Benefits of physical exercise intervention on fitness of people with Down syndrome: a systematic review of randomized controlled trials

Running head: Physical exercise for Down syndrome

Chunxiao Li¹, Shihui Chen², Yew Meng How¹, and Antony Lin Zhang³

¹Physical Education and Sports Science, Nanyang Technological University, Singapore, ²Department of Health and Physical Education, Hong Kong Institute of Education, Hong Kong, China, ³School of Health Sciences, Royal Melbourne Institute of Technology, Melbourne, Australia

Correspondence: Chunxiao Li, Physical Education and Sports Science, National Institute of Education, Nanyang Technological University, 1 Nanyang Walk, Singapore 637616, Tel: +65 8509 1944, E-mail: cxlilee@gmail.com

Statement of conflicts of interests and source of funding: none declared.

Abstract

Objective: This study systematically reviewed the impact of physical exercise interventions on physical fitness for people with Down syndrome (DS).

Methods: Articles published in English were searched from five major electronic databases namely CINAHL, Medline, PsychINFO, SPORTDiscus, and PEDro from inceptions until April 2013. These studies were screened through predefined inclusion and exclusion criteria. Data were then extracted and synthesized from the included studies. Meta-analyses were carried out where appropriate.

Results: Ten studies met the inclusion criteria. Of the ten studies, five studies were found to have high quality of research methodology according to PEDro scale. Varying exercise programs were used and four different fitness outcomes were evaluated: (i) balance, (ii) muscle strength and endurance, (iii) cardiovascular fitness, and (iv) body composition. Exercise interventions led to moderate to high effects on improving muscular strength and balance ($d = 0.74$ to $1.10$) while other outcomes showed less conclusive or limited positive evidence.

Conclusions: Trends in the results suggest that exercise interventions improve muscular strength and balance. Suggestions for future research include follow-ups to the intervention to examine the longitudinal effects of exercise, as well as controlling for confounding factors such as participants’ compliance rate and severity levels of DS to enhance the effectiveness of the interventions.

Keywords: Intellectual disability, physical activity, intervention, research synthesis
Introduction

According to the American Association on Intellectual and Developmental Disabilities (AAIDD), the term intellectual disability is defined as “a disability that originated before the age of 18, and involves significant limitations both in intellectual functioning and in adaptive behavior that covers many everyday social and practical skills” (AAIDD, 2011). Down syndrome (DS), a subcategory of intellectual disability, is one of the most common disabilities around the world and its overall prevalence is approximately 10.4 per 1000 population (Maulik and Mascarenhas, 2011). An important health-related issue for this population is about their low levels of physical fitness (Lloyd et al., 2010; Temple et al., 2006).

Physical fitness refers to a set of attributes related to the ability of people to perform physical activity (U.S. Department of Health and Human Services, 1996). There are three major types of physical fitness (U.S. Department of Health and Human Services, 1996; Bouchard et al., 1994): (i) physiological fitness (e.g. metabolic, morphological, bone integrity, and others); (ii) health-related fitness (e.g. body composition, cardiovascular fitness, flexibility, muscular endurance, and muscular strength); and (iii) skill-related fitness (e.g. agility, balance, coordination, power, speed, reaction time, and others). Studies demonstrated that people with DS had lower levels of physical fitness than those without disabilities (Lloyd et al., 2010; Temple et al., 2006). For example, individuals with DS had a lower level of balance and aerobic fitness than those without DS (Black et al., 2007; Shields et al., 2008). The low levels of physical fitness can result in several health problems (e.g. type 2 diabetes), risk of secondary conditions (e.g. depression), and lower work efficiency in people with DS (Lahtinen et al., 2007; Sutherland et al., 2002).
Although evidence has shown that physical exercise intervention is critical for fitness promotion and maintenance, little attention has been paid to document its effectiveness in people with DS (Rimmer et al., 2010). Evidence-based practice has been a growing movement in the medical area (Schlosser et al., 2006; Toomey and Coote, 2012). For example, healthcare providers can seek evidence-based recommendations to improve physical fitness for people with DS. This is especially important for persons with DS as they have some unique characteristics such as physiologic impairments, impaired response to submaximal exercise, postural deficits, and hypotonia (Abdel Rahman and Shaheen, 2010; Mendonca et al., 2010). These characteristics can affect their development of physical fitness and the effectiveness of exercise intervention programs (Rimmer et al., 2004). Therefore, systematic reviews should be conducted to examine the effectiveness of exercise intervention on physical fitness for people with DS.

Andriolo et al. (2010) reviewed the effectiveness of aerobic exercise programs on both physical and psychological health in adults with DS. However, insufficient evidence of training effects was provided, as only three randomized controlled trials (RCTs) published before 2003 were included in their review. In an effort to provide valuable guidelines for health providers and shed lights on planning future studies within the discipline, the current review was to systematically assess the evidence of physical fitness benefits that derived from randomized controlled physical exercise interventions for people with DS.

**Methods**

This study was conducted following the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). The PRISMA is an evidence-
based guide for reporting systematic reviews and/or meta-analyses in particular to RCTs (Moher et al., 2009).

Search strategy

Data were systematically searched through five electronic databases from the inception until April 2013: CINAHL, Medline, PsychINFO, SPORTDiscus, and PEDro. Combinations of the following three groups of keywords were used for searching: (i) physical activity OR physical fitness OR physical exercise OR sport; AND (ii) mental retardation OR intellectual disability OR Down syndrome OR learning disability; AND (iii) experimental study OR intervention.

Inclusion and exclusion criteria

Articles included in this review satisfied all the following inclusion criteria: (i) participants were diagnosed with DS; (ii) used exercise training as an intervention; (iii) study design was a RCT; and (iv) outcomes on any type or component of physical fitness (e.g. body composition, muscular, and balance) were reported. Articles were excluded from the review if they: (i) recruited mixed participants, but did not present separate data on physical fitness outcomes for participants with DS; (ii) did not use exercise training as an intervention; (iii) did not use a RCT design; or (iv) were not published in English language journals.

Study selection

The first author performed the literature search and removed the duplicates. Two independent reviewers screened titles, abstracts, and full text according to the aforementioned inclusion and exclusion criteria. Advice was sought from a third
experienced reviewer to reach a consensus when disparity about exclusion/inclusion of a paper occurred. All the reviewers were agreed with the final list of studies included in the review.

Data extraction and analysis

The following information were extracted from the included studies by two independent reviewers for assessment of research quality and data synthesis: (i) author and publication year; (ii) participants’ characteristics (e.g. age); (iii) intervention programme (e.g. mode of exercise, exercise intensity, and duration); (iv) outcome measures; (v) summary of results; and (vi) adverse events. Effect sizes (Cohen’s $d$) were either calculated or extracted from the papers where applicable. According to Cohen (Cohen, 1992), a $d$ value of 0.2, 0.5, and 0.8 indicates of a small, a medium, and a large effect respectively.

Research quality

Methodological quality of the included studies was rated through the PEDro (PEDro, 1999). The PEDro was reported with good to fair reliability for use in assessing research quality especially for RCTs in systematic reviews (Maher et al., 2003). There are 11 items in this checklist using Yes (1 point) or No (0 point) rating scale for responses (PEDro, 1999). The item 1 (eligibility criteria) is not counted for overall scale score as it does not influence the internal or statistical validity of the experiment (Maher et al., 2003). A possible score of the scale ranges from 0 to 10 and a higher score indicates better research quality of a study. A study with an overall score higher than 6 is considered to be of high research quality (PEDro, 1999). Two reviewers independently rated the included studies. A third reviewer was again involved in case
of disagreement of rating. All the reviewers were agreed with the final scale scores for the included studies.

Results

Study selection

Figure 1 describes the flow of the study selection for this review. The literature search led to a retrieval of 483 studies. After deleting duplicates (n = 89), it remained 394 articles. A further 361 studies were excluded after reading the abstracts, because they did not satisfy the inclusion criteria. Full-text of the remaining articles (n = 33) were read and a further 23 studies that did not meet the inclusion criteria were excluded. Thus, ten studies were included for the review.

Methodological quality

Table 1 shows the PEDro scores of the included studies (n = 10). Five studies (Shields et al., 2008; Carmeli et al., 2002; Shields and Taylor, 2010; Gupta et al., 2011) were considered to have high methodological quality (a score of 6 or above). All the included studies provided the eligible criteria of the participants. Three studies (Shields et al., 2008; Shields and Taylor, 2010; Gupta et al., 2011; Lin and Wang, 2012) used an allocation concealment method. Only one study (Gupta et al., 2011) did not provide evidence of comparability of baseline data. Double blind (subjects and therapists) was not stated in any of the studies. Two studies (Abdel Rahman and Shaheen, 2010; Ulrich et al., 2011) did not have an adequate follow-up and four studies (Shields et al., 2008; Shields and Taylor, 2010; Gupta et al., 2011; Lin and Wang, 2012) applied an intention-to-treat analysis. All the studies provided information on between-group comparisons and point estimates and variability.
**Cohort details**

Table 2 is the summary of the cohort details from the included studies. All the studies were published after year 2000. A total of 349 participants with DS were recruited in the ten studies and the mean total sample size for each study was 34.9 (16 to 92). The mean age of the participants was 22.0 years old. In general, there were more male participants than the female counterparts. The severity of DS was reported in the most studies, ranging from mild to severe across the studies. Only three studies (Rimmer *et al.*, 2004; González-Agüero *et al.*, 2011; Lin and Wuang, 2012) reported the co-morbidity diagnoses of DS.

**Exercise interventions**

Eight types of intervention programs were used in the included studies (Table 3). These included: a treadmill program (Carmeli *et al.*, 2002), a bicycle program (Ulrich *et al.*, 2011), a rowing ergometer intervention (Varela *et al.*, 2001), a progressive resistance training program (Shields *et al.*, 2008; Shields and Taylor, 2010), a combined program with treadmill training and game-like exercise (Lin and Wuang, 2012), a combined program with progressive resistance training and balance exercise (Gupta *et al.*, 2011), a combined program with cardiovascular and strength exercise (Rimmer *et al.*, 2004; González-Agüero *et al.*, 2011), and a weight bearing exercise program (Abdel Rahman and Shaheen, 2010). The mean duration of intervention programs was 11.9 weeks (6 to 25). Most participants were required to involve 2 to 3 training sessions per week and the duration of each training session ranged from 10 to 80 min across the studies. The intensity of training sessions varied a lot among the
studies. Only three studies (Shields et al., 2008; Shields and Taylor, 2010; Gupta et al., 2011) reported the adherence of training programs, ranging from 82% to 93%.

Outcome measures

Diverse outcome measures were used corresponding to the different kinds of intervention programs (Table 3). The majority of the studies assessed muscular fitness, three studies evaluated balance/body composition, and two studies tested cardiovascular fitness (detailed information were presented below). Given the heterogeneity of intervention programs and outcome measures, random effects meta-analyses were conducted where appropriate (Hunter and Schmidt, 2004). The weighted mean effect size ($d$) was computed. The $Q$-test was applied to examine whether a true $d$ will vary between studies (i.e. heterogeneity). A significant $Q$-value indicates heterogeneity and $I^2$ statistics were then used to interpret the magnitude of heterogeneity (Field and Gillett, 2010). In addition, Fail-safe N was employed to determined the number of nonsignificant missing studies needed to bring a weighted effect size to a small effect ($d \leq .2$) as a measure of publication bias (Orwin, 1983).

Study outcomes – muscle strength and endurance

Seven studies investigated the effectiveness of exercise program on muscle strength and the training methods varied among these studies. An intervention program through combining progressive resistance training and balance training was used in the study conducted by Gupta et al. (2011); they found a significant improvement in lower-limb strength ($d$ not reported). Carmeli et al. (2002) concluded that isokinetic strength (knee extension and flexion) can be improved through a treadmill walking program ($d$ not reported). Similar findings were evidenced in the study by Lin and
Physical exercise for Down syndrome

Wuang (2012), $d = 0.50$ to $0.76$ across different lower-limb muscle groups. The study by Ulrich et al. (2011), on the other hand, found that the bicycle intervention program showed no effect on isokinetic strength of knee extension ($d = 0.55$; 95% CI [-1.64, 2.75]) and knee flexion ($d = 0.70$; 95% CI [-1.37, 2.77]).

Two studies used progressive resistance training. Shields et al. (2008) found no significant group differences on both the upper-limb muscle strength ($d = 0.68$; 95% CI [-0.20, 1.59]) and the lower-limb muscle strength ($d = 0.23$; 95% CI [-0.65, 1.12]). Another study (Shields and Taylor, 2010) also reported no significant differences on both upper-limb muscle strength ($d = 0.57$; 95% CI [-0.27, 1.40]) and lower-limb muscle strength ($d = 0.73$; 95% CI [-0.12, 1.58]) between groups.

However, Rimmer et al. (2010) used the cardiovascular and strength exercise training program, finding that muscle strength on both upper-limb ($d = 0.99$; 95% CI [0.41, 1.58]) and lower-limb ($d = 1.30$; 95% CI [0.70, 1.91]) was significantly improved. The meta-analytic findings showed that exercise programs improved muscular strength on both lower-limb ($d = 0.74$, 95% CI [0.39, 1.10], $Q_{(4)} = 7.73$, $p = .10$, $I^2 = 48.23$, Fail-safe N = 12) and upper-limb ($d = 0.85$, 95% CI [0.44, 1.26], $Q_{(2)} = 0.48$, $p = .79$, $I^2 = 0$, Fail-safe N = 10).

Only one study (Shields et al., 2008) examined the effectiveness of the progressive resistance exercise program on muscle endurance. The results showed a significant improvement in upper-limb muscle endurance ($d = 1.51$; 95% CI [0.46, 2.44]) for the intervention group compared with the control group, but no statistical difference was found on lower-limb muscle endurance ($d = -0.06$; 95% CI [-0.94, 0.82]).

*Study outcomes – balance*
Four studies evaluated the intervention outcome of balance using different exercise programs. One study (Carmeli et al., 2002) showed that treadmill exercise could improve dynamic balance ($d$ not reported). Gupta et al. (2011) found that participants in the intervention group improved their balance through specific balance exercise training ($d = 1.07; 95\% \text{ CI} [0.23, 1.91]$). Abdel Rahman and Shaheen (2010) measured both static and dynamic balance and they found that the weight-bearing exercise program was effective in improving static ($d = 1.29; 95\% \text{ CI} [0.43, 2.14]$) and dynamic balance ($d = 1.32; 95\% \text{ CI} [0.46, 2.18]$) for the intervention group. However, Ulrich et al. (2011) found that the bicycle intervention program did not enhance participants’ standing balance ($d = 0.28; 95\% \text{ CI} [-1.48, 2.04]$). The meta-analytic results indicated that exercise inventions improved balance ($\bar{d} = 1.10, 95\% \text{ CI} [0.55, 1.63], Q_{(2)} = 1.10, p = .58, I^2 = 0$, Fail-safe $N = 14$).

**Study outcomes – cardiovascular fitness**

Two studies assessed the cardiovascular fitness and both of them measured the peak VO2 as an outcome. Rimmer et al. (2004) found that cardiovascular training improved peak VO2 for individuals in the intervention group ($d = 0.87; 95\% \text{ CI} [0.29, 1.44]$). The study by Varela et al. (2001), however, showed no group difference on peak VO2, as measured by treadmill test ($d = 0.37; 95\% \text{ CI} [-0.62, 1.36]$) and rowing ergometer test ($d = 0.30; 95\% \text{ CI} [-0.68, 1.29]$), through rowing ergometer training. The meta-analytic results showed that exercise inventions improved cardiovascular fitness ($\bar{d} = 0.60, 95\% \text{ CI} [0.07, 1.14], Q_{(1)} = 1.74, p = .19, I^2 = 42.41$, Fail-safe $N =$ not applicable).

**Study outcomes – body composition**
Three studies assessed the effects of physical fitness training on body composition. Rimmer (Rimmer et al., 2004) reported that cardiovascular and strength exercise training had no statistically significant impact on body weight ($d = 0.05; 95\% \text{ CI} [-0.50, 0.60]$), body mass index ($d = 0.04; 95\% \text{ CI} [-0.51, 0.59]$), or skinfold score ($d = -0.37; 95\% \text{ CI} [-0.93, 0.18]$). Similarly, the study by Ulrich et al. (2011) found the bicycle program showed no effect on participants’ body mass index ($d = 0.20; 95\% \text{ CI} [-1.24, 1.64]$) and body fat ($d = 0.29; 95\% \text{ CI} [-3.01, 3.60]$). On the contrary, González-Agüero et al. (2011) found that the combined exercise training program (i.e. jumps, press-ups, elastic bands, and medicine-balls) decreased total fat ($d = 1.93; 95\% \text{ CI} [1.45, 2.41]$) and improved lean masses ($d = 2.40; 95\% \text{ CI} [1.56, 3.24]$).

**Adverse events**

Five out of the ten studies reported whether physical fitness training resulted in adverse events. Three studies (Gupta et al., 2011; González-Agüero et al., 2011; Lin and Wuang, 2012) reported no adverse events during the period of treatment. The other two studies (Shields et al., 2008; Shields and Taylor, 2010) indicated no major adverse events throughout the training programs, seven out of 20 participants (combined data for the two studies) from the intervention groups reported sore hands due to the use of weight equipment and/or exercise training.

**Discussion**

This study reviewed the effects of physical exercise training on physical fitness among people with DS. Ten studies using varying interventions (i.e. progressive resistance training, aerobic training, balance training, and training that combined the aforementioned elements) met the inclusion criteria and were reviewed to examine
their effects on four major components of fitness outcomes. These fitness outcomes were: (i) balance, (ii) muscle strength and endurance, (iii) cardiovascular fitness, and (iv) body composition. This review showed that there is currently no study examining the effects of physical exercise program on flexibility, which is one of the common areas of physical fitness component (U.S. Department of Health and Human Services, 1996). As people with DS have deficits of hypermobility and joint laxity, stretching exercises are not recommended (Parker and James, 1985), which highlights that attention should be paid to improve their other components of physical fitness such as muscle strength.

The meta-analytic findings showed that exercise programs can improve muscular strength. The inconsistent findings across individual studies could be due to the effects of different modes of exercise. Specifically, the four studies showing significant impacts \( (d = 0.50 \text{ to } 1.30) \) of exercise training on muscle strength used a combination of cardiovascular and strength exercises (Rimmer et al., 2004), a combination of resistance training and balance exercises (Gupta et al., 2011), a combination of treadmill walking and game-like exercises (Lin and Wuang, 2012), and treadmill walking programs (Carmeli et al., 2002). The other three studies, used either progressive resistance exercises or bicycle exercises (Shields et al., 2008; Shields and Taylor, 2010; Ulrich et al., 2011), found no statistically impact of their training programmes on muscle strength. However, it is worthy to note that the \( d \) values of the three studies ranged from moderate to high (0.23 to 0.73).

Although muscular endurance is essential for performing everyday activities for people with DS, such as maintaining balance while standing (Croce et al., 1996; Shields et al., 2008), only one study (Shields et al., 2008) evaluated muscular endurance. This study found an improvement on upper-limb muscular endurance but
no positive effects on endurance of lower-limb muscle. The poor exercise economy seen in people with DS (e.g. disturbed gait kinetics and kinematics) may be attributed to the non-effectiveness of the intervention program lower-limb muscular endurance (Mendonca et al., 2010).

Cardiovascular exercises are essential for maintaining optimal cardiovascular health (American College of Sports Medicine, 2000). The effects of aerobic exercise on peak VO2 uptake on people with DS was inconsistent from the two studies reviewed (Rimmer et al., 2004; Varela et al., 2001) although the meta-analytic results showed otherwise. The duration of aerobic training sessions from each study may contribute to this inconsistent finding. A larger training effect on aerobic fitness was found in the study conducted by Rimmer et al. (2004) than the other study (Varela et al., 2001). This could be due to different training loads between the two studies. Specifically, the former study (Rimmer et al., 2004) used a training session with longer duration (30-45min vs. 15-20 min) compared with the later one (Varela et al., 2001). Consequently, due to the physiological impairments related with DS such as low respiratory exchange ratio of oxygen (Rimmer et al., 2004), the finding from this study suggests that longer training duration should be used to improve aerobic fitness in individuals with DS.

Body composition as an outcome of exercise interventions was reported. Though individuals with DS often have low to mild obesity, only three out of the ten included studies assessed body composition, with two studies (Rimmer et al., 2004; Ulrich et al., 2011) finding no training effect on improving body weight, body mass index, body fat, or skinfold score. These results may be due to the characteristics of intervention programs per se. For example, in the study by Rimmer et al. (2004), the intensity (50-70% peak VO2 for 30-45 min and 70% 1 repetition maximum for 15-20
min) of exercise training was moderate, which is unlikely to effectively improve body composition for the participants with DS (American College of Sports Medicine, 2000). Another possibility could be the low basal metabolic rate in people with DS (Luke et al., 1994). Thus, the frequency and duration of physical exercise intervention should be increased to improve their body composition compared with the general population.

Regardless of the training outcomes discussed above, it is important to note that only three studies reported the compliance rate of their training programs. Low compliance is likely to negatively influence the effectiveness of training programs (Doorn, 2010). It is recommended that future work need to report participants’ rate of exercise adherence. Another issue that may confound the training effect is related with participants’ level of a disability. As the participants from the included studies were with moderate to severe intellectual disabilities, they may not easily follow instructions or exercise guidelines which will in turn affect the effectiveness of invention programs. Therefore, future intervention studies may need to provide supervision for participants with intellectual disabilities so as to facilitate their understanding of the instructions when they participate in the exercises.

Limitations

The present study was limited by exclusion of non-English journal articles that may preclude potential studies meeting the inclusion criteria. In addition, despite carefully devising search keywords and strategy, some potential literatures may be excluded.

Implications
Several implications can be drawn from this review. Firstly, regardless of the effects of the training programs, it is encouraging to find that physical exercise is safe for people with DS. In the studies reviewed, there were no reported instances of injury sustained by any of the participants. Secondly, there was a lack of studies examining the effects of physical exercise on physical fitness among people with DS, with only one study evaluating the long-term sustainability of the intervention program (i.e. longitudinal effect). Thus, more studies with post-program follow-ups should be warranted in future. Thirdly, half (5/10) of the included studies showed low research methodological quality. Future studies should improve research quality, particularly the use of “blind” assessors in order to increase the reliability and validity of study outcomes. Fourthly, the relatively strong evidence from the included studies indicated that physical exercise could improve muscle strength and balance for individuals with DS. Finally, some of the exercise programs (e.g. treadmill walking program) used the included studies could be referenced by healthcare providers in the formulation of practice.

In conclusion, the current review identified positive evidence that people with DS can benefit from activities such as weight bearing exercises, treadmill walking and balance exercises. These exercise programs showed a trend on improving muscular strength and balance while other outcomes (i.e. muscle endurance, cardiovascular fitness, and body composition) showed less conclusive or limited positive evidence.
References

AAIDD. (2011) Intellectual disability. Available at:

Abdel Rahman SA, Shaheen AAM. (2010) Efficacy of weight bearing exercises on
balance in children with Down syndrome. Egyptian J Neurol Psychiatry
Neurosurg 47: 37-46.

and prescription, Philadelphia: Lippincott Williams & Wilkins.

training programmes for improving physical and psychosocial health in adults

segmental angle variability during walking: Preadolescents with and without


program on muscle strength and balance in elderly people with Down


Croce RV, Pitetti KH, Horvat M, Miller J. (1996) Peak torque, average power, and
hamstrings/quadriceps ratios in nondisabled adults and adults with mental

Physical exercise for Down syndrome


Shields N, Taylor NF, Dodd KJ. (2008) Effects of a community-based progressive resistance training program on muscle performance and physical function in


### Figure 1. Diagram showing study selection process

<table>
<thead>
<tr>
<th>Records identified through database searching (n = 483)</th>
<th>Records identified through other sources (n = 0)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Records after duplicates removed (n = 394)</td>
<td></td>
</tr>
<tr>
<td>Records screened (n = 394)</td>
<td>Records excluded (n = 361)</td>
</tr>
<tr>
<td>Full-text articles assessed for eligibility (n = 33)</td>
<td>Full-text articles excluded, with reasons (n = 23)</td>
</tr>
<tr>
<td>Studies included in qualitative synthesis (n = 10)</td>
<td></td>
</tr>
</tbody>
</table>
### Table 1. Quality assessment of the included studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Item 1 (EC)</th>
<th>Item 2 (RA)</th>
<th>Item 3 (CA)</th>
<th>Item 4 (BC)</th>
<th>Item 5 (BS)</th>
<th>Item 6 (BT)</th>
<th>Item 7 (BA)</th>
<th>Item 8 (AF)</th>
<th>Item 9 (ITT)</th>
<th>Item 10 (BGC)</th>
<th>Item 11 (PEV)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Abdel Rahman and Shaheen, 2010)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>(Carmeli et al., 2002)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>(González-Agüero et al., 2011)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>(Gupta et al., 2011)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>(Lin and Wang, 2012)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>(Rimmer et al., 2004)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>(Shields and Taylor, 2010)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>(Shields et al., 2008)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>(Ulrich et al., 2011)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>(Varela et al., 2001)</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>5</td>
</tr>
</tbody>
</table>

**Note.** Item 1 = Eligibility criteria (EC); Item 2 = Random allocation (RA); Item 3 = Concealed allocation (CA); Item 4 = Baseline comparability (BC); Item 5 = Blind subjects (BS); Item 6 = Blind therapists (BT); Item 7 = Blind assessors (BA); Item 8 = Adequate follow-up (AF); Item 9 = Intention-to-treat analysis (ITT); Item 10 = Between-group comparisons (BGC); Item 11 = Point estimates and variability (PEV). Item 1 does not contribute to total score. Refer to PEDro (1999) for more details about these criteria.
### Table 2. Details of participants

<table>
<thead>
<tr>
<th>Study</th>
<th>Group</th>
<th>Mean age (years)</th>
<th>Male: female</th>
<th>Mean height (cm)</th>
<th>Mean weight (kg)</th>
<th>Severity of DS</th>
<th>Co-morbidity</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Abdel Rahman and Shaheen, 2010)</td>
<td>Intervention (n = 13)</td>
<td>4.2 (0.4)</td>
<td>5:8</td>
<td>ND</td>
<td>ND</td>
<td>Mild-Moderate</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Control (n = 13)</td>
<td>3.9 (1.2)</td>
<td>6:7</td>
<td>ND</td>
<td>ND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Carmeli et al., 2002)</td>
<td>Intervention (n = 16)</td>
<td>63.5 (2.0)</td>
<td>10:6</td>
<td>ND</td>
<td>ND</td>
<td>Mild</td>
<td>15% with cardiac disease</td>
</tr>
<tr>
<td></td>
<td>Control (n = 10)</td>
<td>63.3 (4.8)</td>
<td>6:4</td>
<td>ND</td>
<td>ND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(González-Agüero et al., 2011)</td>
<td>Intervention (n = 12)</td>
<td>13.7 (2.6)</td>
<td>7:5</td>
<td>146.8 (10.7)</td>
<td>13.7 (2.6)</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Control (n = 13)</td>
<td>15.4 (2.5)</td>
<td>8:5</td>
<td>141.9 (12.5)</td>
<td>15.4 (2.5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Gupta et al., 2011)</td>
<td>Intervention (n = 12)</td>
<td>13.0 (ND)</td>
<td>8:4</td>
<td>132.2 (ND)</td>
<td>28.5 (ND)</td>
<td>Mild-Moderate</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Control (n = 11)</td>
<td>13.5 (ND)</td>
<td>6:5</td>
<td>137.3 (ND)</td>
<td>23.9 (ND)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Lin and Wuang, 2012)</td>
<td>Intervention (n = 46)</td>
<td>15.6 (3.6)</td>
<td>25:21</td>
<td>153.0 (8.0)</td>
<td>57.2 (10.2)</td>
<td>Mild-Moderate</td>
<td>Without other impairments</td>
</tr>
<tr>
<td></td>
<td>Control (n = 46)</td>
<td>14.9 (3.9)</td>
<td>24:22</td>
<td>151.0 (6.0)</td>
<td>58.8 (9.9)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Rimmer et al., 2004)</td>
<td>Intervention (n = 30)</td>
<td>38.6 (6.2)</td>
<td>16:14</td>
<td>151.0 (9.0)</td>
<td>80.5 (20.0)</td>
<td>ND</td>
<td>4 with heart disease, 2 with aortic stenosis, 1 with aortic stenosis, and 1 with mitral valve prolapse</td>
</tr>
<tr>
<td></td>
<td>Control (n = 22)</td>
<td>40.6 (6.5)</td>
<td>13:9</td>
<td>151.0 (4.0)</td>
<td>76.0 (18.2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Shields and Taylor, 2010)</td>
<td>Intervention (n = 11)</td>
<td>15.9 (1.5)</td>
<td>8:3</td>
<td>159 (11.0)</td>
<td>63 (6.0)</td>
<td>Mild-Severe</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Control (n = 12)</td>
<td>15.3 (1.7)</td>
<td>9:3</td>
<td>156 (7.0)</td>
<td>58 (7.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Shields et al., 2008)</td>
<td>Intervention (n = 9)</td>
<td>25.8 (5.4)</td>
<td>7:2</td>
<td>158.8 (7.1)</td>
<td>78.4 (13.5)</td>
<td>Mild-Severe</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Control (n = 11)</td>
<td>27.6 (9.5)</td>
<td>6:5</td>
<td>152.0 (10.0)</td>
<td>61.2 (6.7)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Ulrich et al., 2011)</td>
<td>Intervention (n = 19)</td>
<td>12.0 (1.9)</td>
<td>9:10</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Control (n = 27)</td>
<td>12.4 (2.2)</td>
<td>11:16</td>
<td>ND</td>
<td>ND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Varela et al., 2001)</td>
<td>Intervention (n = 8)</td>
<td>22.0 (3.8)</td>
<td>8:0</td>
<td>153.6 (21.5)</td>
<td>62.2 (10.7)</td>
<td>Mild-Severe</td>
<td>ND</td>
</tr>
<tr>
<td></td>
<td>Control (n = 8)</td>
<td>20.8 (2.3)</td>
<td>8:0</td>
<td>157.3 (4.1)</td>
<td>60.1 (7.4)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. ND = no data.*
Table 3. Details of exercise interventions and outcomes

<table>
<thead>
<tr>
<th>Study</th>
<th>Intervention</th>
<th>Outcome measures</th>
<th>Adherence &amp; results</th>
<th>ES (95% CI)</th>
</tr>
</thead>
</table>
| (Abdel Rahman and Shaheen, 2010) | (i) Intervention group: Exercise: traditional physical exercise and weight bearing exercise  
Intensity: ND  
Duration: 80 min  
Frequency: daily  
(ii) Control group: Exercise: traditional physical exercise  
Intensity: ND  
Duration: 60 min  
Frequency: daily  
(iii) Intervention duration: 6 weeks | (i) Static balance  
(ii) Dynamic balance  
(iii) Total balance (static and dynamic balance) | Adherence data was not provided; the results showed that static, dynamic, and total balance were improved in the intervention group compared with the control group | (i) 1.29 (0.43,2.14)  
(ii) 1.32 (0.46,2.18)  
(iii) 1.44 (0.56,2.32) |
| (Carmeli et al., 2002) | (i) Intervention group: Exercise: treadmill walking  
Intensity: based on personal tolerance  
Duration: 10-45min  
Frequency: 3 days/week  
(ii) Control group: continued with usual activities  
(iii) Intervention duration: 25 weeks | Lower-limb strength:  
(i) knee extension  
(ii) knee flexion  
(iii) dynamic balance | Adherence data was not provided; the results showed that isokinetic strength and dynamic balance were improved in the intervention group compared with the control group | (i) NA  
(ii) NA  
(iii) 1.07 (0.23, 1.91) |
| (González-Agüero et al., 2011) | (i) Intervention group: Exercise: combined jumps, press-ups, elastic-fitness bands, and medicine-balls  
Intensity: based on personal capacity  
Duration: 20-25min  
Frequency: 2 days/week  
(ii) Control group: continued with usual activities  
(iii) Intervention duration: 21 weeks | Body composition:  
(i) total fat  
(ii) total lean mass | Adherence to training averaged 82% (70% to 97%); the results showed that the intervention group had lower levels of fat and lean masses compared with the control group | (i) 1.93 (1.45,2.41)  
(ii) 2.40 (1.56,3.24) |
| (Gupta et al., 2011) | (i) Intervention group: | (i) Low-limb muscle | Adherence data was not provided | NA |
### Physical exercise for Down syndrome

<table>
<thead>
<tr>
<th>Study</th>
<th>Exercise Description</th>
<th>Intensity</th>
<th>Duration</th>
<th>Frequency</th>
<th>Control Group</th>
<th>Intervention Duration</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>al., 2011</td>
<td>Exercise: progressive resistance and balance training</td>
<td>2 sets of 10 repetitions for resistive training; various activities for balance training</td>
<td>ND</td>
<td>3 times/week</td>
<td>(i) Control group: continued with usual activities</td>
<td>6 weeks</td>
<td>Improved lower limb strength of muscle and balance were improved in the intervention group compared with the control group</td>
</tr>
<tr>
<td>Lin and Wuang, 2012</td>
<td>Exercise: treadmill walking and game-like exercise</td>
<td>60% maximal heart rate</td>
<td>25 min</td>
<td>3 times/week</td>
<td>(i) Control group: continued with usual activities</td>
<td>6 weeks</td>
<td>Improved lower limb strength (i) hip flexion (ii) hip extension (iii) hip abductor (iv) knee flexion (v) knee extension (vi) ankle plantarflexor</td>
</tr>
<tr>
<td>Rimmer et al., 2004</td>
<td>Exercise: cardiovascular and strength exercise</td>
<td>50-70% peak VO₂, 1 set; 10-12 repetitions at 70% 1RM</td>
<td>30-45 min aerobic exercise, 15-20 min strength exercises</td>
<td>3 days/week</td>
<td>(i) Control group: continued with usual activities</td>
<td>12 weeks</td>
<td>Improved cardiovascular fitness (i) Cardiovascular fitness (ii) Upper-limb strength (iii) Lower-limb strength (iv) handgrip (left &amp; right hand) (v) Weight (vi) BMI (vii) Skinfold score</td>
</tr>
<tr>
<td>Shields and Taylor, 2010</td>
<td>Exercise: progressive resistance training</td>
<td>Performed up to 3 sets of 12 repetitions</td>
<td>ND</td>
<td></td>
<td>(i) Control group: continued with usual activities</td>
<td></td>
<td>Improved lower limb muscle strength (i) Lower-limb muscle strength (ii) Upper-limb muscle strength</td>
</tr>
</tbody>
</table>

Adherence data was not specified; the results showed no group differences on all the measurements.
Physical exercise for Down syndrome

Frequency: twice/week
(ii) Control group: continued with usual activities
(iii) Intervention duration: 10 weeks

(Shields et al., 2008)
(i) Intervention group:
Exercise: progressive resistance training program
Intensity: 2-3 sets of between 10 to 12 repetitions of each exercise
Duration: ND
Frequency: twice/week
(ii) Control group: continued with usual activities 10 weeks
(iii) Intervention duration: 10 weeks

(i) Upper-limb muscle strength
(ii) Lower-limb muscle strength
(iii) Upper-limb muscle endurance
(iv) Lower-limb muscle endurance

Participants attended 93% of training sessions; the results showed that the intervention improved upper-limb muscle endurance compared with the control group; other measures showed no group differences

(Ulrich et al., 2011)
(i) Intervention group
Exercise: bicycle intervention program
Intensity: ND
Duration: ND
Frequency: ND
(ii) Control group: continued with usual activities (iii) Intervention duration: 7 weeks (1 year follow-up)

(i) Isokinetic strength of knee extension
(ii) Isokinetic strength of knee flexion
(iii) Standing balance
(iv) BMI
(v) Body fat

Adherence data was not specified; the results showed no group differences on all the measures

(Varela et al., 2001)
(i) Intervention group:
Exercise: rowing ergometer
Intensity: 55-70% peak VO₂
Duration: 15-25 min
Frequency: 3 days/week
(ii) Control group: continued with usual activities
(iii) Intervention duration: 16 weeks

(i) Exercise test on treadmill
(ii) Exercise test on rowing ergometer

Cardiovascular fitness:
Adherence data was not reported; the results showed no group differences on cardiovascular fitness

Note. ES = Effect Size; CI = Confidence Interval; RM = repetition maximum; ND = no data; NA = not applicable; BMI = body mass index.