

The effect of 8 weeks of freestyle swim training on the functional fitness of adults with Down syndrome

P. H. Boer 

Department of Human Movement Science, Faculty of Education, Cape Peninsula University of Technology, Wellington, South Africa

Abstract

Background Studies conducted on adults with Down syndrome have demonstrated the improvement of functional fitness (aerobic capacity, muscular strength, balance, flexibility, functional ability, body mass or body mass index) with varying exercise modalities but often with one or two components in isolation. Such modalities included walking, running, cycling, rowing or resistance training. Freestyle swim training has shown significant improvements of all parameters associated with functional fitness in the general population. Swimming is an aerobic activity where many of the large muscle groups are involved and may provide more functional fitness benefits. As a consequence, the purpose of our study was to investigate the effect of freestyle swim training on the functional fitness of adults with Down syndrome.

Methods Twenty-six adults with Down syndrome (33 ± 6 years; 34 ± 9 kg/m²) were randomly allocated to an exercise ($n = 13$; 81.3 kg) or control group ($n = 13$; 81.5 kg). The exercise group performed 8 weeks of freestyle swim training, three times a week, 30 min per session (increased to 40 min after 4 weeks). To evaluate differences between groups, a one-way analysis of variance was used, controlling for differences at baseline.

Results After 8 weeks of training, the results showed significant differences between the exercise and control group for body mass, body mass index, aerobic capacity, dynamic balance, muscular strength, 12-m swim time and functional ability ($P < 0.05$). Effect sizes ranged from small to large.

Conclusions Various components of functional fitness improved significantly after an intervention period of freestyle swim training. The collective improvement of many functional fitness parameters shown by this study may hold benefits for these often-neglected and in many cases functionally impaired individuals.

Keywords aerobic capacity, balance, Down syndrome, exercise, flexibility, functional capacity, strength

Introduction

Down syndrome (DS) is a condition caused by a genetic abnormality that negatively impacts on the physical and intellectual development of the individuals. Most of these individuals are born with or develop conditions or illnesses that affect their quality of life (de Asua *et al.* 2015; Pikora *et al.* 2014; Ruiz-González *et al.* 2019). Many individuals adopt a sedentary lifestyle, possibly owing to these medical conditions or the lack of advice and assistance from health and fitness professionals (Nordström *et al.* 2013). Consequently, a large percentage of adults with DS are overweight or obese (Melville

Correspondence: Dr P. H. Boer, Department of Human Movement Science Faculty of Education, Cape Peninsula University of Technology, Jan van Riebeeck Street, Wellington 7654, South Africa (e-mail: boerp011@gmail.com).

et al. 2008; Terblanche and Boer 2013). In addition, a high body fat percentage has been related to low physical and functional ability in this population (Salaun and Berthouze-Aranda 2012). Although the life expectancy of these individuals has increased vastly as a consequence of improved medical interventions, the population ages prematurely, and their quality of life deteriorates even further with age (Arumugam *et al.* 2016; Torr *et al.* 2010).

One way to improve, delay or counter the many challenges that individuals with DS face is to improve their functional fitness. Functional fitness refers to having the physical capacity to perform normal everyday activities safely and independently without undue fatigue (Rikli and Jones 2013). Many researchers have opted to use the term 'functional fitness' instead of 'physical fitness' as it incorporates terms such as health, independence and functional capacity, especially for populations such as the elderly and those with disabilities or chronic medical conditions (Brill 2004; Millán-Calenti *et al.* 2010; Rikli and Jones 2013). Functional fitness components such as cardiorespiratory endurance, muscular strength and endurance, flexibility, balance, functional ability and appropriate body composition are important for the health and well-being of any population group. A limitation in functional fitness hampers the ability to live an independent and disease-free life (Rikli and Jones 2013).

Fortunately, numerous scientific investigations conducted on adults with DS using intervention strategies such as walking, running, cycling, resistance training, water aerobics and combined training have shown significant improvements of cardiorespiratory endurance (Boer and Moss 2016a; Carmeli *et al.* 2002; Mendonca *et al.* 2013; Mendonca and Pereira 2009), muscular strength (Cowley *et al.* 2011; Mendonca *et al.* 2011; Shields *et al.* 2013), balance (Carmeli *et al.* 2002; Tsimaras and Fotiadou 2004) and functional ability (Cowley *et al.* 2011). However, many studies have not reported significant improvements in body mass and/or variables associated with body composition using experimental exercise studies (Mendonca *et al.* 2011, 2013; Boer and de Beer 2019). A recent meta-analytic study performed on individuals with DS reported that there is inconclusive evidence for an improvement in aerobic capacity and a decrease in body mass index (BMI) (Ruiz-González *et al.* 2019). Few studies have

reported significant improvements in both muscular strength and cardiorespiratory endurance amongst adults with DS (Boer and de Beer 2019; Mendonca *et al.* 2013; Rimmer *et al.* 2004).

A recent review and meta-analytic study incorporating randomised or quasi-randomised controlled trials conducted on non-elite swimmers reported significant improvements of body mass, body composition, aerobic capacity, submaximal exercise capacity, muscular strength and various health-related variables (Lahart and Metsios 2018). Collective improvements such as these may be possible as swimming involves full-body continuous aerobic activity where many of the large muscle groups are used (Tanaka 2009). An intervention of this nature conducted on a DS adult population could significantly alter functional fitness parameters previously shown to improve in isolation. As far as we are aware, no studies have explored the effect of freestyle swim training on the functional fitness of adults with DS or with intellectual disability (ID). Subsequently, the purpose of our study is to investigate the effects of freestyle swim training on the functional fitness of adults with DS.

Methods

Participants

The study included 26 adults (13 men and 13 women) with DS (32.7 ± 6 years). Participants were randomly allocated to the experimental and control groups (13 participants per group). Participants drew a number from a hat to determine group allocation. The study was approved by the institutional ethical committee (EFEC 1-11/2019). Risk assessment analyses were conducted, and the mitigation thereof was provided to the ethical committee. All parents had to sign an informed consent form. All participants had to sign an adapted consent form written in simpler language.

Inclusion and exclusion criteria

Participants were included in the study if they were diagnosed as having DS, were between 18 and 45 years of age and had the cognitive ability to perform and understand all testing instructions. They were excluded if they suffered from congenital heart disease or any other chronic physical or mental conditions contraindicative to the demand of physical activity.

Procedures

All participants completed the 11 functional fitness tests. During the first assessment day, body mass, height, balance (static: standing on one leg and dynamic: walking on balance beam), flexibility (shoulder stretch) and functional fitness tests (6-min walk distance and 8-ft up and go) were performed. On the second day, the three muscular strength and endurance tests (sit-to-stand, modified curl-up and isometric push-up) and the aerobic test item (16-m PACER) were performed. Finally, on the third day, the 12- and 24-m sprint tests were conducted. The same tests were repeated after 9 weeks in the same order and at the same time of day as the initial assessments. Familiarisation sessions were conducted before the commencement of the study for all baseline tests. All tests were visually demonstrated and explained step by step to the participants. The participants practised each test on their own under the supervision of the test instructor. A registered nurse and a social worker were always on the premises during training and testing.

Training programme

Both groups continued with their normal everyday activities during the intervention period. The daily routine does not include structured physical activity. Participants in the control group performed no structured exercises. Participants in the swimming training group exercised three times a week for 8 weeks. All participants were able to perform

freestyle swim training. Attendance of all sessions was strictly monitored. Each session was conducted for 30 min during the first 4 weeks. The last 4 weeks consisted of 40 min per session. The training was completed in a swimming pool with a length of 12 m and depth of 1.4 m. All sessions involved a 4-min warm-up. Descriptive information regarding swim training is provided in Table 1. Freestyle swim training was performed where one length was swum at a time. Participants would swim a length of the pool and rest whilst a training partner of similar fitness level also completed a length in the same lane. Continuous swim training was strictly controlled by the primary test instructor using a whistle. As soon as the training partner reached the halfway mark, the other participant was instructed to swim. Four qualified swimming instructors (the primary investigator, two senior human movement science students and one in their honours year) assisted with all training sessions. After 4 weeks of training, the duration of the warm-up remained 4 min, the preparation session increased to 10 min and the main session increased to 26 min. All swimming exercises were accompanied by lively music during training.

Testing session

Body mass and height

Stature and body mass measurements were conducted with a Seca scale and stadiometer (Seca, Hamburg, Germany). Participants wore a shirt and light weight trunks only. The body mass (kg) and

Table 1 Description of training programme for the freestyle swimming group.

Component	Description (all inside the pool)	Time
Warm-up (4 min)	1: Walking in circular motion inside the pool	1 min
	2: Marching in place whilst swinging the arms	1 min
	3: Few simple stretches (single-arm crossover, chest stretch, hamstring, calf and quad stretch)	2 min
Preparation to main session (6–7 minutes)	1: Two intervals of high intensity running on the spot	2 × (1-min interval, 30-s rest)
	2: One set of lunge jumps	45 s (15-s rest)
	3: One set of squat jumps	45 s (15-s rest)
	4: Flutter kicks whilst holding onto the side of the pool	1 min (30-s rest)
Main session (20 min)	1: Repetitive freestyle swim training	17 min
	2: Swimming lengths whilst holding onto kicking board	3 min

Note: Time for organisational purposes is not calculated and presented

height (meter) measurements were used to calculate BMI.

16-m PACER test (modified shuttle-run test)

Cardiorespiratory endurance or aerobic capacity was assessed using the 16-m modified shuttle-run test. At the sound of a tape-recorded beep, participants ran between two lines that were 16 m apart. The final test score recorded was the number of successfully completed shuttles. Only one trial was permitted. The test instructor ran alongside the participant to help with turning and pacing. The 16-m PACER test has been shown to be both feasible and reliable [intraclass correlation coefficient (ICC) = 0.99] in adults with DS (Boer and Moss 2016b). Moreover, the 16-m PACER test has been shown to be valid ($R^2 = 0.86$) when assessed with the gold standard maximal oxygen uptake test using a standardised treadmill protocol for adults with DS (Boer and Moss 2016c).

6-min walk distance test

The 6-min walk distance test (6-MWD) test assesses functional fitness and aerobic capacity (Boer and Moss 2016c; Rikli and Jones 2013). They were instructed to walk as many laps of 50 yards as possible within the allotted 6 min. The distance covered was recorded to the nearest yard, which was then converted to meters. Excellent test-retest reliability and feasibility of this test item have been demonstrated in adults with ID and in adults with DS (ICC = 0.93) (Boer and Moss 2016b; Nasuti *et al.* 2013). It has also shown adequate validity with aerobic capacity in adults with DS (Boer and Moss 2016c).

8-ft 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 a chair, walked as quickly as possible to a marker placed 2.43 m (8 ft) away, walked around the marker and returned to the chair. Excellent test-retest reliability (ICC = 0.94) of this test item has been shown in adults with DS (Boer and Moss 2016b).

Balance

Static balance was evaluated with the participants standing on one leg for as long as they could to a

maximum period of 10 s whilst looking straight ahead and with their hands placed firmly on their hips. The knee of the free leg was bent so the lower leg was parallel to the floor.

Dynamic balance was assessed by walking on a 3.05-m balance beam that is 10.2 cm wide. Participants were instructed to walk with a normal stride, whilst 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 noted. Test-retest reliability for the balance tests is excellent (ICC for static balance = 0.98; ICC for dynamic balance = 0.93) as shown in adults with DS (Boer and Moss 2016b).

Muscular strength and endurance

Chair stand test

Lower-body strength was evaluated using the chair stand test (Rikli and Jones 2013). On the signal 'go', the participant rose to a full stand and then returned to a fully seated position. Participants were scored according to the number of stands in 30 s. Test feasibility and test-retest reliability were shown to be excellent (ICC = 0.94) for adults with DS (Boer and Moss 2016b; Terblanche and Boer 2013).

Isometric push-up

Participants were instructed to hold the push-up position for as long as possible. 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. Time was stopped as soon as the back lifted or sagged. Proper form was strictly controlled. Test feasibility and test-retest reliability (ICC = 0.99) was shown to be excellent for adults with DS (Boer and Moss 2016b; Terblanche and Boer 2013).

Modified curl-up

Participants lay in a supine position with knees bent, feet flat on the floor and hands on the thighs. Participants slid their fingers up the upper legs to the kneecap whilst performing the curl-up and then returned to the initial starting position. Participants performed as many curl-ups as possible (up to a

maximum of 75) for as long as possible by doing one curl-up approximately every 3 s. Excellent test–retest reliability was shown for adults with DS (Boer and Moss 2016b). Test feasibility and test–retest reliability was shown to be excellent ($ICC = 0.99$) for adults with DS (Boer and Moss 2016b; Terblanche and Boer 2013).

Flexibility

Shoulder stretch

The shoulder stretch assesses upper-body flexibility. Participants attempted to touch the fingertips of their two hands behind their backs. The participant reached with his or her right hand over the right shoulder between the scapulae, whilst the left elbow was bent and the left hand reached upwards from the waist. If the middle fingers of the two hands did not touch, the distance was measured and recorded as a negative score. If the middle fingers overlapped, the distance of overlap was recorded as a positive score. Test feasibility and test–retest reliability were shown to be excellent ($ICC = 0.99$) for adults with DS (Boer and Moss 2016b; Terblanche and Boer 2013).

Freestyle swimming test

12- and 24-m freestyle swimming test. Participants swam two trials of the 12-m swimming test as fast as they could. Participants started swimming from inside the pool with one hand on the wall. Two trials were administered for the 24-m swimming test, which incorporated two lengths of the pool. Participants had to touch the wall and return as fast as they could. During the pilot phase of the study, the test–retest reliability of the 12- and 24-m swimming tests was determined. Two practice trials were administered, and the tests were conducted 1 week apart. ICCs of 0.996 and 0.991 and a standard error of the mean (SEM) of 0.185 and 0.384 were shown for the 12- and 24-m swimming tests, respectively.

Statistics

Data were analysed with the Statistical Package for the Social Sciences (SPSS 25.0, Chicago, IL, USA). A significance level of $P < 0.05$ was used. The study followed an ‘intention to treat’ and not the ‘effect of treatment’ procedure (Lewis and Machin 1993). 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 evaluate differences between groups, a one-way analysis of variance (ANOVA) was used, controlling for differences at baseline. A paired sample *T*-test was assessed within groups, pre and post the intervention. Cohen’s *d* effect sizes were calculated. The magnitude of the effect sizes was classified as small (0.10 to < 0.30), medium (0.30 to < 0.50) or large (≥ 0.50) as by Cohen (1988). Effect sizes are calculated between groups as well as pre to post within groups.

The test–retest relative reliability of data for the 12- and 24-m swimming tests was assessed with the ICC by using an ANOVA. This model treats all sources of measurement variation as error, providing an accurate estimate of stability reliability. The test–retest absolute variability was measured by using the SEM to calculate the minimal detectable change at the 90% confidence interval (MDC_{90}) (Stratford 2004).

Results

All participants were able to complete the 11 functional fitness test items. Only one person was not able to perform the isometric push-up test, and another four participants were not able to gain a score from the modified curl-up test (two from each group). They understood how to perform the modified curl-up but did not possess the muscular strength to perform the test. As a consequence, they scored a zero in the baseline assessments. One of the participants from the exercise group was able to record a score after the intervention period.

No serious or adverse events occurred during baseline, intervention or post-testing. The intervention period was met with excellent adherence as 11 of the 13 participants attended more than 90% of exercise sessions (seven had 100% attendance). The participant with the least adherence attended 67% of all sessions.

The test–retest reliability analysis for the 12- and 24-m swim tests revealed ICC values of 0.996 and 0.991, SEM values of 0.19 and 0.38, and MDC_{90} values of 0.43 and 0.77 for the 12- and 24-m swimming tests, respectively. The test–retest

reliability for the other nine functional fitness parameters was reported to be excellent (Boer and Moss 2016b).

No significant differences were reported between groups for all studied variables at baseline. The assumption of homogeneity of variances (Levene's test) was violated for none of the variables, and the assumption of normality (Shapiro–Wilk) was violated for the two balance tests, modified curl-up test, isometric push-up, 16-m PACER test and the two swimming tests. As a result, the analysis for these variables was assessed by the Mann–Whitney (between-group) and Wilcoxon signed-rank (within-group) non-parametric tests.

After 8 weeks of training, the results showed significant differences between the swimming and control group for body mass, BMI, aerobic capacity, dynamic balance, all three muscular strength and endurance tests, 12-m swim time and

8-ft get-up-and-go functional ability ($P < 0.05$). The information is demonstrated in Tables 2 and 3. Large effect sizes between groups are shown for dynamic balance, functional ability and core-body and upper-body strength (Table 4). Medium effect sizes are reported between groups for BMI, aerobic capacity, lower-body strength, shoulder flexibility and 12-m swimming time (Table 4).

Discussion

The purpose of the current study was to determine the effect of an 8-week freestyle swim training intervention on the functional fitness of adults with DS. Both groups continued with their normal everyday activities during the intervention period. The control group performed no structured exercise. No serious or adverse events transpired during the

Table 2 Influence of freestyle swim training on parameters of functional fitness.

Variable	Swimming group ($n = 13$)		Control group ($n = 13$)	
	Pre	Post	Pre	Post
Age (years)	34.2 (5.0)	34.4 (5.0)	30.3 (7.2)	30.5 (7.2)
Body mass and BMI				
Body mass (kg)	81.3 (22.2)	79.1 (21.4) ^{*,†}	81.5 (14.3)	81.6 (14.4)
BMI (kg/m^2)	33.0 (10.1)	32.4 (10.1) ^{*,†}	35.5 (8.3)	35.6 (8.2)
Aerobic capacity				
16-m PACER (shuttles)	19.4 (15.0)	24.5 (19.4) ^{*,†}	18.5 (15.0)	18.7 (15.8)
Static and dynamic balance				
Standing on one leg (s)	4.9 (3.7)	5.9 (3.3)	5.9 (4.1)	5.5 (4.1)
WOBB (steps)	3.6 (2.1)	5.3 (1.2) ^{*,†}	4.2 (2.4)	3.5 (2.6)
Flexibility				
Shoulder flexibility (cm)	−3.8 (7.2)	−4.3 (6.5)	−8.1 (9.1)	−7.5 (8.3)
Functional ability				
8-ft get up and go (s)	5.9 (1.0)	5.4 (1.0) ^{*,†}	5.7 (0.7)	6.0 (0.9)
6-min walk distance (m)	548.8 (113.2)	553.8 (106.9)	502.2 (121.3)	503.1 (118.7)
Muscular strength and endurance				
Sit-to-stand (s)	13.1 (1.7)	14.3 (1.6) ^{*,†}	14.0 (2.1)	13.6 (1.6)
Modified curl-up (n)	23.0 (30.2)	33.3 (30.1) ^{*,†}	17.9 (22.4)	16.6 (22.1)
Isometric push-up (s)	51.9 (33.8)	79.8 (41.9) ^{*,†}	48.0 (33.6)	47.3 (35.1)
12- and 24-m swim time				
12-m swim time (s)	18.7 (10.2)	15.9 (6.4) ^{*,†}	17.9 (5.8)	18.4 (6.9)
24-m swim time (s)	41.2 (19.4)	38.3 (15.2)	42.6 (15.8)	42.5 (15.1)

Data are presented as mean (standard deviation).

BMI, body mass index; n, amount; WOBB, walking on balance beam.

^{*} $P < 0.05$ significant difference within group.

[†] $P < 0.05$ significant difference between swimming and control group.

Table 3 Results of analysis of covariance with each variable (as the difference between pre and post), degrees of freedom, *F*-statistic and significance.

Variables (as deltas)	DF	F	Significance
Body mass	25	21.36	0.000*
BMI	25	8.00	0.009*
16-m PACER	25	8.10	0.009*
Standing on one leg	25	2.38	0.136
WOBB	25	9.35	0.005*
Shoulder flexibility	25	0.82	0.375
8-ft get up and go	25	12.16	0.002*
6-min walk distance	25	0.03	0.875
Sit-to-stand	25	13.57	0.001*
Modified curl-up	25	6.86	0.015*
Isometric push-up	24	13.53	0.001*
12-m swim time	25	5.90	0.023*
24-m swim time	25	0.99	0.331

BMI, body mass index; DF, degrees of freedom; WOBB, walking on balance beam.

**P* < 0.05 significant difference between swimming and control group.

study, and anecdotal evidence suggested that the participants enjoyed the routine-based swim training.

The fact that so many parameters of functional fitness improved significantly is promising, as many studies conducted on adults with DS report significant improvements on some components of functional fitness and not on others (Rimmer *et al.* 2004; Boer and Moss 2016a; Mendonca *et al.* 2011, 2013). Freestyle swim training is a continuous aerobic activity that engages many of the larger muscle groups of the body (Tanaka 2009).

Improving the anthropometric profile of adults with DS is important as many of these individuals are overweight or obese (Pitetti *et al.* 2013). Moreover, conditions associated with obesity in this population are well recognised (Rubin *et al.* 1998; Torr *et al.* 2010). Many studies incorporating an exercise intervention in a DS population have not shown significant improvements in body mass or BMI (Millar *et al.* 1993; Varela *et al.* 2001; Tsimaras

Table 4 Effect sizes of functional fitness parameters (between and within groups).

Variable	Between groups		Swimming group (within)		Control group (within)	
	Effect size	Magnitude	Effect size	Magnitude	Effect size	Magnitude
<i>Body mass and BMI</i>						
Body mass	0.14	Small	−0.10	Small	−0.01	Small
BMI	0.35	Medium	−0.06	Small	0.00	N/A
<i>Aerobic capacity</i>						
16-m PACER	0.33	Medium	0.30	Medium	0.01	Small
<i>Balance</i>						
Standing on one leg	0.11	Small	0.26	Small	−0.11	Small
WOBB	0.90	Large	1.01	Large	−0.29	Small
<i>Flexibility</i>						
Shoulder flexibility	0.43	Medium	−0.07	Small	0.07	Small
<i>Functional ability</i>						
8-ft get up and go	0.63	Large	−0.30	Medium	−0.28	Small
6-min walk distance	0.45	Medium	0.05	Small	0.01	Small
<i>Muscular strength</i>						
Sit-to-stand	0.45	Medium	0.75	Large	−0.21	Small
Modified curl-up	0.63	Large	0.34	Medium	−0.06	Small
Isometric push-up	0.84	Large	0.73	Large	−0.02	Small
<i>Swimming tests</i>						
12-m swim test	0.37	Medium	0.33	Medium	0.08	Small
24-m swim test	0.27	Small	0.16	Small	0.01	Small

BMI, body mass index; n, amount; N/A, not applicable (no improvement); WOBB, walking on balance beam.

et al. 2003; Mendonca *et al.* 2011, 2013). These studies included running, walking, cycling, rowing or combined training. Regarding studies performed in a water environment, an investigation conducted on adolescents with DS demonstrated an improvement in body mass and body fat percentage after 12 weeks of land-based and water-based aerobic activities (Ordonez *et al.* 2006). The authors of this study did not provide information regarding the type, duration or composition of land and water exercises. On the contrary, another study using water aerobics as the training intervention found no significant improvements in body mass or BMI in adults with DS (Boer and de Beer 2019). A longitudinal study conducted by Cox *et al.* (2010) reported more significant improvements in body mass and body fat distribution in elderly women with 12 months of swim training compared with 12 months of land-based walking. They stipulated that the swimmers may have had an increased metabolic rate post exercise as a result of the restoration of core body temperature leading to a greater energy expenditure. This finding was also demonstrated when comparing running and swim training at similar absolute intensities, as the swim training group demonstrated more significant improvements in body composition (Lieber *et al.* 1989). We can only hypothesise that the cooler temperatures of water may increase exercise expenditure and result in larger improvements in body mass and BMI.

The fact that the aerobic capacity and functional ability of the participants improved significantly with a medium and large effect size is important as poor cardiorespiratory endurance is considered a risk factor for cardiovascular disease and can result in a reduced lifespan for adults with DS (González-Agüero *et al.* 2010). Improved physical fitness is also related to reduced body fat percentage in this population (Salaun and Berthouze-Aranda 2012). Moreover, a better aerobic capacity results in a better ability to perform tasks of daily living for individuals with DS (Cowley *et al.* 2010). A recent systematic review, analysing experimental research performed on individuals with DS, reiterated the importance of exercise to support daily life (Hardee and Feters 2017).

The improvement in aerobic capacity could have partially resulted from an improvement in leg strength as shown by the sit-to-stand test (Pitetti and

Boneh 1995). Pitetti and Boneh (1995) found a strong correlation between VO_2 peak and leg strength in persons with DS. Many studies using a combination of aerobic and resistance training reported significant improvements in aerobic capacity for individuals with DS (Rimmer *et al.* 2004; Lewis and Fragala-Pinkham 2005; Mendonca *et al.* 2011, 2013), but studies using aerobic training alone demonstrated impartial results (Millar *et al.* 1993; Varela *et al.* 2001; Tsimaras *et al.* 2003; Mendonca *et al.* 2011; Boer and Moss 2016a). During the swimming intervention, some leg resistance training was performed inside the pool, as the session started with a set of squat jumps, a set of lunge jumps, 1 min of kicking exercises whilst holding onto the side of the pool, two sets of high intensity running on the spot and 3 min of kicking exercises whilst holding onto a kicking board.

Lower-body, upper-body and core strength all improved significantly with medium or large effect sizes. Individuals with DS have reduced muscle strength compared to the general population and those with ID without DS (Croce *et al.* 1996; Pitetti *et al.* 1992). Studies performed on individuals with DS have demonstrated the importance of adequate muscle strength owing to its relationship with functional performance and everyday living activities (Cowley *et al.* 2010; Terblanche and Boer 2013). Improvements of core stability and upper limb strength are of practical significance for these individuals who are often involved with manual labour tasks (Shields *et al.* 2013). The improvement of core strength is also of practical value as Aly and Abonour (2018) demonstrated the correlation of core strength with postural stability and balance in DS individuals. Other researchers have also demonstrated significant improvements in trunk, lower and upper limbs with aerobic training (Boer and Moss 2016a; Carmeli *et al.* 2002; Cowley *et al.* 2011; Tsimaras and Fotiadou 2004) or combined aerobic and resistance training (Rimmer *et al.* 2004; Lewis and Fragala-Pinkham 2005; Mendonca *et al.* 2011, 2013) for individuals with DS.

Rikli and Jones (2013) defined functional fitness as the ability to perform normal everyday activities safely and independently without undue fatigue. The 8-ft get-up-and-go test assesses functional ability as it is similar to an everyday living activity. The significant improvement thereof with a large

effect size is promising and beneficial for this population with poor functional fitness. As stated in previous paragraphs, the improvement of functional ability may be related to an improvement of aerobic capacity and/or muscular strength stemming from the 8-week swimming intervention (Cowley *et al.* 2010; Terblanche and Boer 2013). Other studies conducted on adults with DS have also shown significant improvements in functional ability with aerobic or resistance training (Boer and Moss 2016a; Carmeli *et al.* 2002; Cowley *et al.* 2011).

The current study demonstrated a significant improvement with a large effect size for dynamic balance. Dynamic balance also improved with swim or aquatic training performed on elderly individuals and children with cerebral palsy (Hsu *et al.* 2010; Zverev and Kurnikova 2016). Jung *et al.* (2017) reported that the attainment of appropriate balance skills is one of the hardest to acquire but a major factor for the safety and independence of children with DS. Unfortunately, many individuals with DS exhibit poor static and dynamic balance when compared with the general population (Carmeli *et al.* 2002; Tsimaras and Fotiadou 2004; Villamonte *et al.* 2010). Balance is an important proficiency that this population should possess as it has been reported to be related to fundamental movement skills and the risk of falling in children with DS (Aly and Abonour 2018; Capio *et al.* 2018). Static and dynamic balance is also essential for individuals with DS as Villamonte *et al.* (2010) revealed an association between these measures and physical independence, as well as the ability to participate in leisure and social activities. The improvement in dynamic balance may have resulted from the significant improvement in core strength (shown by the modified curl-up) as Aly and Abonour (2018) reported an association between core strength and dynamic balance in children with DS. However, static balance did not improve significantly in this study. Perhaps the additional buoyancy provided by a water medium and the hydrostatic pressure properties thereof did not result in an enhancement of static balance on land. A recent study conducted on adults with DS also did not improve static balance with water aerobics training (Boer and de Beer 2019). Static balance was however improved in a recent study performed

on young adults with DS using functional training consisting of treadmill walking and step up/down training (Ahmadi *et al.* 2018). Exercise performed on land and/or additional training methods (such as one-legged step-ups) to supplement the core aerobic component may provide the adaptations needed to improve static balance in this population.

The final two swimming specific tests demonstrated dissimilar results. Although 12-m swimming time improved significantly and with a medium effect size, 24-m swimming time did not. A possible reason for this finding could be that during the intervention period, participants only swam one length at a time. Participants then waited for their swimming partner whom they shared the lane with, to complete their length. The length of the pool was 12 m; and as a consequence, participants never trained to swim 24 m. Also, participants never practised to turn efficiently. The use of timed-swimming tests is appropriate to monitor swimming improvement after 8 weeks of swim-specific training, but it is not known whether swimming performance reflects functional fitness as described by Rikli and Jones (2013).

A limitation of the study is that the level of intellectual impairment could not be determined as no intelligence quotient records were available for the participants. However, all participants in the current study fully understood test instructions, test procedures, correct technique and training procedures. Secondly, exercise intensity was not objectively monitored. The primary test instructor and his three qualified swimming instructors continually encouraged participants to swim their lengths at the highest possible intensity and to perform the pre-swimming activities (squat and lunge jumps, flutter kicks and running on the spot) according to the correct technique and appropriate intensity. The swimming instructors were actively involved with the participants inside the pool. A future study could certainly be conducted for a lengthier period (> 8 weeks) whilst monitoring exercise intensity with heart rate monitors. Additionally, the continuous swimming of lengths (without short pauses between lengths) where turning is practised is another suitable progression to the current study. Finally, the effect of freestyle swim training in combination with resistance training may provide larger practical benefits.

Conclusion

The swimming intervention was met with excellent adherence and occurred in the absence of serious or adverse events. A freestyle swimming intervention significantly improved many functional fitness parameters previously shown to improve in isolation for adults with DS.

Source of funding

No external funding was received for the research reported in the paper.

Conflict of Interest

The authors report no conflicts of interest.

References

- Ahmadi N., Peyk F., Hovanloo F. & Hemati G. S. (2018) Effect of functional strength training on gait kinematics, muscle strength and static balance of young adults with Down syndrome. *International Journal of Motor Control and Learning* **1**, 1–10.
- Aly S. M. & Abonour A. A. (2018) Effect of core stability exercise on postural stability in children with Down syndrome. *International Journal of Medicine and Research in Health and Science* **5**, 213–22.
- Arumugam A., Raja K., Venugopalan M., Chandrasekaran B., Kovanur S. K., Muthusamy H. *et al.* (2016) Down syndrome – a narrative review with a focus on anatomical features. *Clinical Anatomy* **29**, 568–77.
- de Asua D. R., Quero M., Moldenhauer F. & Suarez C. (2015) Clinical profile and main comorbidities of Spanish adults with Down syndrome. *European Journal of Internal Medicine* **26**, 385–91.
- Boer P. H. & de Beer Z. (2019) The effect of aquatic exercises on the physical and functional fitness of adults with Down syndrome: a non-randomised controlled trial. *Journal of Intellectual Disability Research* **63**, 1453–63.
- Boer P. H. & Moss S. J. (2016a) Effect of continuous aerobic vs. interval training on selected anthropometrical, physiological and functional parameters of adults with Down syndrome. *Journal of Intellectual Disability Research* **60**, 322–34.
- Boer P. H. & Moss S. J. (2016b) Test–retest reliability and minimal detectable change scores of twelve functional fitness tests in adults with Down syndrome. *Research in Developmental Disabilities* **48**, 176–85.
- Boer P. H. & Moss S. J. (2016c) Validity of the 16-metre PACER and six-minute walk test in adults with Down syndrome. *Disability and Rehabilitation* **38**, 2575–83.
- Brill P. A. (2004) *Functional Fitness for Older Adults*. Human Kinetics, Champaign, IL.
- Capio C. M., Mak T. C. T., Tse M. A. & Masters R. S. W. (2018) Fundamental movement skills and balance of children with Down syndrome. *Journal of Intellectual Disability Research* **62**, 225–36.
- Carmeli E., Kessel S., Coleman R. & Ayalon M. (2002) Effects of a treadmill walking program on muscle strength and balance in elderly people with Down syndrome. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences* **57**, M106–10.
- Cohen J. (1988) *Statistical Power Analysis for the Behavioural Sciences*. Routledge, London.
- Cowley P. M., Ploutz-Snyder L. L., Baynard T., Heffernan K., Jae S. Y., Hsu S. *et al.* (2010) Physical fitness predicts functional tasks in individuals with Down syndrome. *Medicine and Science in Sports and Exercise* **42**, 388–93.
- Cowley P. M., Ploutz-Snyder L. L., Baynard T., Heffernan K. S., Young Jae S., Hsu S. *et al.* (2011) The effect of progressive resistance training on leg strength, aerobic capacity and functional tasks of daily living in persons with Down syndrome. *Disability and Rehabilitation* **33**, 2229–36.
- Cox K. L., Burke V., Beilin L. J. & Puddey I. B. (2010) A comparison of the effects of swimming and walking on body weight, fat distribution, lipids, glucose, and insulin in older women – the Sedentary Women Exercise Adherence Trial 2. *Metabolism* **59**, 1562–73.
- Croce R. V., Pitetti K. H., Horvat M. & Miller J. (1996) Peak torque, average power, and hamstring/quadiceps ratios in nondisabled adults and adults with mental retardation. *Archives of Physical Medicine and Rehabilitation* **77**, 369–72.
- González-Agüero A., Vicente-Rodríguez G., Moreno L. A., Guerra-Balic M., Ara I. & Casajus J. A. (2010) Health-related physical fitness in children and adolescents with Down syndrome and response to training. *Scandinavian Journal of Medicine and Science in Sports* **20**, 716–24.
- Hardee J. P. & Fetters L. (2017) The effect of exercise intervention on daily life activities and social participation in individuals with Down syndrome: a systematic review. *Research in Developmental Disabilities* **62**, 81–103.
- Hsu H. C., Chou S. W., Chen C. P. C., Wong A. M. K., Chen C. K. & Hong J. P. (2010) Effects of swimming on eye hand coordination and balance in the elderly. *The Journal of Nutrition, Health and Aging* **14**, 692–5.
- Jung H. K., Chung E. & Lee B. H. (2017) A comparison of the balance and gait function between children with Down syndrome and typically developing children. *Journal of Physical Therapy in Science* **29**, 123–7.
- Lahart I. M. & Metsios G. S. (2018) Chronic physiological effects of swim training interventions in non-elite swimmers: a systematic review and meta-analysis. *Sports Medicine* **48**, 337–59.
- Lewis C. L. & Fragala-Pinkham M. A. (2005) Effects of aerobic conditioning and strength training on a child with Down syndrome: a case study. *Paediatric Physical Therapy* **17**, 30–6.

- Lewis J. A. & Machin D. (1993) Intention to treat – who should use ITT? *British Journal of Cancer* **68**, 647–50.
- Lieber D. C., Lieber R. L. & Adams W. C. (1989) Effects of run-training and swim-training at similar absolute intensities on treadmill. *Medicine and Science in Sports and Exercise* **21**, 655–61.
- Melville C., Cooper S., Morrison J., Allan L., Smiley E. & Williamson A. (2008) The prevalence and determinants of obesity in adults with intellectual disabilities. *Journal of Applied Research in Intellectual Disabilities* **21**, 425–37.
- Mendonca G. V. & Pereira F. D. (2009) Influence of long-term exercise training on submaximal and peak aerobic capacity and locomotor economy in adult males with Down's syndrome. *Medicine and Science Monitor* **15**, 33–9.
- Mendonca G. V., Pereira F. D. & Fernhall B. (2013) Heart rate recovery and variability following combined aerobic and resistance exercise training in adults with and without Down syndrome. *Research in Developmental Disability* **34**, 353–61.
- Millán-Calenti J. C., Tubío J., Pita-Fernández S., González-Abraldes I., Lorenzo T., Fernández-Arruty T. *et al.* (2010) Prevalence of functional disability in activities of daily living (ADL), instrumental activities of daily living (IADL) and associated factors, as predictors of morbidity and mortality. *Archives of Gerontology and Geriatrics* **50**, 306–10.
- Millar A. L., Fernhall B. & Burkett L. N. (1993) Effects of aerobic training in adolescents with Down syndrome. *Medicine and Science in Sports and Exercise* **25**, 270–4.
- Mendonca G. V., Pereira F. D. & Fernhall B. (2011) Effects of combined aerobic and resistance exercise training in adults with and without Down syndrome. *Archives of Physical Medicine and Rehabilitation* **92**, 37–45.
- Nasuti G., Stuart-Hill L. & Temple V. A. (2013) The six-minute walk test for adults with intellectual disability: a study of validity and reliability. *Journal of Intellectual Developmental Disability* **38**, 31–8.
- Nordström M., Hansen B. H., Paus B. & Kolset S. O. (2013) Accelerometer-determined physical activity and walking capacity in persons with Down syndrome, Williams syndrome and Prader-Willi syndrome. *Research in Developmental Disabilities* **34**, 4395–403.
- Ordóñez F. J., Rosety M. & Rosety-Rodríguez M. (2006) Influence of 12-week exercise training on fat mass percentage in adolescents with Down syndrome. *Medicine Science Monitor* **12**, 416–9.
- Pikora T. J., Bourke J., Bathgate K., Foley K. R., Lennox N. & Leonard H. (2014) Health conditions and their impact among adolescents and young adults with Down syndrome. *PLoS ONE* **9**, 1–8.
- Pitetti K., Baynard T. & Agiovlasis S. (2013) Children and adolescents with Down syndrome, physical fitness and physical activity. *Journal of Sport and Health Sciences* **2**, 47–57.
- Pitetti K. H. & Boneh S. (1995) Cardiovascular fitness as related to leg strength in adults with mental retardation. *Medicine and Science in Sports and Exercise* **27**, 42–8.
- Pitetti K. H., Climstein M., Mays M. J. & Barrett P. J. (1992) Isokinetic arm and leg strength of adults with Down syndrome: a comparative study. *Archives Physical Medical Rehabilitation* **73**, 47–50.
- Rikli R. E. & Jones C. J. (2013) *Senior Fitness Test Manual*, 2nd edn. Human Kinetics, Champaign, IL.
- Rimmer J. H., Heller T., Wang E. & Valerio I. (2004) Improvements in physical fitness in adults with Down syndrome. *American Journal of Mental Retardation* **109**, 165–74.
- Rubin S. S., Rimmer J. H., Chicoine B., Braddock D. & McGuire D. E. (1998) Overweight prevalence in persons with Down syndrome. *Mental Retardation* **36**, 175–81.
- Ruiz-González L., Lucena-Antón D., Salazar A., Martín-Valero R. & Moral-Munoz J. A. (2019) Physical therapy in Down syndrome: systematic review and meta-analysis. *Journal of Intellectual Disability Research* **63**, 1041–67.
- Salaun L. & Berthouze-Aranda S. E. (2012) Physical fitness and fatness in adolescents with intellectual disabilities. *Journal of Applied Research in Intellectual Disabilities* **25**, 231–9.
- Shields N., Taylor N. F., Wee E., Wollersheim D., O'Shea S. D. & Fernhall B. (2013) A community-based strength training programme increases muscle strength and physical activity in young people with Down syndrome: a randomised controlled trial. *Research in Developmental Disabilities* **34**, 4385–94.
- Stratford P. W. (2004) Estimating the standard error of measurement from reliability studies. *Physiotherapy Canada* **56**, 27–30.
- Tanaka H. (2009) Swimming exercise. *Sports Medicine* **39**, 377–87.
- Terblanche E. & Boer P. (2013) The functional fitness capacity of adults with Down syndrome in South Africa. *Journal of Intellectual Disability Research* **57**, 826–36.
- Torr J., Strydom A., Patti P. & Jokinen N. (2010) Aging in Down syndrome: morbidity and mortality. *Practise in Intellectual Disabilities* **7**, 70–81.
- Tsimaras V., Giagazoglou P., Fotiadou E., Christoulas K. & Angelopoulou N. (2003) Jog-walk training in cardiorespiratory fitness of adults with Down syndrome. *Perceptual and Motor Skills* **96**, 1239–51.
- Tsimaras V. K. & Fotiadou E. G. (2004) Effect of training on the muscle strength and dynamic balance ability of adults with Down syndrome. *Journal of Strength and Conditioning Research* **18**, 343–7.
- Varela A. M., Sardinha L. B. & Pitetti K. H. (2001) Effects of an aerobic rowing training regimen in young adults with Down syndrome. *American Journal of Mental Retardation* **106**, 135–44.
- Villamonte R., Vehrs P. R., Feland J. B., Johnson A. W., Seeley M. K. & Eggett D. (2010) Reliability of 16 balance

tests in individuals with Down syndrome. *Perceptual and Motor Skills* **111**, 530–42.

Zverev Y. & Kurnikova M. (2016) Adapted community-based group aquatic program for developing balance: a pilot intervention study involving children and

adolescents with cerebral palsy. *Journal of Physical Education and Sport* **16**, 1258–65.

Accepted 27 July 2020