Effect of isokinetic training on muscle strength and postural balance in children with Down's syndrome

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Children with Down's syndrome (DS) often have greater postural sway and delay in motor development. Muscle weakness and hypotonia, particularly of the lower extremities, are theorized to impair their overall physical health and ability to perform daily activities. Therefore, the aim of this study was to investigate the effects of isokinetic training on muscle strength and postural balance in children with DS. Thirty-one children with DS ranging in age from 9 to 12 years were assigned randomly into two groups. The control group received the conventional physical therapy, whereas the study group received the same therapy as the control group in addition to the isokinetic training 3 days a week for 12 weeks. Measurement of stability indices using the Biodex Stability System as well as peak torque of knee flexors and extensors of both sides using the isokinetic dynamometer was performed before and after 12 weeks of the treatment program. Each group showed significant improvements in postural balance and peak torque of knee flexors and extensors ($P < 0.05$), with significantly greater improvements observed in the study group compared with the control group ($P < 0.05$). These outcomes indicated that participation in the isokinetic training program induced greater improvements in muscle strength and postural balance in children with DS. ***International Journal of Rehabilitation Research*** **00:000–000**

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Introduction

Down's syndrome (DS) is a chromosomal disorder caused by the presence of all or part of an extra 21st chromosome (Dutta *et al.*, 2012). Children with DS have motor disability because of hypotonia and ligamentous laxity, co-contraction of agonist and antagonist muscles, and balance and postural deficits (Aruin *et al.*, 1996). These deficits may contribute toward delayed motor developmental milestones in children with DS and restrict children's movements, with difficulties in maintaining antigravity situations (Shumway-Cook and Woollacott, 1985).

Decreased level of muscle strength is widespread among individuals with DS compared with healthy individuals, particularly the lower extremity muscle strength, which is more important to overall physical health and performance of daily activities (Gupta *et al.*, 2011).

Postural deficits and balance problems have been identified in children with DS. Shumway-Cook and Woollacott, 1985 found that young children with DS have deficits in the postural control system that may result in functional balance problems; they concluded that postural responses to the loss of balance were slow and insufficient for maintaining stability. Postural dysfunctions are the most common problems found in children with DS and associated with impaired proprioception, impaired motor coordination, sensory-motor integration problems, and decreased reaction time for anticipatory postural adjustments (Polastri and Barela, 2005). Although adolescents with DS have postural control strategies similar to adolescents without DS, they may show precarious balance and quantitative differences in the integration of sensory input to control stance (Vuillerme *et al.*, 2001).

Isokinetic dynamometers may be used as scientific devices for testing, comparing, and training body parts. These devices are used regularly in musculoskeletal disorders or in the field of sports training programs (Jee, 2015).

Previous studies were carried out to determine the effect of progressive resistance training in DS and reported increase in muscle strength, physical function, and physical fitness. Four studies included adults with DS (Davis and Sinning, 1987; Rimmer *et al.*, 2004; Tsimaras and Fotiadou, 2004; Shields *et al.*, 2008) and two studies included children and adolescents with DS (Weber and French, 1988; Gupta *et al.*, 2011). They suggested that, following a protocol of progressive resistance training, a significant improvement in leg muscle strength and dynamic balance was observed.

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As isokinetic training in children with DS is less discussed, the aim of this study was, therefore, to assess whether the isokinetic training could improve muscle strength and postural balance in children with DS.

Materials and methods

Study design

A randomized-controlled trial design was selected for testing the effect of the isokinetic training program on the stability indices and peak torque of the knee flexors and extensors in children with DS. Baseline measurements were taken before the intervention at week 0, whereas post-treatment readings were taken at the end of the 12th week.

Participants

Thirty-one (17 males and 14 females) children with DS, ranging in age from 9 to 12 years, were selected and participated in this study. They were recruited from the outpatient clinic of the Physical Therapy Department, College of Applied Medical Sciences, Najran University, Najran, Saudi Arabia. They were assigned randomly, using sealed envelopes, into two groups. The control group included 16 (nine males and seven females) children and received the conventional physical therapy program, whereas the study group included 15 (eight males and seven females) children and received the same program as the control group in addition to the isokinetic training program.

Children in both groups were selected on the basis of the inclusion criteria, including children with DS who can stand and walk independently with balance problems as indicated by a physical examination that was performed by a neurologist, the absence of visual and hearing impairments that could interfere with testing and training protocols, and children with mild intellectual disabilities [intelligence quotient (IQ) range: 50–69] and were capable of understanding visual and verbal instructions. The IQ levels were determined using the Wechsler Intelligence Scale for Children, 3rd ed. (WISC-III Chinese version). This test was administered by a clinical psychologist. It is a standardized test of intellectual aptitude for children between 6 and 16 years of age and has been used in DS (Ching and Wuang, 2012). Children who were on medical treatment that restricted their participation in the study and who had musculoskeletal or cardiac problems were excluded from the study.

All children and their parents were provided an explanation of the purpose, procedures, and potential benefits of the study. All parents of the children signed a consent form before participation and approval was granted by the ethical committee of the university.

Randomization

Thirty-four children with DS were assessed for eligibility. Two children were excluded as they did not fulfill the inclusion criteria and one child was excluded as his parents refused to participate in the study. Following the baseline measurements, a randomization process was performed for 31 children using closed envelopes. The investigator prepared 31 closed envelopes, with each envelope containing a card labeled as either control or study. Each child was asked to draw a closed envelope that determined whether he/she was allocated to the control group or the study group. The experimental design is shown as a flow diagram in Fig. 1.

Procedures

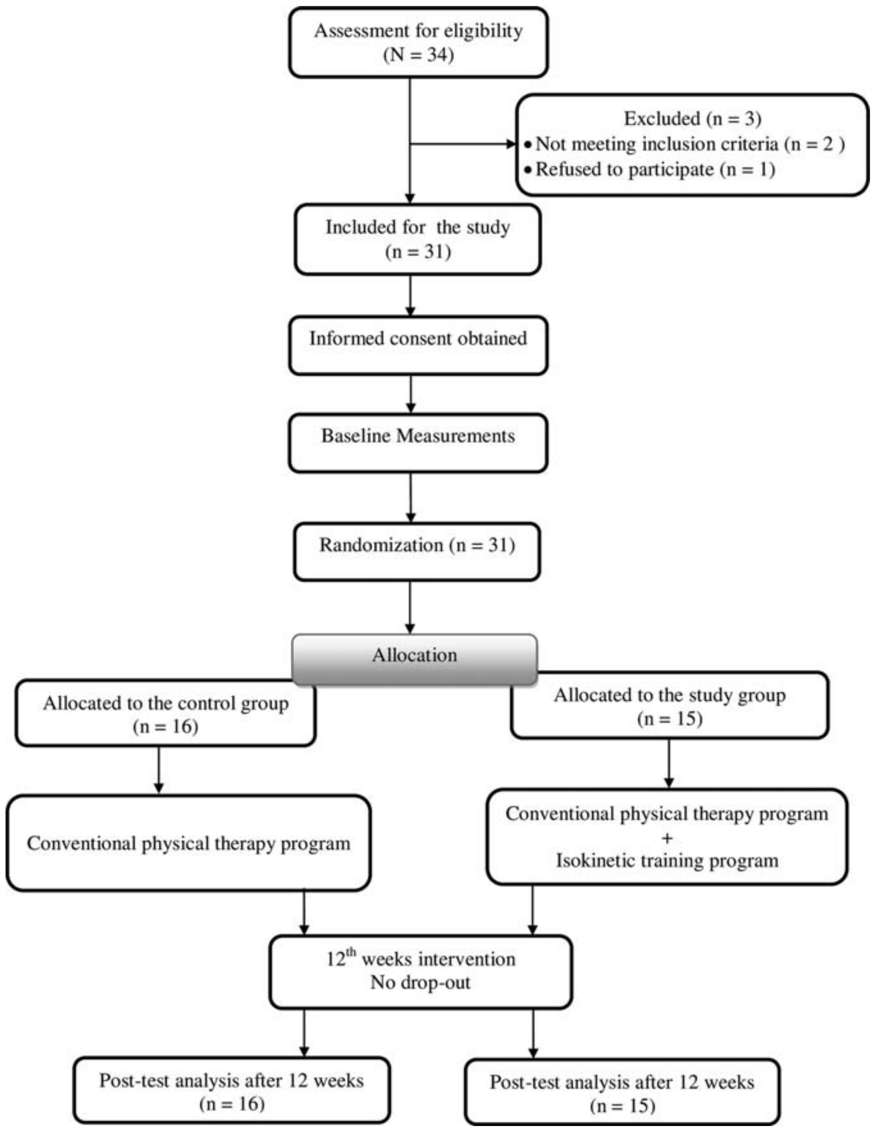
Weight and height were recorded using a calibrated floor scale (ZT-120 model), Hangzhou Tianheng Technology Co. Ltd (Hangzhou, China). Before baseline measurements, all children were familiarized with the equipment and its operation and the protocol of the research through three familiarization sessions. Each child was evaluated for peak torque of the knee flexors and extensors of both sides and postural balance before and at the end of the 12th week of treatment by the same examiner who was blinded in terms of the group to which each child was assigned.

Muscle strength

Muscle strength was measured using an isokinetic dynamometer. The Biodex System 3 multijoint system testing and rehabilitation (Biodex Medical System, Shirley, New York, USA) was used. The system consists of a head assembly housing the servomotor responsible for moving the lever arm and has a fully adjustable orientation, a seat for positioning the child that is adjusted independently vertically or horizontally, and a control unit consisting of a personal computer and operator equipment. Velocity, range of motion setting, and contraction mode were adjusted through the system controller. Dynamometry attachments were selected according to the tested part. Previous studies have shown the reliability and validity of isokinetic devices for measuring muscle strength in individuals with mental retardation, and it facilitates the design of effective training programs for this population (Pitetti, 1990).

Peak torque of the knee flexors and extensors of both sides was measured during concentric contraction at 120°/s. The dynamometer orientation was adjusted according to the standard instructions for knee testing so that the dynamometer head and chair were rotated to 90°. Children sat with their thighs at an angle of 110° to the trunk. With the tested knee positioned at 90° flexion, the mechanical axis of the dynamometer was aligned with the lateral epicondyle of the knee. The trunk and both thighs were stabilized with belts and the knee range of motion was 90° (90°–0° of flexion). The distal aspect of the dynamometer arm was placed 2 cm proximal to the medial malleolus, torque was gravity corrected, and dynamometer calibration was performed before every

Fig. 1



Flow chart showing the experimental design of the study.

session according to the manufacturers' instructions. Each child performed 10 concentric contractions at 120°/s (flexion and extension) of both sides and test sessions lasted ~15 min for recording peak torque of the knee flexors and extensors of both sides. The measurement test was repeated three times and the mean was obtained for data analysis.

Postural balance

Balance assessment was carried out using the Biodex Stability System (BSS; Biodex Medical System), which enables an objective assessment of balance. The BSS consists of a display screen that the child looks at and can be adjusted according to the height of each child. The screen provides visual feedback to the child about the degree of tilting, that the child should maintain the cursor in the center of the screen to obtain a good score of balance. It also consists of a dynamic balance platform that allows movements around the anterior–posterior (AP) and medial–lateral (ML) axes simultaneously. The BSS measures the degree of tilting about each axis under dynamic conditions and calculates a medial–lateral stability index (MLSI), an anterior–posterior stability index (APSI), and overall stability index (OSI), which is a composite of the MLSI and the APSI (Arnold and Schmitz, 1998). The BSS calculates the average position for the child during all motions throughout the test. The higher the scores in all these outcomes, the poorer the balance of the child. The BSS has eight levels of stability, extending from the least stable level (level 1) to the most stable level (level 8). In the present study, all measurements were performed at the level (8) of stability as the children expressed difficulty maintaining their balance and slight muscle discomfort at stability levels less than 8 when performing familiarity sessions before the main clinical testing. Moreover, level 8 represents the most stable and high resistance level of the platform, as high test–retest reliability for the BSS was reported when using high resistance levels (Cachupe *et al.*, 2001). The intratester reliability of the BSS has been reported to be 0.43 for MLSI, 0.80 for APSI, and 0.82 for OSI (Schmitz and Arnold, 1998).

Each child was allowed to stand in the center of the locked platform of the BSS for 1 min with the two-leg stance. Certain parameters such as child's age, weight, height, and stability level (platform firmness) were obtained to be entered in the device. During the assessment period, the platform began to freely move and simultaneously calculate the degree of tilt about both axes (AP and ML). Test sessions lasted ~15 min and a printout was obtained at the end of each test including OSI, APSI, and MLSI. The balance measurement test was repeated three times and the mean was obtained for data analysis.

Treatment

The control group

The children in the control group received the conventional physical therapy program for 1-h per session three times per week for 12 weeks and consisted of the following:

(1) Gentle stretching exercises for the hip flexors, hip adductors, knee flexors, and ankle plantar flexors bilaterally. Thirty seconds of stretching was followed by 30 s of relaxation, repeated five times per session for each muscle.
(2) Isotonic muscle contraction for hip flexors and extensors, hip adductors and abductors, quadriceps, hamstrings, anterior tibial group, and calf muscles. It was performed five times initially, building up to 10 repetitions as tolerated, 2–3 times/day (Jesudason and Stiller, 2002). Each contraction was maintained for five counts and then relaxed for another five counts.
(3) Balance and postural control exercises including the following:
    (a) Standing with both feet together with the therapist sitting behind the child and applying manual locking of both knees, and then slowly tilting him/her to each side forward and backward.
    (b) Standing with the step forward and shift his/her weight forward and then backward alternately.
    (c) High step standing and attempt to remain balanced.
    (d) Standing with manual locking of both knees, then attempt actively to stoop and recover.
    (e) Training for equilibrium, righting, and protective reactions.
    (f) Gait training including the following:
        (a) Forward, backward, and sideways walking between the parallel bars (closed environment gait training).
        (b) Obstacles including rolls and wedges with different diameters and heights were placed inside parallel bars.
        (c) Open environment gait training was conducted with the previous obstacles, but without parallel bars.

The study group

The children in the study group received the same physical therapy program as the control group for 45 min in addition to the isokinetic training program for 15 min.

Isokinetic training protocol

Concentric isokinetic training was selected as it is easy to understand and conduct compared with eccentric training. Moreover, the extremely high torque that can be generated during rapid eccentric contractions places muscles and tendons at risk (Lewis *et al.*, 2012). In addition, repetitive eccentric events have been shown to be responsible for delayed-onset muscle soreness (Hoppeler, 2016).

The isokinetic training protocol was performed three times a week for 12 weeks (36 sessions). Each session started with a warm-up period and consisted of five sets of quadriceps and hamstrings stretching with 30 s of stretching, followed by 30 s of relaxation, walking, slow running, and free gymnastic activities. The child was asked to sit on the isokinetic dynamometer with the dynamometer seat reclined 5° with the vertical. Straps were used to fix the trunk, pelvis, and distal thigh. The leg strap was fastened around the leg 3 cm proximal to the medial malleolus. The child performed five submaximal contractions as a warm-up, followed by three sets of 10 repetitions of maximal concentric isokinetic contractions for knee flexors and extensors (Poletto *et al.*, 2008). The contractions were performed at angular velocities of 90 and 120°/s, with a 3-min rest allowed between the two angular velocities. Each set was preceded by a 3-min rest and there was no stop between the 10 contractions. Verbal encouragement, as well as visual feedback from the equipment, were provided in an attempt to achieve a maximal voluntary effort level during all the contractions that each child was asked to perform.

Data analysis

Participants' characteristics were compared between both groups using a *t*-test. The sample size was determined using Slovin's formula ($n = N/1 + Ne2$), where 'N' represents the population size and 'e' represents the margin of error. Mixed multivariate analysis of variance (MANOVA) was performed to compare the mean values of stability indices and peak torque of the knee flexors and extensors between the study and the control groups and before and after treatments in each group. The level of significance for all statistical tests was set at P value less than 0.05. All statistical analyses were carried out AQ4 using statistical package for the social sciences (SPSS, version 19).

Results

Participants' characteristics

The mean ± SD age, weight, and height of the study group were 10.26 ± 0.79 years, 30.53 ± 3.22 kg, and 120.06 ± 2.81 cm, respectively, and those of the control group were 10.05 ± 0.68 years, 30.2 ± 3.29 kg, and 119.2 ± 2.19 cm, respectively. There was no significant difference between both groups in the mean age, weight, and height ($P = 0.44$, 0.77, and 0.34), respectively. The mean ± SD IQ of the study group was 56.46 ± 5.62 and that of the control group was 57.18 ± 4.38. There was no significant difference in IQ between the study and the control groups ($P = 0.69$) (Table 1).

Effect of treatment on peak torque and stability indices

Mixed MANOVA was carried out to investigate the effect of treatment on the knee flexors and extensors peak torque and stability indices.

Mixed MANOVA showed that there was a significant interaction between treatment and time [Wilks' $\lambda = 0.02$; F (7, 23) = 116.1, $P = 0.0001$]. There was a significant main effect of time [Wilks' $\lambda = 0.009$; F (7, 23) = 368.35, $P = 0.0001$] and a significant main effect of treatment [Wilks' $\lambda = 0.3$; F (7, 23) = 7.53, $P = 0.0001$]. Table 2 shows descriptive statistics of dependent variables as well as the significant level of comparison between groups before and after treatment as well as a significant level of comparison before and after treatment in each group.

There was no significant difference in peak torque and stability indices between the study and the control groups before treatment ($P > 0.05$). At post-treatment measurements, the study group showed a significant increase in right and left knee flexors and extensors peak

Table 1 Descriptive statistics and *t*-test for the mean age, weight, height, and intelligence quotient of the study and the control groups

	Study group ($\bar{X}$ ± SD)	Control group ($\bar{X}$ ± SD)	Mean difference	*t*-value	*P*-value
Age (years)	10.26 ± 0.79	10.05 ± 0.68	0.21	0.78	0.44*
Weight (kg)	30.53 ± 3.22	30.2 ± 3.29	0.33	0.28	0.77*
Height (cm)	120.06 ± 2.81	119.2 ± 2.19	0.86	0.95	0.34*
Intelligence quotient	56.46 ± 5.62	57.18 ± 4.38	−0.72	−0.39	0.69*

*Nonsignificant.

Table 2 Knee flexors and extensors peak torque and stability indices before and after treatment in the study and the control groups

	Pre test ($\bar{X}$ ± SD)			Post test ($\bar{X}$ ± SD)				
	Study group	Control group	*P*	Study group	Control group	P^a	Repeated measures (study group)	Repeated measures (control group)
Right knee flexors peak torque (Nm)	24.33 ± 2.16	25.43 ± 2.22	0.17*	29.06 ± 2.46	27 ± 2.47	0.02**	0.0001**	0.0001**
Right knee extensors peak torque (Nm)	39.66 ± 3.43	40.43 ± 3.28	0.52*	45.06 ± 2.86	42 ± 3.46	0.01**	0.0001**	0.0001**
Left knee flexors peak torque (Nm)	20.13 ± 2.19	20.93 ± 1.69	0.26*	25.23 ± 3.28	22.18 ± 1.88	0.003**	0.0001**	0.001**
Left knee extensors peak torque (Nm)	36.2 ± 3.14	36.68 ± 3.32	0.67*	40.73 ± 3.03	37.93 ± 3.47	0.02**	0.0001**	0.0001**
Anteroposterior stability index	1.42 ± 0.3	1.43 ± 0.13	0.9*	1.19 ± 0.18	1.34 ± 0.09	0.008**	0.0001**	0.01**
Mediolateral stability index	1.67 ± 0.17	1.68 ± 0.15	0.89*	1.3 ± 0.08	1.54 ± 0.13	0.0001**	0.0001**	0.007**
Overall stability index	1.69 ± 0.21	1.71 ± 0.09	0.67*	1.43 ± 0.13	1.6 ± 0.08	0.0001**	0.0001**	0.02**

P-value, significance level between groups before treatment.
P^a, significance level between groups after treatment.
*Nonsignificant.
**Significant.

torque compared with the control group ($P < 0.05$). Moreover, there was a significant decrease in AP, ML, and OSI in the study group compared with the control group ($P < 0.05$).

Comparison before and after treatment in the study group showed that there was a significant increase in right and left knee flexors and extensors peak torque compared with before treatment ($P < 0.0001$) Also, there was a significant decrease in AP, ML, and OSI after treatment compared with before treatment ($P < 0.0001$). Comparison before and after treatment in the control group showed that there was a significant increase in right and left knee flexors and extensors peak torque compared with before treatment ($P < 0.001$) Also, there was a significant decrease in AP, ML, and OSI after treatment compared with before treatment ($P < 0.05$).

Discussion

The aim of this study was to examine the effects of the isokinetic training program on postural balance and peak torque of the knee flexors and extensors in children with DS. The main findings of this study showed that the isokinetic training program induced significant improvements in postural balance and muscle strength in the isokinetic group when comparing post-treatment measurements between both groups. The main strength of this trial is that this was the first randomized-controlled trial that assessed the effects of isokinetic training on muscle strength and postural balance among children with DS.

The results of our study suggest that isokinetic training was an acceptable form of exercise to the children and adolescents with DS. This is an important finding as some individuals with intellectual disability and their caregivers are worried about involvement in exercise and intense activities and believe they should not exercise (Heller *et al.*, 2004). This study alleviates this belief and encourages these individuals to participate in exercise programs and become more active as individuals with DS are at high risk of the health consequences of inactivity (Hill *et al.*, 2003).

In terms of muscle strength, the findings of this study are consistent with the findings of previous studies showing that individuals with mental retardation showed a significant improvement in their muscle strength after participation in a training program (Horvat *et al.*, 1993; Stopka *et al.*, 1998; Gupta *et al.*, 2011).

The significant improvement in muscle strength obtained following the training protocol may be the result of resistance training, which enables better activation of the motor neuron pool and decreases fatigue of the skeletal muscle. These results are consistent with Evetovich *et al.*, 1998, who studied the effects of unilateral concentric isokinetic leg extension training over 12 weeks and found a significant increase in peak torque in the training group. The increase in peak torque of knee extension was suggested to be related to hypertrophy and/or changes in other muscles involved in leg extension.

The normal physiological response to resistance training may be because of increased neural activation and muscle hypertrophy (Ozmun *et al.*, 1994). Neural adaptation predominates in the early phase, whereas hypertrophy occurs in the later phase of training (Suman *et al.*, 2001). Isokinetic concentric training is considered an adequate stimulus for neural factors responsible for gains in the muscle strength during the training program. Moreover, rehabilitation of the skeletal muscle torque using an isokinetic protocol is safe and more effective as the isokinetic modality stimulates neural mechanisms and enzyme activity that improve the resistance of the muscles to fatigue with perfect action of the skeletal muscles (Esselman *et al.*, 1991). AQ5

Isokinetic resistance has several advantages over other exercise modalities. One of these advantages is that a muscle group may be exercised to its maximum potential throughout the range of motion of the joint. Moreover, it is safer than isotonic training as the dynamometer's resistance mechanism essentially disengages when the patient experiences pain or discomfort. Isokinetic training is useful as an exercise modality in the restoration of the preinjury level of strength of a muscle group (Jee, 2015).

In terms of postural balance, the children with DS who participated in this study showed higher scores of the three outcomes of dynamic balance (AP, ML, and OSI) before participation in the training program that indicated poor balance. The delay in the maturation of the cerebellum and the relatively small size of the cerebellum and brain stem in children with DS may be responsible for the disturbance in balance (Cowie, 1970).

In this study, participation in the 12-week training program resulted in an improvement in the dynamic postural balance of the study group. These findings are in agreement with the results of the previous studies (Schmitz and Arnold, 1998; Gupta *et al.*, 2011) that concluded that application of a training program can improve the dynamic balance abilities of individuals with mental retardation.

The improvement in postural balance in children with DS may be attributed to the increased peak torque of the knee flexors and extensors. These results are consistent with the study of Wang and Chen, 1999, who confirmed that muscle strength is an important variable that predicts dynamic balance, in which the musculature of the thighs, legs, feet, and trunk allows the individual to stand erect against the forces of gravity. Moreover, Odunaiya *et al.*, 2009 reported the relationship between the antigravity musculatures and postural control in 6-year-old healthy children. They concluded that the antigravity control was more related to static balance than dynamic balance in late childhood.

This study suggested some clinical implications: the clinicians should take into account the importance of strengthening the muscles of the lower extremities in the rehabilitation of children with balance disorders. As a consequence, the improvement in physical and balance abilities enables children and adolescents with DS to become more active and sociable with healthy peers and capable of engagement in the workplace.

This study has many limitations including the small sample size with a shorter duration, the fact that there was no follow-up as to whether the effects of the intervention were maintained, and whether there were any longer term outcomes after terminating the program. Therefore, future studies can extend the duration of the study to help determine the long-term sustainability of the program with a larger sample size to increase the generalizability of the findings.

Conclusion

The results obtained from this study showed that the isokinetic training program, when combined with proper physical therapy three times a week for 12 weeks, significantly improved muscle strength and postural balance in children with DS.

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Conflicts of interest

AQ6 None declared.

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Q4	Please provide manufacturer (company name) and manufacturer’s location (city, state and country name) for SPSS, version 19.	
Q5	The sentence “resistance of the muscles to fatigue with perfect action ………. ” is not clear. Please rephrase for clarity.	
Q6	Please provide the details of ‘the conflicts of interest disclosure’. If there is nothing to declare, please provide a statement to that effect.	