R. (2013). Reduction measures and percent body fat in individuals with intellectual disabilities: A scoping review. *Disability and Health Journal, 6,* 2-7.

4. Covelli, V., Raggi, A., Meucci, P., Paganelli, C., & Leonardi, M. (2016). Ageing of people with Down's syndrome: a systematic literature review from 2000 to 2014. *International Journal of Rehabilitation Research, 39(1),* 20-28.

5. de Winter, C.F., Magilsen, K.W., van Alfren, J.C., Willemsen, S.P., & Evenhuis, H.M. (2011). Metabolic syndrome in 25% of older people with intellectual disability. *Family Practice,* 28(2), 141-144.

6. Ejskjaer, K., Uldbjerg, N., & Goldstein, H. (2006). Menstrual profile and early menopause in women with Down syndrome aged 26-40 years. *Journal of Intellectual & Developmental Disability, 31(30),* 166-171.

7. Esco, M.R., Nickerson, B.S., Bicard, S.C., Russell, A.R., & Bishop, P.A. (2016). Agreement of BMI-based equations and DXA in determining body-fat percentage in adults with Down syndrome. *Adapted Physical Activity Quarterly, 33(1),* 89-96.

8. Esco, M.R., Nickerson, B.S., & Russell, A.R. (2017). Comparison of bioelectrical impedance and DXA for measuring body composition among adults with Down syndrome. *Disability and Health Journal, 10(4),* 548-551.

9. Fegan, P.L. (2011). Intellectual disabilities. In J.P. Winnick (Ed.), *Adapted Physical Education and Sport* (pp.151-172). Champaign, IL: Human Kinetics.

10. Fernhall, B., Mendonca, G.V., & Baynard, T. (2013). Reduced work capacity in individuals with Down syndrome: a consequence of autonomic dysfunction? *Exercise and Sport Sciences Reviews,* 41(3), 138-147.

11. Fields, D.A., Goran, M.I., & McCrory, M.A. (2002). Body-composition assessment via air-displacement plethysmography in adults and children: a review. *American Journal of Clinical Nutrition, 75,* 453-467.

12. Geijer, J.R., Stanish, H.I., Draheim, C.C., & Dengel, D.R. (2014). Bone mineral density in adults with Down syndrome, intellectual disability, and nondisabled adults. *American Journal on intellectual and developmental disabilities, 119(2),* 107-114.

13. Glasson, E.J., Sullivan, S.G., Hussain, R., Petterson, B.A., Montgomery, P.D., & Bittles, A.H. (2002). The changing survival profile of people with Down's syndrome: implications for genetic counseling. *Clinical Genetics, 62(5),* 390-393.

14. González-Agüero, A., Ara, I., Moreno, L. A., Vicente-Rodríguez, G., & Casajús, J.A. (2011a). Fat and lean masses in youths with Down syndrome: gender differences. *Research in Developmental Disabilities, 32,* 1685-1693.

15. González-Agüero, A., Vicente-Rodríguez, G., Ara, I., Moreno, L.A., & Casajús, J.A. (2011b). Accuracy of prediction equations to assess percentage of body fat in children and adolescents with Down syndrome compared to air displacement plethysmography. *Research in Developmental Disabilities, 32,* 1764-1769.

16. González-Agüero, A., Vicente-Rodríguez, G., Ara, I., Moreno, L.A., & Casajús, J.A. (2011c). Bone mass in male and female children and adolescents with Down syndrome. *Osteoporosis International, 22(7),* 2151-2157.

17. González-Agüero, A., Matute-Llorente, A., Gómez-Cabello, A., Vicente-Rodríguez, G., & Casajús, J.A. (2017). Percentage of body fat in adolescents with Down syndrome: estimation from skinfolds. *Disability and Health Journal, 10,* 100-104.

18. Guijarro, M., Valero, C., Paule, B., Gonzalez-Macias, J., & Riancho, J.A. (2008). Bone mass in young adults with Down syndrome. *Journal of Intellectual Disability Research, 52(3),* 182-189.

19. Heward, W.L. (2013). Exceptional children: An introduction to special education, 10th ed. Boston: Pearson.

20. Hilgenkamp, T., Reisa, D., van Wijckc, R., & Evenhuisa, H. (2012). Physical activity levels in older adults with intellectual disabilities are extremely low. *Research in Developmental Disabilities, 33,* 477-483.

21. Hofsteenge, G.H., Chinapaw, M.J.M., & Weijs, P.J.M. (2015). Fat-free mass prediction equations for bioelectric impedance analysis compared to dual energy x-ray absorptiometry in obese adolescents: a validation study. *BMC Pediatrics, 15,* 158.

22. Izquierdo-Gomez, R., Martinez-Gomez, D., Acha, A., Veiga, O.L., Villagra, A., & Diaz-Cueto, M. (2014). Objective assessment of sedentary time and physical activity throughout the week in adolescents with Down syndrome. The UP&DOWN study. *Research in Developmental Disabilities, 35,* 482-489.

23. Izquierdo-Gomez, R., Martinez-Gomez, D., Villagra, A., Fernhall, B., & Veiga, O.L. (2015). Associations of physical activity with fatness and fitness in adolescents with Down syndrome: The UP&DOWN study. *Research in Developmental Disabilities, 36,* 428-436.

24. Kota, S.K., Tripathy, P.R., Kota, S.K., & Jammula, S. (2013). Type 2 diabetes mellitus: An unusual association with Down's syndrome. *Indian Journal of Human Genetics*, 19(3), 358-359.

25. Laakka, T.A., & Laaksonen, D.E. (2007). Physical activity in prevention and treatment of the metabolic syndrome. *Applied Physiology, Nutrition, and Metabolism*, 32: 76-88.

26. Loveday, S.J., Thompson, J.M.D., & Mitchell, E.A. (2012). Bioelectrical impedance for measuring percentage body fat in young persons with Down syndrome: validation with dual-energy absorptiometry. *Acta Paediatrica, 101,* e491-e495.

27. Lowry, D.W., & Tomiyama, A.J. (2015). Air displacement plethysmography versus dual-energy x-ray absorptiometry in underweight, normal-weight, and overweight/obese individuals. *PLos ONE, 10(1),* e0115086.

28. Määttä, T., Tervo-Määttä, T., Taanila, A., Kaski, M., & Iivanainen, M. (2006). Mental health, behavior and intellectual abilities of people with Down syndrome. *Down Syndrome Research and Practice, 11(1),* 37-43.

29. Macfarlane, D.J., Chan, N.T., Tse, M.A., Joe, G.M. (2016). Agreement between bioelectrical impedance and dual energy x-ray absorptiometry in assessing fat, lean and bone mass changes in adults after a lifestyle intervention. *Journal of Sports Sciences, 34(12),* 1176-1181.

30. Magge, S.N., O'Neill, K.L., Shults, J., Stallings, V.A., & Stettler, N. (2008). Leptin levels among prepubertal children with Down syndrome compared to their siblings. *Journal of Pediatrics*, 152(3), 321-326.

31. Mendonca, G.A., Pereira, F., & Fernhall, G. (2011). Effects of combined aerobic and resistance exercise training in adults with and without Down syndrome. *Archives of Physical Medicine and Rehabilitation, 902*, 37-45.

32. Nateghi, R.M., Douraghi, M., Mohammadi, A.M., & Nikmanesh, B. (2012). Altered serum pro-inflammatory cytokines in children with Down's syndrome. *European Cytokine Network*, 23(2), 64-67.

33. Nickerson, B.S., Esco, M.R., Bicard, S.C., Russell, A.R., Williford, H.N., & Schaefer, G. (2015). Validity of the body adiposity index in adults with Down syndrome. *Research in Developmental Disabilities, 38,* 92-96.

34. Nickerson, B.S., Esco, M.R., Bishop, P.A., Schumacker, R., Richardson, M., Fedewa, M.V., Wingo, J.E., Welborn, B.A. (2017). Validity of selected bioimpedance equations for estimating body composition in men and women: a four-compartment model comparison. *Journal of Strength and Conditioning Research, 31(7),* 1963-1972.

35. Ordonez, F.J., Rosety, M., Rosety-Rodriguez, M. (2006). Influence of 12-week exercise training on fat mass percentage in adolescents with Down syndrome. *Medical Science Monitor, 12,* CR416-CR419.

36. Ordonez, F.J., Rosety, M.A., Camacho, A., Rosety, I., Diaz, A.J., Fornieles, G., Garcia, N., & Rosety-Rodriguez, M. (2014). Aerobic training improved low-grade inflammation in obese women with intellectual disability. *Journal of Intellectual Disability Research*, 58(6), 583-590.

37. Oviedo, G.R., Guerra-Balic, M., Baynard, T., & Javierre, C. (2014). Effects of aerobic, resistance and balance training in adults with intellectual disabilities. *Research in Developmental Disabilities, 35,* 2624-2634.

38. Patil, B., Patkar, D., Mandlik, S., Kuswarkar, M., & Jindal, G. (2012). Estimation of bone mineral content from bioelectrical impedance analysis in Indian adults ages 23-81 years: A comparison with dual energy x-ray absorptiometry. *International Journal of Biomedical Engineering and Technology, 8(1),* 99-114.

39. Real de Asua, D., Parra, P., Costa, R., Moldenhauer, F., & Suarez, C. (2014). Evaluation of the impact of abdominal obesity on glucose and lipid metabolism disorders in adults with Down syndrome. *Research in Developmental Disabilities, 35(11),* 2942-9.

40. Rizvi, A.A. (2010). Hypertension, obesity, and inflammation: the complex designs of the deadly trio. *Metabolic Syndrome and Related Disorders*, 8, 287-294.

41. Rom, O., Reznick, A.Z., Keidar, Z., Karkabi, K., & Aizenbud, D. (2015). Body composition in heavy smokers: comparison of segmental bioelectrical impedance analysis and dual-energy x-ray absorptiometry. *Advances in Experimental Medicine and Biology, 840,* 1-11.

42. Rosety-Rodriguez, M., Camacho, A., Rosety, I., Fornieles, G., Rosety, M.A., Diaz, A.J., Rosety, M., & Ordonez, F.J. (2013). Resistance circuit training reduced inflammatory cytokines in a cohort of male adults with Down syndrome. *Medical Science Monitor,* 19, 949-953.

43. Rosety-Rodriguez, M., Diaz, A.J., Rosety, I., Rosety, M.A., Camacho, A., Fornieles, G., Rosety, M., & Ordonez, F.J. (2014). Exercise reduced inflammation: but for how long after training? *Journal of Intellectual Disability Research,* 58(9), 874-879.

44. Rossato, M., Dellagrana, R.A., da Costa, R.M., Bezerra, E.D., Otacílio, J., dos Santos, L., & Rech, C.R. (2016). The accuracy of anthropometric equations to assess body fat in adults with Down syndrome. *Journal of Applied Research in Intellectual Disabilities,* doi: 10.1111/jar.12290. [Epub ahead of print]

45. Shields, N., Taylor, N.F., Wee, E., Wollersheim, D., O'Shea, S.D., & Fernhall, B. (2013). A community-based strength training program increases muscle strength and physical activity in young people with Down syndrome: A randomized control trial. *Research in Developmental Disabilities, 34,* 4385-4394.

46. Srikanth, R., Cassidy, G., Joiner, C., & Teeluckdharry, S. (2011). Osteoporosis in people with intellectual disabilities: a review and a brief study of risk factors for osteoporosis in a community sample of people with intellectual disabilities. *Journal of Intellectual Disability Research, 55(1),* 53-62.

47. Stanish, H.I. (2004). Accuracy of pedometers and walking activity in adults with mental retardation. *Adapted Physical Activity Quarterly, 21,* 167-79.

48. Sun, S.S., Chumlea, W.C., Heymsfield, S.B., Lukaski, H.C., Schoeller, D., Friedl, K., Kuczmarski, R.J., Flegal, K.M., Johnson, C.L., & Hubbard, V.S. (2003). Development of bioelectrical impedance analysis prediction equations for body composition with the use of a multicomponent model for use in epidemiologic surveys. *The American Journal of Clinical Nutrition, 77,* 331-340.

49. Usera, P.C., Foley, J.T., & Yun, J. (2005). Cross-validation of field-based assessments of body composition for individuals with Down syndrome. *Adapted Physical Activity Quarterly, 22,* 198-206.

50. van Allen, M.I., Fung, J., & Jurenka, S.B. (1999). Health care concerns and guidelines for adults with Down syndrome. *American Joural of Medican Genetics, 89,* 100-110.

51. van Schrojenstein Lantman-de Valk, H.M.J., Haveman, M.J., & Crebolder, H.F.J.M. (1996). Comorbidity in people with Down's syndrome: a criteria-based analysis. *Journal of Intellectual Disability Research, 40(5),* 385-399.

52. Withers, R.T., Laforgia, J., & Heymsfield, S.B. (1999). Critical appraisal of the estimation of body composition via two-, three-, and four-compartment models. *American Journal of Human Biology, 11,* 175-185.

53. Wu, C.S., Chen, Y.Y., Chuang, C.L., Chiang, L.M., Dwyer, G.B., Hsu, Y.L., Huang, A.C., Lai, C.L., & Hsieh, K.C. (2015). Predicting body composition using foot-to-foot bioelectrical impedance analysis in healthy Asian individuals. *Nutrition Journal, 14,* 52.

CHAPTER 2

AGREEMENT BETWEEN AIR DISPLACEMENT PLETHYSMOGRAPHY AND DUAL-ENERGY X-RAY ABSORPTIOMETRY IN DETERMINING BODY FAT PERCENTAGE IN ADULTS WITH DOWN SYNDROME

ABSTRACT

The purpose of this study was to evaluate the agreement of ADP and DXA for measuring BF% in adults with DS. 33 adults with DS (14 male, 19 female) completed the study. 33 healthy adults without DS (14 male, 19 female) served as a control group. BF% was assessed with both ADP and dual-energy x-ray absorptiometry (DXA). A dependent t-test was used to compare mean BF% obtained from ADP and DXA. Pearson correlation was also determined and 95% limits of agreement were identified using the method of Bland and Altman (1986). BF% values from DXA were significantly higher than those obtained from ADP in both DS($t = 5.252$, $df = 32$, $p < .000$) and control ($t = 7.714$, $df = 32$, $p < .000$) adults with males and females combined. DXA also provided higher BF% than ADP when data were analyzed by sex. The difference between methods approached significance in males with DS ($t = 2.107$, $df = 13$, $p = .055$) and was significant for females with DS ($t = 5.392$, $df = 18$, $p < .000$) and control males ($t = 5.278$, $df = 13$, $p < .000$) and females ($t = 5.585$, $df = 18$, $p < .000$). The results of this study show that DXA provides higher BF% values than ADP in both adults with and without DS.

KEY WORDS: Down syndrome, body fat percentage, air displacement plethysmography

INTRODUCTION

Down syndrome (DS) is the leading genetic cause of intellectual disability, affecting around one to three in 1,000 births [Covelli et al., 2016]. While life expectancy has increased dramatically with some individuals with DS living to age 60 and beyond [Glasson et al., 2002], people with DS experience premature aging and earlier development of health conditions associated with older age compared to the general population [Covelli et al., 2016]. Additionally, individuals with Down syndrome (DS) are more likely to be obese than their peers without DS [Izquierdo-Gomez et al., 2014; Izquierdo-Gomez et al., 2015; Nickerson et al., 2015; Oviedo et al., 2014; Shields et al., 2013], placing them at risk of developing a number of adverse health conditions such as Type 2 diabetes [Kota et al., 2013], coronary heart disease [Laaka & Laaksonen, 2007], hypertension, stroke, certain cancers, and the metabolic syndrome [Rizvi, 2010]. Consequently, it is important to be able to provide measures of body fat percentage (BF%) to individuals with DS to assist them in maintaining appropriate body composition to promote good health throughout their lives.

Both air displacement plethysmography (ADP) and dual-energy x-ray absorptiometry (DXA) provide valid and reliable assessments of BF% in many different populations [Casey, 2013; Fields et al., 2002], and are often used as reference methods when examining the validity of various field techniques for BF% assessment [Fields et al., 2002; Lowry & Tomiyama, 2015; Rossato et al., 2016]. However, in the general population, agreement between BF% measures obtained from ADP and DXA vary from study to study, and the two methods can provide very different results for some individuals [Fields et al., 2002]. Furthermore, Lowry & Tomiyama (2015) found that ADP underestimates BF% in overweight and obese adults and overestimates BF% in underweight adults. Therefore, it is important to examine how measurements from ADP

compare to those derived from DXA in populations that deviate from the general population in body composition.

Individuals with DS differ from the general population in both overall BF% and distribution of body fat [González-Agüero, 2017; Usera et al., 2005]. In addition to the high prevalence of obesity in the DS population [Fegan, 2011], González-Agüero et al. (2011) found that both males and females with DS have reduced fat-free mass (FFM) in the lower limbs compared to age-matched individuals without DS, and that females with DS have both greater fat mass (FM) and (FFM) in the trunk and males with DS have greater FM in the upper limbs compared to their peers without DS. However, despite these differences, agreement between BF% values from ADP and other laboratory measures such as DXA have not been established for adults with DS. When compared to ADP, DXA has the disadvantages of involving exposure to radiation and requiring subjects to remain motionless for several minutes, which may be difficult and even anxiety-provoking for individuals with DS [González-Agüero, 2017; Määttä et al., 2006]. Thus, ADP may be able to offer an alternative to more invasive procedures such as DXA. Therefore, the purpose of this study was to evaluate the agreement of ADP and DXA for measuring BF% in adults with DS.

METHODS

Participants

Thirty-four adults with DS from the local community volunteered to participate in the study. One participant experienced anxiety and did not complete the study. Thirty-three men (n = 14) and women (n = 19) with DS completed all study procedures. Thirty-three healthy adult men (n = 14) and women (n = 19) without DS participated as a control group. Participants were all age 19 or older and individuals in the control group were matched by age, sex, and race to study

participants with DS (Table 2.1). Prior to completing any testing, all subjects provided written consent. Additionally, a parent or guardian of each participant with DS also provided consent and remained with the individual with DS throughout the testing procedures to assist with the consent process and reduce anxiety. Prior to participating in the study, participants were instructed not to eat or drink anything other than water for 3 hours before testing, and not to exercise 12 hours before testing.

Procedures

After providing written informed consent, study participants' urine specific gravity (USG) was measured with a handheld refractometer (Atago SUR-NE, Atago Corp Ltd., Tokyo, Japan) to ensure they were appropriately hydrated with USG < 1.020 [Kavouras, 2002]. Three participants had a USG ≥ 1.020 and were given the chance to drink water. These participants' USG was retested after thirty minutes at which time all three attained USG < 1.020 and then participated in the remainder of the study. Before BF% testing, all study participants also completed the Godin Leisure-Time Exercise Questionnaire [Godin & Shephard, 1997], a four-item questionnaire that asks people to record how many times per week they engage in strenuous, moderate, or light physical activity. From this questionnaire, a total leisure activity score (TLAS) was calculated for each participant with the following formula: TLAS = (9 × Strenuous) + (5 × Moderate) + (3 × Light). Participants with a TLAS of 24 or higher were classified as active, those with a TLAS of 14 to 23 were classified as moderately active, and individuals with a TLAS of less than 14 were classified as sedentary. A parent or guardian completed the questionnaire for participants with DS. Participants' classifications from the Godin Leisure-Time Exercise Questionnaire are presented in Table 2.2.

Parents or guardians of participants with DS also completed the Adaptive Behavior Assessment System, Third Edition (ABAS-3) [Harrison & Oakland, 2015] to assess their adult relative's adaptive behaviors in the following skill areas: communication, community use, functional academics, home living, health and safety, leisure, self-care, self-direction, social, and work. Participants were evaluated on 20 to 26 items in each skill area and given a score for each item ranging from 0 to 3, with a zero indicating that the participant cannot perform the skill and a 3 indicating that the participant is able to perform the skill and always or almost always does so when needed. Scores for each item were added to calculate a score for each skill area, and scores from each skill area were combined into a General Adaptive Composite, which was used to classify each individual's overall adaptive behavior as high, above average, average, below average, low, or extremely low. Sample items from the ABAS-3 are presented in the Appendix, and the results of the ABAS-3 are presented in Table 2.3.

Height was measured to the nearest 0.10 cm with a wall-mounted stadiometer (SECA; Seca Instruments Ltd., Hamburg, Germany), and body weight was measured to the nearest 0.10 kg with a digital scale (Tanita BWB-800A, Tanita Corp., Tokyo, Japan). BMI was then calculated from height and weight (Table 2.1). BF% was obtained with both a calibrated DXA (GE Lunar Prodigy, Software version 10.50.086, GE Lunar Corp., Madison, WI) and with ADP (BOD POD Body Composition System, Cosmed). During the ADP measurement, participants wore minimal, tight clothing and a swim cap as recommended by the manufacturer. Participants were also instructed to remove all metal for the test. Study participants with DS were unable to complete the measured thoracic gas volume correctly, and therefore predicted thoracic gas volume was used for all study participants. For the DXA scan, subjects removed their shoes and any metal. During the scan, subjects were instructed to lie still in a supine position on the bed of

the scanner with their arms down by their side. For subjects with DS, the laboratory technician administering the DXA scan and the parent or guardian of the subject on the scanning bed stood the required distance away from the scanner, but remained within view of the subject to provide verbal encouragement and instruction to remain still during the DXA scan.

Statistical Analysis

All data were analyzed using SPSS version 24.0 (Somers, NY, USA). Mean BF% obtained by DXA and ADP were compared with a dependent t-test, and Cohen's *d* was calculated to determine the effect size (ES) of the mean difference in BF%. The following values were used to determine the magnitude of the ES: trivial = ES < 0.2; small = 0.2-0.6; moderate = 0.6-1.2; large = 1.2-2.0; and very large > 2.0 [Hopkins et al., 2009]. Pearson correlation was also used to examine the relationship between BF% obtained with DXA and BF% obtained with ADP, using the following values to describe the correlation: small < 0.30; moderate = 0.31-0.49; large = 0.50-0.69; very large = 0.70-0.89; and near perfect = 0.90-1.00 [Hopkins et al., 2009]. Additionally, 95% limits of agreement between BF% from DXA and ADP were identified using the method of Bland and Altman (1986) (Figure 2.1 and Table 2.5). Data were also analyzed with both males and females combined and separately by sex. Additionally, data were analyzed separately for participants with a BMI under 30.0 and for those with a BMI 30.0 or higher. The level of significance was set at $p < .05$.

RESULTS

Overall agreement between DXA and ADP

Results are presented in Tables 2.4 and 2.5. In adults with DS with men and women combined, BF% values from DXA were significantly higher than BF% values from ADP ($t = 5.252$, $df = 32$, $p < .000$), with a mean difference of 3.2 ± 3.5% between the two methods. The

Cohen's *d* statistic showed a moderate ES of 0.91, and the Pearson correlation was near perfect (r = 0.91, p < .000). With men and women combined, BF% from DXA was also significantly higher than BF% from ADP in control subjects (t = 7.714, df = 32, p < .000), with a mean difference of 5.3 ± 3.9 % between the two methods. The Cohen's *d* statistic showed a large effect size of 1.34, and the Pearson correlation was near perfect (r = .95, p < .000). The Bland-Altman plots are presented in Figure 2.1. For both adults with and without DS, DXA provided higher BF% values compared to ADP. In control adults, this difference was greater for participants with lower BF% compared to those with higher BF%. The 95% limits of agreement were smaller for the DS group compared to the control group.

Agreement by sex

In males with DS, BF% values from DXA were higher than BF% values from ADP and this difference approached significance (t = 2.107, df = 13, p = .055). The Cohen's *d* statistic showed a small ES of 0.56, while the Pearson correlation was very large (r = 0.85, p < .000). Similar to males with DS, BF% values from DXA were significantly higher than BF% values from ADP in females with DS (t = 5.392, df = 18, p < .000), with a mean difference of 4.2 ± 3.4% between the two methods. The Cohen's *d* statistic showed a large ES of 1.24, and the Pearson correlation was very large (r = 0.84, p < .000).

BF% from DXA was significantly higher than BF% from ADP in male control subjects (t = 5.278, df = 13, p < .000), with a mean difference of 5.0 ± 3.5% between the two methods. The Cohen's *d* statistic showed a large ES of 1.41, and the Pearson correlation was near perfect (r = .91, p < .000). BF% values from DXA were also significantly higher than BF% from ADP in female control subjects (t = 5.585, df = 18, p < .000), with a mean difference of 5.5 ± 4.3% between the two methods. The Cohen's *d* statistic showed a large ES of 1.28, and the Pearson

correlation was near perfect (r = .96, p < .000). The Bland-Altman plots are presented in Figure 2.1. BF% values from DXA were higher than those from ADP in both males and females with and without DS. However, both male and female control subjects showed a larger difference between methods at as BF% decreased, which was not observed in male or female subjects with DS. The 95% limits of agreement were larger for control females compared to males and females with DS and control males.

Agreement by BMI

Eleven adults with DS had a BMI below 30.0. In these adults, BF% from DXA was significantly higher than BF% from ADP (t = 2.653, df = 10, p = .024), with a mean difference of 2.1 ± 2.6% between the two methods. The Cohen's *d* statistic showed a moderate ES of 0.80, while the Pearson correlation was near perfect (r = .96, p < .000). Twenty-two adults with DS had a BMI greater than or equal to 30.0. In these adults, BF% from DXA was also significantly higher than BF% from ADP (t = 4.640, df = 21, p < .000), with a mean difference of 3.8 ± 3.8 % between the two methods. The Cohen's *d* statistic showed a moderate ES of 0.99, while the Pearson correlation was very large (r = .86, p < .000).

Twenty-seven control subjects had a BMI below 30.0. In these subjects, BF% from DXA was significantly higher than BF% from ADP (t = 8.327, df = 26, p < .000), with a mean difference of 6.1 ± 3.8 % between the two methods. The Cohen's *d* showed a large ES of 1.60, and the Pearson correlation was near perfect (r = .90, p < .000). Only six control subjects had a BMI greater than or equal to 30.0. In these subjects, the mean difference in BF% between DXA and ADP (1.6 ± 1.8 %) was not significant (t = 2.167, df = 6, p = .083). The Cohen's *d* statistic showed a moderate ES of 0.88, and the Pearson correlation was near perfect (r = .99, p < .000).

The Bland-Altman plots are presented in Figure 1. In both adults with and without DS, BF% from DXA was higher than BF% from ADP for subjects at both BMI levels. For adults with DS who had a BMI under 30.0, higher BF% from DXA compared to ADP was greatest in individuals with higher BF%. The opposite was seen in controls with a BMI under 30. DXA consistently provided higher BF% values than ADP in adults both with and without DS who had a BMI of 30.0 or above. In subjects with DS, the 95% limits of agreement for the BMI < 30.0 group were smaller than those for the BMI ≥ 30.0 group. The opposite was seen in control subjects.

DISCUSSION

In contrast to other reports in the literature [Mahy et al., 2010; Stanish, 2004; Temple & Stanish, 2009], the present study reported high levels of physical activity among adults with DS, with only 12.1 percent of study participants classified as sedentary, and the remaining participants classified as either moderately active (39.4 percent) or active (48.5 percent). This may be due in part to recruitment of subjects from established exercise groups at fitness centers. Because only 4 study participants were classified as sedentary, separate analysis of results by physical activity level was not performed. The results of this study may therefore not apply to more sedentary groups of individuals with DS, but they do provide the opportunity to examine individuals with DS who have higher physical activity levels than are generally reported. Additionally, the participant sample in this study included only 3 black participants with DS compared to 30 white participants with DS. Separate analysis by race was therefore not performed, and future research with a more racially diverse sample is warranted to determine if the results of the present study apply across racial groups.

The results of this study found that overall BF% values from DXA were significantly higher than those obtained from ADP in both adults with and without DS when males and females were analyzed together. Although DXA provided average BF% values nearly 2 percent higher than ADP in males with DS and this difference was not significant, only 14 male participants with DS participated in the study and the difference approached significance ($p = .055$). Study of a larger sample of adult males with DS may yield significant results. The difference in BF% between DXA and ADP was also not statistically significant in control males and females with a BMI ≥ 30.0, but the ability to interpret that finding is limited as only six control subjects fell into this BMI category.

While Lowry & Tomiyama (2015) reported higher BF% values from ADP than DXA in general population adults of normal weight, they reported the opposite for individuals classified by BMI as overweight or obese. In the present study, despite reporting high levels of physical activity, only two participants with DS had a normal BMI, with the remainder of subjects with DS classified as overweight or obese. Fourteen control subjects had a normal BMI compared to nineteen subjects with an overweight or obese BMI. Normal weight and overweight subjects were therefore analyzed together and obese subjects were analyzed separately. The inclusion of overweight subjects with normal weight subjects may explain why the lower BMI group in this study did not see identical results to the normal weight group from Lowry & Tomiyama (2015). While the results of this study suggest similar agreement to the general population between ADP and DXA for adults with DS, further study of subjects with DS of normal weight is needed. However, obtaining an adequate sample size for analysis of normal weight individuals may be difficult due to the high prevalence of overweight and obesity in DS.

An additional challenge is the measurement of thoracic gas volume (TGV) because of intellectual disability in individuals with DS. Rossato et al. (2016) reported problems with obtaining measured TGV in adults with DS due to the subjects' difficulty in understanding the protocol, and the same trouble occurred in the present study in which 70 percent of subjects scored in the extremely low category on the ABAS-3. Previous research in the general population suggests that the effects on of using predicted TGV instead of measured TGV on BF% measurements are not significant [McCrory et al, 1998; Nickerson et al., 2017]. However, as there are currently no reports of measured TGV during ADP for adults with DS in the literature, it is not clear whether using the predicted TGV affected the results. Additional research is needed to examine the agreement of BF% from ADP between tests using measured and predicted TGV. Even so, measuring TGV is unlikely to be practical for the majority of individuals with DS without significant practice and instruction.

CONCLUSIONS

DXA provides significantly higher measures of BF% than ADP in adults with and without DS in both males and females. However, while the present study found no significant difference in BF% between DXA and ADP in males with DS, this difference did approach significance and significant results may be found with a larger sample size. There do not appear to be differences by sex in agreement between measures of BF% from DXA and ADP in the general population.

REFERENCES

1. Bland, J.M., & Altman, D.G. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet, 1(8476)*, 307-310.

2. Casey, A.F. (2013). Measuring body composition in individuals with intellectual disability: a scoping review. *Journal of Obesity, 3,* Article ID 28428.

3. Covelli, V., Raggi, A., Meucci, P., Paganelli, C., & Leonardi, M. (2016). Ageing of people with Down's syndrome: a systematic literature review from 2000 to 2014. *International Journal of Rehabilitation Research, 39(1),* 20-28.

4. Fegan, P.L. (2011). Intellectual disabilities. In J.P. Winnick (Ed.), *Adapted Physical Education and Sport* (pp.151-172). Champaign, IL: Human Kinetics.

5. Fields, D.A., Goran, M.I., & McCrory, M.A. (2002). Body-composition assessment via air-displacement plethysmography in adults and children: a review. *American Journal of Clinical Nutrition, 75,* 453-467.

6. Glasson, E.J., Sullivan, S.G., Hussain, R., Petterson, B.A., Montgomery, P.D., & Bittles, A.H. (2002). The changing survival profile of people with Down's syndrome: implications for genetic counseling. *Clinical Genetics, 62(5),* 390-393.

7. Godin, G., & Shephard, R. J. (1997). Godin leisure-time exercise questionnaire. *Medicine & Science in Sports and Exercise*, 29(6), 36-38.

8. González-Agüero, A., Ara, I., Moreno, L. A., Vicente-Rodríguez, G., & Casajús, J.A. (2011). Fat and lean masses in youths with Down syndrome: gender differences. *Research in Developmental Disabilities, 32,* 1685-1693.

9. González-Agüero, A., Matute-Llorente, A., Gómez-Cabello, A., Vicente-Rodríguez, G., & Casajús, J.A. (2017). Percentage of body fat in adolescents with Down syndrome: estimation from skinfolds. *Disability and Health Journal, 10,* 100-104.

10. Harrison, P.L., & Oakland, T. (2015). *Adaptive Behavior Assessment System, Third Edition*. Torrance,CA: Western Psychological Services.

11. Hopkins, W.G., Marshall, S.W., Batterham, A.M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise, 41,* 3-13.

12. Izquierdo-Gomez, R., Martinez-Gomez, D., Acha, A., Veiga, O.L., Villagra, A., & Diaz-Cueto, M. (2014). Objective assessment of sedentary time and physical activity throughout the week in adolescents with Down syndrome. The UP&DOWN study. *Research in Developmental Disabilities, 35,* 482-489.

13. Izquierdo-Gomez, R., Martinez-Gomez, D., Villagra, A., Fernhall, B., & Veiga, O.L. (2015). Associations of physical activity with fatness and fitness in adolescents with Down syndrome: The UP&DOWN study. *Research in Developmental Disabilities, 36,* 428-436.

14. Kavouras, S.A. (2002). Assessing hydration status. *Current Opinion in Clinical Nutrition & Metabolic Care, 5(5),* 519-524.

15. Kota, S.K., Tripathy, P.R., Kota, S.K., & Jammula, S. (2013). Type 2 diabetes mellitus: An unusual association with Down's syndrome. *Indian Journal of Human Genetics*, 19(3), 358-359.

16. Laakka, T.A., & Laaksonen, D.E. (2007). Physical activity in prevention and treatment of the metabolic syndrome. *Applied Physiology, Nutrition, and Metabolism*, 32: 76-88.

17. Lowry, D.W., & Tomiyama, A.J. (2015). Air displacement plethysmography versus dual-energy x-ray absorptiometry in underweight, normal-weight, and overweight/obese individuals. *PLos ONE, 10(1),* e0115086.

18. Määttä, T., Tervo-Määttä, T., Taanila, A., Kaski, M., & Iivanainen, M. (2006). Mental health, behavior and intellectual abilities of people with Down syndrome. *Down Syndrome Research and Practice, 11(1),* 37-43.

19. Macfarlane, D.J., Chan, N.T., Tse, M.A., Joe, G.M. (2016). Agreement between bioelectrical impedance and dual energy x-ray absorptiometry in assessing fat, lean and bone mass changes in adults after a lifestyle intervention. *Journal of Sports Sciences, 34(12),* 1176-1181.

20. Mahy, J., Shields, N., Taylor, N.F., & Dodd, K.J. (2010). Identifying facilitators and barriers to physical activity for adults with Down syndrome. *Journal of Intellectual Disability Research, 54(9),* 795-805.

21. McCrory, M.A., Molé, P.A., Gomez, T.D., Dewey, K.G., & Bernauer, E.M. (1998). Body composition by air-displacement plethysmography by using predicted and measured thoracic gas volumes. *Journal of Applied Physiology, 84,* 1475-1479.

22. Nickerson, B.S., Esco, M.R., Bicard, S.C., Russell, A.R., Williford, H.N., & Schaefer, G. (2015). Validity of the body adiposity index in adults with Down syndrome. *Research in Developmental Disabilities, 38,* 92-96.

23. Nickerson, B.S., Esco, M.R., Bishop, P.A., Schumacker, R., Richardson, M., Fedewa, M.V., Wingo, J.E., Welborn, B.A. (2017). Impact of measured vs. predicted residual lung volume on body fat percentage using underwater weighing and 4-compartment model. *Journal of Strength and Conditioning Research, 31(9),* 2519-2527.

24. Oviedo, G.R., Guerra-Balic, M., Baynard, T., & Javierre, C. (2014). Effects of aerobic, resistance and balance training in adults with intellectual disabilities. *Research in Developmental Disabilities, 35,* 2624-2634.

25. Rizvi, A.A. (2010). Hypertension, obesity, and inflammation: the complex designs of the deadly trio. *Metabolic Syndrome and Related Disorders*, 8, 287-294.

26. Rossato, M., Dellagrana, R.A., da Costa, R.M., Bezerra, E.D., Otacílio, J., dos Santos, L., & Rech, C.R. (2016). The accuracy of anthropometric equations to assess body fat in adults with Down syndrome. *Journal of Applied Research in Intellectual Disabilities*, doi: 10.1111/jar.12290. [Epub ahead of print]

27. Shields, N., Taylor, N.F., Wee, E., Wollersheim, D., O'Shea, S.D., & Fernhall, B. (2013). A community-based strength training program increases muscle strength and physical activity in young people with Down syndrome: A randomized control trial. *Research in Developmental Disabilities, 34*, 4385-4394.

28. Stanish, H.I. (2004). Accuracy of pedometers and walking activity in adults with mental retardation. *Adapted Physical Activity Quarterly, 21*, 167-79.

29. Temple, V.A., & Stanish, H. (2009). Pedometer-measured physical activity of adults with intellectual disability: predicting weekly step counts. *American Journal on Intellectual and Developmental Disabilities, 114*, 15-22.

30. Usera, P.C., Foley, J.T., & Yun, J. (2005). Cross-validation of field-based assessments of body composition for individuals with Down syndrome. *Adapted Physical Activity Quarterly, 22*, 198-206.

Table 2.1. *Participant Characteristics*

		Down syndrome (n = 33)	Control (n = 33)
Sex			
	Male	n = 14	n = 14
	Female	n = 19	n = 19
Race			
	Black	n = 3	n = 3
	White	n = 30	n = 30
Age			
	Overall	29.3 ± 10.5	29.5 ± 10.3
	Male	25.8 ± 6.7	26.4 ± 6.9
	Female	31.9 ± 12.1	31.8 ± 11.9
Height (cm)			
	Overall	146.5 ± 10.8	171.5 ± 10.2
	Male	152.1 ± 11.3	181.1 ± 7.3
	Female	142.3 ± 8.5	164.5 ± 4.7
Weight (kg)			
	Overall	69.6 ± 16.4	78.5 ± 16.9
	Male	73.4 ± 15.3	88.9 ± 12.1
	Female	66.7 ± 17.2	70.9 ± 16.1
BMI			
	Overall	32.4 ± 6.7	26.4 ± 4.4
	Male	31.9 ± 6.8	27.0 ± 3.1
	Female	32.7 ± 6.8	25.9 ± 5.2

Table 2.2. *Godin Leisure Time Questionnaire*

	Down syndrome (n)	Control (n)
Sedentary		
Total	4	0
Male	3	0
Female	1	0
Moderately Active		
Total	13	4
Male	4	0
Female	9	4
Active		
Total	16	29
Male	7	14
Female	9	15

Table 2.3. *Adaptive Behavior Assessment System, Third Edition*

Classification	Male (n)	Female (n)	Total (n)
Extremely Low	9	14	23
Low	4	3	7
Below Average	1	2	3

Table 2.4. *Correlations and group means ± standard deviation*

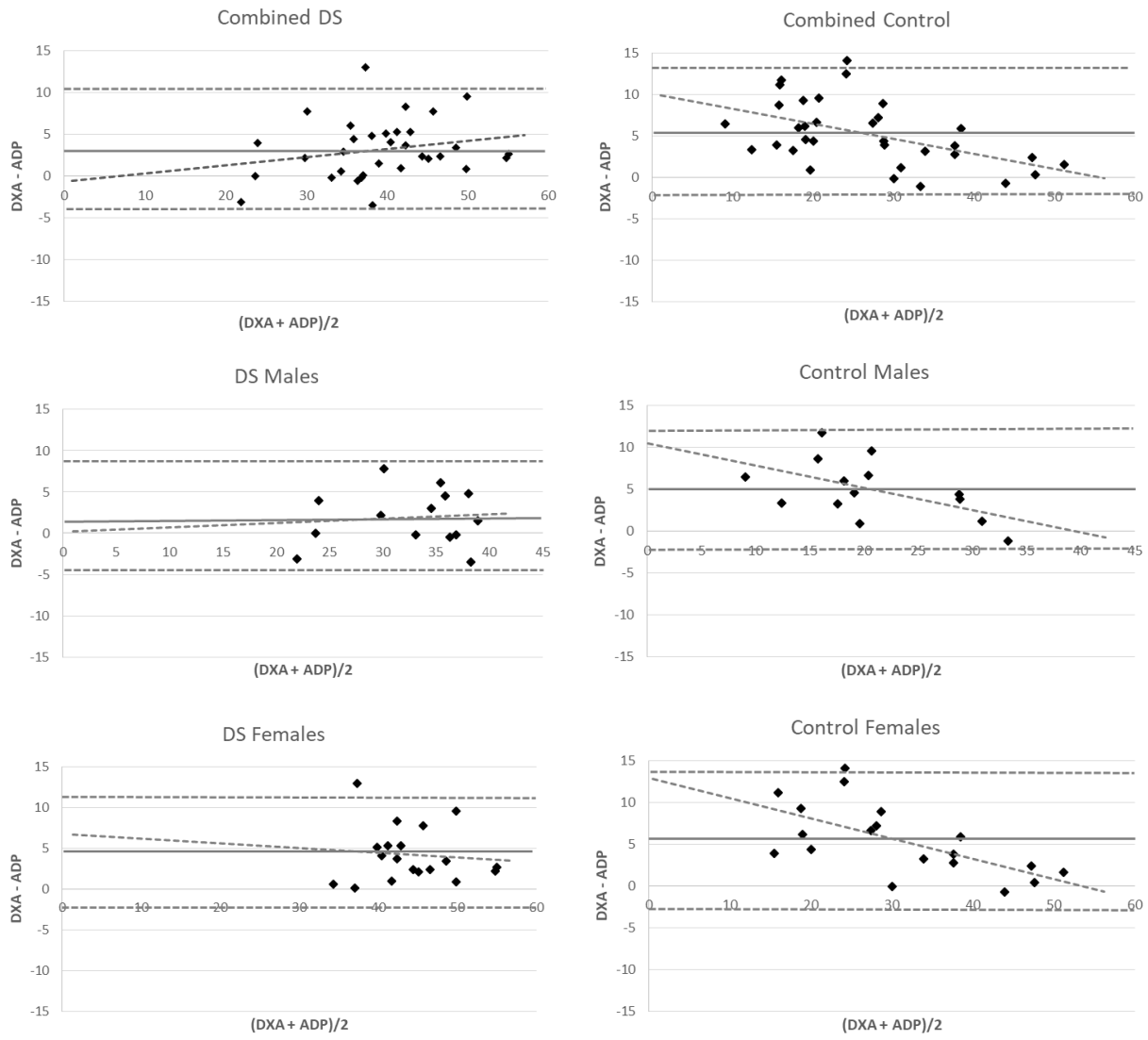
	Down syndrome (n = 33)	Control (n = 33)
DXA BF% (mean ± SD)		
Overall	40.9 ± 8.6 %	29.3 ± 10.0 %
Male	33.6 ± 6.2 %	23.3 ± 6.4 %
Female	46.3 ± 5.8 %	33.7 ± 10.0 %
BMI < 30.0	35.3 ± 8.8 %	26.4 ± 7.7 %
BMI ≥ 30.0	43.7 ± 7.2 %	42.4 ± 9.0 %
ADP BF% (mean ± SD)		
Overall	37.7 ± 7.9 %	24.0 ± 12.0 %
Male	31.7 ± 5.9 %	18.3 ± 8.2 %
Female	42.1 ± 6.1 %	28.3 ± 12.7 %
BMI < 30.0	33.2 ± 7.3 %	20.3 ± 8.8 %
BMI ≥ 30.0	39.9 ± 7.3 %	40.8 ± 9.9 %
Mean Difference (DXA-ADP)		
Overall	3.2 ± 3.5 %*	5.3 ± 3.9 %*
Male	1.9 ± 3.3 %	5.0 ± 3.5 %*
Female	4.2 ± 3.4 %*	5.5 ± 4.3 %*
BMI < 30.0	2.1 ± 2.6 %*	6.1 ± 3.8 %*
BMI ≥ 30.0	3.8 ± 3.8 %*	1.6 ± 1.8 %
Correlation		
Overall	.91*	.95*
Male	.85*	.91*
Female	.84*	.96*
BMI < 30.0	.96*	.90*
BMI ≥ 30.0	.86*	.99*

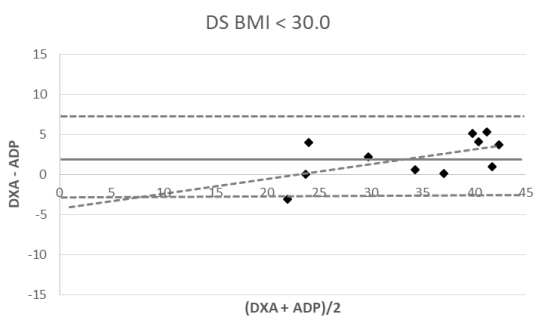
*indicates statistical significance at $p < .05$

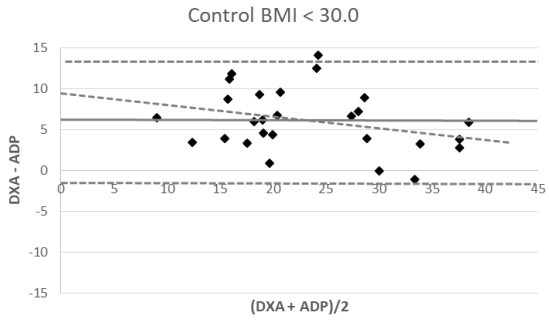
Table 2.5. *95% Limits of Agreement*

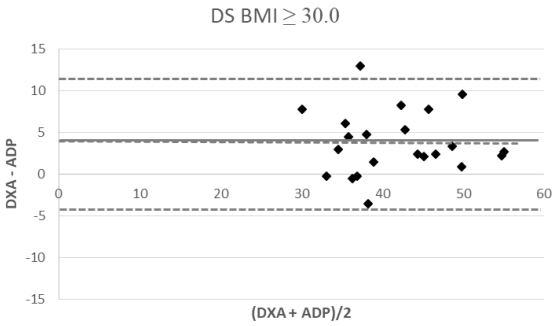
	95% Limits of Agreement		
	Mean difference ± 1.96×SD	Upper	Lower
Combined DS	3.2 ± 6.9	10.1	-3.7
DS Males	1.9 ± 6.6	8.5	-4.7
DS Females	4.2 ± 6.7	10.9	-2.5
DS BMI < 30.0	2.1 ± 5.1	7.2	-3.0
DS BMI ≥ 30.0	3.8 ± 7.5	11.3	-3.7
Combined Control	5.3 ± 7.7	12.9	-2.4
Control Males	5.0 ± 6.9	11.9	-1.9
Control Females	5.5 ± 8.3	13.8	-2.9
Control BMI < 30.0	6.1 ± 7.4	13.5	-1.4
Control BMI ≥ 30.0	1.6 ± 3.4	5.0	-1.9

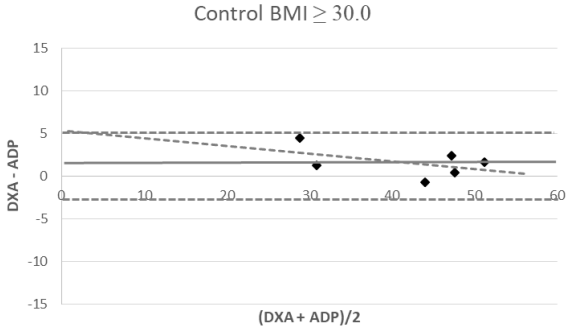
Figure 2.1. Bland-Altman plots showing the agreement between BF% values from DXA and ADP for combined, male, and female groups for subjects with DS and controls. The outside dashed lines show the upper and lower limits of agreement, while the solid middle line shows the mean difference between the two methods. The dashed regression line shows the trend between the difference of DXA and ADP and their mean.




DS BMI < 30.0
DXA - ADP
(DXA + ADP)/2


Control BMI < 30.0
DXA - ADP
(DXA + ADP)/2


DS BMI ≥ 30.0
DXA - ADP
(DXA + ADP)/2


Control BMI ≥ 30.0
DXA - ADP
(DXA + ADP)/2

CHAPTER 3

AGREEMENT BETWEEN COMMON FIELD MEASURES AND A FOUR-COMPARTMENT MODEL IN DETERMINING BODY FAT PERCENTAGE IN ADULTS WITH DOWN SYNDROME

ABSTRACT

The purpose of this study was to compare BF% from selected field measures for adult men and women with DS to a four-compartment model (4CBF%). Thirty-three adults over 19 with DS (14 men, 19 women) completed the study. Thirty-three healthy adults over 19 without DS (14 men, 19 women) served as a control group. Height, weight, and body circumferences were measured. Skinfolds were taken at the following sites: chest, mid-axilla, biceps, triceps, abdomen, suprailium, subscapular, thigh, mid-calf, and back calf. BF% was obtained from single-frequency BIA. BF% was calculated from selected prediction equations based on the anthropometric measures and compared to 4CBF%. Dependent t-tests were used to compare BF% obtained from skinfolds and BIA with BF% obtained from 4CBF%. Pearson correlation was also used to examine the relationship between the field measures and 4CBF%, and 95% limits of agreement were determined using the method of Bland and Altman (1986). Although mean BF% from all but one of the five BIA equations was not significantly different from 4CBF% ($p > .01$) in adults with DS, these equations had a standard error of estimate (SEE) ranging from 4.8 to 6.0 and wide limits of agreement ranging from ± 9.5% to ± 11.6%. Only two of the five BIA equations were significantly different than 4CBF% in control subjects ($p < .01$),

but these equations had SEE's of 7.2 and 7.8 and very wide limits of agreement (± 24.6% and ± 22.9%). Of the seven SF equations analyzed in both males and females with DS, only two did not provide a mean BF% different from 4CBF% ($p < .007$). Of those two, one (SFRO) was specifically developed for adults with DS. However, SFRO had a SEE of 4.8 and wide limits of agreement (± 17.2%). One SF equation (SFKR) was analyzed only on male subjects with DS because it was developed for adult males with intellectual disability. BF% from SFKR was not significantly different from 4CBF% ($p = .582$), but had a SEE of 7.3 and wide limits of agreement (± 13.7%). Only two of the SF equations were significantly different from 4CBF% in control subjects ($p < .008$). However, the four SF equations that were not significantly different from 4CBF% in control subjects had SEE's between 5.0 and 6.9 as well as wide limits of agreement ranging from ± 14.2% to ± 17.6%. Because equations developed on the general population may provide significantly different BF% to 4CBF%, care should be taken to select only the appropriate equations for individuals with DS.

KEY WORDS: Down syndrome, body fat assessment, skinfolds, bioelectrical impedance analysis

INTRODUCTION

Individuals with Down syndrome (DS) are more likely to be obese than their peers without DS [Izquierdo-Gomez et al., 2014; Izquierdo-Gomez et al., 2015; Nickerson et al., 2015; Oviedo et al., 2014; Shields et al., 2013], placing them at risk for developing a number of adverse health conditions such as Type 2 diabetes [Kota et al., 2013], coronary heart disease [Laaka & Laaksonen, 2007], hypertension, stroke, certain cancers, and the metabolic syndrome [Rizvi, 2010]. Many lab techniques such as dual-energy x-ray absorptiometry (DXA),

hydrostatic weighing, and air displacement plethysmography (ADP) can provide accurate measures of body composition, but are costly, time-consuming, and not always available [Casey, 2013; Esco et al., 2016; González-Agüero et al., 2011b]. Additionally, the procedures involved in these techniques are not practical for individuals with DS, who may struggle to maintain a stationary position for several minutes and experience anxiety during invasive procedures [González-Agüero, 2017; Määttä et al., 2006]. Consequently, it is important to develop methods to assess body fat percent (BF%) that can be used in a variety of field settings when laboratory equipment is not available and/or not suitable for individuals with DS.

Anthropometric measures such as skinfold measurements and circumferences are cost-effective, non-invasive, take little time to perform, and can therefore be used across many settings. While multiple equations have been developed with anthropometric measures for many specific populations, few have been developed specifically for individuals with DS who have distinct physical characteristics which differ from the general population [González-Agüero et al., 2011a; Rossato et al., 2016]. This is of concern, as prediction equations are only accurate for the populations from which they were developed. Although studies have assessed BF% in people with DS using models developed on the general population [Izquierdo-Gomez et al., 2015; Ordonez et al., 2006; Oviedo et al., 2014], common field techniques such as skinfolds, BMI-based equations, and the body adiposity index, which compares hip circumference and height, have been found to be inaccurate for individuals with DS [Esco et al., 2016; Nickerson et al., 2015; Rossato et al., 2016; Usera et al., 2005].

Recently, BF% prediction equations using anthropometric measures have been developed specifically for adolescents [González-Agüero, 2017] and adults [Rossato et al., 2016] with DS. However, both these studies and those examining the validity of anthropomorphic equations in

individuals with DS have reported small sample size as a limitation [González-Agüero, 2017; Rossato et al., 2016; Usera et al., 2005]. Therefore, further testing of these equations with other groups of individuals with DS is needed, and the present study will include a larger sample size of both men and women with DS. Another limitation reported by Rossato et al. (2016) is the use of ADP as the reference method. ADP is a two-compartment model that relies on the assumption that that fat free mass is 73% water and has a density of 1.100 kg/L [Withers et al., 1999]. However, the density of fat free mass is variable [Withers et al., 1999] and individuals with DS display different physical characteristics compared to the general population and even others with intellectual disability [González-Agüero, 2011; Usera et al., 2005], such as short stature and short limbs relative to the length of the torso [Fegan, 2011], reduced FFM and bone mass [González-Agüero et al., 2011c; McKelvey et al., 2013], and differences in regional FM and FFM distribution [González-Agüero, 2011a]. Therefore, the use of a four-compartment model to examine the accuracy of these predictive equations could provide valuable information about the accuracy of these equations for predicting BF% in individuals with DS. Therefore, one purpose of this study was to compare BF% from selected anthropometric prediction equations for adult men and women with DS to a four-compartment model (4CBF%).

Another potential field technique that may be beneficial for individuals with DS is bioelectrical impedance analysis (BIA) [Loveday et al., 2012]. Compared to laboratory methods, BIA is a relatively inexpensive and simple technique for assessing BF% [Macfarlane, 2016]. However, a person's fat distribution may influence BF% obtained from BIA [Nickerson et al., 2017a], and individuals with DS display different physical characteristics [Fegan, 2011] and body fat distribution compared to the general population [González-Agüero, 2011a; González-Agüero, 2017; Usera et al., 2005]. Additionally, less accurate measures may be obtained in obese

individuals [Hofsteenge et al., 2015], a concern in the DS population, which has a high prevalence of obesity. Nonetheless, BIA has been validated for use for diverse populations [Sun et al., 2003; Wu et al., 2015], including children and adolescents with DS [Loveday et al., 2012]. Recently, Esco et al. (2017) found that compared to DXA, BIA significantly underestimates BF% in adults with DS. However, the study included a small sample size and only tested the manufacturer's equation. Therefore, a larger number of individuals with DS need to be tested, and other equations should be evaluated. As such, the second purpose of this study was to examine the agreement between selected BIA equations and 4CBF% in measuring BF% in adults with DS.

METHODS

Participants

Thirty-four adults with DS from the local community volunteered to participate in the study. One participant experienced anxiety and did not complete the study. Thirty-three men (n = 14) and women (n = 19) with DS completed all study procedures. Thirty-three healthy adult men (n = 14) and women (n = 19) without DS participated as a control group. Control subjects and subjects with DS were matched by age, sex, and race (Table 3.1). Study subjects were all over the age of 19, and all provided written consent. Additionally, written consent was obtained from a parent or legal guardian for all subjects with DS. The parent or guardian of subjects with DS also remained with these subjects throughout the consent process and all testing procedures. Subjects were instructed not to eat or drink anything other than water for 3 hours before participating in the study and not to exercise in the 12 hours before testing.

Procedures

After providing written consent, control subjects and a parent or guardian of subjects with DS completed the Godin Leisure-Time Exercise Questionnaire [Godin & Shephard, 1997], a four-item questionnaire that asks people to list how many times per week they engage in strenuous, moderate, or light physical activity. A total leisure activity score (TLAS) was then calculated for each participant using the following formula: TLAS = (9 × Strenuous) + (5 × Moderate) + (3 × Light). Individuals with TLAS scores of 24 or higher were classified as active, those with TLAS scores of 14 to 23 were classified as moderately active, and subjects with TLAS scores of less than 14 were classified as sedentary. Subject classifications from the Godin Leisure-Time Exercise Questionnaire are presented in Table 3.2.

Parents or guardians of subjects with DS also completed the Adaptive Behavior Assessment System, Third Edition (ABAS-3) [Harrison & Oakland, 2015] to assess their adult relative's adaptive behaviors in the following skill areas: communication, community use, functional academics, home living, health and safety, leisure, self-care, self-direction, social, and work. Subjects were evaluated on 20 to 26 items in each skill area and given a score for each item ranging from 0 to 3. A score of zero indicated that the participant cannot perform the skill, while a score of 3 indicated that the subject can perform the skill and always or almost always performs the skill when needed. Scores for each item were added to calculate a score for each skill area, and scores from each skill area were combined into a General Adaptive Composite, which was used to classify each individual's overall adaptive behavior as high, above average, average, below average, low, or extremely low. Sample items from the ABAS-3 are presented in the Appendix, and the results of the ABAS-3 are presented in Table 3.3.

Before BF% testing, urine specific gravity (USG) was tested with a handheld refractometer (Atago SUR-NE, Atago Corp Ltd., Tokyo, Japan) to ensure subjects were appropriately hydrated with a USG of < 1.020 [Kavouras, 2002). Three subjects had a USG ≥ 1.020, and were given the chance to drink water and be retested after thirty minutes. After 30 minutes, adequate hydration was achieved in all three of these subjects, and they then participated in the remainder of the study. Height was measured to the nearest 0.10 cm with a wall-mounted stadiometer (SECA; Seca Instruments Ltd., Hamburg, Germany), and body mass (BM) was measured to the nearest 0.10 kg with a digital scale (Tanita BWB-800A, Tanita Corp., Tokyo, Japan).

Skinfolds and Circumferences

All SF measurements were taken with a calibrated Harpenden skinfold caliper on the right side of the subject's body. Measurements were taken at the following sites: chest, mid-axilla, biceps, triceps, abdomen, suprailium, subscapular, thigh, mid-calf, and back calf. Waist circumference was measured at the level of the umbilicus. Forearm circumferences were measured around the point with the largest diameter with the subject holding the arm parallel to the floor with the hand in supination. The following equations were used to calculate BD:

Durnin & Womersley (1974) (SFDW)

BD Men = $1.1765 - 0.0744 \times \log_{10}$(sum of four skinfolds: triceps, subscapular, biceps, & suprailiac)

BD Women = $1.1567 - 0.0717 \times \log_{10}$(sum of four skinfolds: triceps, subscapular, biceps, & suprailiac)

Jackson & Pollock (1978) (SFJ)

BD Men = 1.10938 – 0.0008267 × (sum of three skinfolds: chest, thigh, & abdominal) + 0.0000016 × (sum of three skinfolds: chest, thigh, & abdominal)^2 – 0.0002574 × age

Jackson et al. (1980) (SFJ)

BD Women = 1.0994921 – 0.0009929 × (sum of three skinfolds: triceps, thigh, & suprailiac) + 0.0000023 × (sum of three skinfolds: triceps, thigh, & suprailiac)^2 – 0.0001392 × age

Lohman (1981) (SFLO)

BD Men = 1.0982 – 0.000815 × (sum of three skinfolds: triceps, abdominal, & subscapular) + (0.00000084 × (sum of three skinfolds: triceps, abdominal, & subscapular)^2)

BD Women = 1.0982 – 0.000815 × (sum of three skinfolds: triceps, abdominal, & subscapular) + (0.00000084 × (sum of three skinfolds: triceps, abdominal, & subscapular)^2)

Rossato et al. (2016) (SFRO)

BD Men = 1.234819 – (0.091015 × sum of four skinfolds: triceps, subscapular, biceps, & suprailiac) – (0.000801 × age) – (0.000465 × BMI)

BD Women = 1.207915 – (0.087303 × sum of four skinfolds: triceps, subscapular, biceps, & suprailiac) – (0.000044 × age) – (0.000796 × BMI)

BD from these equations was then used to calculate BF% with the Siri equation (1961): BF% = (495/BD) – 450.

BF% was also calculated from the following equations:

Kelly and Rimmer (1987) (SFKR)

BF% Men = 13.545 + .48691649 × waist circumference (cm) – 0.52662145 × forearm circumference (cm) – 0.15504013 × height (cm) + .077079958 × weight (kg).

Leahy et al. (2013) (SFLE)

BF% Men = (age × 0.1) + (logtricepsSF × 7.6) + (logmidaxillaSF × 8.8) + (logsupraillimSF × 11.9) – 11.3

BF% Women = (age × 0.1) + (logabdominalgirth × 39.4) + (logmidaxillaSF × 4.9) + (logbicepsSF × 11.0) + (logmedialcalfSF × 9.1) – 73.5

O'Connor et al. (2010) (SFO10)

BF% Men (white) = (0.272 × sum of three SF: chest, abdomen, thigh) – (0.0005 × (sum of three SF: chest, abdomen, thigh)^2) + 4.972

BF% Men (black) = (0.272 × sum of three SF: chest, abdomen, thigh) – (0.0005 × (sum of three SF: chest, abdomen, thigh)^2) + 3.860

BF% Women (white) = (0.387 × sum of three SF: triceps, suprailium, thigh) – (0.0011 × (sum of three SF: triceps, suprailium, thigh)^2) + 8.341

BF% Women (black) = (0.387 × sum of three SF: triceps, suprailium, thigh) – (0.0011 × (sum of three SF: triceps, suprailium, thigh)^2) + 10.861

O'Connor et al. (2010), SF and BMI (SFOBMI)

BF% Men (white) = (0.190 × sum of three SF: chest, abdomen, thigh) – (0.0005 × (sum of three SF: chest, abdomen, thigh)^2) + (0.604 × BMI) – 5.377

BF% Men (black) = (0.206 × sum of three SF: chest, abdomen, thigh) – (0.0005 × (sum of three SF: chest, abdomen, thigh)^2) + (0.604 × BMI) – 1.987

BF% Women (white) = (0.169 × sum of three SF: triceps, suprailium, thigh) – (0.0007 × (sum of three SF: triceps, suprailium, thigh)^2) + (0.849 × BMI) + 1.260

BF% Women (black) = (0.169 × sum of three SF: triceps, suprailium, thigh) – (0.0007 × (sum of three SF: triceps, suprailium, thigh)^2) + (0.849 × BMI) + 0.078

Air Displacement Plethysmography

ADP was performed using a calibrated Bod Pod (BOD POD Body Composition System, Cosmed USA, Inc.). During the ADP measurement, subjects wore minimal and tight clothing, as well as a swim cap as recommended by the manufacturer. Subjects were also instructed to remove all metal for the test. Study participants with DS experienced difficulty performing the technique to measure thoracic gas volume inside of the Bod Pod. Therefore, predicted thoracic gas volume was used for all study participants. BV obtained from ADP was used in the 4CBF% model.

Bioimpedance Spectroscopy

TBW was determined with BIS (IMP^{TM}SFB7, ImpediMed Limited, Queensland, Australia). For this measurement subjects were instructed to lie down supine on an exam table with their legs separated and their arms slightly away from their body. Electrodes were placed at the distal ends of the right hand and foot. Age, sex, height, and weight were entered and the average TBW from two trials (within ± 0.5 L) was recorded and used in the 4CBF% model.

Dual Energy X-ray Absorptiometry

Bone mineral content (BMC) was assessed using a calibrated DXA (GE Lunar Prodigy, Software version 10.50.086, GE Lunar Corp., Madison, WI). Subjects removed their shoes and any metal and were then instructed to lie in a supine position on the bed of the scanner with their arms down by their side for around 6 to 10 minutes. Subjects with DS received verbal encouragement and instruction from the technician to remain still throughout the scan. A parent also stood within view of each subject with DS throughout the scan.

Single-Frequency Bioelectrical Impedance Analysis

Subjects removed all jewelry, socks, and shoes before the test. They were then instructed to lie supine on an exam table with the legs separated and the arms 30° from the body. Electrodes were placed on the right hand and foot, and a single-frequency (50 kHz) hand-to-foot BIA device (Quantum IV, RJL systems, Clinton, MI) was used to determine fat free mass (FFM) and BF%. Using values obtained from the BIA device, FFM was estimated with the following equations, where R = Resistance, Xc = Reactance, Wt = Weight, and Ht = Height:

Chumlea et al. (2002) (BIACH)

FFM Men = $-10.678 + (0.262 \times Wt) + (0.652 \times Ht^2/R) + (0.015 \times R)$

FFM Women = -9.529 + (0.168 × Wt) + (0.696 × Ht^2/R) + (0.016 × R)

Deurenberg et al. (1991) (BIADE)

FFM = – 12.44 + (0.34 × Ht^2/R) + (0.1534 × Ht) + (0.273 × Wt) – (0.127 × age) + (4.56 × sex; men = 1, women = 0)

Kyle et al. (2001) (BIAK)

FFM = – 4.104 + (0.518 × Ht^2/R) + (0.231 × Wt) + (0.130 × Xc) + (4.229 × sex; men = 1, women = 0)

Lohman (1992) (BIALO)

FFM Men age 18-29 = 5.32 + (0.485 × Ht^2)/R + (0.338 × Wt)

FFM Women age 18-29 = 5.49 + (0.476 × Ht^2)/R + (0.295 × Wt)

FFM Men age 30-49 = 4.51 + (0.549 × Ht^2)/R + (0.163 × Wt) + (0.092 × Xc)

FFM Women age 30-49 = 11.59 + (0.493 × Ht^2)/R + (0.141 × Wt)

FFM Women age 50-70 = 6.34 + (0.485 × Ht^2)/R + (0.180 × Wt)

Sun et al. (2003) (BIASU)

FFM Men = -10.68 + (0.65 × Ht^2/R) + (0.26 × Wt) + (0.02 × R)

FFM Women = - 9.53 + (0.69 × Ht^2/R) + (0.17 × Wt) + (0.02 × R)

BF% was then calculated from FFM and BM: BF% = ([BM – FFM] / BM) × 100.

Four-Compartment Model Calculation

The model by Wang et al. (2005) was used to calculate 4CBF%: FM (kg) = 2.748(BV) – 0.699(TBW) + 1.129(TBBM) – 2.051(BM). BF% = (FM/BM) × 100. TBW was determined with BIS, and BV was measured with ADP. BMC obtained from DXA was converted to total body bone mineral (TBBM) as follows: TBBM = BMC(kg)*1.0436 [Heymsfield et al., 1989]. The following equations were then used to determine 4CBF%:

FM (kg) = 2.748*BV – 0.699*TBW + 1.129*TBBM – 2.051*BM

BF% = (FM/BM)*100

Statistical Analysis

All data were analyzed using SPSS version 24.0 (Somers, NY, USA). Mean BF% obtained by each SF equation and the 4C model was compared with dependent t-tests, using the Bonferroni-adjusted alpha level of $p < .00625$ for DS males, $p < .007$ for combined DS and DS females, and $p < .008$ for controls. Mean BF% obtained by each BIA equation and the 4C model was compared with dependent t-tests, using the Bonferroni-adjusted alpha level of $p < .01$. Cohen's *d* was calculated to determine the effect size (ES) of the mean differences in BF%. The following values were used to determine the magnitude of the ES: trivial = ES < 0.2; small = 0.2-0.6; moderate = 0.6-1.2; large = 1.2-2.0; and very large > 2.0 [Hopkins et al., 2009]. Pearson correlation was also used to examine the relationship between BF% obtained with each equation and the 4C model, using the following values to describe the correlation: small < 0.30; moderate = 0.31-0.49; large = 0.50-0.69; very large = 0.70-0.89; and near perfect = 0.90-1.00 [Hopkins et al., 2009]. Additionally, 95% limits of agreement between BF% from each SF and BIA equation and the 4C model were identified using the method of Bland and Altman (1986). Data were analyzed with both males and females combined and separately by sex.

RESULTS

Overall agreement between BIA and 4CBF%

Results are presented in Tables 3.4-3.7 and Figure 3.1. When male and female subjects with DS were analyzed together, there was no significant difference in BF% between 4CBF% and BIACH, BIADE, BIAK, or BIASU. BF% from BIALO was significantly lower than 4CBF%. The Cohen's *d* statistic showed a small ES for BIACH, BIADE, and BIASU; a trivial ES for BIAK; and a moderate ES for BIALO. Pearson's correlation was very large for all BIA equations, and the SEE ranged from 4.8 (BIAK) to 6.0 (BIADE). The 95% limits of agreement were widest for BIADE (± 11.6%) and narrowest for BIAK (± 9.5%).

When male and female control subjects were analyzed together, all equations had a higher mean BF% compared to 4CBF%, but there was no statistically significant difference in BF% between 4CBF% and BIAK, BIALO, and BIASU. BF% from BIACH and BIADE was significantly higher than 4CBF%. The Cohen's *d* statistic showed a small ES for BIAK, BIALO, BIASU, and BIACH, and a moderate ES for BIADE. Pearson's correlation was small for BIACH, BIAK, and BIASU, and moderate for BIADE and BIALO. The SEE ranged from 7.2 (BIADE) to 8.4 (BIALO). The 95% limits of agreement were widest for BIACH and BIAK (± 24.6%) and narrowest for BIADE (± 22.9%).

Agreement between BIA and 4CBF% in males

When male subjects with DS were analyzed separately, there was no significant difference in BF% between 4CBF% and any of the equations. The Cohen's *d* statistic showed a trivial ES for BIACH and BIADE, a small ES for BIAK and BIASU, and a moderate ES for BIALO. Pearson's correlation was moderate for BIACH and large for BIADE, BIAK, BIALO,

and BIASU. The SEE ranged from 5.7 (BIAK) to 8.1 (BIALO). The 95% limits of agreement were widest for BIALO (± 15.3%) and narrowest for BIAK (± 10.8%).

When male control subjects were analyzed separately, there was no significant difference in BF% between 4CBF% and any of the equations. The Cohen's *d* statistic showed a small ES for all equations. Pearson's correlation was small for BIADE, BIAK, BIALO, and BIASU, and moderate for BIACH. The SEE ranged from 3.0 (BIACH) to 5.1 (BIALO). The 95% limits of agreement were widest for BIALO (± 24.4%) and narrowest for BIADE (± 23.1%).

Agreement between BIA and 4CBF% in females

When female subjects with DS were analyzed separately, there was no significant difference in BF% between 4CBF% and BIACH, BIAK, or BIASU. BF% from BIADE was significantly higher than 4CBF%, while BF% from BIALO was significantly lower than 4CBF%. The Cohen's *d* statistic showed a trivial ES for BIASU, a small ES for BIAK and BIACH, and a moderate ES for BIADE and BIALO. Pearson's correlation was very large for all equations. The SEE ranged from 3.1 (BIAK) to 4.1 (BIASU). The 95% limits of agreement were widest for BIADE (± 9.5%) and narrowest for BIAK and BIALO (± 8.0%).

When female control subjects were analyzed separately, there were no significant difference in BF% between 4CBF% and BIACH, BIAK, BIALO, or BIASU. BF% from BIADE was significantly higher than 4CBF%. The Cohen's *d* statistic showed a small ES for BIACH, BIAK, BIALO, and BIASU, and a moderate ES for BIADE. Pearson's correlation was small for all equations. The SEE ranged from 6.4 (BIADE) to 8.2 (BIASU). The 95% limits of agreement were widest for BIASU (± 26.6%) and narrowest for BIADE (± 23.4%).

Overall agreement between SF and 4CBF%

Results are presented in Tables 3.8-3.11 and in Figure 3.2. When male and female subjects with DS were analyzed together, there was no significant difference in BF% between 4CBF% and SFRO or SFLE. BF% from SFDW, SFJ, SFLO, SFO10, and SFOBMI was significantly lower than 4CBF%. Cohen's *d* statistic showed a small ES for SFDW, SFRO, and SFLE, a moderate ES for SFO10 and SFOBMI, and a large ES for SFJ and SFLO. Pearson's correlation was small for SFRO, large for SFLO, and very large for SFDW, SFJ, SFLE, SFO10, and SFOBMI. The SEE ranged from 4.7 (SFLE) to 6.3 (SFJ). The 95% limits of agreement were widest for SFRO (± 17.2%) and narrowest for SFOBMI (± 10.4%).

When male and female control subjects were analyzed together, there was no significant difference in BF% between 4CBF% and SFDW, SFLE, SFO10, or SFOBMI. BF% from SFJ and SFLO was significantly lower than 4CBF%. Cohen's *d* statistic showed a trivial ES for SFDW, SFOBMI and SFLE, a small ES for SFO10, and a moderate ES for SFJ and SFLO. Pearson's correlation was large for SFLO and SFO10, and very large for SFDW, SFJ, SFLE, and SFOBMI. The SEE ranged from 5.0 (SFLE) to 6.9 (SFJ). The 95% limits of agreement were widest for SFO10 (± 17.6%) and narrowest for SFLE (± 14.2%).

Agreement between SF and 4CBF% in males

When male subjects with DS were analyzed separately, there was no significant difference in BF% between 4CBF% and SFDW, SFRO, SFKR, or SFLE. BF% was significantly lower than 4CBF% for SFJ, SFLO, SFO10, and SFOBMI. Cohen's *d* statistic showed a trivial ES for SFKR and SFRO, a moderate ES for SFDW, SFLE, and SFOBMI, and a large ES for SFJ, SFLO, and SFO10. Pearson's correlation was small for SFDW, SFRO and SFO10, moderate for SFJ, SFLO, and SFLE, and large for SFKR and SFOBMI. The SEE ranged from

3.3 (SFDW and SFLE) to 7.3 (SFKR). The 95% limits of agreement were widest for SFKR (± 13.7%) and narrowest for SFLE (± 8.6%).

When male control subjects were analyzed separately, there was no significant difference in BF% between 4CBF% and SFDW, SFLO, SFLE, SFO10, or SFOBMI. BF% from SFJ was significantly lower than 4CBF%. The Cohen's *d* statistic showed a trivial ES for SFLE, a small ES for SFOBMI and SFDW, a moderate ES for SFJ, SFLO and SFO10. Pearson's correlation was moderate for SFOBMI and large for SFDW, SFJ, SFLO, SFLE, and SFO10. The SEE ranged from 2.7 (SFO10) to 4.4 (SFLE). The 95% limits of agreement were widest for SFOBMI (± 18.6%) and narrowest for SFLE (± 15.4%).

Agreement between SF and 4CBF% in females

When female subjects with DS were analyzed separately, there was no significant difference in BF% between 4CBF% and SFDW, SFRO, SFLE, or SFOBMI. BF% was significantly lower than 4CBF% for SFJ, SFLO, and SFO10. Cohen's d statistic showed a small ES for SFDW, SFRO, SFLE, and SFOBMI, a moderate ES for SFJ and SFO10, and a large ES for SFLO. Pearson's correlation was moderate for SFDW, SFJ, SFLO, SFRO, and SFO10, large for SFLE, and very large for SFOBMI. The SEE ranged from 3.2 (SFRO) to 7.0 (SFLO). The 95% limits of agreement were widest for SFRO (± 20.1%) and narrowest for SFOBMI (± 10.7%).

When female control subjects were analyzed separately, there was no difference in BF% between 4CBF% and SFDW, SFJ, SFLE, SFO10, or SFOBMI. BF% was significantly lower than 4CBF% for SFLO. Cohen's *d* statistic showed a trivial ES for SFDW, SFO10, and SFOBMI, a small ES for SFLE and SFJ, and a moderate ES for SFLO. Pearson's correlation was large for SFLO and SFO10, and very large for SFDW, SFJ, SFLE, and SFOBMI. The SEE

ranged from 3.5 (SFOBMI) to 6.3 (SFJ and SFLO). The 95% limits of agreement were widest for SFLO (± 17.5%) and narrowest for SFLE (± 13.5).

DISCUSSION

The present study found no significant differences in BF% between BIA and 4CBF% for BIACH, BIADE, BIAK, and BIALO in adults with DS, while BIALO underestimated BF% compared to 4CBF%. Results from the control group found no significant difference between 4CBF% and BIAK, BIALO, and BIASU, while BIACH and BIADE overestimated BF% compared to 4CBF%. Previous work by Nickerson et al. (2017a) also found no significant difference in BF% between a four-compartment model and BIASU in the general population, but reported higher BF% compared to a four-compartment model for BIADE and BIAK. When results were analyzed by sex, both DS and control males showed no difference in BF% between 4CBF% and all BIA equations. However, not all equations showed no difference in BF% compared to 4CBF% in females with and without DS.

One possible explanation for the difference in results for combined male and female adults with DS is the high prevalence of obesity in this population [Nickerson et al., 2015]. If BIA tends to overestimate BF% in the general population, then it could be expected that BF% from BIA will be more accurate in individuals with DS, who have higher BF% compared to age-matched peers. Furthermore, control subjects in the present study were older and included individuals who were less active than subjects from Nickerson et al. (2015), which may explain the slight difference in results for general population subjects.

In agreement with previous research [Rosatto et al., 2016; Usera et al., 2005], many skinfold equations developed for use in the general population were not accurate for adults with DS. However, this study did identify equations appropriate for use in both the general population

and in adults with DS. The recently developed DS-specific equation by Rossato et al. (2016) provided the lowest SEE for both males and females with DS, but also had the widest limits of agreement. Therefore, practitioners may want to consider other equations, such as SFLE, which has a similar SEE to SFRO, but narrower limits of agreement. Additionally, SFKR shows good agreement of mean BF% with 4CBF% in males with DS, while SFOBMI shows good agreement with 4CBF% in females with DS. Despite the practicality and ease of availability of SF measures in a field setting, several participants in the present study were initially afraid of the skinfold calipers and struggled to stand sill long enough for the technician to complete the measurements. Additionally, two subjects initially displayed tactile defensiveness during the measurements. Although the measurements were eventually obtained, SF may not be an ideal method of BF% assessment for some individuals with DS.

An additional consideration in the interpretation of the present study's results is the use of ADP instead of underwater weighing (UWW) to measure body volume for the four-compartment model. Although UWW with measurement of residual lung volume was used for body volume to develop 4CBF% [Wang et al., 2005], UWW is not feasible in individuals with DS, and thus ADP was substituted. Measurement of thoracic gas volume (TGV) was also not possible for subjects with DS due to their difficulty in understanding the procedures, so predicted TGV was used. Because the agreement of measurements by ADP using measured versus predicted TGV is not known in individuals with DS, it is possible that using predicted TGV may have affected the results. However, work in the general population suggests that there are no significant differences from using predicted versus measured TGV [McCrory et al, 1998; Nickerson et al., 2017b].

CONCLUSIONS

Several single-frequency BIA equations show good agreement with 4CBF% in adults with DS for mean BF%. However, not all equations are appropriate for females with DS. BIAK consistently had the lowest SEE and narrowest limits of agreement in combined adults, males, and females with DS and therefore appears to be the best choice of the equations tested. Practitioners can use single-frequency BIA as a convenient method to assess BF% in adults with DS, but attention should be given to the equation used, especially for females. Additionally, most BIA equations had higher SEE's and wider 95% limits of agreement than are generally recommended. However, the benefits of BIA, namely the availability and ease of use in individuals with DS, make BIA a reasonable option for BF% assessment in this population. Similarly, all of the single-frequency BIA equations tested in this study showed good agreement to 4CBF% in male control subjects. However, BIADE significantly overestimated BF% compared to 4CBF% in female control subjects and had a moderate ES. Therefore, equations other than BIADE should be used to assess female subjects in the general population.

Most SF equations showed good agreement with 4CBF% in control subjects. However, SFJ underestimated BF% in males and had a large ES. Additionally, SFLO underestimated BF% in females and had a moderate ES. Therefore, SFJ should be avoided for males in the general population and SFLO should be avoided for females in the general population. The SEE and limits of agreement of each SF equation vary slightly by sex in the general population, so practitioners may wish to select equations based on the sex of the individuals being assessed. In contrast, many SF equations developed for the general population are not appropriate for use in adults with DS. Recently developed SFRO appears to provide reasonable mean BF% measures compared to 4CBF% in both males and females with DS along with SFLE and SFOBMI.

Additionally, mean BF% from SFKR was close to 4CBF% in males with DS. However, these equations showed high SEE's and wide 95% limits of agreement and not all adults with DS tolerate SF measurements well. Therefore, SF may not be ideal for some individuals with DS. Nonetheless, it appears that both BIA and SF may in many cases be appropriate for use in DS. Because equations developed on the general population may provide significantly different BF% to 4CBF%, however, care should be taken to select only the appropriate equations for individuals with DS.

REFERENCES

1. Bland, J.M., & Altman, D.G. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet, 1(8476),* 307-310.

2. Casey, A.F. (2013). Measuring body composition in individuals with intellectual disability: a scoping review. *Journal of Obesity, 3,* 28428.

3. Chumlea, W.C., Guo, S.S., Kuczmarski, R.J., Flegal, K.M., Johnson, C.L., Heymsfield, S.B. et al. (2002). Body composition estimates from NHANES III bioelectrical impedance data. *International Journal of Obesity and Related Metabolic Disorders,* 26, 1596-609.

4. Deurenberg, P., Van der Kooy, K., Leenen, R., Weststrate, J., & Seidell, J. (1991). Sex and age specific prediction formulas for estimating body composition from bioelectrical impedance: a cross-validation study. *International Journal of Obesity,* 15, 17-25.

5. Durnin, J.V., & Womersley, J. (1974). Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. *The British Journal of Nutrition, 32,* 77-97.

6. Esco, M.R., Nickerson, B.S., & Russell, A.R. (2017). Comparison of bioelectrical impedance and DXA for measuring body composition among adults with Down syndrome. *Disability and Health Journal, 10(4),* 548-551.

7. Esco, M.R., Nickerson, B.S., Bicard, S.C., Russell, A.R., & Bishop, P.A. (2016). Agreement of BMI-based equations and DXA in determining body-fat percentage in adults with Down syndrome. *Adapted Physical Activity Quarterly, 33(1),* 89-96.

8. Fegan, P.L. (2011). Intellectual disabilities. In J.P. Winnick (Ed.), *Adapted Physical Education and Sport* (pp.151-172). Champaign, IL: Human Kinetics.

9. Godin, G., & Shephard, R. J. (1997). Godin leisure-time exercise questionnaire. *Medicine & Science in Sports and Exercise*, 29(6), 36-38.

10. González-Agüero, A., Ara, I., Moreno, L. A., Vicente-Rodríguez, G., & Casajús, J.A. (2011a). Fat and lean masses in youths with Down syndrome: gender differences. *Research in Developmental Disabilities, 32,* 1685-1693.

11. González-Agüero, A., Vicente-Rodríguez, G., Ara, I., Moreno, L.A., & Casajús, J.A. (2011b). Accuracy of prediction equations to assess percentage of body fat in children and adolescents with Down syndrome compared to air displacement plethysmography. *Research in Developmental Disabilities, 32,* 1764-1769.

12. González-Agüero, A., Vicente-Rodríguez, G., Ara, I., Moreno, L.A., & Casajús, J.A. (2011c). Bone mass in male and female children and adolescents with Down syndrome. *Osteoporosis International, 22(7),* 2151-2157.

13. González-Agüero, A., Matute-Llorente, A., Gómez-Cabello, A., Vicente-Rodríguez, G., & Casajús, J.A. (2017). Percentage of body fat in adolescents with Down syndrome: estimation from skinfolds. *Disability and Health Journal, 10,* 100-104.

14. Harrison, P.L., & Oakland, T. (2015). *Adaptive Behavior Assessment System, Third Edition*. Torrance,CA: Western Psychological Services.

15. Heymsfield, S.B., Wang, J., Heshka, S., Kehayias, J.J., & Pierson, R.N. (1989). Dual-photon absorptiometry: comparison of bone mineral and soft tissue mass measurements in vivo with established methods. *American Journal of Clinical Nutrition,* 49, 1283-1289.

16. Hofsteenge, G.H., Chinapaw, M.J.M., & Weijs, P.J.M. (2015). Fat-free mass prediction equations for bioelectric impedance analysis compared to dual energy x-ray absorptiometry in obese adolescents: a validation study. *BMC Pediatrics, 15,* 158.

17. Hopkins, W.G., Marshall, S.W., Batterham, A.M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise, 41,* 3-13.

18. Izquierdo-Gomez, R., Martinez-Gomez, D., Acha, A., Veiga, O.L., Villagra, A., & Diaz-Cueto, M. (2014). Objective assessment of sedentary time and physical activity throughout the week in adolescents with Down syndrome. The UP&DOWN study. *Research in Developmental Disabilities, 35,* 482-489.

19. Izquierdo-Gomez, R., Martinez-Gomez, D., Villagra, A., Fernhall, B., & Veiga, O.L. (2015). Associations of physical activity with fatness and fitness in adolescents with

Down syndrome: The UP&DOWN study. *Research in Developmental Disabilities, 36,* 428-436.

20. Jackson, A.S., & Pollock, M.L. (1978). Generalized equations for predicting body density of men. *The British Journal of Nutrition, 40,* 497-504.

21. Jackson, A.S., Pollock, M.L., & Ward, A. (1980). Generalized equations for predicting body density of women. *Medicine and Science in Sports and Exercise, 12,* 175-181.

22. Kavouras, S.A. (2002). Assessing hydration status. *Current Opinion in Clinical Nutrition & Metabolic Care, 5(5),* 519-524.

23. Kelly, L.E., & Rimmer, J. (1987). A practical method for estimating percent body fat of adult mentally retarded males. *Adapted Physical Activity Quarterly, 4,* 117-125.

24. Kota, S.K., Tripathy, P.R., Kota, S.K., & Jammula, S. (2013). Type 2 diabetes mellitus: An unusual association with Down's syndrome. *Indian Journal of Human Genetics,* 19(3), 358-359.

25. Kyle, U.G., Genton, L., Karsegard, L., Slosman, D.O., & Prichard, C. (2001). Single prediction equation for bioelectrical impedance analysis in adults aged 20-94 years. *Nutrition,* 17, 248-253.

26. Laakka, T.A., & Laaksonen, D.E. (2007). Physical activity in prevention and treatment of the metabolic syndrome. *Applied Physiology, Nutrition, and Metabolism,* 32: 76-88.

27. Leahy, S., O'Neill, C., Sohun, R., Toomey, C., & Jakeman, P. (2013). Generalized equations for the prediction of body fat by anthropometry in adult men and women aged 18-81 years. *British Journal of Nutrition, 109,* 678-685.

28. Lohman, T.G. (1981). Skinfolds and body density and their relation to body fatness: a review. *Human Biology, 53,* 181-225.

29. Lohman, T. G. (1992). Advances in body composition assessment. Champaign, IL: Human Kinetics.

30. Loveday, S.J., Thompson, J.M.D., & Mitchell, E.A. (2012). Bioelectrical impedance for measuring percentage body fat in young persons with Down syndrome: validation with dual-energy absorptiometry. *Acta Paediatrica, 101,* e491-e495.

31. Määttä, T., Tervo-Määttä, T., Taanila, A., Kaski, M., & Iivanainen, M. (2006). Mental health, behavior and intellectual abilities of people with Down syndrome. *Down Syndrome Research and Practice, 11(1),* 37-43.

32. Macfarlane, D.J., Chan, N.T., Tse, M.A., Joe, G.M. (2016). Agreement between bioelectrical impedance and dual energy x-ray absorptiometry in assessing fat, lean and bone mass changes in adults after a lifestyle intervention. *Journal of Sports Sciences, 34(12),* 1176-1181.

33. McCrory, M.A., Molé, P.A., Gomez, T.D., Dewey, K.G., & Bernauer, E.M. (1998). Body composition by air-displacement plethysmography by using predicted and measured thoracic gas volumes. *Journal of Applied Physiology, 84,* 1475-1479.

34. Nickerson, B.S., Esco, M.R., Bicard, S.C., Russell, A.R., Williford, H.N., & Schaefer, G. (2015). Validity of the body adiposity index in adults with Down syndrome. *Research in Developmental Disabilities, 38,* 92-96.

35. Nickerson, B.S., Esco, M.R., Bishop, P.A., Schumacker, R., Richardson, M., Fedewa, M.V., Wingo, J.E., Welborn, B.A. (2017a). Validity of selected bioimpedance equations for estimating body composition in men and women: a four-compartment model comparison. *Journal of Strength and Conditioning Research, 31(7),* 1963-1972.

36. Nickerson, B.S., Esco, M.R., Bishop, P.A., Schumacker, R., Richardson, M., Fedewa, M.V., Wingo, J.E., Welborn, B.A. (2017b). Impact of measured vs. predicted residual lung volume on body fat percentage using underwater weighing and 4-compartment model. *Journal of Strength and Conditioning Research, 31(9),* 2519-2527.

37. O'Connor, D.P., Bray, M.S., McFarlin, B.K., Sailors, M.H., Ellis, K.J., & Jackson, A.S. (2010). Generalized equations for estimating DXA percent fat of diverse young women and men: the TIGER study. *Medicine & Science in Sports & Exercise, 42(10),* 1959-1965.

38. Ordonez, F.J., Rosety, M., Rosety-Rodriguez, M. (2006). Influence of 12-week exercise training on fat mass percentage in adolescents with Down syndrome. *Medical Science Monitor, 12,* CR416-CR419.

39. Oviedo, G.R., Guerra-Balic, M., Baynard, T., & Javierre, C. (2014). Effects of aerobic, resistance and balance training in adults with intellectual disabilities. *Research in Developmental Disabilities, 35,* 2624-2634.

40. Rizvi, A.A. (2010). Hypertension, obesity, and inflammation: the complex designs of the deadly trio. *Metabolic Syndrome and Related Disorders,* 8, 287-294.

41. Rossato, M., Dellagrana, R.A., da Costa, R.M., Bezerra, E.D., Otacílio, J., dos Santos, L., & Rech, C.R. (2016). The accuracy of anthropometric equations to assess body fat in adults with Down syndrome. *Journal of Applied Research in Intellectual Disabilities,* doi: 10.1111/jar.12290. [Epub ahead of print]

42. Shields, N., Taylor, N.F., Wee, E., Wollersheim, D., O'Shea, S.D., & Fernhall, B. (2013). A community-based strength training program increases muscle strength and physical activity in young people with Down syndrome: A randomized control trial. *Research in Developmental Disabilities, 34,* 4385-4394.

43. Siri, W.E. (1961). Body composition from fluid spaces and density: analysis of methods. *Nutrition, 9,* 480-491.

44. Sun, S.S., Chumlea, W.C., Heymsfield, S.B., Lukaski, H.C., Schoeller, D., Friedl, K., Kuczmarski, R.J., Flegal, K.M., Johnson, C.L., & Hubbard, V.S. (2003). Development of bioelectrical impedance analysis prediction equations for body composition with the use of a multicomponent model for use in epidemiologic surveys. *The American Journal of Clinical Nutrition, 77,* 331-340.

45. Usera, P.C., Foley, J.T., & Yun, J. (2005). Cross-validation of field-based assessments of body composition for individuals with Down syndrome. *Adapted Physical Activity Quarterly, 22,* 198-206.

46. Wang, Z., Shen, W., & Withers, R.T. (2005). Multicomponent molecular-level models of body composition analysis. Champaign, IL: Human Kinetics.

47. Withers, R.T., Laforgia, J., & Heymsfield, S.B. (1999). Critical appraisal of the estimation of body composition via two-, three-, and four-compartment models. *American Journal of Human Biology, 11,* 175-185.

48. Wu, C.S., Chen, Y.Y., Chuang, C.L., Chiang, L.M., Dwyer, G.B., Hsu, Y.L., Huang, A.C., Lai, C.L., & Hsieh, K.C. (2015). Predicting body composition using foot-to-foot bioelectrical impedance analysis in healthy Asian individuals. *Nutrition Journal, 14,* 52.

Table 3.1. *Participant Characteristics*

		Down syndrome (n = 33)	Control (n = 33)
Sex			
	Male	n = 14	n = 14
	Female	n = 19	n = 19
Race			
	Black	n = 3	n = 3
	White	n = 30	n = 30
Age			
	Overall	29.3 ± 10.5	29.5 ± 10.3
	Male	25.8 ± 6.7	26.4 ± 6.9
	Female	31.9 ± 12.1	31.8 ± 11.9
Height (cm)			
	Overall	146.5 ± 10.8	171.5 ± 10.2
	Male	152.1 ± 11.3	181.1 ± 7.3
	Female	142.3 ± 8.5	164.5 ± 4.7
Weight (kg)			
	Overall	69.6 ± 16.4	78.5 ± 16.9
	Male	73.4 ± 15.3	88.9 ± 12.1
	Female	66.7 ± 17.2	70.9 ± 16.1
BMI			
	Overall	32.4 ± 6.7	26.4 ± 4.4
	Male	31.9 ± 6.8	27.0 ± 3.1
	Female	32.7 ± 6.8	25.9 ± 5.2

Table 3.2. *Study 2 Godin Leisure Time Questionnaire*

	Down syndrome (n)	Control (n)
Sedentary		
Total	4	0
Male	3	0
Female	1	0
Moderately Active		
Total	13	4
Male	4	0
Female	9	4
Active		
Total	16	29
Male	7	14
Female	9	15

Table 3.3. *Adaptive Behavior Assessment System, Third Edition*

Classification	Male (n)	Female (n)	Total (n)
Extremely Low	9	14	23
Low	4	3	7
Below Average	1	2	3

Table 3.4. *DS BIA Results*

DS Group					
	Mean ± SD	p	Cohen's *d*	r	SEE
Combined (n = 33)					
4CBF%	36.0 ± 8.6				
BIACH	37.8 ± 9.1	.063	-0.34	0.82	5.3
BIADE	38.1 ± 9.7	.054	-0.35	0.80	6.0
BIAK	36.1 ± 9.1	.925	-0.02	0.85	4.8
BIALO	31.3 ± 9.8	<.000	0.81	0.81	5.9
BIASU	34.7 ± 9.5	.163	0.25	0.83	5.3
Males (n = 14)					
4CBF%	29.9 ± 4.4				
BIACH	30.7 ± 7.2	.627	-0.13	0.49	6.5
BIADE	30.0 ± 8.0	.955	-0.02	0.52	7.1
BIAK	28.5 ± 6.5	.359	0.25	0.55	5.7
BIALO	24.9 ± 9.0	.035	0.63	0.50	8.1
BIASU	27.9 ± 7.6	.270	0.31	0.52	6.8
Females (n = 19)					
4CBF%	40.5 ± 8.2				
BIACH	43.0 ± 6.6	.026	-0.56	0.84	3.6
BIADE	44.0 ± 5.6	.006	-0.72	0.81	3.4
BIAK	41.7 ± 6.2	.229	-0.29	0.87	3.1
BIALO	35.9 ± 7.6	<.000	1.13	0.87	3.9
BIASU	39.7 ± 7.5	.423	0.19	0.85	4.1

Table 3.5. *Control BIA Results*

Control Group					
	Mean ± SD	p	Cohen's *d*	r	SEE
Combined (n = 33)					
4CBF%	25.6 ± 11.9				
BIACH	32.6 ± 7.9	.003	-0.57	0.25	7.8
BIADE	33.2 ± 7.6	.001	-0.65	0.34	7.2
BIAK	31.4 ± 7.5	.011	-0.47	0.22	7.5
BIALO	29.5 ± 8.8	.072	-0.32	0.33	8.4
BIASU	29.6 ± 7.9	.078	-0.32	0.22	7.8
Males (n = 14)					
4CBF%	20.4 ± 10.6				
BIACH	26.6 ± 3.1	.072	-0.52	-0.32	3.0
BIADE	27.1 ± 3.9	.052	-0.57	-0.12	4.1
BIAK	26.4 ± 3.9	.085	-0.50	-0.22	4.0
BIALO	23.3 ± 4.9	.404	-0.23	-0.17	5.1
BIASU	24.2 ± 3.3	.252	-0.32	-0.29	3.3
Females (n = 19)					
4CBF%	29.4 ± 11.5				
BIACH	37.1 ± 7.5	.021	-0.58	0.08	7.7
BIADE	37.7 ± 6.4	.007	-0.70	0.21	6.4
BIAK	35.2 ± 7.5	.073	-0.44	0.08	7.6
BIALO	34.1 ± 8.1	.110	-0.39	0.25	8.1
BIASU	33.5 ± 8.0	.197	-0.31	0.07	8.2

Table 3.6. *95% Limits of Agreement DS 4CBF%-BIA*

	95% Limits of Agreement		
	Mean difference ± 1.96×SD	Upper	Lower
BIACH Combined DS	-1.7 ± 10.4	8.6	-12.1
BIACH DS Males	-0.8 ± 12.4	11.6	-13.3
BIACH DS Females	-2.5 ± 8.6	6.2	-11.1
BIADE Combined DS	-2.1 ± 11.6	9.6	-13.7
BIADE DS Males	-0.1 ± 13.4	13.3	-13.5
BIADE DS Females	-3.5 ± 9.5	6.0	-13.1
BIAK Combined DS	-0.1 ± 9.5	9.4	-9.6
BIAK DS Males	1.4 ± 10.8	12.2	-9.4
BIAK DS Females	-1.2 ± 8.0	6.9	-9.2
BIALO Combined DS	4.8 ± 11.5	16.2	-6.7
BIALO DS Males	4.9 ± 15.3	20.2	-10.4
BIALO DS Females	4.6 ± 8.0	12.6	-3.4
BIASU Combined DS	1.3 ± 10.4	11.7	-9.1
BIASU DS Males	2.0 ± 12.8	14.8	-10.8
BIASU DS Females	0.8 ± 8.5	9.3	-7.7

Table 3.7. *95% Limits of Agreement Control 4CBF%-BIA*

	95% Limits of Agreement		
	Mean difference ± 1.96×SD	Upper	Lower
BIACH Control	-7.1 ± 24.6	17.5	-31.6
BIACH Control Males	-6.3 ± 23.4	17.2	-29.7
BIACH Control Females	-7.7 ± 25.9	18.2	-33.6
BIADE Control	-7.6 ± 22.9	15.3	-30.6
BIADE Control Males	-6.7 ± 23.1	16.4	-29.8
BIADE Control Females	-8.3 ± 23.4	15.0	-31.7
BIAK Control	-5.9 ± 24.6	18.8	-30.5
BIAK Control Males	-6.0 ± 23.7	17.7	-29.8
BIAK Control Females	-5.8 ± 25.9	20.2	-31.7
BIALO Control	-4.0 ± 23.9	20.0	-27.9
BIALO Control Males	-2.9 ± 24.4	21.6	-27.3
BIALO Control Females	-4.7 ± 24.1	19.4	-28.8
BIASU Control	-4.0 ± 23.8	19.8	-27.8
BIASU Control Males	-3.9 ± 23.5	19.7	-27.4
BIASU Control Females	-4.2 ± 26.6	22.4	-30.8

Table 3.8. *DS SF Results*

DS Group					
	Mean ± SD	p	Cohen's *d*	r	SEE
Combined (n = 33)					
4CBF%	36.0 ± 8.6				
SFDW	32.3 ± 6.7	.002	0.59	0.70	4.9
SFJ	27.7 ± 8.6	<.000	1.24	0.70	6.3
SFLO	26.6 ± 7.2	<.000	1.24	0.55	6.1
SFRO	34.1 ± 4.9	.220	0.22	0.26	4.8
SFLE	33.4 ± 7.2	.012	0.47	0.77	4.7
SFO10	28.7 ± 7.5	<.000	1.16	0.70	5.4
SFOBMI	32.7 ± 8.9	.001	0.62	0.82	5.2
Males (n = 14)					
4CBF%	29.9 ± 4.4				
SFDW	25.8 ± 3.3	.007	0.85	0.26	3.3
SFJ	20.5 ± 4.7	<.000	1.86	0.40	4.5
SFLO	22.9 ± 5.0	<.000	1.36	0.41	4.8
SFRO	30.0 ± 3.4	.936	-0.02	-0.16	3.5
SFKR	28.8 ± 8.2	.582	0.15	0.52	7.3
SFLE	26.7 ± 3.4	.017	0.73	0.40	3.3
SFO10	21.4 ± 3.6	<.000	1.73	0.27	3.6
SFOBMI	25.3 ± 6.2	.005	0.89	0.59	5.2
Females (n = 19)					
4CBF%	40.5 ± 8.2				
SFDW	37.1 ± 3.7	.055	0.47	0.47	3.4
SFJ	32.9 ± 6.9	<.000	0.97	0.48	6.3
SFLO	20.4 ± 7.4	<.000	1.28	0.38	7.0
SFRO	37.1 ± 3.5	.164	0.33	-0.45	3.2
SFLE	38.4 ± 4.8	.166	0.33	0.64	3.7
SFO10	34.0 ± 4.8	.001	0.90	0.48	4.0
SFOBMI	38.1 ± 6.4	.067	0.45	0.75	4.4

Table 3.9. *Control SF Results*

Control Group					
	Mean ± SD	p	Cohen's *d*	r	SEE
Combined (n = 33)					
4CBF%	25.6 ± 11.9				
SFDW	24.8 ± 8.5	.616	0.09	0.71	6.0
SFJ	20.0 ± 9.6	.001	0.66	0.71	6.9
SFLO	18.4 ± 7.3	<.000	0.83	0.69	5.4
SFLE	26.8 ± 8.2	.341	-0.17	0.80	5.0
SFO10	22.7 ± 8.7	.078	0.32	0.66	6.6
SFOBMI	25.5 ± 8.1	.961	0.01	.71	5.8
Males (n = 14)					
4CBF%	20.4 ± 10.6				
SFDW	17.9 ± 5.2	.270	0.31	0.66	4.1
SFJ	12.5 ± 4.9	.004	0.93	0.62	4.0
SFLO	15.5 ± 5.3	.040	0.61	0.68	4.1
SFLE	20.9 ± 5.8	.804	-0.07	0.69	4.4
SFO10	14.9 ± 3.4	.037	0.62	0.64	2.7
SFOBMI	18.4 ± 4.4	.456	0.21	0.46	4.0
Females (n = 19)					
4CBF%	29.4 ± 11.5				
SFDW	30.0 ± 6.5	.769	-0.07	0.70	4.8
SFJ	25.5 ± 8.5	.054	0.47	0.70	6.3
SFLO	20.5 ± 7.9	<.000	1.00	0.64	6.3
SFLE	31.1 ± 7.1	.292	-0.25	0.83	4.1
SFO10	28.5 ± 6.5	.664	0.10	0.65	5.1
SFOBMI	30.7 ± 6.0	.449	-0.18	0.83	3.5

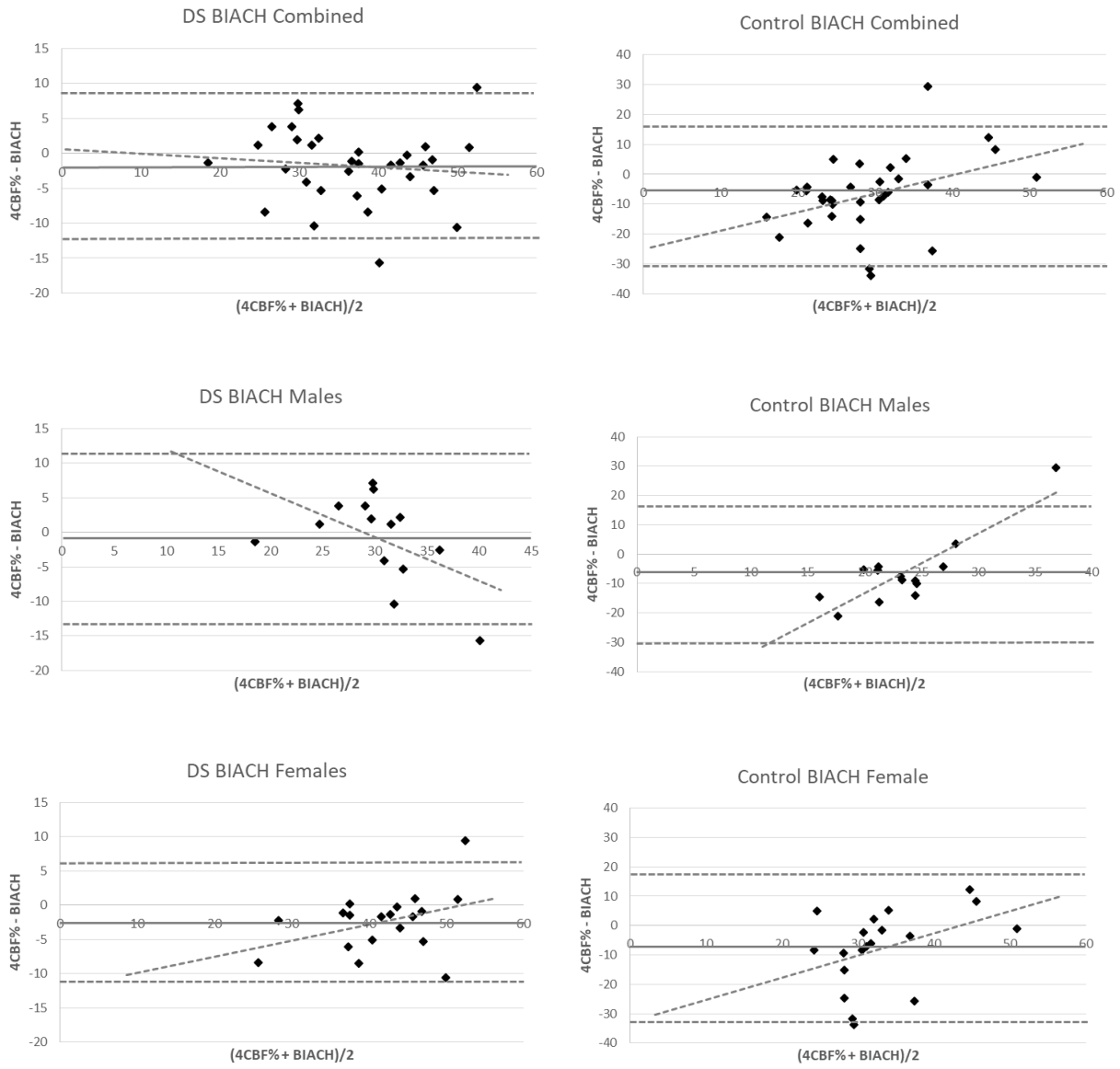
Table 3.10. *95% Limits of Agreement DS 4CBF%-SF*

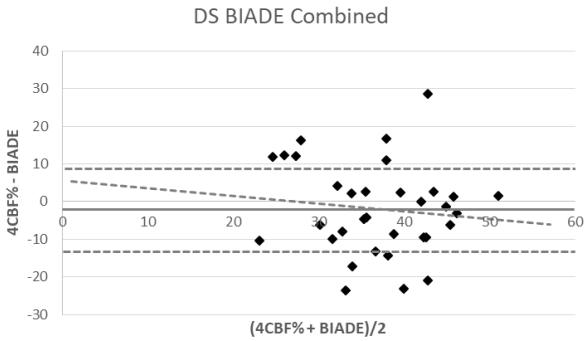
	95% Limits of Agreement		
	Mean difference ± 1.96×SD	Upper	Lower
SFDW Combined DS	3.7 ± 12.2	15.9	-8.5
SFDW DS Males	4.1 ± 9.3	13.4	-5.3
SFDW DS Females	3.4 ± 14.2	17.6	-10.8
SFJ Combined DS	8.3 ± 13.2	21.5	-4.9
SFJ DS Males	9.3 ± 9.8	19.2	-0.5
SFJ DS Females	7.6 ± 15.3	22.9	-7.7
SFLO Combined DS	9.4 ± 14.9	24.3	-5.5
SFLO DS Males	7.0 ± 10.1	17.1	-3.1
SFLO DS Females	11.2 ± 17.1	28.2	-5.9
SFRO Combined DS	1.9 ± 17.2	19.1	-15.3
SFRO DS Males	-0.1 ± 11.7	11.6	-11.8
SFRO DS Females	3.4 ± 20.1	23.5	-16.7
SFKR DS Males	1.1 ± 13.7	14.8	-12.7
SFLE Combined DS	2.6 ± 10.8	13.3	-8.2
SFLE DS Males	3.2 ± 8.6	11.8	-5.4
SFLE DS Females	2.1 ± 12.3	14.4	-10.2
SFO10 Combined DS	7.3 ± 12.3	19.7	-5.0
SFO10 DS Males	8.4 ± 9.6	18.0	-1.1
SFO10 DS Females	6.5 ± 14.1	20.6	-7.6
SFOBMI Combined DS	3.3 ± 10.4	13.8	-7.1
SFOBMI DS Males	4.5 ± 10.0	14.5	-5.5
SFOBMI DS Females	2.4 ± 10.7	13.1	-8.3

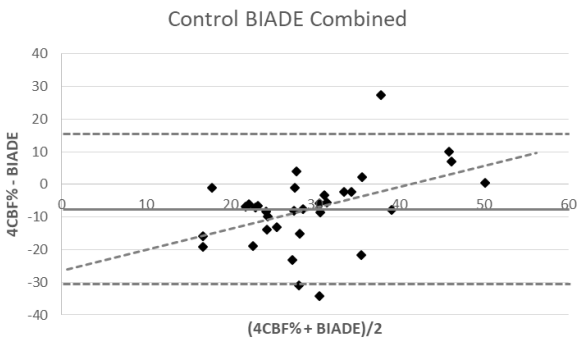
Table 3.11. *95% Limits of Agreement Control 4CBF%-SF*

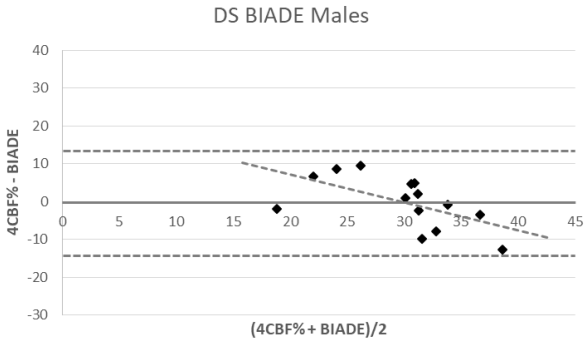
	95% Limits of Agreement		
	Mean difference ± 1.96×SD	Upper	Lower
SFDW Control	0.7 ± 16.3	17.1	-15.6
SFDW Control Males	2.5 ± 16.0	18.5	-13.5
SFDW Control Females	-0.6 ± 16.5	15.9	-17.1
SFJ Control	5.6 ± 16.6	22.2	-11.0
SFJ Control Males	7.9 ± 16.7	24.5	-8.8
SFJ Control Females	3.9 ± 16.3	20.2	-12.3
SFLO Control	7.2 ± 17.0	24.1	-9.8
SFLO Control Males	4.9 ± 15.8	20.7	-10.9
SFLO Control Females	8.9 ± 17.5	26.3	-8.6
SFLE Control	-1.2 ± 14.2	12.9	-15.4
SFLE Control Males	-0.5 ± 15.4	14.9	-15.9
SFLE Control Females	-1.7 ± 13.5	11.8	-15.2
SFO10 Control	2.9 ± 17.6	20.5	-14.8
SFO10 Control Males	5.5 ± 17.4	22.9	-11.9
SFO10 Control Females	0.9 ± 17.2	18.1	-16.3
SFOBMI Control	0.1 ± 16.4	16.4	-16.3
SFOBMI Control Males	1.9 ± 18.6	20.5	-16.6
SFOBMI Control Females	-1.3 ± 14.5	13.2	-15.8

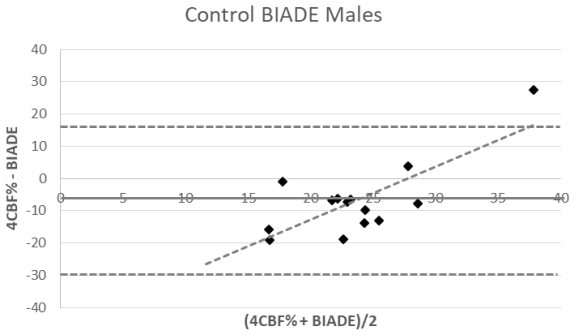
Figure 3.1. Bland-Altman plots showing the agreement between BF% values from 4CBF% and BIA for combined, male, and female groups for subjects with DS and controls. The outside dashed lines show the upper and lower limits of agreement, while the solid middle line shows the mean difference between the methods. The dashed regression line shows the trend between the difference of 4CBF% and BIA and their mean.

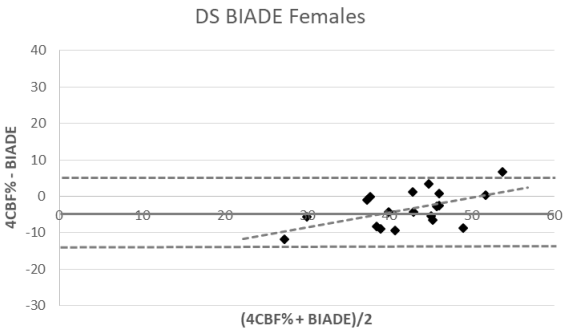


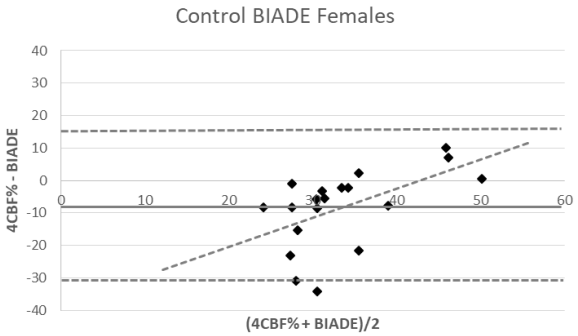

DS BIADE Combined
4CBF% - BIADE
(4CBF%+ BIADE)/2

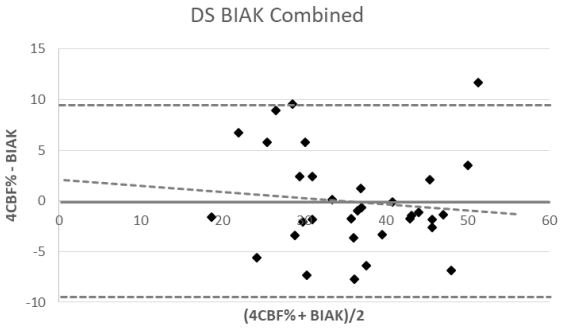

Control BIADE Combined
4CBF% - BIADE
(4CBF%+ BIADE)/2

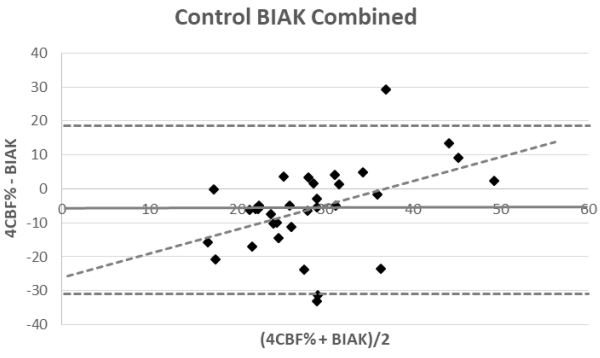

DS BIADE Males
4CBF% - BIADE
(4CBF%+ BIADE)/2


Control BIADE Males
4CBF% - BIADE
(4CBF%+ BIADE)/2


DS BIADE Females
4CBF% - BIADE
(4CBF%+ BIADE)/2


Control BIADE Females
4CBF% - BIADE
(4CBF%+ BIADE)/2


DS BIAK Combined
4CBF% - BIAK
(4CBF%+ BIAK)/2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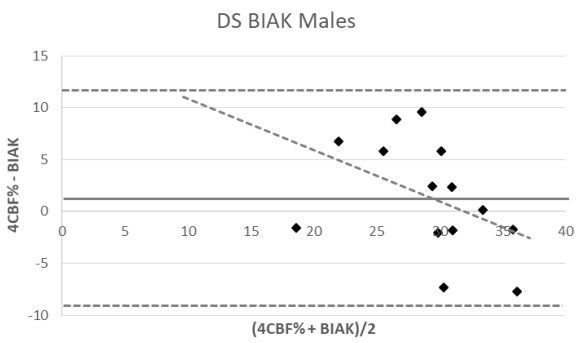
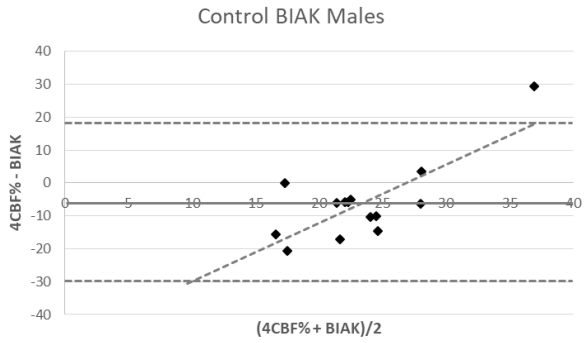
4CBF% - BIAK
(4CBF%+ BIAK)/2


DS BIAK Males
4CBF% - BIAK
(4CBF%+ BIAK)/2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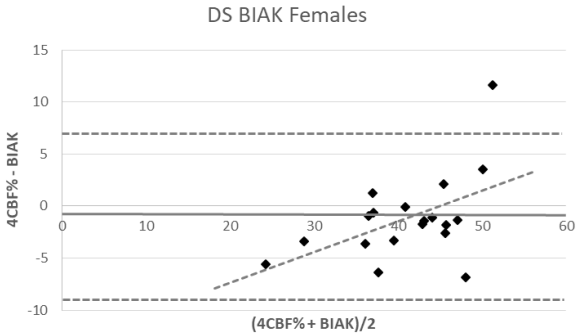
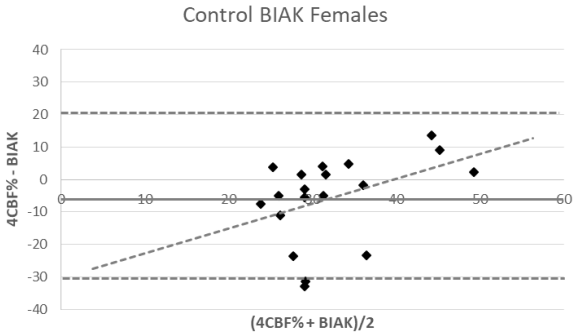
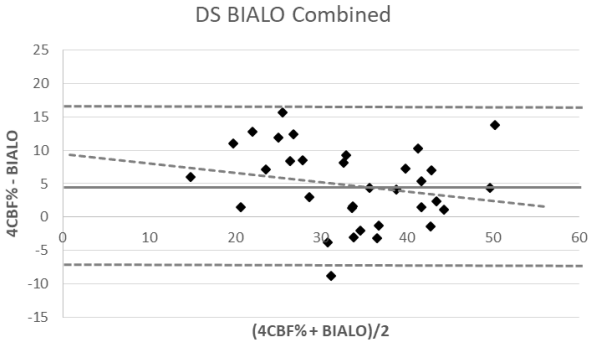
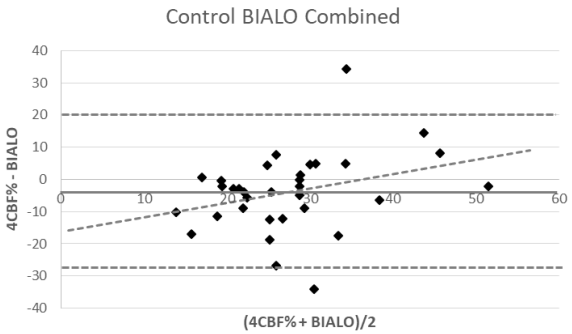
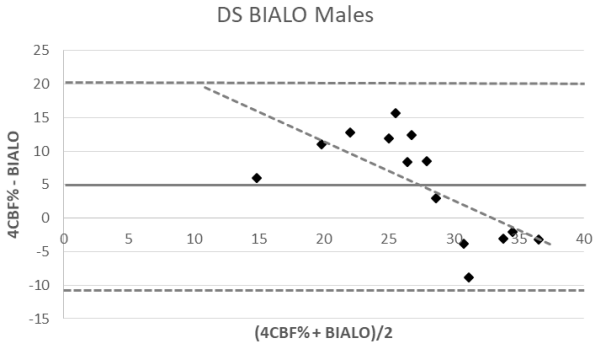
4CBF% - BIAK
(4CBF%+ BIAK)/2

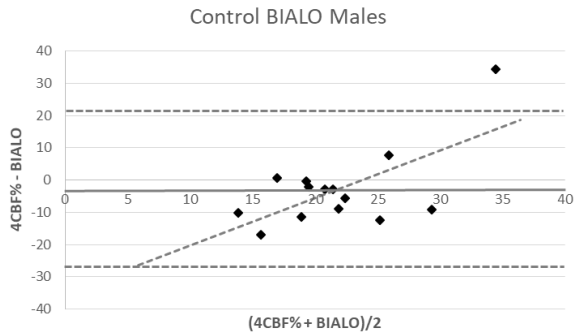

DS BIAK Females
4CBF% - BIAK
(4CBF%+ BIAK)/2

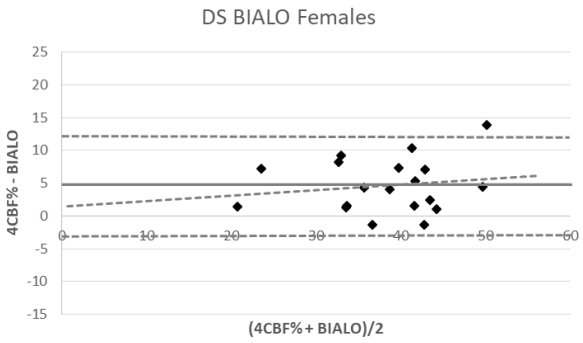

Control BIAK Females
4CBF% - BIAK
(4CBF%+ BIAK)/2

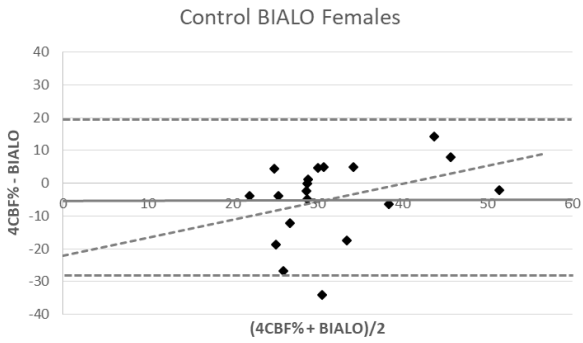

DS BIALO Combined
4CBF% - BIALO
(4CBF%+ BIALO)/2

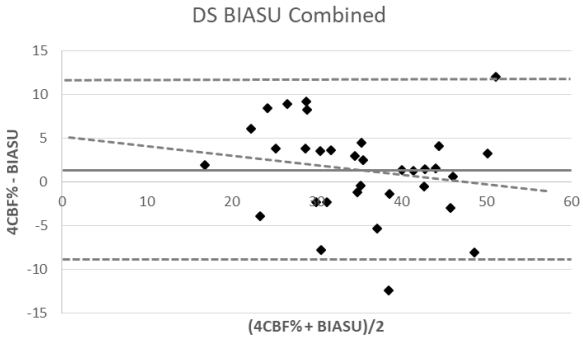

Control BIALO Combined
4CBF% - BIALO
(4CBF%+ BIALO)/2


DS BIALO Males
4CBF% - BIALO
(4CBF%+ BIALO)/2


Control BIALO Males
4CBF% - BIALO
(4CBF%+ BIALO)/2


DS BIALO Females
4CBF% - BIALO
(4CBF%+ BIALO)/2


Control BIALO Females
4CBF% - BIALO
(4CBF%+ BIALO)/2


DS BIASU Combined
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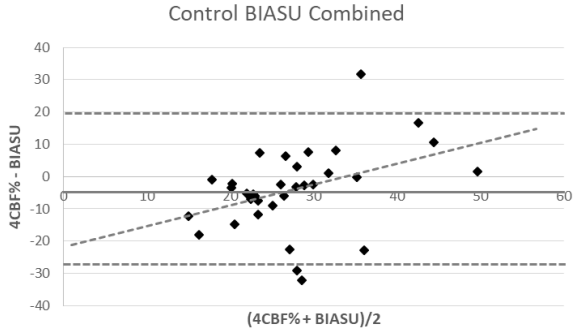
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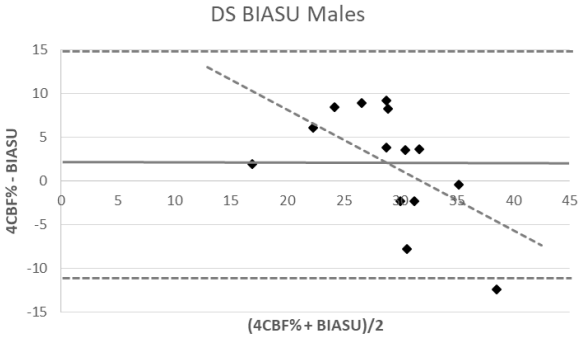
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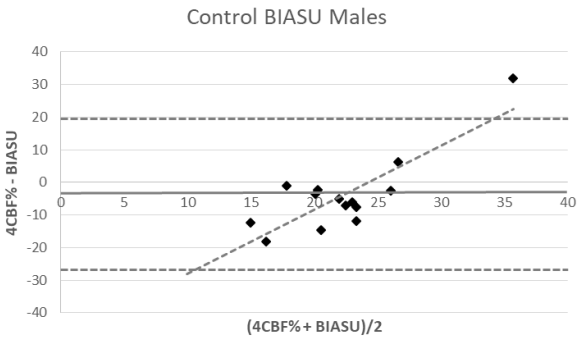
(4CBF%+ BIASU)/2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4CBF% - BIASU
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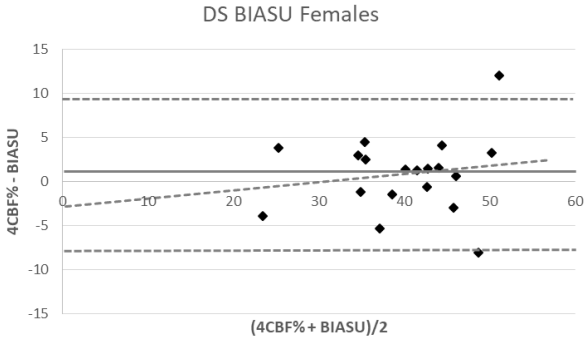

DS BIASU Females
4CBF% - BIASU
(4CBF%+ BIASU)/2

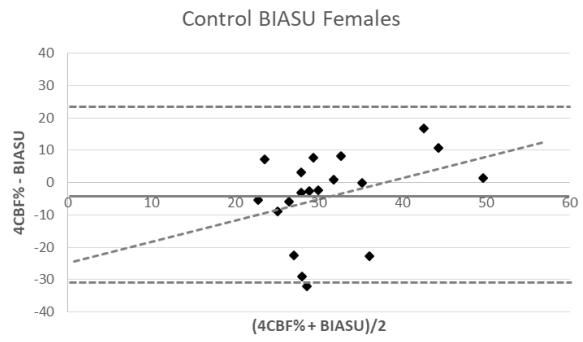
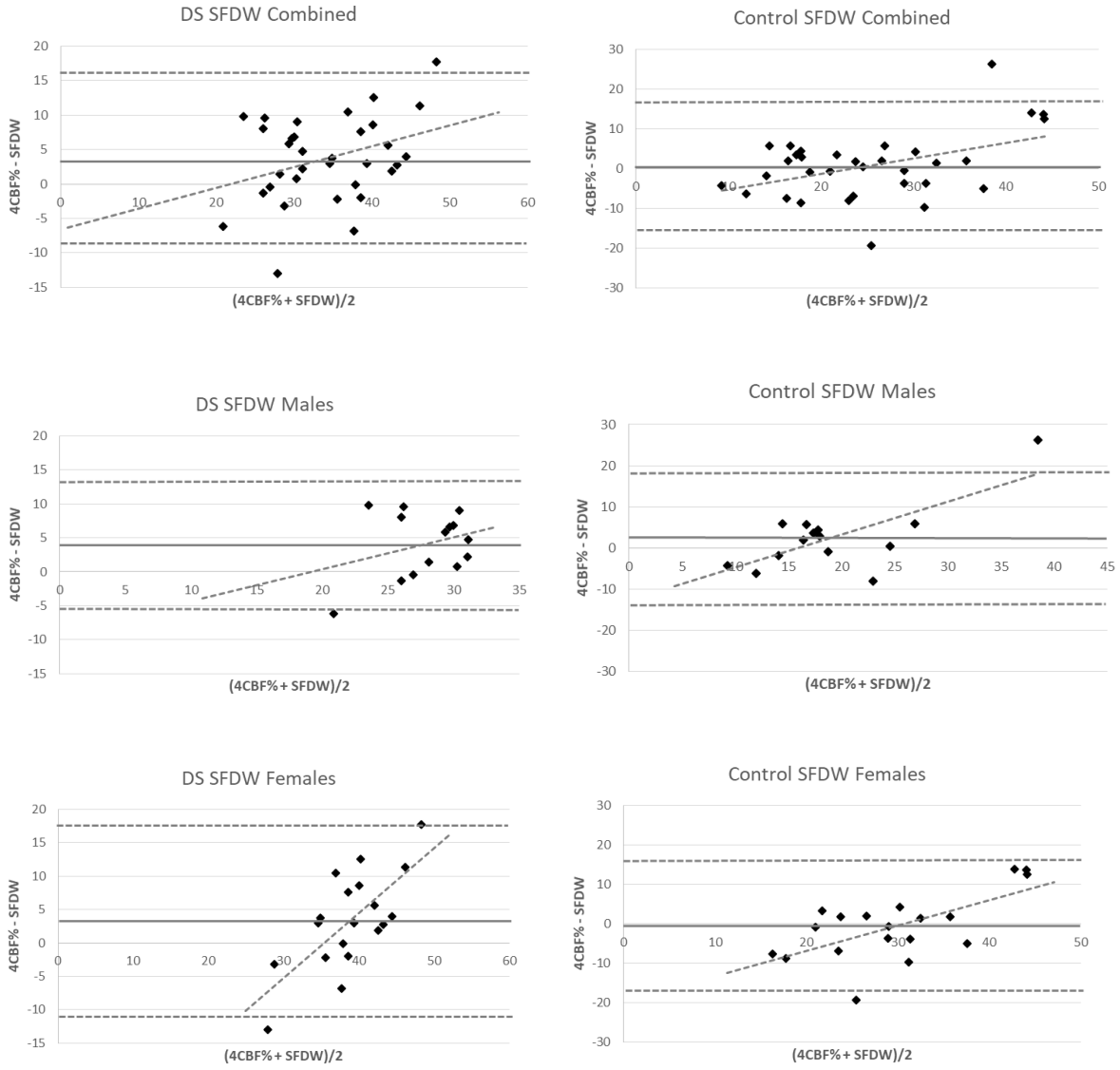
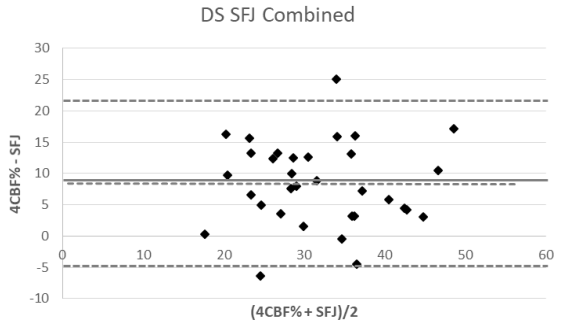
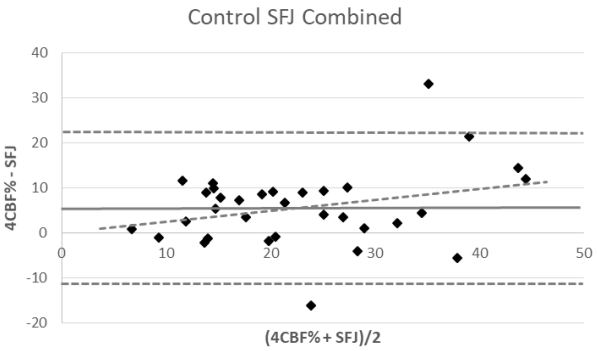

Control BIASU Females
4CBF% - BIASU
(4CBF%+ BIASU)/2

Figure 3.2. Bland-Altman plots showing the agreement between BF% values from 4CBF% and SF for combined, male, and female groups for subjects with DS and controls. The outside dashed lines show the upper and lower limits of agreement, while the solid middle line shows the mean difference between the methods. The dashed regression line shows the trend between difference of 4CBF% and SF and their mean.




DS SFJ Combined
4CBF% - SFJ
(4CBF%+ SFJ)/2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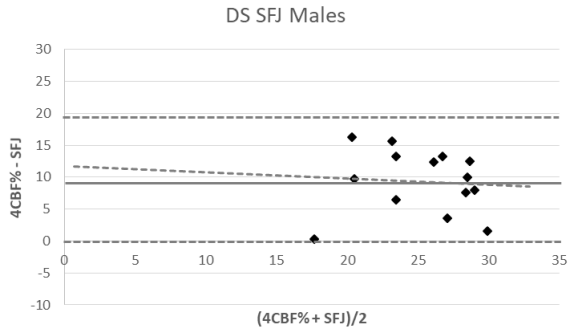
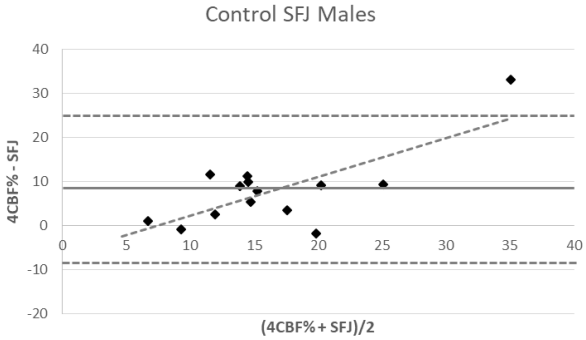
4CBF% - SFJ
(4CBF%+ SFJ)/2


DS SFJ Males
4CBF% - SFJ
(4CBF%+ SFJ)/2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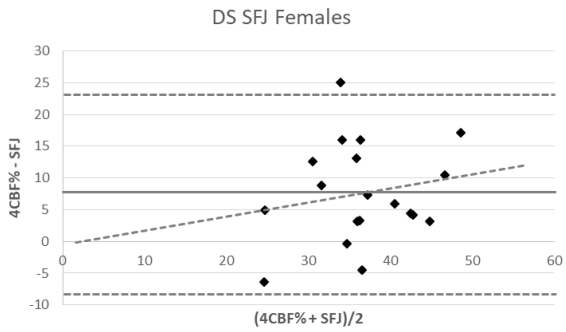
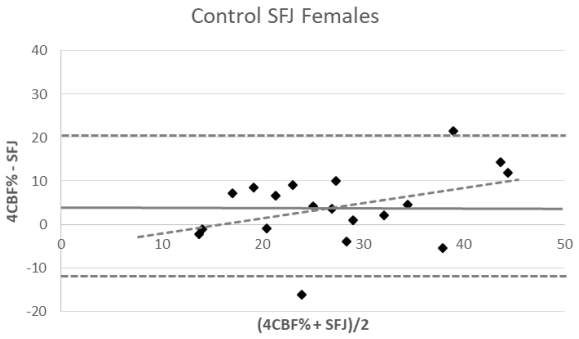
4CBF% - SFJ
(4CBF%+ SFJ)/2


DS SFJ Females
4CBF% - SFJ
(4CBF%+ SFJ)/2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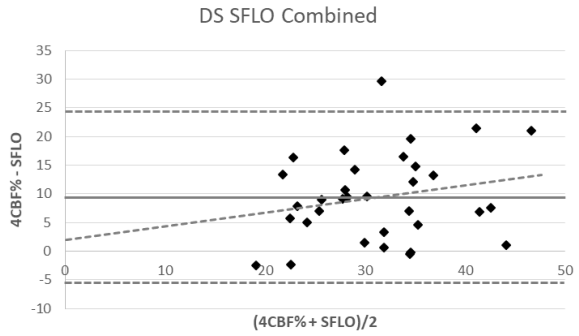
(4CBF%+ SFJ)/2


DS SFLO Combined
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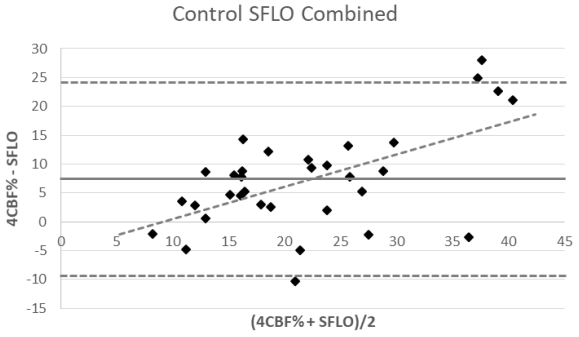
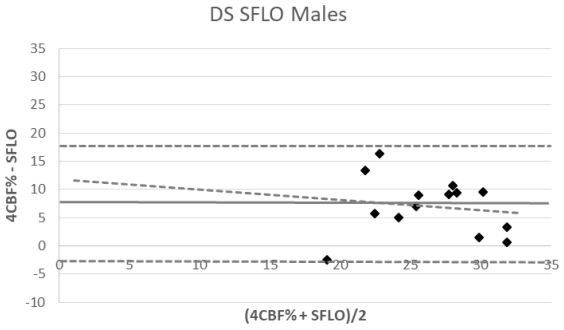
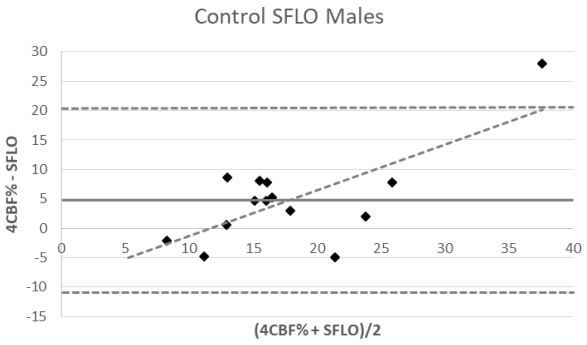
(4CBF%+ SFLO)/2


Control SFLO Combined
4CBF% - SFLO
(4CBF%+ SFLO)/2


DS SFLO Males
4CBF% - SFLO
(4CBF%+ SFLO)/2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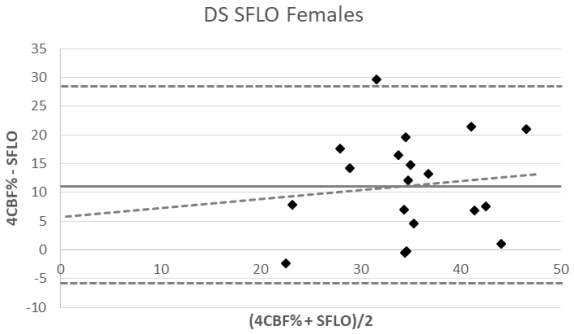
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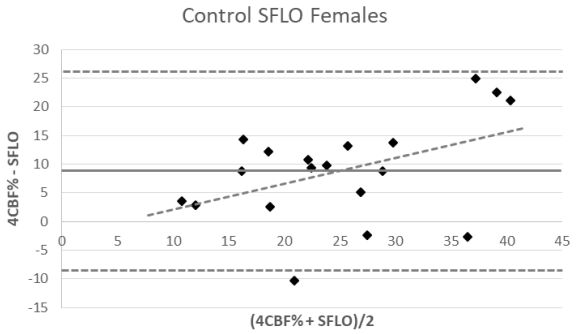
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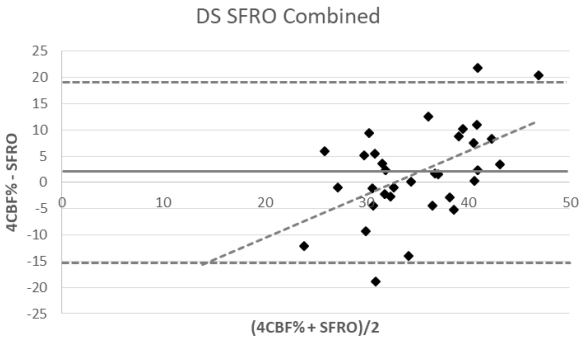
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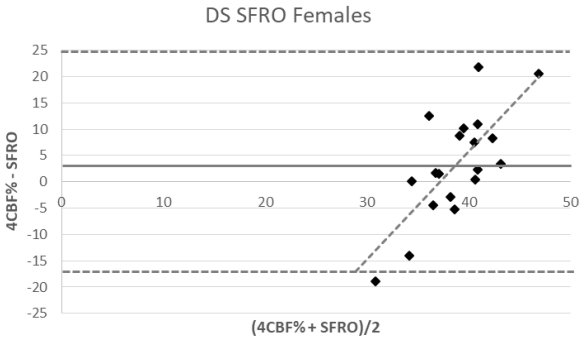
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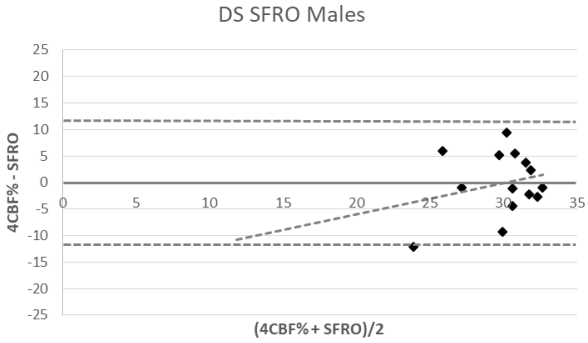
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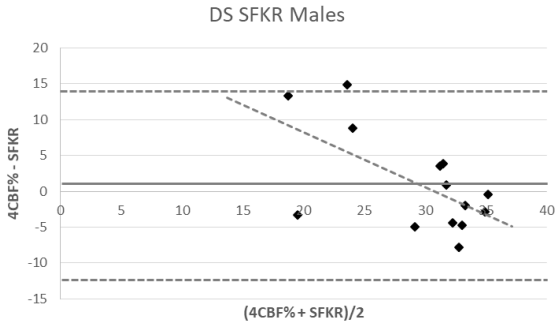
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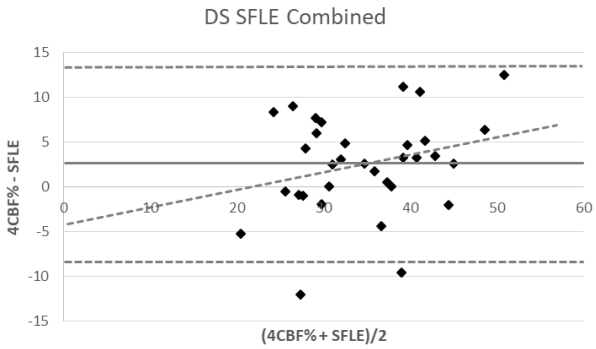
DS SFLE Combined
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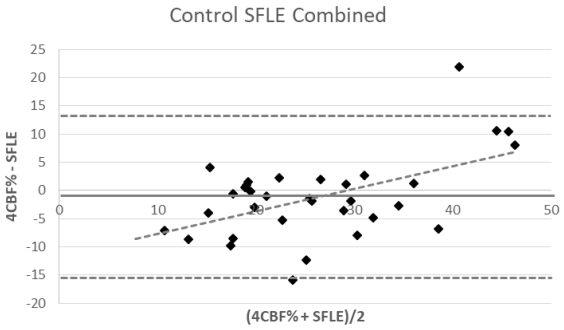
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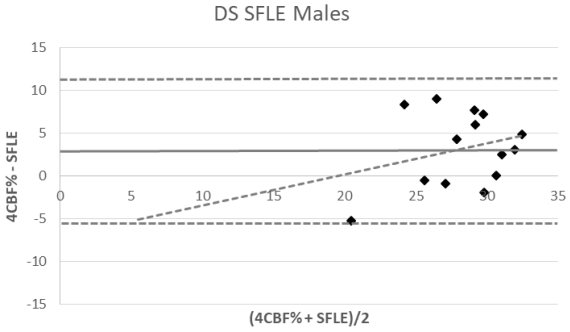
DS SFLE Males
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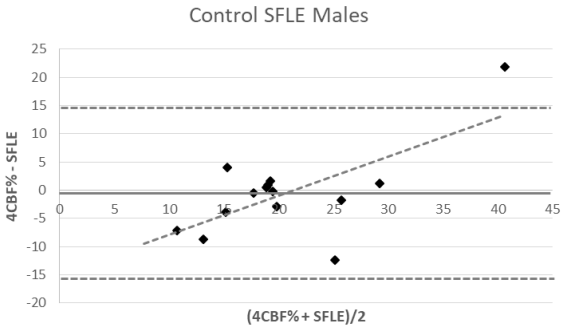
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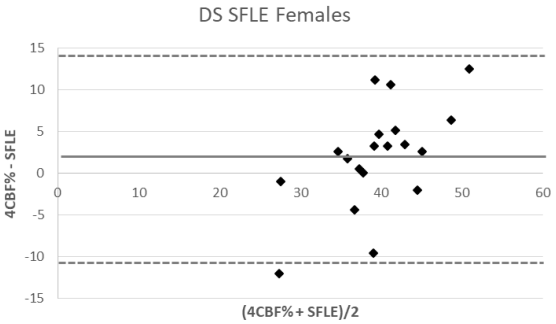
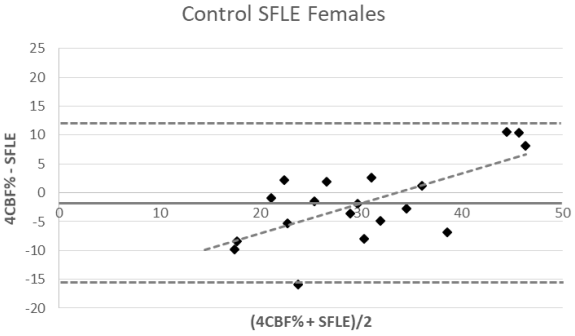
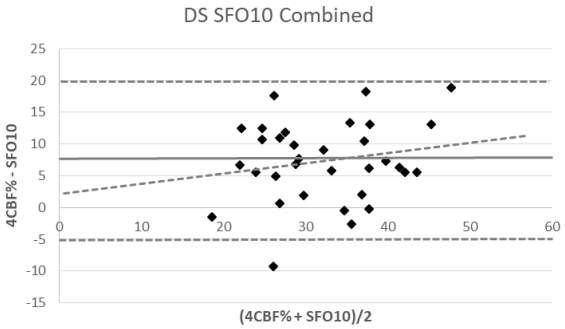
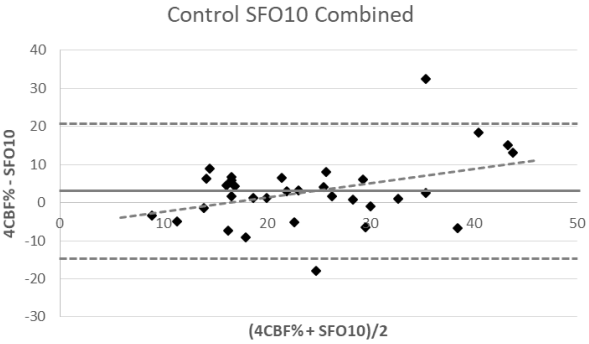
(4CBF%+ SFLE)/2


DS SFLE Females
4CBF% - SFLE
(4CBF%+ SFLE)/2


Control SFLE Females
4CBF% - SFLE
(4CBF%+ SFLE)/2


DS SFO10 Combined
4CBF% - SFO10
(4CBF%+ SFO10)/2


Control SFO10 Combined
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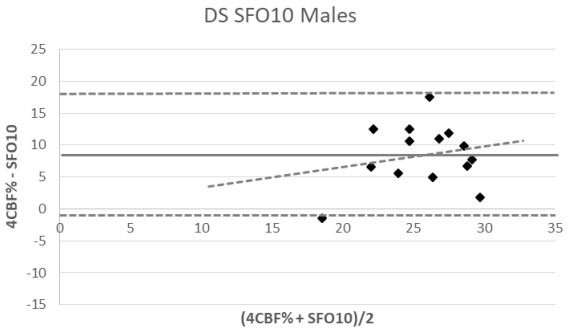
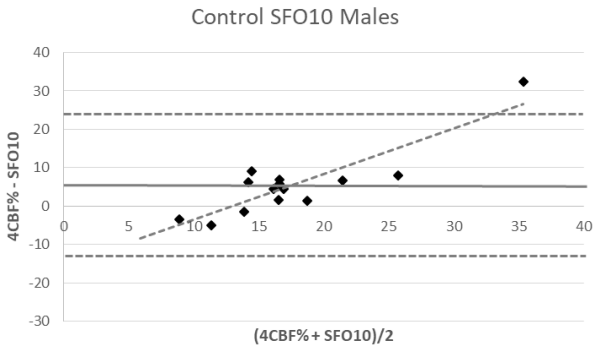
(4CBF%+ SFO10)/2


DS SFO10 Males
4CBF% - SFO10
(4CBF% + SFO10)/2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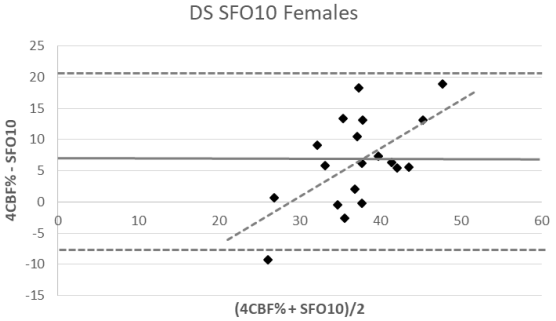
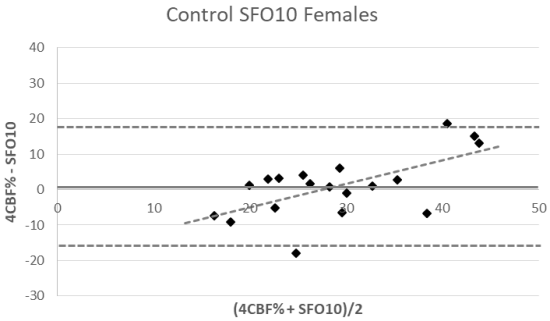
(4CBF% + SFO10)/2


DS SFO10 Females
4CBF% - SFO10
(4CBF% + SFO10)/2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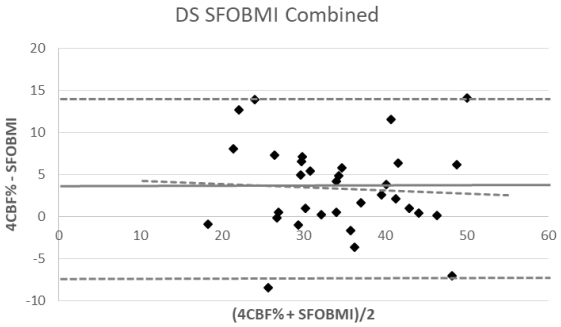
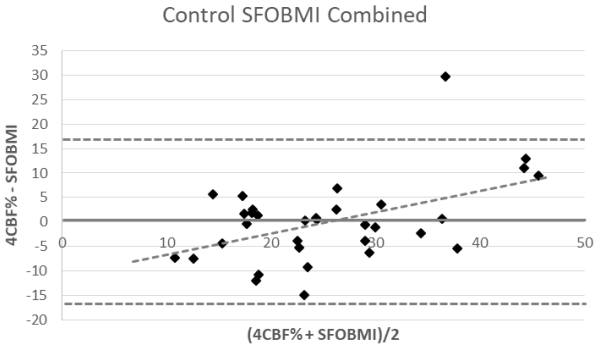
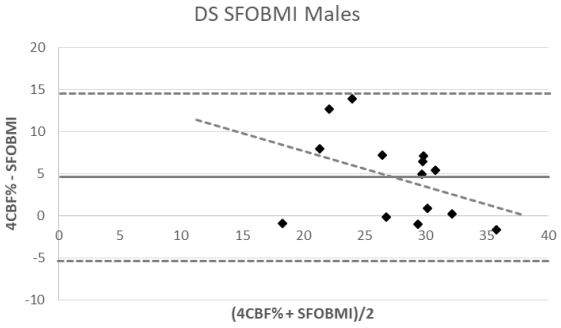
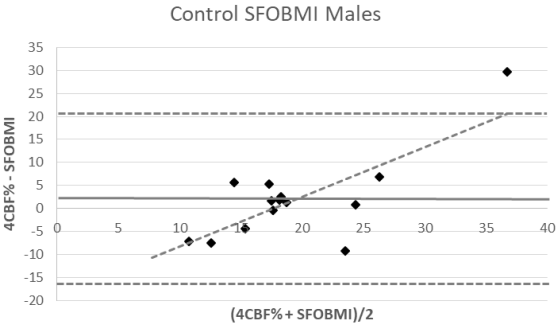
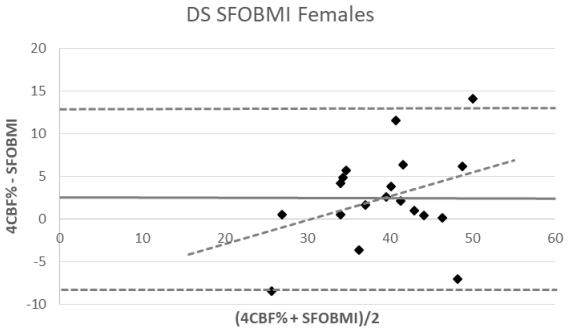
4CBF% - SFO10
(4CBF% + SFO10)/2

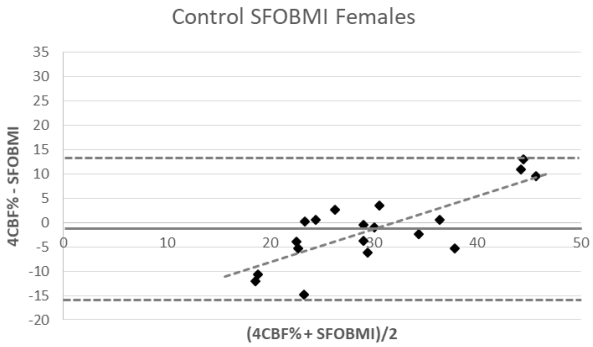

DS SFOBMI Combined
4CBF% - SFOBMI
(4CBF% + SFOBMI)/2


Control SFOBMI Combined
4CBF% - SFOBMI
(4CBF% + SFOBMI)/2


DS SFOBMI Males
4CBF% - SFOBMI
(4CBF% + SFOBMI)/2


Control SFOBMI Males
4CBF% - SFOBMI
(4CBF% + SFOBMI)/2


DS SFOBMI Females
4CBF% - SFOBMI
(4CBF% + SFOBMI)/2
20
15
10
5
0
-5
-10
0
10
20
30
40
50
60


Control SFOBMI Females
4CBF% - SFOBMI
(4CBF% + SFOBMI)/2
35
30
25
20
15
10
5
0
-5
-10
-15
-20
0
10
20
30
40
50

CHAPTER 4

AGREEMENT BETWEEN BIOELECTRICAL IMPEDANCE ANALYSIS AND DUAL-ENERGY X-RAY ABSORPTIOMETRY IN ASSESSING BONE MINERAL CONTENT IN ADULTS WITH DOWN SYNDROME

ABSTRACT

The purpose of this study was to examine the agreement between BIA and DXA in measuring BMC in adults with DS. Twenty-one adults (8 men, 13 women) over age 23 with DS completed the study. Twenty-one healthy adults (8 men, 13 women) over age 23 without DS served as a control group. For each group, BMC was assessed with both bioelectrical impedance analysis (BIA) and DXA. BMC values from BIA and DXA were compared using dependent t-tests. Pearson correlation was also used and 95% limits of agreement were determined using the method of Bland and Altman (1986). In adults with DS, BIA overestimated BMC compared to DXA when men and women were analyzed together ($t = -5.237$, $df = 20$, $p < .000$). There were no differences in mean BMC between BMC and DXA in males with DS ($t = -1.116$, $df = 7$, $p = .301$), but individual data points suggest that agreement is different for individuals with high and low BMC. In females with DS, BMC from DXA was significantly lower than BMC from P12BIA ($t = -7.978$, $df = 12$, $p = .000$). BIA underestimated BMC compared to DXA in control males ($t = 5.641$, $df = 7$, $p = .001$), but was not significantly different from DXA in control females ($t = .879$, $df = 12$, $p = .397$). *Conclusions:* The BIA method tested in the present study provides reasonable estimates of BMC for adult females in the general population. However,

additional population-specific equations should be developed for adult males in the general population and for adult males and females with DS using individuals with a wider range of heights.

KEY WORDS: Down syndrome, bioelectrical impedance analysis, bone density, body fat assessment

INTRODUCTION

Down syndrome (DS) is a common cause of intellectual disability, affecting around one to three in 1,000 births [Covelli et al., 2016]. People with DS display distinct physical characteristics [Fegan, 2011; Fernhall et al., 2013; Heward, 2013] and have a propensity for obesity [Izquierdo-Gomez et al., 2014; Izquierdo-Gomez et al., 2015; Nickerson et al., 2015; Oviedo et al., 2014] and low bone mineral content (BMC) [Geijer et al., 2014; Guijarro et al., 2008; Srikanth et al., 2011; Van Allen et al., 1999]. In recent years, life expectancy for this population has increased dramatically to around age 60 [Glasson et al., 2002]. However, individuals with DS experience premature aging and must contend with age-related health conditions earlier than people in the general population [Covelli et al., 2016]. As those with DS also often display multiple risk factors for osteoporosis and experience poor bone health at earlier ages than individuals in the general population [Geijer et al., 2014], providing accurate measures of BMC and effective interventions for low BMC is critical to helping individuals with DS manage their health throughout life.

Laboratory measures such as dual-energy x-ray absorptiometry (DXA) can assess BMC [Lowry & Tomiyama, 2015] with high precision across many populations [Casey, 2013]. However, DXA scans are expensive and often unavailable outside of a medical or laboratory setting, thus making them impractical for large-scale use [Casey, 2013; Esco et al., 2016;

González-Agüero et al., 2011]. In addition, individuals undergoing a DXA scan also are exposed to small levels of radiation [Esco et al., 2016]. Furthermore, DXA requires a person to lie still for several minutes, which may be a challenge and even cause anxiety for people with DS [González-Agüero, 2017; Määttä et al., 2006]. Therefore, despite the precision of DXA measurements, field alternatives are needed to assess BMC in this population in settings outside of the laboratory.

Because of the limited availability of DXA and the increased risk of osteoporosis in DS, having a simple field measure to measure BMC would be valuable for individuals with DS. Although BIA has been validated to assess BMC in healthy and obese adults over the age of 23 [Patil et al., 2012], research examining the validity of BIA to assess BMC has not been conducted on individuals with DS. Additionally, the equation [Patil et al., 2012] developed to estimate BMC from BIA was developed with Indian adults, and therefore further research is warranted to determine if this equation is appropriate for use in other populations. A further consideration is the finding of poor agreement between BMC values obtained from BIA and those from DXA in adult smokers, who have lower BMC than individuals in the general population [Rom et al., 2015]. Since individuals with DS also display reduced BMC, further study is needed before BIA can be considered a valid method for assessing BMC in DS. Therefore, the purpose of this study was to examine the agreement of BMC in adults with DS between DXA and multi-frequency BIA using the equation developed by Patil et al. (2012) (P12BIA).

METHODS

Participants

Study participants were recruited from the local community and met the following inclusion criteria: 23 years of age or older, male or female, and diagnosed with DS. Twenty-four adults with DS volunteered to participate in the study, but one subject was unable to stand still long enough to complete the BIA measurement, and one participant was afraid to hold the handles for the BIA measurement due to difficulty with balance. An additional subject was afraid of lying supine and did not complete the DXA. Twenty-one adults with DS (8 men, 13 women) completed the study along with a control group of twenty-one healthy adults without DS (8 men, 13 women). Control subjects and subjects with DS were matched by age, sex, and race (Table 4.1). All participants as well as a parent or guardian of participants with DS provided written consent. In order to assist with the consent process and reduce the potential for anxiety during testing, a parent or guardian for each subject with DS was present during all procedures.

Procedures

Before testing, adequate hydration was established with urine specific gravity (USG) of < 1.020 [Kavouras, 2002] assessed with a handheld refractometer (Atago SUR-NE, Atago Corp Ltd., Tokyo, Japan). Three subjects with a USG ≥ 1.020 were given the chance to drink water and were retested after thirty minutes. All three subjects achieved adequate hydration and completed the remainder of the study. Height was measured to the nearest 0.10 cm with a wall-mounted stadiometer (SECA; Seca Instruments Ltd., Hamburg, Germany), and body weight was measured to the nearest 0.10 kg with a digital scale (Tanita BWB-800A, Tanita Corp., Tokyo, Japan) (Table 4.1).

Control subjects and a parent or guardian of subjects with DS also completed the Godin Leisure-Time Exercise Questionnaire [Godin & Shephard, 1997], a four-item questionnaire for assessing the frequency of a person's strenuous, moderate, or light physical activity during a typical week. A total leisure activity score (TLAS) was then calculated for each participant using the following formula: TLAS = (9 × Strenuous) + (5 × Moderate) + (3 × Light). Individuals with TLAS scores of 24 or higher were classified as active, those with TLAS scores of 14 to 23 were classified as moderately active, and subjects with TLAS scores of less than 14 were classified as sedentary. Subject classifications from the Godin Leisure-Time Exercise Questionnaire are presented in Table 4.2.

Parents or guardians of subjects with DS also completed the Adaptive Behavior Assessment System, Third Edition (ABAS-3) [Harrison & Oakland, 2015] to assess their adult relative's adaptive behaviors in the following skill areas: communication, community use, functional academics, home living, health and safety, leisure, self-care, self-direction, social, and work. Subjects were evaluated on 20 to 26 items in each skill area and given a score for each item ranging from 0 to 3. A score of zero indicated that the participant cannot perform the skill, while a score of 3 indicated that the subject can perform the skill and always or almost always performs the skill when needed. Scores for each item were added to calculate a score for each skill area, and scores from each skill area were combined into a General Adaptive Composite, which was used to classify each individual's overall adaptive behavior as high, above average, average, below average, low, or extremely low. Sample items from the ABAS-3 are presented in the Appendix, and the results of the ABAS-3 are presented in Table 4.3.

Multi-Frequency Bioelectrical Impedance Analysis

Multi-frequency BIA was performed with the InBody 720 (InBody CO., LTD., Cerritos, CA). Subjects removed their socks and shoes, and stood with the heel and ball of each foot on metal electrodes on a scale. They also held a handle in each hand with the palm and thumb of each hand in contact with metal electrodes on the handles. Subjects were told to hold their arms extended and down to their sides, abducted 20 degrees. Once in the correct position, subjects were instructed to stand still for approximately one minute. A technician physically assisted subjects with DS to attain the correct position. A technician and parent also remained with subjects with DS during the procedure to remind subjects to remain still.

The equation developed by Patil et al. (2012) was used to estimate BMC (P12BIA): BMC = $-0.243 - (634 \times (Ht^2/Z_{body250})) - (0.0159 \times age) + (5.79 \times Ht) - (0.0041 \times R_{body250}) + (0.048 \times X_{body250}/Ht) - (0.05 \times (Z_{body5} - Z_{body250})/age) - (0.48 \times \phi_{body250})$, where X = reactance, R = resistance, Z = impedance, ϕ = phase angle, and Ht = height. The following formulas were used to calculate the components of P12BIA:

Resistance of a segment at *f* kHz: $R_{sf} = \text{sqrt}\ (Z_{sf}^2 - X_{sf}^2)$

Phase angle of a segment at *f* kHz: $\phi_{sf} = \tan^{-1}\ (X_{sf} / R_{sf})$

Body resistance at *f* kHz: $R_{bodyf} = R_{RAf} + R_{LAf} + R_{TRf} + R_{RLf} + R_{LLf}$

Body reactance at *f* kHz: $X_{bodyf} = X_{RAf} + X_{LAf} + X_{TRf} + X_{RLf} + X_{LLf}$

Body impedance at *f* kHz: $Z_{bodyf} = \text{sqrt}\ (R_{bodyf}^2 + X_{bodyf}^2)$

Phase angle of the body at *f* kHz: $\phi_{bodyf} = \tan^{-1}\ (X_{bodyf} / R_{bodyf})$

RA, LA, TR, RL, and LL are right arm, left arm, trunk, right leg, and left leg.

Dual Energy X-ray Absorptiometry

BMC was measured with a calibrated DXA scanner (GE Lunar Prodigy, Software version 10.50.086, GE Lunar Corp., Madison, WI). Before the scan, subjects removed their shoes and any metal. During the scan, subjects were instructed to lie still in a supine position on the bed of the scanner with their arms down by their side. Each scan lasted around 6 to 11 minutes. For subjects with DS, both the laboratory technician and a parent or guardian spoke to the subject from the required distance away from the scanner during the scan to provide reassurance and verbal reminders to remain still.

Statistical Analysis

All data were analyzed using SPSS version 24.0 (Somers, NY, USA). Mean BMC obtained by DXA and P12BIA were compared with a dependent t-test, and Cohen's *d* was calculated to determine the effect size (ES) of the mean difference in BMC. The following values were used to determine the magnitude of the ES: trivial = ES < 0.2; small = 0.2-0.6; moderate = 0.6-1.2; large = 1.2-2.0; and very large > 2.0 [Hopkins et al., 2009]. Pearson correlation was also used to examine the relationship between BMC obtained with DXA and P12BIA, using the following values to describe the correlation: small < 0.30; moderate = 0.31-0.49; large = 0.50-0.69; very large = 0.70-0.89; and near perfect = 0.90-1.00 [Hopkins et al., 2009]. Additionally, 95% limits of agreement between BMC from DXA and P12BIA were identified using the method of Bland and Altman (1986). Data were also analyzed with both males and females combined and separately by sex. The level of significance was set at $p < .05$.

RESULTS

Overall agreement between DXA and P12BIA

Results are presented in Tables 4.4 and 4.5. In adults with DS with men and women combined, mean BMC from DXA was significantly lower than mean BMC from P12BIA (t = -5.237, df = 20, p < .000), with a mean difference of -378.5 ± 331.2 g between the two methods. The Cohen's *d* statistic showed a moderate ES of -1.14, and the Pearson correlation was large (r = .64, p = .002). In combined male and female control subjects, mean BMC from DXA was significantly higher than mean BMC from P12BIA (t = 3.110, df = 20, p = .006), with a mean difference of 228.5 ± 336.6 g between the two methods. The Cohen's *d* statistic showed a moderate ES of 0.68, and the Pearson correlation was very large (r = .85, p < .000). The Bland-Altman plots are presented in Figure 4.1. P12BIA over-predicted BMC compared to DXA in adults with DS and under-predicted BMC compared to DXA in control adults. The 95% limits of agreement were similar for both DS and control subjects.

Agreement between DXA and P12BIA in males

In male subjects with DS, there was no significant difference in BMC between DXA and P12BIA (t = -1.116, df = 7, p = .301). The Cohen's *d* statistic showed a small ES of -0.39, while the Pearson correlation was very large (r = .81, p = .016). In male control subjects, BMC from DXA was significantly higher than BMC from P12BIA (t = 5.641, df = 7, p = .001), with a mean difference of 543.5 ± 272.5 g between the two methods. The Cohen's *d* statistic showed a large ES of 1.99, while the Pearson correlation was moderate (r = .34), but not significant (p = .410). The Bland-Altman plots are presented in Figure 4. In male subjects with DS, P12BIA overestimated BMC compared to DXA for subjects with BMC below 2,000 g and underestimated BMC compared to DXA for subjects with BMC above 2,000 g. In male control

subjects, P12BIA provided lower BMC values compared to DXA. The 95% limits of agreement were similar for both DS and control subjects.

Agreement between DXA and P12BIA in females

In female subjects with DS, BMC from DXA was significantly lower than BMC from P12BIA ($t = -7.978$, $df = 12$, $p = .000$), with a mean difference of -548.3 ± 247.8 g between the two methods. The Cohen's *d* statistic showed a very large ES of -2.21, and the Pearson correlation was large ($r = .63$, $p = .021$). In female control subjects, there was no significant difference in BMC between DXA and P12BIA ($t = .879$, $df = 12$, $p = .397$). The Cohen's *d* statistic showed a trivial ES of 0.18, and the Pearson correlation was large ($r = .67$, $p = .005$). The Bland-Altman plots are presented in Figure 4. P12BIA over-predicted BMC compared to DXA in females with DS. P12BIA over-predicted BMC compared to DXA in most control females. The 95% limits of agreement were smaller for control females compared to females with DS.

DISCUSSION

The results of this study suggest that P12BIA does not provide accurate BMC estimates for adults with DS. Although there was no significant difference in BMC between DXA and P12BIA for males with DS, a closer examination of the individual data points reveals that P12BIA overestimated BMC for subjects with BMC below 2,000 g and underestimated BMC for subjects with BMC above 2,000 g. Similar to DS males with higher BMC values, in control males, P12BIA consistently underestimated BMC compared to DXA. Similar to DS males with lower BMC values, P12BIA significantly overestimated BMC in females with DS. P12BIA BMC values were not significantly different from DXA in control females, who also had the smallest limits of agreement.

The study population on which P12BIA was developed [Patil et al., 2012] may provide an explanation for the different results between control males and females. More women (n = 85) than men (n = 28) were used to develop P12BIA, which may explain why P12BIA agreed with DXA for control females and was less accurate for control males. Because males with DS with higher BMC values showed similar results to control males, P12BIA may not agree well with DXA due to differences in total BMC between DS and controls, as both males and females with DS had lower BMC on average compared to controls. This suggests that height differences may also account for differences in P12BIA and DXA, as taller individuals have greater BMC than shorter individuals, and male DS subjects with the highest DXA BMC were also the tallest subjects with DS. DS males in the present study had an average height 19.4 cm shorter than males from Patil et al. (2012) and females with DS were 14.8 cm shorter as a group than females from Patil et al. (2012). Therefore, individuals of the height of the average person with DS were likely not well-represented in the original subject sample taken from the general population. Additionally, control males in the present study were an average of 12.4 cm taller than males from Patil et al. (2012), which offers a possible explanation for the underestimation of BMC from P12BIA compared to DXA. In contrast, control females in this study were only 5.9 cm taller than females from Patil et al. (2012).

A further consideration in interpreting the results of the study is the physical activity level of the adults with DS included in the analysis. Although individuals with DS have poor bone health compared to their age-matched peers [Geijer et al., 2014], they also are often sedentary [Oviedo et al., 2014], which itself contributes to poor bone health. Unlike other subjects reported in the literature [Mahy et al., 2010; Stanish, 2004; Temple & Stanish, 2009], however, the adults with DS in this study reported mainly moderate and high levels of physical activity, with only

three subjects classified as sedentary. Therefore, it is possible that the adults with DS in this study may have higher BMC values compared to their less active peers with DS and the results of this study may primarily apply to physically active individuals with DS. Despite high activity levels, only two out of twenty-one subjects with DS were classified as normal weight with a BMI < 25.0. However, overweight and obese subjects were used to develop P12BIA, and good agreement was found between BMC from P12BIA and DXA [Patil et al., 2012]. Therefore, it is unlikely that overweight and obesity affected the results of the present study.

Finally, P12BIA was developed on Indian adults, while the present study included white (n =19) and black (n = 2) American adults. The results of this study therefore apply primarily to white Americans, and further research with a more racially diverse subject sample is warranted to determine if P12BIA provides acceptable BMC estimates in different racial and ethnic groups.

CONCLUSIONS

P12BIA may be used to provide reasonable estimates of BMC for adult females in the general white American population. However, P12BIA does not provide accurate BMC estimates for adult males in the general white American population or for adult males and females with DS. Additional equations should be developed in individuals over a wider range of heights to determine if BIA can accurately predict BMC in shorter and taller individuals. Although two subjects with DS were unable to complete the BIA measure due to difficulties with standing still and balancing, BIA is still a method worth exploring further in DS as it is more widely available than DXA and does not involve radiation. However, practitioners should not use P12BIA to estimate BMC in adults with DS. Further research is needed to develop population-specific equations to estimate BMC in individuals with DS.

REFERENCES

1. Bland, J.M., & Altman, D.G. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet, 1(8476),* 307-310.

2. Casey, A.F. (2013). Measuring body composition in individuals with intellectual disability: a scoping review. *Journal of Obesity, 3,* 28428.

3. Covelli, V., Raggi, A., Meucci, P., Paganelli, C., & Leonardi, M. (2016). Ageing of people with Down's syndrome: a systematic literature review from 2000 to 2014. *International Journal of Rehabilitation Research, 39(1),* 20-28.

4. Esco, M.R., Nickerson, B.S., Bicard, S.C., Russell, A.R., & Bishop, P.A. (2016). Agreement of BMI-based equations and DXA in determining body-fat percentage in adults with Down syndrome. *Adapted Physical Activity Quarterly, 33(1),* 89-96.

5. Fegan, P.L. (2011). Intellectual disabilities. In J.P. Winnick (Ed.), *Adapted Physical Education and Sport* (pp.151-172). Champaign, IL: Human Kinetics.

6. Fernhall, B., Mendonca, G.V., & Baynard, T. (2013). Reduced work capacity in individuals with Down syndrome: a consequence of autonomic dysfunction? *Exercise and Sport Sciences Reviews,* 41(3), 138-147.

7. Geijer, J.R., Stanish, H.I., Draheim, C.C., & Dengel, D.R. (2014). Bone mineral density in adults with Down syndrome, intellectual disability, and nondisabled adults. *American Journal on intellectual and developmental disabilities, 119(2),* 107-114.

8. Glasson, E.J., Sullivan, S.G., Hussain, R., Petterson, B.A., Montgomery, P.D., & Bittles, A.H. (2002). The changing survival profile of people with Down's syndrome: implications for genetic counseling. *Clinical Genetics, 62(5),* 390-393.

9. Godin, G., & Shephard, R. J. (1997). Godin leisure-time exercise questionnaire. *Medicine & Science in Sports and Exercise,* 29(6), 36-38.

10. González-Agüero, A., Vicente-Rodríguez, G., Ara, I., Moreno, L.A., & Casajús, J.A. (2011). Bone mass in male and female children and adolescents with Down syndrome. *Osteoporosis International, 22(7),* 2151-2157.

11. González-Agüero, A., Matute-Llorente, A., Gómez-Cabello, A., Vicente-Rodríguez, G., & Casajús, J.A. (2017). Percentage of body fat in adolescents with Down syndrome: estimation from skinfolds. *Disability and Health Journal, 10,* 100-104.

12. Guijarro, M., Valero, C., Paule, B., Gonzalez-Macias, J., & Riancho, J.A. (2008). Bone mass in young adults with Down syndrome. *Journal of Intellectual Disability Research, 52(3),* 182-189.

13. Harrison, P.L., & Oakland, T. (2015). *Adaptive Behavior Assessment System, Third Edition*. Torrance,CA: Western Psychological Services.

14. Heward, W.L. (2013). Exceptional children: An introduction to special education, 10th ed. Boston: Pearson.

15. Hopkins, W.G., Marshall, S.W., Batterham, A.M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise, 41,* 3-13.

16. Izquierdo-Gomez, R., Martinez-Gomez, D., Acha, A., Veiga, O.L., Villagra, A., & Diaz-Cueto, M. (2014). Objective assessment of sedentary time and physical activity throughout the week in adolescents with Down syndrome. The UP&DOWN study. *Research in Developmental Disabilities, 35,* 482-489.

17. Izquierdo-Gomez, R., Martinez-Gomez, D., Villagra, A., Fernhall, B., & Veiga, O.L. (2015). Associations of physical activity with fatness and fitness in adolescents with Down syndrome: The UP&DOWN study. *Research in Developmental Disabilities, 36,* 428-436.

18. Kavouras, S.A. (2002). Assessing hydration status. *Current Opinion in Clinical Nutrition & Metabolic Care, 5(5),* 519-524.

19. Lowry, D.W., & Tomiyama, A.J. (2015). Air displacement plethysmography versus dual-energy x-ray absorptiometry in underweight, normal-weight, and overweight/obese individuals. *PLos ONE, 10(1),* e0115086.

20. Määttä, T., Tervo-Määttä, T., Taanila, A., Kaski, M., & Iivanainen, M. (2006). Mental health, behavior and intellectual abilities of people with Down syndrome. *Down Syndrome Research and Practice, 11(1),* 37-43.

21. Mahy, J., Shields, N., Taylor, N.F., & Dodd, K.J. (2010). Identifying facilitators and barriers to physical activity for adults with Down syndrome. *Journal of Intellectual Disability Research, 54(9),* 795-805.

22. Nickerson, B.S., Esco, M.R., Bicard, S.C., Russell, A.R., Williford, H.N., & Schaefer, G. (2015). Validity of the body adiposity index in adults with Down syndrome. *Research in Developmental Disabilities, 38,* 92-96.

23. Oviedo, G.R., Guerra-Balic, M., Baynard, T., & Javierre, C. (2014). Effects of aerobic, resistance and balance training in adults with intellectual disabilities. *Research in Developmental Disabilities, 35,* 2624-2634.

24. Patil, B., Patkar, D., Mandlik, S., Kuswarkar, M., & Jindal, G. (2012). Estimation of bone mineral content from bioelectrical impedance analysis in Indian adults ages 23-81 years: A comparison with dual energy x-ray absorptiometry. *International Journal of Biomedical Engineering and Technology, 8(1),* 99-114.

25. Rom, O., Reznick, A.Z., Keidar, Z., Karkabi, K., & Aizenbud, D. (2015). Body composition in heavy smokers: comparison of segmental bioelectrical impedance analysis and dual-energy x-ray absorptiometry. *Advances in Experimental Medicine and Biology, 840,* 1-11.

26. Srikanth, R., Cassidy, G., Joiner, C., & Teeluckdharry, S. (2011). Osteoporosis in people with intellectual disabilities: a review and a brief study of risk factors for osteoporosis in a community sample of people with intellectual disabilities. *Journal of Intellectual Disability Research, 55(1),* 53-62.

27. Stanish, H.I. (2004). Accuracy of pedometers and walking activity in adults with mental retardation. *Adapted Physical Activity Quarterly, 21,* 167-79.

28. Temple, V.A., & Stanish, H. (2009). Pedometer-measured physical activity of adults with intellectual disability: predicting weekly step counts. *American Journal on Intellectual and Developmental Disabilities, 114,* 15-22.

29. van Allen, M.I., Fung, J., & Jurenka, S.B. (1999). Health care concerns and guidelines for adults with Down syndrome. *American Joural of Medican Genetics, 89,* 100-110.

Table 4.1. *Descriptive Characteristics of Subjects*

		Down syndrome (n = 21)	Control (n = 21)
Sex			
	Male	n = 8	n = 8
	Female	n = 13	n = 13
Race			
	Black	n = 2	n = 2
	White	n = 19	n = 19
Age			
	Overall	33.1 ± 9.9	33.4 ± 9.8
	Male	29.9 ± 5.7	30.3 ± 6.8
	Female	35.1 ± 11.5	35.3 ± 11.0
Height (cm)			
	Overall	144.9 ± 11.6	169.8 ± 10.9
	Male	150.1 ± 14.6	181.9 ± 6.5
	Female	141.7 ± 8.4	162.4 ± 3.9
Weight (kg)			
	Overall	71.0 ± 16.3	76.5 ± 17.6
	Male	78.8 ± 13.4	94.1 ± 10.1
	Female	66.1 ± 16.6	65.6 ± 10.9
BMI			
	Overall	33.7 ± 6.5	26.1 ± 4.1
	Male	35.2 ± 5.8	28.4 ± 3.0
	Female	32.8 ± 6.9	24.6 ± 4.0

Table 4.2. *Godin Leisure Time Questionnaire*

	Down syndrome (n)	Control (n)
Sedentary		
Total	3	0
Male	2	0
Female	1	0
Moderately Active		
Total	7	5
Male	1	0
Female	6	5
Active		
Total	11	16
Male	5	8
Female	6	8

Table 4.3. *Study 3 Adaptive Behavior Assessment System, Third Edition*

Classification	Male (n)	Female (n)	Total (n)
Extremely Low	5	10	15
Low	3	1	4
Below Average	0	2	2

Table 4.4. *Correlation, mean BMC, and mean difference by group*

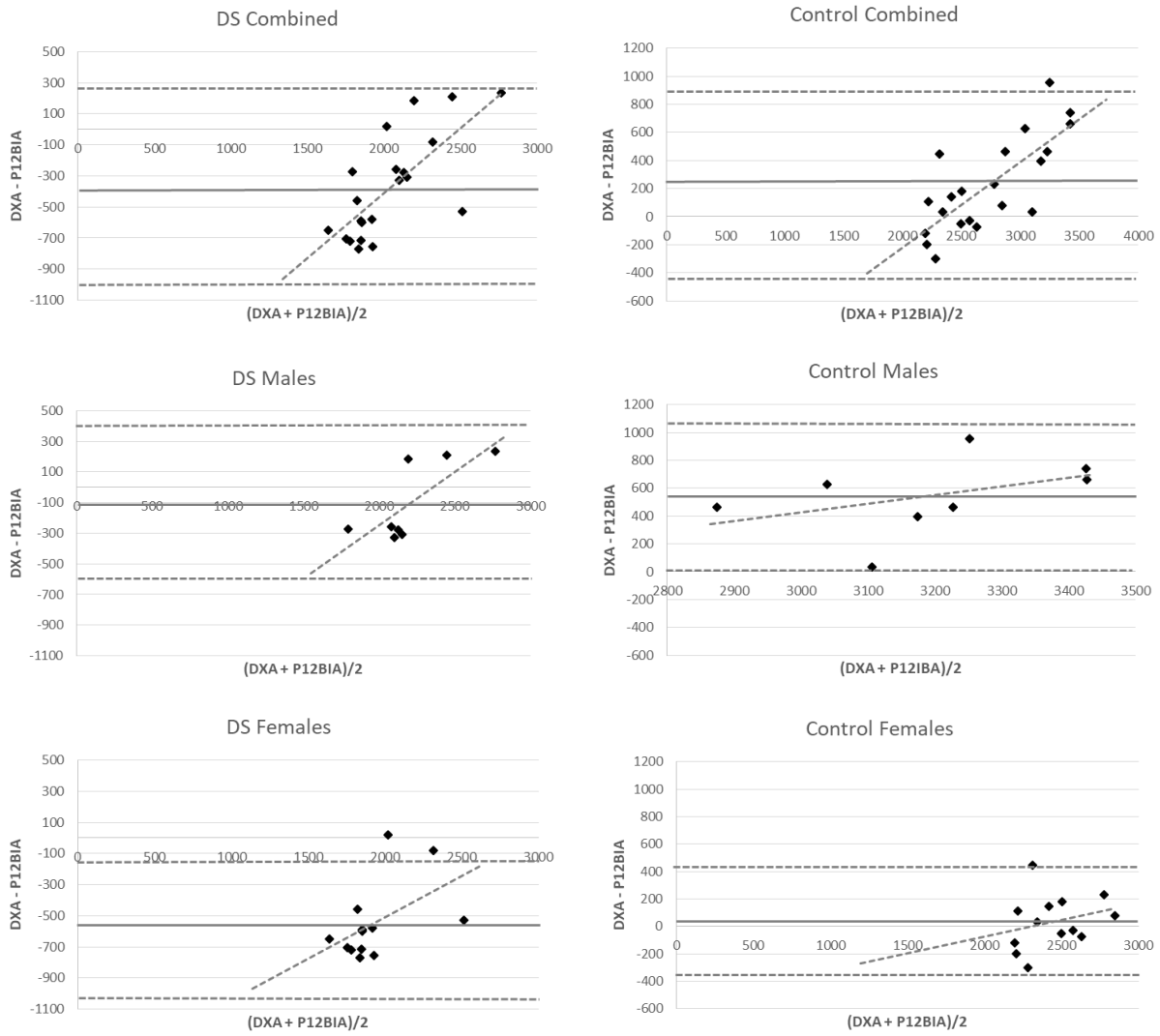
	Down syndrome (n = 21)	Control (n = 21)
DXA (mean ± SD)		
Overall	1846.6 g ± 421.9 g	2845.0 g ± 559.8 g
Male	2157.3 g ± 395.3 g	3462.8 g ± 275.2 g
Female	1655.5 g ± 318.7 g	2464.8 g ± 259.2 g
P12BIA (mean ± SD)		
Overall	2225.1 g ± 201.8 g	2616.5 g ± 311.9 g
Male	2259.7 g ± 205.8 g	2919.3 g ± 178.6 g
Female	2203.8 g ± 204.6 g	2430.2 g ± 211.6 g
Mean Difference (DXA-P12BIA)		
Overall	-378.5 g ± 331.2 g*	228.5 g ± 336.6 g*
Male	-102.4 g ± 259.7 g	543.5 g ± 272.5 g*
Female	-548.3 g ± 247.8 g*	34.6 g ± 196.7 g
Correlation		
Overall	.64*	.85*
Male	.81*	.34
Female	.63*	.67*

*indicates statistical significance at $p < .05$

Table 4.5. *95% Limits of Agreement*

	95% Limits of Agreement		
	Mean difference ± 1.96×SD	Upper	Lower
Combined DS	-389.5 ± 649.1	270.6	-1027.6
DS Males	-102.4 ± 508.9	406.5	-611.4
DS Females	-548.3 ± 485.7	-62.6	-1034.0
Combined Control	228.5 ± 659.8	888.2	-431.3
Control Males	543.5 ± 534.1	1077.5	9.4
Control Females	34.6 ± 385.5	420.2	-350.9

Figure 4.1. Bland-Altman plots showing the agreement between BMC values from DXA and P12BIA for combined, male, and female groups for subjects with DS and controls. The outside dashed lines show the upper and lower limits of agreement, while the solid middle line shows the mean difference between the two methods. The dashed regression line shows the trend between difference of DXA and P12BIA and their mean.



CHAPTER 5

CONCLUSION

Individuals with Down syndrome (DS) have a high prevalence of obesity and low bone mineral content (BMC) compared to individuals in the general population. Consequently, managing obesity and assessing BMC is critical to the health of individuals with DS, especially as people with DS now live to age 60 and beyond. However, laboratory measures commonly used to measure body fat percentage (BF%) and BMC are often unavailable and can be expensive, time-consuming, and impractical for use with the DS population. Additionally, many field techniques for assessing body composition have not been validated for use in individuals with DS. Skinfold (SF) measurements, bioelectrical impedance analysis (BIA) and air displacement plethysmography (ADP) are promising methods for assessing body composition in individuals with DS, but require additional study to ensure that individuals with DS receive accurate and meaningful measures of body composition.

Air displacement plethysmography (ADP) is a relatively fast and non-invasive procedure for assessing BF%. Both ADP and DXA are often used as reference methods to assess validity of field measures of BF%, but ADP may not be as accurate for individuals with a body mass index outside of the normal range, and agreement between BF% values from ADP and other laboratory measures such as DXA has not been established for adults with DS. Therefore, the first study evaluated the agreement of ADP and DXA for measuring BF% in adults with DS. BF% values from DXA were significantly higher than those obtained from ADP in both DS ($t = 5.252$, $df =$

32, $p < .000$) and control ($t = 7.714$, $df = 32$, $p < .000$) adults with males and females combined. BF% from DXA was also significantly higher in females with DS ($t = 5.392$, $df = 18$, $p < .000$), female controls ($t = 5.585$, $df = 18$, $p < .000$), and male controls ($t = 5.278$, $df = 13$, $p < .000$). BF% from DXA was also higher in males with DS and this difference approached significance ($t = 2.107$, $df = 13$, $p = .055$). The results of this study show that DXA provides higher BF% compared to ADP in adults both with and without DS.

Field measures of body composition provide viable alternatives to more invasive and expensive laboratory procedures, which are not widely available. Multiple equations to predict BF% based on anthropometric measures exist, but few have been developed specifically for individuals DS, who differ from the general population in both overall BF% and distribution of body fat. Therefore, the second study compared BF% from selected field measures in adult men and women with DS to a four-compartment model (4CBF%). A control group of healthy adults without DS was also included in the study. Although mean BF% from all but one of the five BIA equations was not significantly different from 4CBF% ($p > .01$) in adults with DS, these equations had a standard error of estimate (SEE) ranging from 4.8 to 6.0 and wide limits of agreement ranging from ± 9.5% to ± 11.6%. Only two of the five BIA equations were significantly different than 4CBF% in control subjects ($p < .01$), but these equations had SEE's of 7.2 and 7.8 and very wide limits of agreement (± 24.6% and ± 22.9%).

Of the seven SF equations analyzed in both males and females with DS, only two did not provide a mean BF% different from 4CBF% ($p < .007$). Of these two equations, one (SFRO) was specifically developed for adults with DS. However, SFRO had a SEE of 4.8 and wide limits of agreement (± 17.2%). One SF equation (SFKR) was analyzed only on male subjects with DS because it was developed for adult males with intellectual disability. BF% from SFKR was not

significantly different from 4CBF% ($p = .582$), but had a SEE of 7.3 and wide limits of agreement (± 13.7%). Only two of the SF equations were significantly different from 4CBF% in control subjects ($p < .008$). However, the four SF equations that were not significantly different from 4CBF% in control subjects had SEE's between 5.0 and 6.9 as well as wide limits of agreement ranging from ± 14.2% to ± 17.6%. While it appears that both BIA and SF may in some cases be appropriate for use in DS, because equations developed on the general population may provide significantly different BF% to 4CBF%, care should be taken to select only the appropriate equations for individuals with DS.

Individuals with DS also have a high prevalence of BMC and osteoporosis compared to the general population and other individuals with intellectual disability, and providing accurate measures of BMC can help health-care practitioners and individuals with DS manage these conditions. Laboratory techniques such as DXA can assess BMC with high precision, but are expensive and unavailable in field settings. Additionally, individuals with DS may struggle to stay still for the several minutes required for DXA. Therefore, the third study examined the agreement between a BIA equation developed to assess BMC (P12BIA) and DXA in adults with DS. P12BIA provided reasonable estimates of BMC for control females ($t = .879$, $df = 12$, $p = .397$), but not for control males ($t = 5.641$, $df = 7$, $p = .001$) or subjects with DS ($t = -5.237$, $df = 20$, $p < .000$).

These differences may be due to total BMC and height differences between the subjects of the current study and subjects used to develop P12BIA. Additional equations should be developed in individuals over a wider range of heights to determine if BIA can accurately predict BMC in shorter and taller individuals. While two subjects with DS were unable to stand still long enough to complete the BIA measure, further research with BIA is still warranted in DS as it is

more widely available than DXA and does not involve radiation. However, P12BIA should not be used to estimate BMC in adults with DS.

Individuals with DS comprise a unique group in terms of body composition, with different distributions of both fat mass and fat free mass compared to the general population, a high prevalence of obesity, and low BMC compared to age-matched peers. Because of these differences, methods of body composition assessment developed in the general population often provide inaccurate results in individuals with DS. Nonetheless, the results of the present studies show that when appropriate tests are selected, many of the same techniques used on the general population, including ADP, BIA and SF, can be used successfully in adults with DS. However, further research is warranted in order to develop more accurate techniques for assessing BMC in DS outside of the laboratory setting. Body composition assessment in DS is an emerging area of research that can assist individuals with DS in managing their unique health conditions. Practitioners should carefully select appropriate methods of assessment when measuring BF% and BMC in adults with DS to ensure that individuals in this population are provided with accurate results.

REFERENCES

1. Bland, J.M., & Altman, D.G. (1986). Statistical methods for assessing agreement between two methods of clinical measurement. *Lancet, 1(8476),* 307-310.

2. Calders, P., Elmahgoub, S., de Mettelinge, T.R., Vandenbroeck, C., Dewandele, I., Rombaut, L., Vandevelde, A., & Cambier, D. (2011). Effect of combined exercise training on physical and metabolic fitness in adults with intellectual disability: a controlled trial. *Clinical Rehabilitation, 25(12),* 1097-1108.

3. Casey, A.F. (2013). Measuring body composition in individuals with intellectual disability: a scoping review. *Journal of Obesity, 3,* 28428.

4. Casey, A.F., & Rasmussen, R. (2013). Reduction measures and percent body fat in individuals with intellectual disabilities: A scoping review. *Disability and Health Journal, 6,* 2-7.

5. Chumlea, W.C., Guo, S.S., Kuczmarski, R.J., Flegal, K.M., Johnson, C.L., Heymsfield, S.B. et al. (2002). Body composition estimates from NHANES III bioelectrical impedance data. *International Journal of Obesity and Related Metabolic Disorders,* 26, 1596-609.

6. Covelli, V., Raggi, A., Meucci, P., Paganelli, C., & Leonardi, M. (2016). Ageing of people with Down's syndrome: a systematic literature review from 2000 to 2014. *International Journal of Rehabilitation Research, 39(1),* 20-28.

7. de Winter, C.F., Magilsen, K.W., van Alfren, J.C., Willemsen, S.P., & Evenhuis, H.M. (2011). Metabolic syndrome in 25% of older people with intellectual disability. *Family Practice,* 28(2), 141-144.

8. Deurenberg, P., Van der Kooy, K., Leenen, R., Weststrate, J., & Seidell, J. (1991). Sex and age specific prediction formulas for estimating body composition from bioelectrical impedance: a cross-validation study. *International Journal of Obesity,* 15, 17-25.

9. Durnin, J.V., & Womersley, J. (1974). Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. *The British Journal of Nutrition, 32,* 77-97.

10. Ejskjaer, K., Uldbjerg, N., & Goldstein, H. (2006). Menstrual profile and early menopause in women with Down syndrome aged 26-40 years. *Journal of Intellectual & Developmental Disability, 31(30),* 166-171.

11. Esco, M.R., Nickerson, B.S., & Russell, A.R. (2017). Comparison of bioelectrical impedance and DXA for measuring body composition among adults with Down syndrome. *Disability and Health Journal, 10(4),* 548-551.

12. Esco, M.R., Nickerson, B.S., Bicard, S.C., Russell, A.R., & Bishop, P.A. (2016). Agreement of BMI-based equations and DXA in determining body-fat percentage in adults with Down syndrome. *Adapted Physical Activity Quarterly, 33(1),* 89-96.

13. Fegan, P.L. (2011). Intellectual disabilities. In J.P. Winnick (Ed.), *Adapted Physical Education and Sport* (pp.151-172). Champaign, IL: Human Kinetics.

14. Fernhall, B., Mendonca, G.V., & Baynard, T. (2013). Reduced work capacity in individuals with Down syndrome: a consequence of autonomic dysfunction? *Exercise and Sport Sciences Reviews*, 41(3), 138-147.

15. Fields, D.A., Goran, M.I., & McCrory, M.A. (2002). Body-composition assessment via air-displacement plethysmography in adults and children: a review. *American Journal of Clinical Nutrition, 75,* 453-467.

16. Geijer, J.R., Stanish, H.I., Draheim, C.C., & Dengel, D.R. (2014). Bone mineral density in adults with Down syndrome, intellectual disability, and nondisabled adults. *American Journal on intellectual and developmental disabilities, 119(2),* 107-114.

17. Glasson, E.J., Sullivan, S.G., Hussain, R., Petterson, B.A., Montgomery, P.D., & Bittles, A.H. (2002). The changing survival profile of people with Down's syndrome: implications for genetic counseling. *Clinical Genetics, 62(5),* 390-393.

18. Godin, G., & Shephard, R. J. (1997). Godin leisure-time exercise questionnaire. *Medicine & Science in Sports and Exercise*, 29(6), 36-38.

19. González-Agüero, A., Ara, I., Moreno, L. A., Vicente-Rodríguez, G., & Casajús, J.A. (2011a). Fat and lean masses in youths with Down syndrome: gender differences. *Research in Developmental Disabilities, 32,* 1685-1693.

20. González-Agüero, A., Vicente-Rodríguez, G., Ara, I., Moreno, L.A., & Casajús, J.A. (2011b). Accuracy of prediction equations to assess percentage of body fat in children and adolescents with Down syndrome compared to air displacement plethysmography. *Research in Developmental Disabilities, 32,* 1764-1769.

21. González-Agüero, A., Vicente-Rodríguez, G., Ara, I., Moreno, L.A., & Casajús, J.A. (2011c). Bone mass in male and female children and adolescents with Down syndrome. *Osteoporosis International, 22(7),* 2151-2157.

22. González-Agüero, A., Matute-Llorente, A., Gómez-Cabello, A., Vicente-Rodríguez, G., & Casajús, J.A. (2017). Percentage of body fat in adolescents with Down syndrome: estimation from skinfolds. *Disability and Health Journal, 10,* 100-104.

23. Guijarro, M., Valero, C., Paule, B., Gonzalez-Macias, J., & Riancho, J.A. (2008). Bone mass in young adults with Down syndrome. *Journal of Intellectual Disability Research, 52(3),* 182-189.

24. Harrison, P.L., & Oakland, T. (2015). *Adaptive Behavior Assessment System, Third Edition*. Torrance,CA: Western Psychological Services.

25. Heward, W.L. (2013). Exceptional children: An introduction to special education, 10th ed. Boston: Pearson.

26. Heymsfield, S.B., Wang, J., Heshka, S., Kehayias, J.J., & Pierson, R.N. (1989). Dual-photon absorptiometry: comparison of bone mineral and soft tissue mass measurements in vivo with established methods. *American Journal of Clinical Nutrition,* 49, 1283-1289.

27. Hilgenkamp, T., Reisa, D., van Wijckc, R., & Evenhuisa, H. (2012). Physical activity levels in older adults with intellectual disabilities are extremely low. *Research in Developmental Disabilities, 33,* 477-483.

28. Hofsteenge, G.H., Chinapaw, M.J.M., & Weijs, P.J.M. (2015). Fat-free mass prediction equations for bioelectric impedance analysis compared to dual energy x-ray absorptiometry in obese adolescents: a validation study. *BMC Pediatrics, 15,* 158.

29. Hopkins, W.G., Marshall, S.W., Batterham, A.M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise, 41,* 3-13.

30. Hopkins, W.G., Marshall, S.W., Batterham, A.M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine & Science in Sports & Exercise, 41,* 3-13.

31. Izquierdo-Gomez, R., Martinez-Gomez, D., Acha, A., Veiga, O.L., Villagra, A., & Diaz-Cueto, M. (2014). Objective assessment of sedentary time and physical activity throughout the week in adolescents with Down syndrome. The UP&DOWN study. *Research in Developmental Disabilities, 35,* 482-489.

32. Izquierdo-Gomez, R., Martinez-Gomez, D., Villagra, A., Fernhall, B., & Veiga, O.L. (2015). Associations of physical activity with fatness and fitness in adolescents with

Down syndrome: The UP&DOWN study. *Research in Developmental Disabilities, 36,* 428-436.

33. Jackson, A.S., & Pollock, M.L. (1978). Generalized equations for predicting body density of men. *The British Journal of Nutrition, 40,* 497-504.

34. Jackson, A.S., Pollock, M.L., & Ward, A. (1980). Generalized equations for predicting body density of women. *Medicine and Science in Sports and Exercise, 12,* 175-181.

35. Kavouras, S.A. (2002). Assessing hydration status. *Current Opinion in Clinical Nutrition & Metabolic Care, 5(5),* 519-524.

36. Kelly, L.E., & Rimmer, J. (1987). A practical method for estimating percent body fat of adult mentally retarded males. *Adapted Physical Activity Quarterly, 4,* 117-125.

37. Kota, S.K., Tripathy, P.R., Kota, S.K., & Jammula, S. (2013). Type 2 diabetes mellitus: An unusual association with Down's syndrome. *Indian Journal of Human Genetics,* 19(3), 358-359.

38. Kyle, U.G., Genton, L., Karsegard, L., Slosman, D.O., & Prichard, C. (2001). Single prediction equation for bioelectrical impedance analysis in adults aged 20-94 years. *Nutrition,* 17, 248-253.

39. Laakka, T.A., & Laaksonen, D.E. (2007). Physical activity in prevention and treatment of the metabolic syndrome. *Applied Physiology, Nutrition, and Metabolism,* 32: 76-88.

40. Leahy, S., O'Neill, C., Sohun, R., Toomey, C., & Jakeman, P. (2013). Generalized equations for the prediction of body fat by anthropometry in adult men and women aged 18-81 years. *British Journal of Nutrition, 109,* 678-685.

41. Lohman, T. G. (1992). Advances in body composition assessment. Champaign, IL: Human Kinetics.

42. Loveday, S.J., Thompson, J.M.D., & Mitchell, E.A. (2012). Bioelectrical impedance for measuring percentage body fat in young persons with Down syndrome: validation with dual-energy absorptiometry. *Acta Paediatrica, 101,* e491-e495.

43. Lowry, D.W., & Tomiyama, A.J. (2015). Air displacement plethysmography versus dual-energy x-ray absorptiometry in underweight, normal-weight, and overweight/obese individuals. *PLos ONE, 10(1),* e0115086.

44. Määttä, T., Tervo-Määttä, T., Taanila, A., Kaski, M., & Iivanainen, M. (2006). Mental health, behavior and intellectual abilities of people with Down syndrome. *Down Syndrome Research and Practice, 11(1),* 37-43.

45. Macfarlane, D.J., Chan, N.T., Tse, M.A., Joe, G.M. (2016). Agreement between bioelectrical impedance and dual energy x-ray absorptiometry in assessing fat, lean and bone mass changes in adults after a lifestyle intervention. *Journal of Sports Sciences, 34(12),* 1176-1181.

46. Magge, S.N., O'Neill, K.L., Shults, J., Stallings, V.A., & Stettler, N. (2008). Leptin levels among prepubertal children with Down syndrome compared to their siblings. *Journal of Pediatrics*, 152(3), 321-326.

47. Mahy, J., Shields, N., Taylor, N.F., & Dodd, K.J. (2010). Identifying facilitators and barriers to physical activity for adults with Down syndrome. *Journal of Intellectual Disability Research, 54(9),* 795-805.

48. McCrory, M.A., Molé, P.A., Gomez, T.D., Dewey, K.G., & Bernauer, E.M. (1998). Body composition by air-displacement plethysmography by using predicted and measured thoracic gas volumes. *Journal of Applied Physiology, 84,* 1475-1479.

49. Mendonca, G.A., Pereira, F., & Fernhall, G. (2011). Effects of combined aerobic and resistance exercise training in adults with and without Down syndrome. *Archives of Physical Medicine and Rehabilitation, 902*, 37-45.

50. Nateghi, R.M., Douraghi, M., Mohammadi, A.M., & Nikmanesh, B. (2012). Altered serum pro-inflammatory cytokines in children with Down's syndrome. *European Cytokine Network*, 23(2), 64-67.

51. Nickerson, B.S., Esco, M.R., Bicard, S.C., Russell, A.R., Williford, H.N., & Schaefer, G. (2015). Validity of the body adiposity index in adults with Down syndrome. *Research in Developmental Disabilities, 38,* 92-96.

52. Nickerson, B.S., Esco, M.R., Bishop, P.A., Schumacker, R., Richardson, M., Fedewa, M.V., Wingo, J.E., Welborn, B.A. (2017). Validity of selected bioimpedance equations for estimating body composition in men and women: a four-compartment model comparison. *Journal of Strength and Conditioning Research, 31(7),* 1963-1972.

53. Nickerson, B.S., Esco, M.R., Bishop, P.A., Schumacker, R., Richardson, M., Fedewa, M.V., Wingo, J.E., Welborn, B.A. (2017a). Validity of selected bioimpedance equations for estimating body composition in men and women: a four-compartment model comparison. *Journal of Strength and Conditioning Research, 31(7),* 1963-1972.

54. Nickerson, B.S., Esco, M.R., Bishop, P.A., Schumacker, R., Richardson, M., Fedewa, M.V., Wingo, J.E., Welborn, B.A. (2017b). Impact of measured vs. predicted residual lung volume on body fat percentage using underwater weighing and 4-compartment model. *Journal of Strength and Conditioning Research, 31(9),* 2519-2527.

55. O'Connor, D.P., Bray, M.S., McFarlin, B.K., Sailors, M.H., Ellis, K.J., & Jackson, A.S. (2010). Generalized equations for estimating DXA percent fat of diverse young women and men: the TIGER study. *Medicine & Science in Sports & Exercise, 42(10),* 1959-1965.

56. Ordonez, F.J., Rosety, M., Rosety-Rodriguez, M. (2006). Influence of 12-week exercise training on fat mass percentage in adolescents with Down syndrome. *Medical Science Monitor, 12,* CR416-CR419.

57. Ordonez, F.J., Rosety, M.A., Camacho, A., Rosety, I., Diaz, A.J., Fornieles, G., Garcia, N., & Rosety-Rodriguez, M. (2014). Aerobic training improved low-grade inflammation in obese women with intellectual disability. *Journal of Intellectual Disability Research,* 58(6), 583-590.

58. Oviedo, G.R., Guerra-Balic, M., Baynard, T., & Javierre, C. (2014). Effects of aerobic, resistance and balance training in adults with intellectual disabilities. *Research in Developmental Disabilities, 35,* 2624-2634.

59. Patil, B., Patkar, D., Mandlik, S., Kuswarkar, M., & Jindal, G. (2012). Estimation of bone mineral content from bioelectrical impedance analysis in Indian adults ages 23-81 years: A comparison with dual energy x-ray absorptiometry. *International Journal of Biomedical Engineering and Technology, 8(1),* 99-114.

60. Real de Asua, D., Parra, P., Costa, R., Moldenhauer, F., & Suarez, C. (2014). Evaluation of the impact of abdominal obesity on glucose and lipid metabolism disorders in adults with Down syndrome. *Research in Developmental Disabilities, 35(11),* 2942-9.

61. Rizvi, A.A. (2010). Hypertension, obesity, and inflammation: the complex designs of the deadly trio. *Metabolic Syndrome and Related Disorders,* 8, 287-294.

62. Rom, O., Reznick, A.Z., Keidar, Z., Karkabi, K., & Aizenbud, D. (2015). Body composition in heavy smokers: comparison of segmental bioelectrical impedance analysis and dual-energy x-ray absorptiometry. *Advances in Experimental Medicine and Biology, 840,* 1-11.

63. Rosety-Rodriguez, M., Camacho, A., Rosety, I., Fornieles, G., Rosety, M.A., Diaz, A.J., Rosety, M., & Ordonez, F.J. (2013). Resistance circuit training reduced inflammatory cytokines in a cohort of male adults with Down syndrome. *Medical Science Monitor,* 19, 949-953.

64. Rosety-Rodriguez, M., Diaz, A.J., Rosety, I., Rosety, M.A., Camacho, A., Fornieles, G., Rosety, M., & Ordonez, F.J. (2014). Exercise reduced inflammation: but for how long after training? *Journal of Intellectual Disability Research,* 58(9), 874-879.

65. Rossato, M., Dellagrana, R.A., da Costa, R.M., Bezerra, E.D., Otacílio, J., dos Santos, L., & Rech, C.R. (2016). The accuracy of anthropometric equations to assess body fat in adults with Down syndrome. *Journal of Applied Research in Intellectual Disabilities,* doi: 10.1111/jar.12290. [Epub ahead of print]

66. Shields, N., Taylor, N.F., Wee, E., Wollersheim, D., O'Shea, S.D., & Fernhall, B. (2013). A community-based strength training program increases muscle strength and physical activity in young people with Down syndrome: A randomized control trial. *Research in Developmental Disabilities, 34,* 4385-4394.

67. Siri, W.E. (1961). Body composition from fluid spaces and density: analysis of methods. *Nutrition, 9,* 480-491.

68. Srikanth, R., Cassidy, G., Joiner, C., & Teeluckdharry, S. (2011). Osteoporosis in people with intellectual disabilities: a review and a brief study of risk factors for osteoporosis in a community sample of people with intellectual disabilities. *Journal of Intellectual Disability Research, 55(1),* 53-62.

69. Stanish, H.I. (2004). Accuracy of pedometers and walking activity in adults with mental retardation. *Adapted Physical Activity Quarterly, 21,* 167-79.

70. Sun, S.S., Chumlea, W.C., Heymsfield, S.B., Lukaski, H.C., Schoeller, D., Friedl, K., Kuczmarski, R.J., Flegal, K.M., Johnson, C.L., & Hubbard, V.S. (2003). Development of bioelectrical impedance analysis prediction equations for body composition with the use of a multicomponent model for use in epidemiologic surveys. *The American Journal of Clinical Nutrition, 77,* 331-340.

71. Temple, V.A., & Stanish, H. (2009). Pedometer-measured physical activity of adults with intellectual disability: predicting weekly step counts. *American Journal on Intellectual and Developmental Disabilities, 114,* 15-22.

72. Usera, P.C., Foley, J.T., & Yun, J. (2005). Cross-validation of field-based assessments of body composition for individuals with Down syndrome. *Adapted Physical Activity Quarterly, 22,* 198-206.

73. van Allen, M.I., Fung, J., & Jurenka, S.B. (1999). Health care concerns and guidelines for adults with Down syndrome. *American Joural of Medican Genetics, 89,* 100-110.

74. van Schrojenstein Lantman-de Valk, H.M.J., Haveman, M.J., & Crebolder, H.F.J.M. (1996). Comorbidity in people with Down's syndrome: a criteria-based analysis. *Journal of Intellectual Disability Research, 40(5),* 385-399.

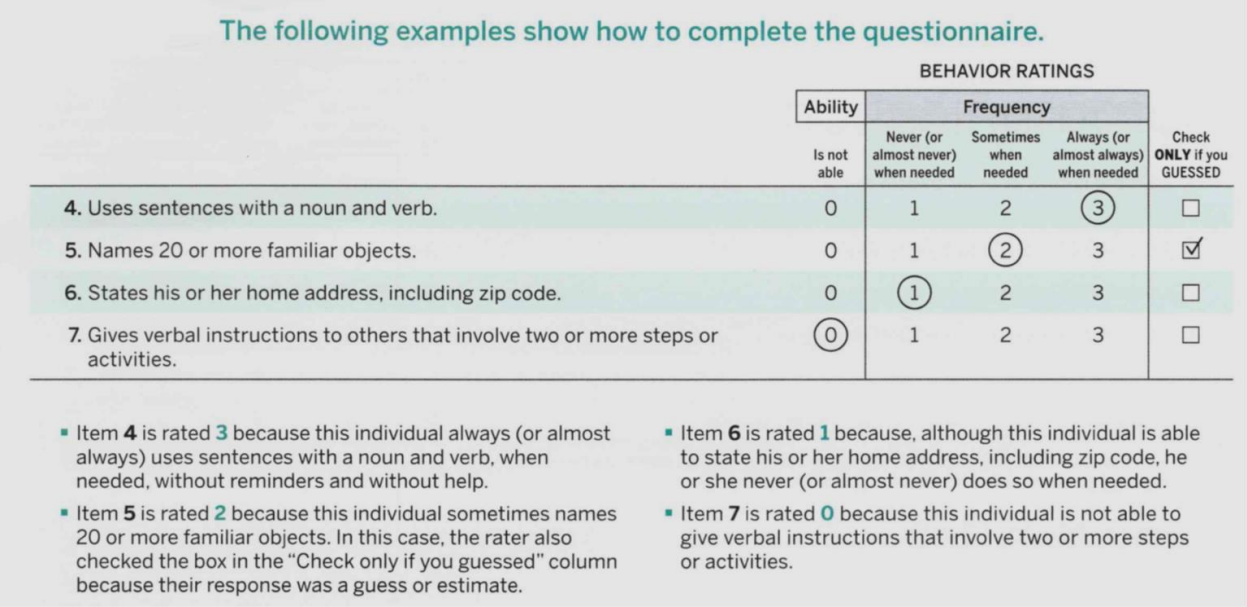
75. Wang, Z., Shen, W., & Withers, R.T. (2005). Multicomponent molecular-level models of body composition analysis. Champaign, IL: Human Kinetics.

76. Withers, R.T., Laforgia, J., & Heymsfield, S.B. (1999). Critical appraisal of the estimation of body composition via two-, three-, and four-compartment models. *American Journal of Human Biology, 11,* 175-185.

77. Wu, C.S., Chen, Y.Y., Chuang, C.L., Chiang, L.M., Dwyer, G.B., Hsu, Y.L., Huang, A.C., Lai, C.L., & Hsieh, K.C. (2015). Predicting body composition using foot-to-foot bioelectrical impedance analysis in healthy Asian individuals. *Nutrition Journal, 14,* 52.

APPENDIX

*Sample ABAS-3 Items**



The following examples show how to complete the questionnaire.

	BEHAVIOR RATINGS				
	Ability	Frequency			
	Is not able	Never (or almost never) when needed	Sometimes when needed	Always (or almost always) when needed	Check **ONLY** if you GUESSED
4. Uses sentences with a noun and verb.	0	1	2	(3)	☐
5. Names 20 or more familiar objects.	0	1	(2)	3	☑
6. States his or her home address, including zip code.	0	(1)	2	3	☐
7. Gives verbal instructions to others that involve two or more steps or activities.	(0)	1	2	3	☐

- Item **4** is rated **3** because this individual always (or almost always) uses sentences with a noun and verb, when needed, without reminders and without help.
- Item **5** is rated **2** because this individual sometimes names 20 or more familiar objects. In this case, the rater also checked the box in the "Check only if you guessed" column because their response was a guess or estimate.
- Item **6** is rated **1** because, although this individual is able to state his or her home address, including zip code, he or she never (or almost never) does so when needed.
- Item **7** is rated **0** because this individual is not able to give verbal instructions that involve two or more steps or activities.

*The following examples were taken from page 3 of the ABAS-3 Adult Form.

THE UNIVERSITY OF ALABAMA | Office of the Vice President for Research & Economic Development
Office for Research Compliance

September 6, 2017

Angela Russell
Department of Kinesiology
College of Education
The University of Alabama
Box 870312

Re: IRB Protocol # 17-007-ME-A
"Body Composition Assessment in Adults with Down Syndrome"

Ms. Russell:

The University of Alabama Medical Institutional Review Board has reviewed the revision to your previously approved full board protocol. The board has approved the change in your protocol.

Please remember that your protocol will expire on April 12, 2018.

Should you need to submit any further correspondence regarding this proposal, please include the assigned IRB application number. Changes in this study cannot be initiated without IRB approval, except when necessary to eliminate apparent immediate hazards to participants.

Good luck with your research.

Sincerely,

J. Grier Stewart, MD, FACP
Medical IRB Chair

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