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The effect of aquatic exercises on the physical and functional fitness of adults with Down syndrome: A non-randomised controlled trial

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Abstract

Background The importance of exercise for individuals with Down syndrome (DS) has been well documented. The use of aquatic exercises may be an attractive alternative to land-based exercises for individuals with musculoskeletal conditions such as low muscle tone and excess adiposity as found in adults with DS. As a result, the purpose of the current study was to study the effect of an aquatic training intervention on the functional fitness for adults with DS.
Methods Participants were recruited from two intellectually disabled care centres in the Western Cape of South Africa. Twenty-three adults with DS (13 men and 10 women) (31.4 ± 7.4 years) were allocated to an aquatic training group or a control group. The exercise group performed 35 min of aquatic training, three times a week for 6 weeks, with an increase duration of 45 min after 3 weeks. Outcome measures assessed were aerobic capacity, muscular strength, functional ability and balance.
Results The aerobic capacity and functional ability of the participants in the aquatic group improved significantly than in the control group with strong to medium effect sizes. Two out of the three strength parameters also improved significantly than in the control group.
Conclusions The functional fitness of adults with DS improved with an aquatic intervention but was insufficient to improve balance and upper body strength. The improvement of various parameters associated with functional fitness is important in this population who age prematurely, suffer from the early onset of age-related conditions, are vulnerable to falls and susceptible to chronic conditions.

Keywords aquatic, balance, Down syndrome, exercise, fitness, water activities

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Introduction

Down syndrome (DS) is the most prevalent genetic condition associated with intellectual disabilities (Winnick 2005). According to the Down syndrome South Africa (2019), one in 500 people are affected by this chromosome anomaly. Most persons with DS have muscle hypotonicity, ligamentous laxity and congenital heart disease and are often overweight (Carmeli *et al.* 2002a; Abbag 2006; Pitetti *et al.* 2013). Regrettably, many individuals with DS live a habitual inactive lifestyle (Nordstrøm *et al.* 2013). A lifestyle of this nature does not help their already low functional fitness including aerobic capacity and muscle strength (Baynard *et al.* 2008; Cowley *et al.* 2010). Rikli and Jones (2013) defined functional fitness as having the physical capacity to perform normal everyday activities safely and independently without undue fatigue. The authors explained that functional fitness refers to having adequate strength, balance, mobility and endurance to execute essential tasks efficiently and effortlessly. Being functionally fit is important for all populations, but even more so for populations at risk of deteriorating functional capacity such as the elderly, persons with disabilities and those with chronic medical conditions.

Fortunately, a vast number of research studies have shown that adults with DS can improve their functional fitness through structured activities of aerobic (Carmeli *et al.* 2002b; Mendonca and Pereira 2009; Boer and Moss 2016a), resistance (Cowley *et al.* 2011), combined aerobic and resistance (Mendonca *et al.* 2013) or balance (Tsimaras and Fotiadou 2004) training. Aerobic activities that are primarily used included modalities consisting of running (Tsimaras *et al.* 2003; Boer and Moss 2016a), cycling (Mendonca and Pereira 2009) and rowing (Varela *et al.* 2001). An improvement in aerobic capacity is important for individuals with DS, as a poor aerobic capacity is considered to be a risk factor for cardiovascular diseases and can result in a reduced lifespan for this population (González-Agüero *et al.* 2010). Low levels of physical fitness may cause functional deterioration as well as reduce bone mineral density and worsening existing clinical conditions (González-Agüero *et al.* 2010). An improvement in muscular strength is also important, as this variable has been shown to predict functional performance and the ability to perform everyday living activities specifically in adults with DS (Cowley *et al.* 2010; Terblanche and Boer 2013).

We are not aware of any studies that have used solely aquatic exercises and the associated effect on anthropometry and functional fitness for adults with DS. The use of aquatic exercises may be an attractive alternative to land-based exercises for individuals with musculoskeletal conditions such as low muscle tone and excess adiposity as found in adults with DS (Meredith-Jones *et al.* 2011). Aquatic-based exercise can improve cardiorespiratory fitness, muscular strength and body fat percentage as reported in a qualitative review on individuals with various medical conditions (Meredith-Jones *et al.* 2011). There is only one study that we are aware of that has conducted aquatic exercises on adolescents with DS, but it was combined with land-based exercises (Ordonez *et al.* 2006). This study found that the body fat percentage did significantly decrease after 12 weeks of training but did not explore the effects on physical or functional fitness. A study that did explore the effect of aquatic exercises on cardiovascular endurance, muscular strength, speed, agility and balance reported significant improvements, but it was conducted on children with intellectual disability (ID) without DS (Yılmaz *et al.* 2009).

Mahy *et al.* (2010) and Heller *et al.* (2003) provided solutions to help facilitate physical activity for persons with DS. They found that exercises that were fun, understood and mastered, stimulating, accessible, and routine based and with support from others provided the necessary platform to overcome the barriers to exercise participation. Owing to a lack of research studies using aquatic exercises on adults with DS, we wanted to explore the effect of such an intervention that is stimulating, enjoyable, easy to perform and routine based on adults with DS. Moreover, we wanted to determine whether such a programme could improve the aerobic capacity, muscular strength, functional ability, balance and body mass of these participants. Subsequently, the purpose of the current study was to determine the effect of aquatic activities on the physical and functional fitness of adults with DS in South Africa.

Methods

The study included 25 participants (14 men and 11 women) with DS from two intellectually disabled care centres in the Western Cape of South Africa (Centre A, 14 participants; Centre B, 11 participants). Participants lived at the intellectually disabled care centres. Participants are mostly involved with manual tasks such as folding pamphlets, packing boxes, sticking notes and cutting shapes. Ethical clearance was obtained from the Ethical Committee of the University (EFEC 6-11/2018). The parent or legal guardian signed an informed consent, and the participant signed a consent form that was adapted for persons with DS. Participants were included if they had the cognitive ability to perform the tests and training according to the technical specifications. All baseline tests used in this study were found to be feasible, reliable and valid for persons with DS (Terblanche and Boer 2013; Boer and Moss 2016b;

Boer and Moss 2016c). Individuals were excluded if they suffered from ear infections, congestive heart disease or any other chronic physical or mental condition contraindicative to the demands of physical activity. There were no records of the level of ID of the participants at either of the two centres.

Procedures

Upon the first visit, the primary researcher introduced the study to participants and their guardians/parents who were interested. The baseline and post-intervention tests and training procedures were explained and physically demonstrated. The parents or legal guardian of those who were interested were given information sheets, consent forms and adapted (easier-to-read) consent forms. A second visit was conducted 1 week later where the two consent forms were collected. Familiarisation sessions were conducted where the participants physically performed the baseline functional fitness tests. Participants were familiarised with each test on at least one occasion. More sessions were provided if deemed necessary. The participants from the one intellectually disabled care centre performed aquatic exercises, and the participants from the other intellectually disabled care centre served as the control group. The reason for purposive allocation is that the two centres were 50 km apart and only one centre had a swimming pool.

Tests

The items chosen are all considered feasible, valid and reliable, field based and easy to administer (Terblanche and Boer 2013; Boer and Moss 2016b; Boer and Moss 2016c). Adequate rest was allocated during testing days. Four adults were tested simultaneously on a turn basis (i.e. participant 1 – trial 1; and participant 2 – trial 1), which also provided sufficient rest between tests. Participant results obtained during the tests were not communicated to other participants. The tests included an aerobic activity, two functional activities, a static balance activity and a dynamic balance activity, two upper body strength and endurance activities and one lower body strength and endurance activity. All tests were performed at the intellectually disabled care centre in a large, adequately ventilated indoor venue with non-slippery flooring, free from noise or disturbances. Participants were asked to avoid intense physical activity and alcohol or caffeine intake 24 h before the testing day. Four participants were tested at a time, and each session lasted approximately 2 h. Participants were given a 7- to 10-min warm-up with stretching activities under the supervision of the researcher. These activities were not tiring and involved warming up the large muscle groups (marching in place and swinging arms) and simple stretches (head turn, single arm crossover, chest stretch, calf stretch and hamstring stretch).

Participants were visually shown and verbally instructed on how to perform each test. Participants were tested individually for all test items. Continuous encouragement and motivation were given to all participants, as described by Varela *et al.* (2001) and Waninge *et al.* (2011). Stations were arranged in the following order to minimise fatigue: 8-ft up and go, balance items, muscular strength and endurance (modified curl-up, chair stand and isometric push-up) and finally the 6-min walk distance (6MWD) test. Body mass and stature were always measured first. The 16-m shuttle-run test was performed the following day. All tests were performed by the same researcher with specific emphasis on scoring either successful measurement with a score or an unsuccessful measurement without any score, to avoid uncertainty. Participants performed the eight tests on the first and second days and again after 6 weeks of training or no training. The tests were performed on the same time of day.

Training programme

Both groups continued with their normal everyday activities during the intervention period. Participants in the aquatic training group exercised three times a week for 6 weeks. A 6-week intervention period was chosen to match a typical school term. The baseline and post-intervention tests also had to be completed during the term and before the holidays, as most of the residents leave during the break to their parental homes. Compliance was monitored. Each session was conducted for 35 min during the first 3 weeks. The last 3 weeks lasted 45 min. All sessions involved a 5-min warm-up and a 2-min cool down (not included in the core 35-min session). The training was completed in a swimming pool with a depth of 1.4 m. Participants were trained as a group using a face-to-face approach. The primary researcher conducted the training session with six students providing help and motivation in the swimming pool. The exercises included arm circles, side twists, walk in place, run in place, water scoops, side leg lift, flutter kick on back, flutter kick on stomach, jumping jacks, knee twists, side shuffle, squat jumps, lunge jumps and a longer jog in place. The aquatic exercise was accompanied by lively music during the sessions. The exercise sessions were controlled and monitored by a high ratio of test instructor and senior Human Movement Science students to exercise participants (approximately one test instructor to two participants).

Body mass and height

Body mass and standing height were obtained conducted with a Seca scale and stadiometer (Seca, Hamburg, Germany). Participants wore a shirt and lightweight trunks only. The body mass and height measurements were used to calculate body mass index (BMI).

Sixteen-metre Progressive Aerobic Cardiovascular Endurance Run test (modified shuttle-run test)

Aerobic capacity or cardiorespiratory endurance was assessed by means of a 16-m modified shuttle-run test. The 16-m Progressive Aerobic Cardiovascular Endurance Run (PACER) test can be performed indoors, is fun, does not require self-monitored pacing and incurs fewer motivational problems. At the sound of a tape-recorded beep, participants ran between two lines, 16 m apart. The test score will be the number of shuttles completed on pace. Only one trial was permitted. Familiarisation sessions were conducted before the commencement of the study. The test instructor ran alongside the participant to help with pacing and turning when a shuttle was completed. We have previously demonstrated that the 16-m PACER test was both feasible and reliable in adults with DS (Boer and Moss 2016b). Moreover, the 16-m PACER test was shown to be a valid test when assessed with the gold standard VO_2 max test using a standardised protocol for adults with DS (Boer and Moss 2016c). The regression formula obtained from this study was as follows: VO_2 peak = 48.2 + 0.32 (shuttles from 16-m PACER) – 0.45 (BMI) – 2.88 (Gender) – 0.13 (Age) [gender: male (1) and female (2)].

Six-minute walk distance test

The 6MWD test is not only a functional fitness test item but also a test assessing aerobic capacity (Rikli and Jones 2013; Boer and Moss 2016c). The participants completed a standardised, self-paced 6MWD test. They were instructed to walk as many laps as possible of 50 yards within the allocated 6 min. The distance covered was recorded to the nearest yard, which was converted to metres. This test assesses aerobic endurance and functional ability, which are important for many everyday living activities such as walking distances for shopping and sightseeing while on vacation. Excellent test–retest reliability and feasibility of this test item have been demonstrated in adults with ID and in adults with DS (Nasuti *et al.* 2013; Boer and Moss 2016b). They have also shown adequate validity with aerobic capacity in adults with DS (Boer and Moss 2016c).

Eight-foot get-up-and-go test

The 8-ft get-up-and-go test is a functional fitness test item. On the signal 'go', the participant got up from the chair, walked as quickly as possible to a cone placed 2.43 m (8 ft) away, walked around the cone and returned to the chair. After one practice trial, two test trials were administered, and the best time is recorded in seconds. Excellent test–retest reliability of this test item has been shown in adults with DS (Boer and Moss 2016b). Discriminant validity has been reported in adults with DS between age categories (18–25, 26–35, 36–45 and >45) (Terblanche and Boer 2013).

Balance

Static balance was evaluated with the participants standing on one leg for as long as they could to a maximum of 10 s while looking straight ahead (eyes open) and with their hands on their hips. The knee of the free leg was bent so the lower leg was parallel to the floor. The test was terminated when too much body sway occurred or once the hands moved off the hips. The test was performed with both legs, and the best score of each leg was noted as static balance performance.

Dynamic balance was assessed by walking on a 3.05-m balance beam that is 10.16 cm wide. Participants were instructed to walk with a normal stride while maintaining hands on the hips. The number of consecutive steps completed on the balance beam, up to a maximum of six steps, was recorded. In both tests, two trials were administered, and the best score was noted. Test–retest reliability for the balance tests is excellent as shown in adults with DS (Boer and Moss 2016b).

Muscular strength and endurance

Chair stand test

Lower body strength was assessed with the chair stand test (Rikli and Jones 2013). Participants sat on a straight-backed chair (43.18 cm in height and with no arm rests), feet flat on the floor and arms across the chest. On the signal go, the participant rose to a full stand and then returned to a fully seated position. The score was the number of stands completed in 30 s. Two trials were conducted. In the general older population, test–retest reliability was good [intraclass correlation coefficients (ICCs) of 0.84 for men and 0.92 for women] (Rikli and Jones 2013). Test–retest reliability in older adults with ID was moderate (ICC = 0.72 for same-day interval and 0.65 for 2-week interval) (Hilgenkamp *et al.* 2012). Test–retest reliability was shown to be excellent for adults with DS (Boer and Moss 2016b).

Isometric push-up

The isometric push-up assesses upper body strength. Participants attempted to hold the push-up position for as long as they could. Hands had to be placed directly below the shoulders, arms had to be extended, the back had to be perfectly aligned with the rest of the body and toes had to be on the floor. The time that the position was kept was taken to the nearest second. Only one trial was administered. Time was stopped as soon as the back sagged or lifted. Proper form was strictly controlled. Test–retest reliability measured 2 weeks apart in adolescents with ID was good (ICC = 0.98) (Winnick and Short 1998). Test–retest reliability was shown to be excellent for adults with DS (Boer and Moss 2016b).

Modified curl-up

The modified curl-up test was included to assess abdominal strength. Participants lay in a supine position with knees bent, hands on the thighs and feet flat on the floor. Participants slid their hands up the thighs to the kneecap while performing the curl-up and then returned to the starting position. The fingers had to slide at minimum of 10 cm along the legs to the kneecaps. The test assessor's hands were placed on the superior aspect of the kneecap, thereby assisting the subject in performing the correct technique. Hands had to slide up simultaneously to the left and right kneecap with the fingers not allowed to lift off the legs. Participants performed as many curl-ups as possible (up to a maximum of 75) for as long as possible by doing one curl-up every 3 s. The researcher verbally counted the number of curl-ups. Only one trial was administered. Excellent test–retest reliability was shown for adults with DS (Boer and Moss 2016b).

Statistics

Data were analysed with the Statistical Package for the Social Sciences (SPSS 25.0, Chicago, IL, USA). All data were screened for normality and homogeneity of variance with the Shapiro–Wilk statistic and Levene's test, respectively. Data are presented as mean and standard deviation. Significant differences between groups before the intervention were analysed with an independent samples *T*-test. To calculate mean differences with a 95% confidence interval between groups, a one-way analysis of variance was used, controlling for differences at baseline. Lastly, Cohen's *d* effect sizes with 95% confidence interval were calculated. The magnitude of the effect sizes were classified as small (0.10 to <0.30), medium (0.30 to <0.79) or large (≥0.80) as by Cohen (1988). A significance level of $p < 0.05$ was used.

Results

A total of 23 participants completed the study (13 men and 10 women). The aquatic group consisted of 13 participants (eight men and five women), while the control group consisted of 10 participants (five men and five women). The mean age and BMI of all the participants was 31.4 ± 7.4 and 31.1 ± 6.8, respectively. Only one participant in the control group did not perform the post-intervention tests, as this person was absent on testing days. Another person from the intervention group dropped out, as he relocated. A breakdown of the participants and dropouts is presented in Figure 1 as a flow chart. All participants were able perform the water aquatic exercises during the intervention period. Compliance during the intervention period was excellent, with the majority of participants completing all 18 sessions and a few missed a maximum of one or two sessions. The average percentage of attendance during the intervention trial was 94.5%. Training sessions missed were due to personal commitments or illness. No serious or adverse events occurred during the tests or training phases of the study. The aquatic training sessions were purported to be safe and fun by all participants.

The assumption of homogeneity of variances (Levene's test) was violated for none of the variables, but the assumption of normality (Shapiro–Wilk) was violated for the two balance tests, sit-to-stand test, isometric push-up and the PACER test and as a result assessed by the Mann–Whitney non-parametric test. There were no missing values in the data set and no significant differences between groups at baseline.

After 6 weeks of exercise, the aquatic training group improved significantly than did the control group on the 16-m PACER and 6MWD test and on the sit-to-stand and modified curl-up tests (Tables 1 and 2). The mean difference and 95% confidence interval limits are shown in Table 2. The use of effect sizes demonstrated large effects for aerobic capacity and muscular strength items, medium effect sizes for functional ability and dynamic balance, and a small effect size for static balance (Table 3).

Discussion

The primary purpose of the study was to explore the effects of an aquatic training intervention amongst adults with DS. As far as we know, no other study has explored the effects of an aquatic-based intervention on the functional fitness of adults with DS. Compliance during the intervention period was excellent, and no adverse events or injuries resulted during the study period.

No significant ameliorations resulted in body mass or BMI with the use of aquatic-based exercises. This is in a group of adults where the mean BMI of the aquatic group was 29.6 kg/m^2 with 85% of the participants being overweight or obese (BMI > 25). Other studies have also shown that the vast majority of adults with DS are overweight and/or obese (Melville *et al.* 2008; Pitetti *et al.* 2013). Lower BMI values are important for adults with DS, as this variable, in association with the level of physical activity, relates to better cardiorespiratory endurance (Ringenbach *et al.* 2017). Perhaps the length of the intervention programme was not sufficient to result in significant weight loss. Also, the intensity of the aquatic exercises was possibly not high enough during 6 weeks of training. The importance of programme length and intensity was stipulated in a review study considering children and adolescents with DS (González-Agüero *et al.* 2010). There are studies that have also demonstrated no weight loss and/or body fat loss with aerobic training (Varela *et al.* 2001; Tsimaras *et al.* 2003) or with combined aerobic and resistance training (Mendonca *et al.* 2011) in adults with DS. The lack of improvement in body or fat mass was confirmed in a meta-analytic study (Dodd and Shields 2005). However, studies with a longer intervention period involving aerobic or combined aerobic and resistance training or combined water and land-based aerobic activities resulted in weight or fat loss after 12 or more weeks of training (Rimmer *et al.* 2004; Ordonez *et al.* 2006; Mendonca and Pereira 2009). The study using combined water and land training intervention did not provide information regarding the type, duration or composition of land and water exercise nor the mechanisms responsible for the loss in fat percentage in adolescents with DS

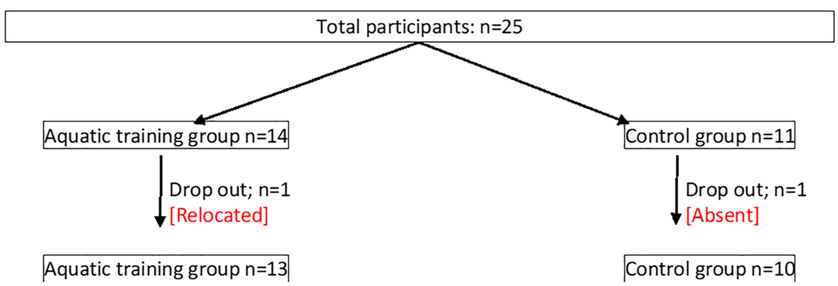

Figure 1. Flow diagram depicting total initial participants, dropouts and final study sample. [Colour figure can be viewed at wileyonlinelibrary.com]

Table 1 Descriptive statistics of the functional fitness parameters for the aquatic and control group

Variable	Aquatic group (*n* = 13)		Control group (*n* = 10)	
	Pre	Post	Pre	Post
Age (years)	31.2 (6.9)	31.3 (6.9)	31.7 (8.4)	31.8 (8.4)
Body mass (kg)	77.6 (20.4)	76.2 (20.1)	76.4 (11.8)	76.2 (12.5)
Body mass index (kg/m^2)	29.6 (6.5)	29.1 (6.4)	33.1 (7.0)	33.0 (7.3)
16-m PACER (shuttles)	18.8 (10.6)	29.1 (20.4)†	17.0 (15.9)	14.8 (16.2)
6-min walk distance (m)	543. 2 (110.6)	602.1(98.7)†	542.7 (106.5)	519. 9 (111.9)
Standing on one leg (s)	6.0 (3.5)	6.6 (3.5)	5.1 (3.5)	5.1 (3.6)
Walking on balance beam (steps)	4.0 (2.3)	5.6 (0.8)	3.7 (2.2)	4.6 (2.1)
8-ft up and go (s)	5.9 (1.6)	5.3 (0.9)	5.7 (0.9)	5.5 (0.9)
Sit-to-stand (s)	12.7 (2.3)	14.5 (2.2)†	12.6 (1.5)	13.0 (1.8)
Modified curl-up (n)	21.2 (26.0)	37.9 (30.1)†	15.7 (24.7)	20.0 (28.3)
Isometric push-up (s)	68.0 (47.5)	82.2 (50.9)	44.3 (39.8)	36.5 (32.5)

Data are presented as mean (standard deviation).
n: amount; PACER, Progressive Aerobic Cardiovascular Endurance Run.
†Significant difference between groups.

Table 2 Mean difference with associated 95% confidence interval between the aquatic and control group

Variable	Mean difference	95% confidence interval	
		Lower	Upper
Body mass (kg)	1.07	−0.10	2.24
Body mass index (kg/m^2)	0.40	−0.74	0.87
16-m PACER (shuttles)	12.43	5.55	19.31
6-min walk distance (m)	81.74	46.73	116.75
Standing on one leg (s)	0.53	−1.39	2.44
Walking on balance beam (steps)	0.72	−0.76	2.19
8-ft up and go (s)	0.42	−0.35	1.18
Sit-to-stand (s)	1.20	0.13	2.27
Modified curl-up (n)	12.32	0.40	24.23
Isometric push-up (s)	22.00	−3.82	47.82

PACER, Progressive Aerobic Cardiovascular Endurance Run.

Table 3 Effect sizes with associated 95% confidence interval calculated between groups for functional fitness parameters

Variable	Effect size (±95% CI)	Magnitude
16-m PACER (shuttles)	1.68 (0.72; 2.64)	Large
6-min walk distance (m)	2.12 (1.09; 3.15)	Large
Standing on one leg (s)	0.25 (−0.58; 1.08)	Small
Walking on balance beam (steps)	0.43 (−0.41; 1.26)	Medium
8-ft up and go (s)	0.49 (−0.34; 1.33)	Medium
Sit-to-stand (s)	1.00 (0.13; 1.87)	Large
Modified curl-up (n)	0.91 (0.05; 1.78)	Large
Isometric push-up (s)	0.72 (−0.13; 1.56)	Large

CI, confidence interval; PACER, Progressive Aerobic Cardiovascular Endurance Run.

(Ordonez *et al.* 2006). A more recent study involving running/walking where one group performed interval training and the other continuous aerobic training of 12 weeks also demonstrated significant weight loss but not fat loss (Boer and Moss 2016a). Significant weight loss could possibly have occurred if the pool depth was less than 1.4 m, as the physiological demand is lower in deep-water conditions, as shown by comparative studies using heart rate, lactate, and VO_2 max parameters (Town and Bradley 1991; Dowzer *et al.* 1999; Benelli *et al.* 2004). In summary, the absence of weight loss in the current study could possibly be attributed to the insufficient length and/or intensity of the intervention.

On the other hand, significant improvements resulted in aerobic capacity and functional ability. Previously, both the 6MWD and 16-m PACER tests have shown strong correlations and linear regression with the gold standard VO_2 max test using a standardised treadmill protocol specifically adapted for adults with DS (Boer and Moss 2016c). The

6MWD test has also been shown to correlate with functional fitness (Rikli and Jones 2013). Both the 6MWD and 16-m PACER tests resulted in significant improvements with large effect sizes. The participants performed various exercises such as jumping jacks, shuttle movements, running on the spot, sprinting on the spot, flutter kicks, lunge and squat jumps, which improved the cardiovascular endurance and functional ability. Significant improvements shown in the upper leg musculature as shown by the sit-to-stand test could also explain enhancement in the cardiovascular ability as the study by Pitetti and Boneh (1995) demonstrated a close relationship between leg strength and aerobic capacity in adults with DS. Numerous studies reported significant improvements in physical or functional fitness with running, cycling, rowing or combined training regimens in adults with DS (Varela *et al.* 2001; Rimmer *et al.* 2004; Carmeli *et al.* 2004a; Mendonca and Pereira 2009; Mendonca *et al.* 2013; Boer and Moss 2016a). The only aquatic intervention study that we are aware of that was conducted on adolescents with DS did not explore the effect on physical or functional fitness (Ordonez *et al.* 2006). A recent systematic review (Hardee and Fetters 2017) demonstrated the importance of any exercise intervention in individuals with DS, as it is related to the ability to perform activities of daily life.

The improvement seen in functional and cardiovascular fitness is essential for adults with DS, as they have already low physical and functional fitness across all age groups than have individuals with ID without DS and the general population (Baynard *et al.* 2008). Moreover, the improvement in functional fitness could help adults with DS with various debilitating factors shown in this population such as premature ageing (Carmeli *et al.* 2004b; Terblanche and Boer 2013; Pikora *et al.* 2014), the early onset of age-related conditions (Torr *et al.* 2010), vulnerability to falls (Hsieh *et al.* 2012) and susceptibility to chronic conditions such as Alzheimer's, depression and epilepsy (Hermon *et al.* 2001; Zigman and Lott 2007). Cowley *et al.* (2010) reiterated the importance of adequate functional fitness, as poor aerobic capacity limits the ability to perform functional tasks of daily living in individuals with DS.

As stated already, lower limb muscular strength and endurance improved significantly as demonstrated by the sit-to-stand test. Significant improvements shown for not only leg strength but also abdominal and upper body strength (all large effect sizes). Muscular strength is a predictor of functional performance and the ability to perform everyday living activities in adults with DS (Cowley *et al.* 2010; Terblanche and Boer 2013). The improvement thereof is important, as many individuals with DS have already reduced muscle strength than have the general population and individuals with ID but without DS (Pitetti *et al.* 1992; Croce *et al.* 1996; Carmeli *et al.* 2002a). Other studies using aerobic training regimens also demonstrated improvements in muscle strength and functional ability (Carmeli *et al.* 2002b; Lewis and Fragala-Pinkham 2005; Boer and Moss 2016a). An improvement in muscle strength is important for this population who is often engaged in physical-related rather than cognitive-related work.

Regarding the final functional fitness parameter that was assessed, namely, static and dynamic balance, no significant improvement between groups was reported, even though balance activities were performed in the swimming pool. However, a medium effect size for dynamic balance was demonstrated. Carmeli *et al.* (2002b) reported that older adults with DS did improve dynamic balance (timed up-and-go test) by adopting a treadmill walking programme lasting 6 months. However, a year later, the same researchers conducted a study on adults with ID but without DS and found a significant improvement in only two of the five balance tests after an intervention of treadmill walking and ball exercises (Carmeli *et al.* 2003). Another study used dynamic balance and plyometric land-based exercises during the 12-week intervention period and reported significant improvement in dynamic balance as measured on a balance deck and determined by a stabilometer in adults with DS (Tsimaras and Fotiadou 2004). Balance is an important skill that individuals with DS should possess, as it has been demonstrated that better balance is associated with the proficiency to conduct fundamental movement skills in children with DS (Capio *et al.* 2018). The lack of improvement in dynamic and especially static balance shown in the current study could possibly be attributed to the shorter intervention period, few balance type activities during the intervention period (side leg lift, lunge and squat jumps) or the additional buoyancy provided by the hydrostatic pressure of the water.

Conclusion

An aquatic training programme provided physical conditioning that was safe and feasible for adults with DS as evidenced by excellent compliance, low dropouts and the absence of serious or adverse conditions. Moreover, significant improvements were reported for various functional fitness parameters such as aerobic capacity, muscular strength and functional ability.

Limitations and future studies

A limitation of the current study was that the exercise intervention was short in duration (6 weeks) and that exercise intensity was not monitored with heart rate monitors. However, the study used two test instructors and six senior Human Movement Science students during the exercise sessions for the 13 adults with DS to motivate, monitor and ensure optimal training technique and intensity. The students were actively involved with the participants in the swimming pool. A second limitation of the study was that the level of ID is not known, as the centres did not have information pertaining to the level of ID. All participants in the current study were able to understand test instructions and follow the correct technique as demonstrated by the principal investigator. Thirdly, the group allocation of the current study was not performed randomly. Participants from two ID care centres were selected, as the participants of one centre were not enough for statistical accuracy. Both centres did not have heated swimming pools of 1.4-m depth and were located 50 km apart. However, there was no significant difference for the baseline values between groups for all the variables studied (Table 1). Lastly, there was no control for usual physical activity, which could have differed between the groups.

Future studies could investigate the effect of aquatic exercise, which is physiologically more demanding by using an intervention that is longer in length, higher in intensity or in water that is waist level deep. Another study could explore the effect of freestyle swim training, for those who are able to, and the associated effect on physical or functional fitness and swimming performance. A future study could also include a standardised aquatic specific test to monitor training-related improvements.

Conflict of Interest

No conflicts of interest have been declared.

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