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Functional fitness of adults with Down syndrome: a longitudinal study

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Abstract

Background Individuals with Down syndrome (DS) are born with and develop many health-related complications. The purpose of this study was to determine the longitudinal functional fitness profile of adults with DS.

Methods The functional fitness of adults with DS was tested twice, 12 years apart. Sixty-six adults with DS were tested for body mass, stature and 10 functional fitness tests. Data were categorised according to gender and age-specific categories.

Results Static balance, shoulder flexibility, trunk strength and aerobic capacity deteriorated significantly with medium to large effect sizes for both DS men and women (most age categories). For women, dynamic balance deteriorated significantly, and for men, leg- and upper body-strength deteriorated significantly.

Conclusions Practitioners working in the field of adapted physical activity should take cognisance of the functional fitness ageing profile of adults with DS and timeously develop habitual physical activity interventions to reduce the effect of accelerated ageing experienced by this population.

Keywords Aerobic capacity, Ageing, Balance, Down syndrome, Functional fitness, Longitudinal

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Introduction

Individuals with Down syndrome (DS) are born with and suffer from many health-related complications (Bergström *et al.* 2016; Capone *et al.* 2018; Foley & Killeen 2019). These conditions are further exacerbated by a sedentary lifestyle, lack of exercise and obesity (Bertapelli *et al.* 2016; Diaz 2020). Together and in combination with the genetic material associated with DS, these factors may contribute to the accelerated ageing process and in some cases early onset Alzheimer's disease experienced by this population (Terblanche & Boer 2013; Horvath *et al.* 2015; Wiseman *et al.* 2015). Although the mean life expectancy of individuals with DS have increased, so have the many complications associated with an accelerated ageing profile such as a deterioration in the quality of life, inability to perform activities of daily living and dependence on others (Covelli *et al.* 2016; Bayen *et al.* 2018; O'Leary *et al.* 2018).

These complications can be thwarted or slowed down by living a functionally fit lifestyle (Boer 2022). Functional fitness is defined as 'having the physical capacity to perform normal everyday activities safely and independently without undue fatigue' (Rikli & Jones 2013). Although the functional fitness of individuals with DS is poor, compared not only with the general population but also with those with intellectual disability (ID) without DS (Carmeli *et al.* 2002a; Baynard *et al.* 2008; Mendonca *et al.* 2011), many studies have shown that the parameters associated with functional fitness can be improved with structured physical activity interventions (Li *et al*. 2013; Kerstiens & Green 2015; Hardee & Fetters 2017). It is important to monitor functional fitness over time so that appropriate intervention strategies can be implemented and tailored to an individual's unique strengths and weaknesses. Often, functional fitness is assessed with a battery of standardised tests adapted to the unique needs of that population group. Physical and functional fitness batteries exist for the general population (Meredith & Welk, 2010), the elderly (Rikli & Jones 2013), those with physical and IDs (Winnick & Short 1999; Hilgenkamp *et al*. 2012) and those with DS (Boer 2022).

Previously the functional fitness was assessed in 371 adults with DS (Terblanche & Boer 2013). Now, 12 years later, the purpose of this study was to assess the functional fitness of a sample of this group again. By doing this, it can determined which parameters of functional fitness (balance, flexibility, functional ability, aerobic capacity and muscular strength and endurance), if any, deteriorate significantly and by what magnitude. The mean performance of all functional fitness follow-up tests was also compared with minimum preferred criterion-referenced standards needed for healthy and independent living identified for specific gender and age categories of DS individuals (Boer 2022). A longitudinal study of this nature will assist adapted physical activity health practioners to develop training and lifestyle adaptations to the unique needs of adults living with DS.

Methods

This is a longitudinal study on data available from the year 2010 (Boer 2010) and on data collected in 2022. A sample of adults with DS, who were tested in 2010, was asked if they wish to participate in a voluntary follow-up study (Western Cape, Free State, Northern Cape, KwaZulu-Natal and Eastern Cape). In 2010, the inclusion criteria read 'Individuals were included if they had Down syndrome, were between 18 and 65 years of age, had the cognitive ability to understand and perform the exercises in a technically correct manner and if they provided written informed assent. Individuals were excluded if they suffered from congenital heart disease or any other physical or medical condition that was considered a contraindication for exercise participation' (Terblanche & Boer 2013). The same inclusion criteria were applied. None of the participants we tested in 2010 were older than 65 years in 2022.

This study had a purposive sampling technique in that any participants who were tested in 2010 and who the researcher could find by contacting the participants' parents or by visiting the intellectually disabled care centres where they reside/work were contacted. The proportion of participants who resided in an ID care centre (97%) or in a private home (3%) remained the same for both the 2010 and 2022 cohorts.

All participants and their parents were informed about the purpose of the study, the testing to be undertaken and the possible risks related to the study. Informed written consent was required from the parents or legal guardian from all participants before being allowed to take part in the study and was given the right to withdraw, at any time without reason or prejudice. Assent was also obtained from the participant himself or herself, and an adapted assent form with simpler language was used. The study was approved by the Faculty Health Sciences Research Ethics Committee of the University of Pretoria (67/2021).

Participants were evaluated on 10 functional fitness tests. The methodology, feasibility, reliability and validity for all of these tests in a DS adult-specific population is well described in various studies (Terblanche & Boer 2013; Boer & Moss 2016a; Boer & Moss 2016b). The 10 tests included two balance items, two flexibility items, four muscular strength and endurance items, one functional capacity item and one cardiovascular endurance item.

Normative and criterion referenced tables for each of the 10 functional fitness tests have been established for adults with DS (Boer 2022). The tables have been categorised according to gender and four age group categories (18–25; 26–35; 36–45 and >45 years).

Procedure

The 10 functional fitness tests were performed in the same manner and same order as 12 years previously. Five participants were tested at a time, and each session lasted approximately 3 h. Subjects were verbally instructed and visually demonstrated on how

Table 1 Longitudinal results (2010 vs. 2022) of anthropometry and functional fitness parameters (mean and *SD* unless otherwise stated)

	Males (*n* = 38)						**Females (*n* = 28)**					
	Age category 1 (18–25) (*n* = 15)		**Age category 2 (26–35) (*n* = 8)**		**Age category 3 (36–45) (*n* = 15)**		**Age category 1 (18–25) (*n* = 8)**		**Age category 2 (26–35) (*n* = 12)**		**Age category 3 (36–45) (*n* = 8)**	
Description	**2010**	**2022**	**2010**	**2022**	**2010**	**2022**	**2010**	**2022**	**2010**	**2022**	**2010**	**2022**
General												
Age (year)	20.6(1.8)	33.0(1.6)	29.8(2.8)	41.9(3.0)	42.3(4.9)	54.5(5.1)	22.1(1.1)	34.3(1.0)	30.0(2.6)	42.5(2.4)	37.5(1.7)	49.8(1.8)
Anthropometry												
Weight (kg)	75.6.(13.0)	77.4(20.1)	73.8(14.9)	62.1(10.8)*	66.5(10.7)	62.5(11.1)*	67.5(9.0)	71.5(12.9)	70.3(15.8)	66.8(19.3)	72.7(10.2)	63.4(6.8)*
Height (cm)	161.3(7.0)	160.9(7.0)	161.3(7.8)	160.9(7.6)	159.3(6.7)	158.3(7.0)	146.4(5.0)	146.0(4.9)	149.1(4.7)	148.5(5.1)	147.9(5.3)	146.6(5.3)
BMI (kg/m^2)	29.0(4.1)	29.9(7.2)	28.2(3.9)	23.9(2.9)*	27.2(3.6)	24.9(3.7)	31.5(4.3)	33.4(4.8)	31.7(7.2)	30.1(7.6)	33.5(6.3)	29.7(4.2)
Balance												
SOOL (s)	8.1(2.8)	6.8(3.1)*	8.3(2.9)	5.6(3.6)*	6.1(3.6)	1.9(1.3)*	3.8(3.5)	2.2(2.6)*	4.9(3.1)	2.6(2.6)*	5.9(3.4)	2.5(1.4)*
$	9.7(3.1)	6.0(6.2)*	10.0(2.9)	5.0(7.6)*	5.1(7.4)	2.2(1.7)*	2.6(5.71)	1.3(2.3)*	4.4(5.6)	1.9(2.2)*	5.3(6.9)	2.7(2.7)*
WOBB (steps)	5.1(1.8)	4.7(2.1)	4.6(2.0)	3.6(2.4)	3.3(2.4)	0.7(1.7)*	3.5(2.5)	2.1(2.2)*	3.5(2.7)	2.2(2.2)*	3.8(1.8)	1.8(1.3)*
$	6.0(1.0)	6.0(3.0)	5.5(3.0)	4.0(5.0)	3.0(5.0)	0.0(1.0)*	4.5(5.0)	2.0(4.0)*	4.5(6.0)	1.0(5.0)*	3.5(4.0)	1.5(2.0)*
Flexibility												
Shoulder (cm)	1.7(7.6)	−2.8(9.2)*	−4.0(10.9)	−6.4(8.8)	0.9(7.5)	−8.9(8.5)*	−3.3(6.1)	−13.3(7.0)*	−1.0(5.7)	−9.0(9.5)*	−6.3(7.6)	−9.4(6.7)
S&R (cm)	6.4(13.6)	3.3(12.5)	3.5(6.8)	0.4(3.8)	3.3(10.2)	0.7(8.3)	4.5(10.6)	−0.8(10.3)*	7.5(5.3)	5.8(8.1)	6.4(6.1)	1.6(6.5)
Functional ability												
GUG (s)	5.8(1.4)	6.1(1.5)*	5.9(0.8)	5.7(1.6)	6.4(1.6)	9.9(5.5)*	6.5(2.0)	7.3(1.9)	6.5(0.9)	7.3(1.7)*	6.3(0.7)	7.7(2.4)
$	5.5(2.3)	5.5(2.1)	5.9(1.4)	5.1(1.6)	6.2(2.0)	7.8(6.2)*	6.4(2.2)	6.8(2.6)	6.3(0.8)	6.7(1.6)*	6.1(1.2)	7.3(1.7)
Muscular strength and endurance												
CS (n)	12.8(2.6)	12.2(2.4)*	12.4(1.9)	12.4(3.0)	11.1(2.6)	8.8(2.8)*	12.6(2.6)	12.0(2.6)	11.4(1.7)	11.1(2.5)	13.8(1.3)	10.6(2.3)*
IPU (s)	69.8(51.7)	55.4(41.0)*	67.4(51.2)	71.0 (53.5)	48.2(24.2)	28.9(21.2)*	18.0(20.5)	13.5(14.3)	28.6(17.9)	23.0(16.9)	31.3(12.7)	29.1(19.6)
MCU (n)	30.8(31.4)	23.8(30.4)	47.1(36.7)	24.4(26.1)	16.1(14.9)	8.8(12.7)	11.4(13.3)	9.5(10.3)	17.3(28.1)	9.6(16.0)	14.3(12.5)	9.5(15.5)
$	31.0(74.0)	12.0(60.0)	71.5(72.0)	16.0(41.0)	15.0(25.0)	3.0(14.0)	7.0(22.0)	6.5(21.0)	2.0(22.0)	3.5(15.0)	18.5(24.0)	3.5(15.0)
TL (cm)	30.1(7.5)	27.5(8.1)	31.9(4.2)	26.4(5.5)*	31.3(10.0)	17.1(7.8)*	28.0(8.5)	22.1(7.8)*	32.3(5.7)	24.4(7.0)*	26.9(3.0)	18.9(3.1)*
Aerobic capacity												
Bleep (n)	33.7(20.6)	19.6(13.5)*	30.8(19.9)	26.4(18.3)	17.0(12.2)	7.2(7.9)*	15.7(3.5)	8.4(3.0)*	16.4(15.9)	9.2(6.5)*	11.8(2.9)	4.8(2.5)*

*Significant difference between 2010 and 2022 ($P < 0.05$).

$, median and interquartile range; BMI, body mass index; cm, centimetre; CS, Chair stand; GUG, 8-foot get-up-and-go; kg, kilogramme; IPU, isometric push-up; m, meter; MCU, modified curl-up; n, amount; s, seconds; S&R, sit-and-reach; SOOL, standing on one leg; TL, trunk lift; WOBB, walking on balance beam.

to perform each test. Standing height and body mass were taken before the physical tests were performed. Participants were tested individually for all the test items. All testing was completed by the primary researcher as was conducted in 2010. Familiarisation sessions were conducted before the commencement of the study.

Statistics

Data were analysed with the Statistical Package for the Social Sciences (SPSS 28.0, Chicago, IL, USA). Participants were allocated into gender and age categories as performed in 2010. The allocated age categories are 18–25, 26–35, 36–45 and >45 years. Data were screened for normality and outliers by using descriptive statistics and the Shapiro–Wilk test statistic. Data are presented as mean and standard deviation and non-Gaussian data as median and interquartile range.

The results of participant data from 2010 were compared with the 2022 data for all 10 functional fitness tests using two-tailed paired sample T-tests. Data were screened to analyse whether T-test assumptions were violated. If normality assumptions were violated the non-parametric Wilcoxon signed-rank test statistic was used. Cohen's d effect sizes are provided to demonstrate the magnitude of improvement or deterioration. A conventional rule is to consider a Cohen's d of 0.2 as small, 0.5 as medium and 0.8 as large (Cohen 1988). A significance level of $P < 0.05$ was used.

Results

Sixty-six individuals (38 males and 28 females) with DS (42.9 ± 8.7 years) were tested again after 12 years on 10 functional fitness tests as well as body mass (68.1 ± 15.6 kg) and standing height (154.5 ± 8.9 cm). All participants were able to perform all tests safely, and no injuries or falls resulted due to functional fitness exercise testing.

The results as depicted in Table 1 demonstrate numerous significant results (shown by *) for longitudinal data (2010 vs. 2022). Results for both balance tests (standing on one leg and walking on balance beam), the functional test (8-foot get-up-and-go) and abdominal strength (modified curl-up) were not normally distributed, and for these, the median and interquartile range values are also provided (shown by $) and the non-parametric test statistic were (Wilcoxon signed-rank test statistic) reported. For both DS men and women, significant differences were reported for static balance (standing on one leg), shoulder flexibility (shoulder stretch), trunk strength (trunk lift) and aerobic capacity (bleep shuttles) for most age categories. Dynamic balance decreased significantly between 2010 and 2022 for DS women, and for men, leg- and upper body-strength decreased significantly over two of the three age categories (Table 1). Significant deteriorations are reported for DS men in the oldest age category for all tests (except lower limb flexibility and abdominal strength) and body mass. For all the follow-up results with a significant change, mean values did not meet minimum criterion referenced standards for DS adults expected for healthy and independent living (Boer 2022).

Effect sizes are reported in Table 2. Medium to large effect sizes are reported for static balance, shoulder flexibility, trunk lift and aerobic capacity across most longitudinal results for both genders. Large effect sizes are shown for leg strength, trunk strength and aerobic capacity for the eldest age categories for both genders. Large effect sizes are also reported for the eldest male age category for both balance tests, shoulder flexibility, functional ability and upper body strength.

Negligible, small and medium effect sizes mostly reported for lower limb flexibility, upper body strength (except eldest males) and abdominal strength.

Discussion

This is the first study that studied the functional fitness of adults with DS over a longitudinal period. The results of the study showed that the parameters associated with functional fitness with a significant deterioration over the 12-year study period for both DS men and women were static balance, shoulder flexibility, trunk strength and aerobic capacity (most age categories). Medium to large effect sizes are also represented for these parameters.

The ability to control balance deteriorates with age because of alternations in the visual, somatosensory, vestibular, musculoskeletal and central nervous systems (Dunsky *et al.* 2017). The median values reported for static balance after 12 years is lower than

Table 2 Effect sizes for weight, body mass index and functional fitness

	Males (*n* = 38)			Females (*n* = 28)		
	Age Cat 1	Age Cat 2	Age Cat 3	Age Cat 1	Age Cat 2	Age Cat 3
Description	2010 vs. 2022	2010 vs. 2022	2010 vs. 2022	2010 vs. 2022	2010 vs. 2022	2010 vs. 2022
Anthropometry						
Weight (kg)	0.11	−0.90§	−0.37†	0.36†	−0.20	−1.10§
BMI (kg/m^2)	0.15	−1.25§	−0.63‡	0.42†	−0.22	−0.71‡
Balance						
SOOL (s)	−0.44†	−0.83§	−1.55§	−0.52‡	−0.80§	−1.31§
WOBB (steps)	−0.20†	−0.45†	−1.25§	−0.59‡	−0.53‡	−1.11§
Flexibility						
Shoulder (cm)	−0.53‡	−0.24†	−1.22§	−1.52§	−1.02§	−0.50‡
Sit-and-reach (cm)	−0.24†	−0.56‡	−0.28†	−0.51‡	−0.25	−0.76‡
Functional ability						
8-foot up-and-go (s)	0.21†	−0.16	0.86§	0.41†	0.59‡	0.79‡
Muscular strength and endurance						
Chair stand (n)	−0.24†	0.00	−0.85§	−0.23†	−0.14	−1.71§
IPU (s)	−0.31†	0.07	−0.85§	−0.25†	−0.32†	0.13†
MCU (n)	−0.23†	−0.71‡	−0.53‡	−0.16	−0.34†	−0.34†
Trunk lift (cm)	−0.33†	−1.12§	−1.58§	−0.72‡	−1.24§	−2.62§
Aerobic capacity						
Bleep shuttles (n)	−0.81§	−0.23†	−0.95§	−2.24§	−0.59‡	−2.59§

†Small effect size.
‡Medium effect size.
§Large effect size.
BMI, body mass index; Cat, category; cm, centimetre; kg, kilogramme; IPU, isometric push-up; m, meter; MCU, modified curl-up; n, amount; s, seconds; SOOL, standing on one leg; WOBB, walking on balance beam.

the recommended criterion reference values for healthy living as reported in the functional fitness manual for adults with DS (Boer 2022, p. 34). A decreased static and dynamic balance ability has been reported for most individuals with DS compared with age-matched non-DS individuals (Carmeli *et al.* 2002b; Tsimaras & Fotiadou 2004; Villamonte *et al.* 2010), which has led to an increased susceptibility of falls and increased dependence on others (Cowley *et al.* 2010). Tsimaras & Fotiadou (2004) have reported increased balance ability after a period of lower muscular strength and plyometric training for young adult individuals with DS. Increased balance ability was also reported by Ahmadi *et al.* (2018) after treadmill walking and step up/down training in young adults with DS and with the use of dance training (Gutiérrez-Vilahú *et al.* 2016). Balance and lower limb strength improvements have also been reported for elderly adults with DS after a period of 6 months of treadmill walking (Carmeli *et al.* 2002c). These findings of increased muscle strength and balance are also confirmed by a systematic review study that focussed on randomised controlled trials (Li *et al.* 2013). It is possible that an increased lower leg muscle strength may improve balance ability in this population although a possible cause–effect was not studied in these investigations. However, it has been demonstrated that muscle strength is an important predictor of functional performance and everyday living activities in this population (Cowley *et al.* 2010; Terblanche & Boer 2013).

It is worrying that the aerobic capacity of the participants decreased significantly and with such large effect sizes considering that the aerobic capacity of individuals with DS is already low compared with age-matched peers from the general population and those with ID, without DS (Baynard *et al.* 2008).

Optimal aerobic capacity is important for individuals with DS as low aerobic capacity has been associated with cardiovascular disease in this population (González-Agüero *et al.* 2010) and increased body fat percentage (Salaun & Berthouze-Aranda 2012) and inability to perform everyday functional activities (Cowley *et al.* 2010; Boer & Moss 2016b). The fact that the oldest male and female age categories slumped to 7.2 and 4.8 shuttles, respectively (level 1 of the modified multistage shuttle run test) is problematic as these values are well below the criterion referenced tables (16 for males and 9.5 for females) which are minimum preferred reference values for healthy living (Boer 2022, p. 44). The large significant decrease seen in aerobic capacity, especially for the elderly categories may also be related to a large decrease in lower limb strength (Table 2) as Pitetti and Boneh (1995) found a strong correlation between aerobic capacity and leg strength in persons with DS. This could be why most studies utilising a combined aerobic and resistance training programme have demonstrated a significant improvement in aerobic capacity for this population (Mendonca *et al.* 2011; Mendonca *et al.* 2013) whereas some aerobic training alone studies reported limited improvement (Carmeli *et al.* 2002c; Mendonca & Pereira 2009; Boer 2020) and others no improvement (Varela *et al.* 2001). However, irrespective of the training modality, the low aerobic capacity, sedentary lifestyle and lack of exercise (Bertapelli *et al.* 2016; Diaz 2020) for adults with DS, should be addressed by studying the barriers and facilitators to physical activity that have been identified for this population. Barriers such as a lack of financial means, transportation problems, inaccessibility of training programmes, competing family responsibilities and a lack of educated physical activity professionals (Hutzler & Korsensky 2010; Mahy *et al.* 2010; Barr & Shields 2011; Schultz *et al.* 2023) and facilitators to physical activity such as support from others and familiar and routine activities that are fun and stimulating (Mahy *et al.* 2010) should be considered by the executive management of ID care centres to find ways and methods in enhancing physical activity. For example, a successful and intuitive study by Heller *et al.* (2004) conducted on older adults with DS proved that a combined exercise and health education programme could overcome the many barriers associated with physical activity for this population. After 12 weeks of health education and training, the exercise group demonstrated significant changes on their perception of exercise. These included improved life satisfaction, lower depression, increased exercise self-efficacy, less cognitive–emotional barriers and more positive anticipated results. Another study by Shields *et al.* (2011) demonstrated that the perceptions and attitudes of those individuals who facilitate training in this population could be positively and significantly altered. Mahy *et al.* (2010) also stipulated the importance of educating support staff about the significance of a physically active lifestyle for individuals living with ID. A long-term, sustainable and integrated community-based programme revealed that over time adults with ID spent less time in sedentary behaviour or light activity and more in moderate to vigorous zones (Lante *et al.* 2011). They showed that psychosocial benefits such as meeting new people and attaining social respect spurred the individuals to a habitually active lifestyle. The process was gradual but ameliorated common misconceptions that exercise is too boring and difficult (Lante *et al.* 2011).

Regarding trunk strength for both men and women with DS, a significant decrease with large effect sizes in many of the age group categories were reported (Tables 1 and 2). Again, the mean trunk strength for each age group did not meet the minimum criterion referenced values for preferred healthy living (Boer 2022, p. 42). Trunk strength is important for posture, balance and functional ability and is associated with falls in older adults as reported in a systematic review (Granacher *et al.* 2013). Shahtahmassebi *et al.* (2017) also reported significant correlations between trunk strength and functional ability and balance in elderly community living adults and recommended specific training strategies targeting the trunk and abdominal musculature.

The final functional fitness parameter that deteriorated significantly for both DS men and women with medium to large effect sizes for most age group categories was shoulder flexibility. A multiple direction and adequate range of motion is needed in the upper extremity joints to perform activities of daily living such as reaching, washing the lower back or putting on your seatbelt; otherwise, compensatory movements or help from others would be needed (Metzger *et al.* 2012; Oosterwijk *et al.* 2018). A study by Singh *et al*. (2006) showed that adequate flexibility is a particularly important contributor to functional performance for elderly women and optimal training programmes should be tailored accordingly. Considering this finding, training programmes for women with DS could be even more important because their shoulder flexibility is poor compared with elderly women in the general population but not for men (Boer 2010). This is not the case for lower limb flexibility (sit-and-reach test) as both men and women with DS outperformed elderly adults in the general population (Boer 2010). An interesting study by Faber *et al*. (2007) demonstrated that upper body flexibility decreases even in the 10th decade of life in the general elderly population and this decrease is still associated with physical limitations.

Significant gender-specific deteriorations were also reported. Dynamic balance deteriorated significantly (medium to large effect sizes) for women with DS and for the men, leg- and upper body-strength deteriorated significantly for two of the three age categories (large effect sizes for oldest age category only). A training programme consisting of leg strength and plyometric training have demonstrated that the leg strength and dynamic balance (as assessed by a balance deck (Lafayette)) significantly improved after 12 weeks of training for adults with DS (Tsimaras & Fotiadou 2004). A recent systematic review also revealed that exercise interventions have been effective to improve static and dynamic balance in individuals with DS although the review was conducted in children and adolescents (Maïano *et al*. 2019). Carmeli *et al*. (2002c) hypothesised that the increases in leg strength after 6 months of treadmill walking in elderly adults with DS may have contributed to the improvement in dynamic balance. There is no clear reason why the dynamic balance of women with DS in the current study deteriorated significantly and only with the eldest men category, but training programmes may improve the age-associated loss for both genders. Also, training programmes should be tailored to slow down the age associated loss in leg- and upper body-strength, particularly for men with DS. It was shown in a 3-year longitudinal study that the age-associated decreases in muscle strength was more (nearly double) for elderly men compared with elderly women in the general population and this decrease was associated with a decrease in muscle mass (Goodpaster *et al*. 2006). This is important as upper body strength is associated with manual labour tasks for individuals with DS and particularly men who are employed to perform these types of activities (Shields *et al*. 2013). Also, lower limb strength is associated with functional capacity in adults with DS (Terblanche & Boer 2013) and aerobic capacity (Pitetti & Boneh 1995). Strength training programmes developed according to the guidelines of the American College of Sport Medicine have been shown to be safe, feasible and effective for adults with DS (Shields *et al*. 2008; Cowley *et al*. 2011; Shields *et al*. 2013). The National Strength and Conditioning Association also provided a positional statement regarding recommendations for successful resistance training in older adults, which can be adapted to elderly adults with frailty and mobility problems, intellectual impairment or other chronic conditions (Fragala *et al*. 2019). The researchers also reiterated the association between muscular strength and functional independence.

Another finding that has emerged from the results is the significant deteriorations and large effect sizes reported for the male eldest age category (except lower limb flexibility and abdominal strength). The mean age after the longitudinal follow-up for men was 55 years. The low mean values for most functional fitness parameters shown in 2022 together with lower than recommended criterion referenced standards should be a worrying statistic for adapted physical activity health practioners and professionals working in the field of rehabilitation and medical sciences. These findings may also hold true for women with DS in the eldest age category where many significant deteriorations with large effect sizes were also reported. A recent study by Magistro *et al*. (2021) successfully demonstrated that a one-year lifestyle intervention (improving the amount of time spent every week in active behaviour and physical activity) significantly improved physical function and basic activities of daily living in elderly adults (mean age of 82 years) in a quasi-experimental intervention study with a non-exercise/active control group. The results held true for those adults with dementia which is an important finding for health professionals working in the field of adapted physical activity as many elderly individuals with DS develop dementia and early onset Alzheimer's (Wiseman *et al*. 2015).

The final finding that emanated from this study that also concerned men with DS was the significant body mass loss for the elderly two age groups (also eldest female category). These plummeting body mass values (in association with other functional fitness parameters) may be indicative of premature ageing as demonstrated in a large cross-sectional study for adults with DS (age category 26–35 to 36–45 and 36–45 to >45) (Terblanche & Boer 2013). These plummeting weight loss values is concerning as weight loss from middle to late adulthood have been associated with increased risks of mortality (Chen *et al.* 2019). The researchers stated that maintaining normal weight across adulthood is important for preventing premature deaths. Interestingly, normal body mass index status for the elderly in the general population (>70 years) showed a higher risk for mortality than obesity in a longitudinal study (Stessman *et al.* 2009). Similar future studies should be conducted for individuals with DS, because their ageing profile and body build (short stature and mostly overweight) is different to the general population (Terblanche & Boer 2013; Horvath *et al.* 2015).

Limitations and future studies

The current study does not have information pertaining to the level of physical activity for the 66 adults with DS over the past 12 years. Also, follow-up analysis could not track/trace all DS participants from 12 years earlier (possible relocation including immigration, withdrawal from ID care centre, sickness or death). Many of the staff working at the ID care centres have not worked at that centre for 12 years and often participant records are not kept to accurately report on physical activity levels or reasons for that person leaving the centre. Some participants were found to have passed away, but these were not enough to model data for possible associations between functional fitness limitations and mortality as performed by O'Leary *et al.* (2018) for individuals living with DS. Another limitation of the current study is that the level of ID was not known, as most parents/guardians of adults with DS and the management of ID care centres do not have this information in South Africa. However, all participants had the cognitive ability to understand and perform the exercises in a technically correct manner as stipulated in the 2010 and 2022 inclusion criteria. The final limitation of the current study that should be noted is that information regarding the medical profile of each participant was not collected to study the possible confounding influence of medical and chronic disease conditions on the functional fitness ageing profile of the adults with DS. However, no visible or marked medical or chronic conditions were noted during the follow-up phase and the inclusion and exclusion criteria remained the same for both data collection periods. More longitudinal functional fitness studies should be conducted for individuals with DS in association with the medical history of the person living with DS. Future studies should also identify individuals with a habitual physical active lifestyle (type, frequency, duration and intensity of activity) and compare their functional fitness ageing profile with those who are sedentary. Furthermore, possible predictors or risk factors for mortality or premature mortality can be modelled with regression models, adjusting for confounding variables.

Conclusion

Static balance, shoulder flexibility, trunk strength and aerobic capacity decreased significantly with medium to large effect sizes for most age categories for both men and women with DS. Furthermore, dynamic balance deteriorated significantly for women with and leg- and upper body-strength for men with DS. These results are shown for all or most age group categories. The mean values for all these statistically significant results at 12-year follow up, are lower than the minimum preferred criterion referenced values for healthy and independent living for that specific age and gender as presented by Boer (2022).

Functional fitness deterioration will eventually lead to a loss of independence, increased healthcare costs and possible institutionalisation. Therefore, adults with DS who are at high risk for functional limitations need to be identified. Screening for functionally relevant weakness is crucial in developing effective strategies to prevent or at least delay functional decline in the DS ageing population. The executive management of ID care centres should appoint an adapted physical activity exercise professional who actively seeks methods to improve the level of physical activity for all persons living with DS using an individualised monitoring approach. Such professionals should consider the findings that have emanated from a myriad of aerobic research investigations that used modalities consisting of swimming, running, cycling, walking, resistance training, dancing, interval training and many others.

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Data availability statement

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