ORIGINAL ARTICLE

Dual-Energy X-Ray Absorptiometry to Measure the Influence of a 16-Week Community-Based Swim Training Program on Body Fat in Children and Adolescents With Intellectual Disabilities

Amanda Faith Casey, MSc, PhD, Roy Rasmussen, MSc, PhD, Sasho J. Mackenzie, MSc, PhD, Jillian Glenn, BSc

ABSTRACT. Casey AF, Rasmussen R, Mackenzie SJ, Glenn J. Dual-energy x-ray absorptiometry to measure the influence of a 16-week community-based swim training program on body fat in children and adolescents with intellectual disabilities. Arch Phys Med Rehabil 2010;91:1064-9.

Objective: To use dual-energy x-ray absorptiometry (DXA) to measure the effects of a 16-week community-based swim training program on percent body fat in children and adolescents with intellectual disability (ID).

Design: Convenience sample.

Setting: University sport complex and exercise science laboratory.

Participants: Children and adolescents (n=8; mean age ± SD, 13.1 ± 3.4y), 2 girls and 6 boys with ID, of varying fat levels (11%–35%).

Intervention: A swim training program lasting for the duration of 16 weeks with three 1-hour sessions held at a 25-m pool each week.

Main Outcome Measure: Assessing percent body fat at pretest and posttest through the use of DXA.

Results: After the 16-week exercise training program, we observed a 1.2% median increase in body fat percentage with a range from −0.3% to 4.5%. Wilcoxon matched-pairs signed-ranks tests suggest that these results are statistically significant (P=.039; exact).

Conclusions: Exercise training alone proved ineffectual in reducing percent body fat in 8 children and adolescents with ID. Further research should consider implementing a combined diet and exercise program. To gauge the effectiveness of intervention programs, valid methods and complex measurement tools such as DXA should be used to assess changes in percent body fat in such a heterogeneous population.

Key Words: Absorptiometry, photon; Body composition; Rehabilitation; Swimming.

PEOPLE WITH INTELLECTUAL disabilities may be 30% more obese and 7% more extremely obese than people without ID.[1] A lack of participation in physical activity remains a serious concern,[2,3] and there exists an urgent need to find effective interventions to address and prevent elevated levels of obesity among people with ID.[4] Research has associated obesity with a number of health concerns such as coronary heart disease, type 2 diabetes, and osteoarthritis.[3] Heyward and Stolarczyk[5] recommended researchers assess percent body fat levels because people may be classified as obese if they possess excessive body fat even if they are not necessarily defined as overweight according to body mass index. However, an extensive literature review[6] on nutrition and people with ID emphasized the limited number of validated anthropometric methods and acceptable guidelines for classifying adiposity based on health risk for people with ID. Researchers found that the discrepancy in measurement methods made it virtually impossible to undertake a meta-analysis of weight-related nutritional risk research in this population.

Certain studies have already demonstrated that participation in exercise training programs by people with ID may contribute to a decrease in percent body fat.[7,8] However, additional preventative research has shown percent body fat might not necessarily change after exercise-alone programs.[9-10] More specifically, children or adolescents have not decreased in percent body fat after involvement in various exercise training programs.[10,11] The variation in the type of measurement used to estimate percent body fat might explain the fairly inconsistent results produced in the limited number of studies conducted to date. In order to calculate percent body fat accurately, researchers have thus far used anthropometric methods such as bioelectric impedance analysis[10] and skin fold measurements,[7,9,11] which rely on different regression equation calculations. These prediction equations should, in theory, take into account the specific physical and body composition characteristics of the participants measured because sex, age, residency, and even primary disability diagnosis have all been shown to affect results when using such equations.[12] However, past studies exploring change in percent body fat in this population have not implemented equations specifically designed for people with ID, which calls into question the accuracy of research findings to date.[7-11] The importance of finding an accurate measure for people with ID is exacerbated by the challenges of often having small sample sizes and the great variability that

List of Abbreviations

ACSM	American College of Sports Medicine
DXA	dual-energy x-ray absorptiometry
ID	intellectual disability

From the Department of Human Kinetics (Casey, Rasmussen, Mackenzie), St Francis Xavier University (Glenn), Antigonish, NS, Canada.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated.

Reprint requests to Amanda Faith Casey, MSc, PhD, Dept of Human Kinetics, St Francis Xavier University, PO Box 5000, Antigonish, NS, Canada, B2G 2W5, e-mail: *acasey@stfx.ca*.

0003-9993/10/9107-00311$36.00/0
doi:10.1016/j.apmr.2010.04.006

exists within separate subtypes of ID.[13] In the absence of population specific equations, it may be necessary to use more complex measurement tools that account for this variability such as DXA, hydrostatic weighing, or air displacement plethysmography. However, Pitetti and Tan,[9] measuring participants with varying degrees of fat levels (21% body fat on average at baseline pretest), declined to use hydrostatic weighing in their study because of difficulty obtaining reliable spirometry measurements and participants' fear of water.

Research has yet to use DXA to examine changes in percent body fat in participants with ID involved in an aerobic exercise training program. Other studies have used DXA on people without ID and have shown the method to exhibit minimal bias based on factors such as age, sex, physical activity level, race, or proportion of body fat.[14] Researchers have often relied on the DXA because of its precise measurements in different populations.[13,15,16] The DXA possesses a quick scan time and also does not require active participant involvement, all of which are important factors when working with participants who have an ID. Furthermore, the method has proved effective as a criterion measure for a number of other instruments[14] and has also been validated against underwater weighing[15] and the 4-compartment model.[16]

In addition to using valid and reliable testing measurements, it is also important to follow specific exercise training guidelines when assessing changes in percent body fat in participants with ID. The ACSM guidelines advises people with ID to undertake an aerobic exercise program at an intensity reaching up to 60% to 80% of their maximum heart rate for the duration of 20 to 60 minutes, 3 or more times a week.[4] It has been suggested that the length of time required to reduce percent body fat may range from anywhere between 4 and 6 months. Despite inactivity and the prevalence of obesity among people with ID,[17] the meta-analysis by Dodd and Shields[18] examined 156 articles and found that, by excluding trials of low methodologic quality (PEDro score <4), only 4 cardiovascular programs for participants with ID as a result of Down syndrome met recommended training procedure guidelines for exercise.

Aquatic exercise training has been shown to offer benefits for people with ID in terms of cardiorespiratory endurance, muscular endurance, speed, static balance, and agility.[19,20] Moreover, although it used skin fold measurements based on nonpopulation-specific prediction equations, a 12-week combined water and land exercise program demonstrated change in percent body fat for men with Down syndrome of varying degrees of fat level (1/4 defined as obese according to body mass index). However, a purely water-based, sports-specific swim training program combined with a more complex measurement method has not yet been used to instigate change in percent of body fat among people with ID as a whole. Indeed, studies implementing aerobic exercise programs to assess percent body fat thus far have tended to use laboratory-based exercise programs.[7-10] A sports-specific competitive swim training program provides a necessary model for service delivery, which may in turn facilitate widespread accessibility to children and their families.

In view of the inconsistent methods used for measuring body fat in previous studies and also the limited research that follows specific exercise training guidelines, the purpose of this study was to use DXA to measure the effects of a 16-week swim training program following ACSM guidelines on percent body fat in adolescents with ID. The hypothesis was that the swim training program would lead to a decrease in the participants' overall body fat percentage as measured by DXA.

METHODS

Participants

Eight children and adolescents with IDs (2 girls and 6 boys; mean age ± SD, 13.1±3.4y) were referred for participation in the study by service providers for ID at local schools. The study recruited a community sample in order to duplicate a real-world scenario in which various subtypes of ID as well as percent body fat ranges are often present (table 1). Verification that the sample represented participants with ID was based on parental knowledge, strong adherence to school placement, and service provider confirmation of an ID. In addition, because this study was aimed at future obesity prevention, child and adolescent participant body fat ranged from 11.4% to 35.2% at pretest baseline. Based on the standards by Lohman[21] for percent body fat levels in children, 4 boys maintained optimal fat levels, 2 more had very high levels, and the 2 girl participants had moderately high and high body fat levels, respectively.

Prior to commencement of the intervention, participants had already reached a swimming level that satisfied the Royal Lifesaving Society's Swim to Survive Standard.[22] Participants were excluded from the study if they were unable to attend the exercise training program without parental support, if they had any underlying health condition that would prevent them from participation, or if they were taking part in any other training programs.[7-9] Given the participants' respective IDs, it was necessary to outline the testing procedures, potential benefits, associated risks, and the time required for the study in an information letter and discussion session prepared for partici-

Table 1: Demographic Information and Levels of Percent Body Fat at Pretest and Posttest

	Measure			Pretest			Posttest		
Participant	Sex	Age (y)	Disability	BMI (kg/m^2)	BMI *z* Score	BF%	BMI (kg/m^2)	BMI *z* Score	BF%
1	Boy	9	NS; Moderate ID	17.7	–1.15	17.2	17.9	–1.03	17.0
2	Boy	15	NS; Mild ID	17.3	−1.23	12.4	16.6	−1.41	12.9
3	Boy	17	DS, Moderate ID	20.8	−0.38	11.4	20.2	−0.52	12.9
4	Girl	13	DS, Moderate ID	23.4	0.26	26.5	24.5	0.55	27.4
5	Girl	15	NS; Moderate ID	27.2	1.21	32.7	28.9	1.63	37.5
6	Boy	10	NS; Moderate ID	28.6	1.55	35.2	29.9	1.87	36.8
7	Boy	9	Autism; Mild ID	21.0	−0.33	32.0	21.0	−0.32	31.7
8	Boy	17	DS; Mild ID	22.6	0.07	16.3	23.7	0.34	19.3
Overall (Mean ± SD)	NA	13.1±3.4	NA	22.3±4.0	0.08±1.0	22.9±9.7	22.8±4.8	0.22±1.2	24.4±10.2

Abbreviations: BF%, percent body fat; BMI, body mass index; DS, Down syndrome; NA, not applicable; NS, no known syndrome.

pants and their parents and/or guardians. In addition, the participants' guardians all provided written informed consent and the participants themselves gave assent prior to the commencement of the study. The study protocol was approved by the institutional research ethics board.

Procedures

Protocol. For assessment of percent body fat, pretest occurred immediately prior to the commencement of the swim training intervention program, and posttest took place immediately after the end of the 16-week training intervention. Participants were required to follow specific guidelines on testing days: (1) they were asked to have no water or food 2 hours prior to testing, and (2) they were asked to wear a standardized light cotton shirt and shorts that contained no metal to minimize clothing absorption.[15]

Height and weight. Using a stadiometer (Tanita HR-200),[a] the participants' height, without footwear, was measured to the nearest 0.1cm. Participants stood erect with head straight forward and eyes fixed in the Frankfort plane. Each participant's back and shoulders were directly against the wall with feet together flat on the floor. Weight was measured to the nearest 0.1kg using a calibrated digital scale. Body mass index was calculated by dividing weight (kg) by height (m) squared.

Dual-energy x-ray absorptiometry. DXA Hologic QDR-1000W Whole Body Bone Densitometer (Version 6.10[b]) performed all scans to assess percent body fat in the participants. Using an anthropometric phantom (Hologic X-CALIBER Model DPA/QDR-1[b]) of known densities, technicians calibrated the DXA scanner on each day of testing following the procedures recommended by the manufacturer to ensure reliability between scans. We used Software Version 6.10[b] to analyze the scans. The same DXA technician performed every scan throughout each test following the guidelines instructed by the manufacturer. Each scan lasted approximately 20 minutes with the participant lying down to complete the scan.

Swim training intervention. The swim training sessions took place in an indoor 25-m competitive-size swimming pool (78°F) in swim lanes alongside members of the local competitive swim team in order to provide the real-world environment of a competitive, sports-specific program. Participants focused on performing the front crawl stroke and also carrying out exercises with the assistance of a flutter board device. The program lasted 16 weeks with 3 one-hour sessions occurring each week. The training program followed ACSM guidelines with participants exercising at 60% to 80% of their theoretic maximum heart rate.[4] Despite the fact that numerous methods are available to assess levels of intensity during activities, research has frequently turned to heart rate monitoring because of its objectivity, reliability, and validity.[23] In this study, adapted physical activity and clinical exercise physiology researchers tested each participant's heart rate regularly during each training session to ensure that the necessary intensity levels were being met on a consistent basis.[7,8] Researchers used Polar Heart Rate Monitor (A1) CE 537, T31[c] transmitter and receiver sets to provide accurate heart rate measures (±1%) during exercise. As each participant adjusted to the exercise regimen, the volume of the swim training gradually increased throughout the study.[8,9] At the outset of the study, participants swam approximately 200 to 500m a session with variation based on ability. By the end of the study, however, participants could swim approximately 1000m a session depending on their ability level. During each session, participants were given short rest breaks of no more than 1 to 2 minutes between sets. Participants also engaged in 10 minutes of dry land training (stroke instruction, stretching, sit-ups) as well as partaking in aerobic tasks and velocity training.

Support staff. Two qualified swim coaches, certified in the National Coaching Certificate Program (level 1), led the exercise training sessions with an adapted physical activity specialist, an exercise physiologist, and approximately 4 clinical exercise physiology and 5 adapted physical activity researchers frequenting each session in order to assist the participants and ensure adherence to the study protocol. The extensive support system guaranteed better than a 1:1 ratio of assistants to participants and, in theory, may have increased the probability of success. Motivational strategies included verbal reinforcement (eg, cheering and positive feedback) and physical praise (eg, high-fives)[7] as well as pool sharing with a competitive swim team to provide participants with a visual image and better understanding of exercise training.

Statistical analysis. Given the small sample size (N= 8), we assumed that standard normality tests (Shapiro-Wilk, D'Agostino-Pearson, or Kolmogorov-Smirnov) would not have sufficient power to detect whether the data departed significantly from a normal distribution. Therefore, we used a 2-tailed Wilcoxon matched-pairs signed-ranks test to determine the impact of swim training on body fat percentage in individuals with ID. The Wilcoxon matched-pairs signed-ranks test is a nonparametric alternative to the paired-sample *t* test, which does not require that the data follow a normal distribution[24,25] and has been used recently in repeated-measures designs with small sample size.[26] We set statistical significance at P less than .05 and applied the software package GraphPad Prism 3.03,[d] which provides an exact P value calculation for the Wilcoxon matched-pairs signed-ranks test.

RESULTS

After the 16-week exercise training program, we observed a 1.2% median increase body fat percentage with a range from −0.3% to 4.5%. The results of the Wilcoxon matched-pairs signed-ranks test indicate that this increase was statistically significant, P equal to .039 (exact), as shown in figure 1.

DISCUSSION

This study sought to use the DXA to measure the effects of a 16-week exercise training program following ACSM guidelines on percent body fat in 8 children and adolescents with ID of various body fat levels. The swim training program, taking

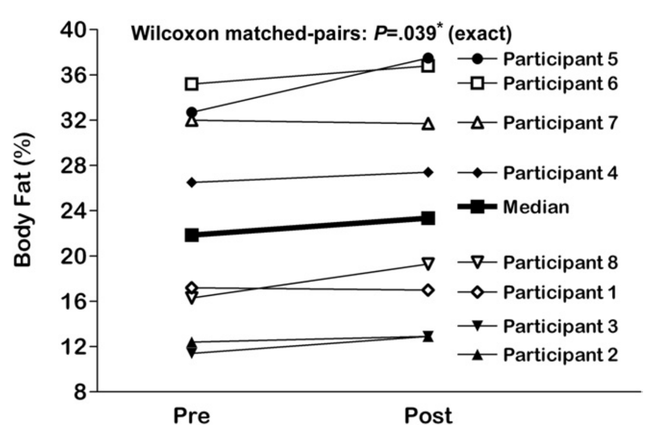

Fig 1. Change in percent body fat (%) for all children and adolescent participants with intellectual disability (n=8) after a 16-week swim training intervention according to DXA.

place for 1 hour, 3 times a week for 16 weeks, proved ineffective with participants significantly gaining percent body fat after the intervention. The hypothesis was not supported. In addition, neither body mass index nor weight decreased after the swim training program.

This study was the first to use DXA, a more complex measurement tool, to assess changes in percent body fat after an exercise intervention based in a community setting. The findings, although only preliminary given the small sample size and nonrandom method of recruitment, are consistent with those of Pitetti and Tan,[9] who used skinfold measurement to assess 12 participants of different fat levels and failed to witness an overall significant loss of percent body fat. Similarly, although using different testing measurements, Pommering et al[10] and Ozmen et al[11] reported no significant changes in percent body fat after aerobic exercise programs. Interestingly, Pommering et al[10] also found certain participants to increase in percent body fat after a 10-week program according to bioelectric impedance analysis. As of yet, no exercise intervention has produced a reduction in percent body fat among children and adolescents with ID. These results agree with data collected for children without ID as a meta-analysis by Resnicow and Robinson[27] underlined that only 7 of 77 cardiovascular prevention programs significantly improved adiposity. Ordoñez et al,[8] admittedly focusing only on men with Down syndrome, did find a decrease in body fat after a 12-week exercise program, but this study remains an exception and may be a result of the fact that body fat distribution in this population may be more truncal, indicating increased levels of abdominal and visceral fat stores.[13] The results of our study, when aligned with other studies using different measurement techniques, indicate that there may be a need for a change of direction with regard to future prevention programs for people with ID. At the very least, the lack of effect exercise interventions alone are having on reducing percent body fat in people with ID warrants closer scrutiny, because past research has yet to document clearly the pattern emerging in studies to date.

This study became the first to apply aquatic exercise alone as a means to decrease percent body fat in people with various IDs and simultaneously meet specific health guidelines in terms of frequency, intensity, and duration of exercise.[4] However, the swim training intervention did not reduce body fat in participants, and this finding may be a consequence of several noteworthy factors. All 8 participants lived in family settings, and this would have made supervision and control of dietary intake extremely challenging. Results show that people with ID living in less supervised settings such as at home or in small group homes are 23% more likely to be overweight than those who live in more supervised settings such as institutions.[17] During the course of this study, researchers witnessed, first-hand, parents using food as an incentive and motivational tool to encourage their children to participate cooperatively. This is perhaps unsurprising when one considers that even researchers working with individuals with ID in the area of fitness have admitted using soft drinks as an incentive for performance.[28] Bertoli et al[29] examined the nutritional status and food intake of 13 people with ID and found that they adopted inadequate diets. Moreover, Jobling and Cuskelly[30] demonstrated that people with Down syndrome, when given a choice between foods, would often choose unhealthy options such as hamburgers, soft drinks, and chips, despite encouragement to make healthy selections.

A negative energy balance may be required to reduce body fat,[7,31] and future research should ensure that caloric expenditure remains greater than caloric intake. Exercise interventions facilitate caloric expenditure but may also need to be combined with diet interventions aimed at decreasing caloric intake. Although nutritionists have not yet validated a method to examine dietary intake assessment for individuals with ID,[6] introducing a combined program may offer the possibility for people with ID to preserve lean muscle mass while also losing body fat. Exercisers in general face a dilemma of how best to strike a balance between calories burnt and calories consumed. In terms of comprehension, this quandary may be even more troublesome for certain children and adolescents with ID, especially in light of the abrupt lifestyle changes made after the introduction of an exercise training intervention held 3 times a week.

The study by Croce,[7] despite examining only 3 obese young adult participants (age range, 24–30y) and using nonpopulation-specific prediction equations for measurement, demonstrated the underlying potential and feasibility of combining exercise and diet to produce body fat loss in participants with ID. The study's diet intervention required a weekly reduction of 3500kcal from the participants' diet below what was required to maintain body weight in addition to five 1-hour sessions of aerobic exercise a week using treadmills and cycle ergometers. At a reduction rate of 3500kcal a week, it has been suggested that participants may experience a weight loss of approximately .45kg each week.[7] Using DXA, future studies may consider analyzing the effects on a larger sample of a joint exercise and food monitoring intervention. Closer collaboration between researchers in nutrition and other health science related fields may offer great potential to examine changes in percent body fat in this population.

Study Limitations

The authors acknowledge that the study's hypothesis may not have been supported in part because of errors in the estimation of percent body fat by DXA itself. However, researchers have been hard pressed to find an accurate method to measure percent body fat in people with ID. As a result of the questionable validity and reliability of the methods used to date, it has been difficult to draw conclusions with regard to measuring changes in percent body fat in this population. In comparison with previous studies, we used a measurement tool that has proved useful as a criterion measure for different instruments[14] and has already been validated against both underwater weighing[15] and the 4-compartment model.[16] DXA has previously provided accurate measurements in diverse populations[32,33] and has demonstrated minimal bias with regard to age, sex, physical activity level, race, or proportion of body fat.[13]

Ideally, the study should have been conducted in the form of a randomized controlled trial, which is regarded as the most efficient way of determining the effectiveness of an exercise intervention. However, this limitation is consistent with most exercise interventions conducted on different populations with disabilities. A recent exhaustive literature review by Rimmer et al[34] documented the difficulties associated with implementing exercise interventions on people with various disabilities. The review underlined the unique challenges involved in conducting randomized controlled trials in particular and offered explanations for why so few have been adopted on people with ID. The researchers highlighted the ethical concerns raised by withholding treatment for people with disabilities who may benefit from such an intervention, especially in light of the lack of community-based opportunities available to engage in different forms of exercise.[18] Moreover, controlled trials often require transportation, an extensive support staff, and access to numerous laboratory resources needed specifically for working with people with different disabilities.

Participants consisted of a small, heterogeneous group, which makes it troublesome to generalize findings to a larger population. This study took place in a small community, and it proved extremely difficult to obtain participants who had reached an adequate level of swimming based on the Royal Lifesaving Society's Swim to Survive Standard[22] at the commencement of the research. Even without consideration of swimming ability level, the lack of homogeneity within ID and the low incidence of this type of disability within the community made it extremely challenging to obtain a large sample size for a study occurring 3 times a week for 16 weeks. Similar to Croce,[7] new research may want to examine participants who are more obese in order to assess the effectiveness of interventions in producing changes in percent body fat. It is plausible that percentage body fat change may occur to a lesser degree among participants with lower baseline percentage body fat values. However, in the only other study to concentrate on obese participants, Pommering et al[10] found no change in percent body fat after an exercise intervention. Moreover, 2 systematic reviews[35,36] addressing obesity in children without ID suggest that there exists insufficient evidence to determine the nature of the relationship between degree of obesity at treatment initiation and outcome.

Nevertheless, it is probable clinicians or researchers in school, institution, or group home settings would likely encounter similar variation within sample population when working with people with ID. This factor again emphasizes the need to find appropriate testing methods that account for such a heterogeneous population and the likelihood of encountering a variety of disabilities in communities to comprehend fully the effectiveness of health promotion initiatives. Our study's diverse population sample replicated the real-world nature of applying methods to measure the effectiveness of a percent body fat intervention on people with ID. Results should be read cautiously because of the small sample size and lack of control group, but this research nonetheless offers an important framework for more rigorously designed future studies that use DXA, use a control group, and follow specific exercise guidelines in terms of frequency, intensity, and duration.

CONCLUSIONS

In conclusion, this study's results suggest that percent body fat did not decrease in 8 adolescents with ID after a 16-week community-based swim training program. This study, when considered with findings from similar studies for people with and without ID, promotes the need to implement a dietary intervention alongside an exercise intervention when assessing methods of reducing percent body fat in people with ID. In addition, this study shows that DXA, as a more complex measurement tool, may be used successfully to assess changes in percent body fat among adolescents with ID during an intervention program.

References

1. Rimmer JH, Yamaki K. Obesity and intellectual disability. Ment Retard Devel Disabil 2006;12:22-7.
2. Havercamp S, Scandlin D, Roth M. Health disparities among adults with developmental disabilities, adults with other disabilities, and adults not reporting disability in North Carolina. Pub Health Rep 2004;119:418-26.
3. Hoffman J. Norms for fitness, performance, and health. Champaign: Human Kinetics; 2006.
4. Fegan P. Intellectual disabilities. In Durstine JL, Moore GE, Painter PL, Roberts SO, editors. American College of Sports Medicine exercise management for persons with chronic diseases and disabilities. 2nd ed. Champaign: Human Kinetics; 2009. p 359-67.
5. Heyward VH, Stolarczyk LM. Body composition and children. In Heyward VH, Stolarczyk LM, editors. Applied body composition assessment. Champaign: Human Kinetics; 1996. p 90-8.
6. Humphries K, Traci MA, Seekins T. Nutrition and adults with intellectual or developmental disabilities: systematic literature review results. Intell Dev Disabil 2009;47:163-5.
7. Croce RV. Effects of exercise and diet on body composition and cardiovascular fitness in adults with severe mental retardation. Educ Train Ment Retard 1990;25:176-87.
8. Ordoñez RJ, Rosety M, Rosety-Rodriquez M. Influence of 12-week exercise training on fat mass percentage in adolescents with Down syndrome. Med Sci Monit 2006;12:416-9.
9. Pitetti KH, Tan DM. Effects of a minimally supervised exercise program for mentally retarded adults. Med Sci Sports Exerc 1991;23:594-601.
10. Pommering TL, Brose JA, Randolph E, Murray TF, Purdy RW Cadamagnani PE. Effects of an aerobic exercise program on community-based adults with mental retardation. Ment Retard 1994;32:218-26.
11. Ozmen T, Yidirim NU, Yuktasir B, Beets MW. Effects of school-based cardiovascular-fitness training in children with mental retardation. Pediatr Exerc Sci 2007;19:171-8.
12. Deurenberg P. Limitations of the bioelectrical impedance method for the assessment of body fat in severe obesity. Am J Clin Nutr 1996;64:449S-452S.
13. Guijarro M, Valero C, Paule B, Gonzalez-Macias J, Riancho JA. Bone mass in young adults with Down syndrome. J Intellect Disabil Res 2007;52:182-9.
14. Prior BM, Cureton KJ, Modlesky CM, Evans EM, Sloniger MA, Saunders M. In vivo validation of whole body composition estimates from dual-energy X-ray absorptiometry. J Appl Physiol 1997;83:623-30.
15. Lazzer SG, Bedogni F, Agosti A, De Col D, Mornati A, Sartorio A. Comparison of dual-energy X-ray absorpiometry, air displacement plethysmography and bioelectrical impedance analysis for the assessment of body composition in severely obese Caucasian children and adolescents. Br J Nutr 2008;100:918-24.
16. Tataranni PA, Ravussin E. Use of dual–energy X-ray absorpiometry in obese individuals. Am J Clin Nutr 1995;62:730-4.
17. Rimmer JH, Braddock D, Fujiura G. Prevalence of obesity in adults with mental retardation: Implications for health promotions and disease prevention. Ment Retard 1993;31:105-10.
18. Dodd KJ, Shields NS. A systematic review of the outcomes of cardiovascular exercise programs for people with Down syndrome. Arch Phys Med Rehab 2005;86:2051-8.
19. Yilmaz I, Ergu N, Lonukman F, Agbuga B, Zorbas E, Cimen Z. The Effects of water exercises and swimming on physical fitness of children with mental retardation. J Hum Kinet 2009;21:105-11.
20. Fragala-Pinkham MA, Haley SM, O'Neil ME. Group aquatic aerobic exercise for children with disabilities. Dev Med Child Neurol 2008;50:822-7.
21. Lohman TG. Measuring percent body fat using skinfolds [Motion picture]. Champaign, IL: Human Kinetics; 1987.
22. Royal Life Saving Society Canada. The Royal Lifesaving Society's Swim to Survive Standard. 2001. Available at: http://lifesaving.nfld.net/Swim%20to%20Survive%20Statement%20Jan%2001.pdf. Accessed November 10, 2009.
23. DuRant RH, Baranowski T, Davis H. Reliability and validity of heart rate monitoring in 3-, 4-, or 5-yr-old children. Med Sci Sports Exerc 1992;24:265-71.
24. Altman DG, editor. Practical statistics for medical research. London: Chapman and Hall; 1991. p 203-5.
25. Jackson SL. Research methods and statistics: a critical thinking approach. 3rd ed. Belmont: Cengage Learning; 2008. p 242-5.
26. Tepas III JJ, Sharmab R, Leapharta CL, Celsoc BG, Piepera P, Esquivia-Leea V. Timing of surgical intervention in necrotizing

enterocolitis can be determined by trajectory of metabolic derangement. J Pediatr Surg 2010;45:310-4.
27. Resnicow K, Robinson TN. School-based cardiovascular disease prevention studies: review and synthesis. Ann Epidemiol 1997; (7 Suppl): S14-31. Available at: http://www.annalsofepidemiology.org/article/S1047-2797(97)80005-1/abstract. Accessed May 26, 2010.
28. Fernhall B, Pitetti KH, Vukovich MD, et al. Validation of cardiovascular fitness field tests in children with mental retardation. Am J Ment Retard 1998;102:602-12.
29. Bertoli S, Battezzati A, Merati G, et al. Nutritional status and dietary patterns in disabled people. Nutr Metab Cardiovasc Dis 2006;16:100-12.
30. Jobling A, Cuskelly M. Young people with Down syndrome: a preliminary investigation of health knowledge and associated behaviours. J Intellect Dev Disabil 2006;31:210-8.
31. Horvat M, Eichstaedt C, Kalakian L, Croce R. Developmental/adapted physical education. 4th ed. San Francisco: Benjamin Cummings; 2003.
32. Svendsen OL, Haarbo J, Hassager C, Christiansen C. Accuracy of measurements of body composition by dual energy X-ray absorptiometry in vivo. Am J Clin Nutr 1993;57:605-8.
33. Pritchard JE, Nowson CA, Strauss BJ, Carlson JS, Kaymakci B, Wark JD. Evaluation of dual-energy X-ray absorpiometry as a method of measurement of body fat. Eur J Clin Nutr 1993;47:216-28.
34. Rimmer JH, Chen MD, McCubbin JA, Drum C, Peterson J. Exercise intervention research on persons with disabilities: what we know and where we need to go. Am J Phys Med Rehabil 2010;89:249-63.
35. Haddock CK, Shadish WR, Klesges RC, Stein RJ. Treatments for childhood and adolescent obesity. Ann Behav Med 1994;16:235-44.
36. Goldfield GS, Rynor HA, Epstein LH. Treatment of pediatric obesity. In Wadden TA, Stunkard AJ, editors. Handbook of obesity treatment. New York: Guilford; 2002. 532-55.

Suppliers

a. Tanita Corp of America Inc, Arlington Heights, IL 60005.
b. Hologic, Inc, 35 Crosby Dr, Bedford, MA 01730-1401.
c. Polar Electro Canada Inc., Lachine, QC, Canada, H8T 2P3.
d. GraphPad Software, Inc, La Jolla, CA, USA 92037.