Effect of Isokinetic Training on Knee Muscle Strength and Balance Control in Children with Developmental Coordination Disorder: A Randomized Controlled Trial

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Abstract

Background: Children with Developmental coordination disorder (DCD) have lower knee muscle strength and altered timing of postural muscle contraction that might increase the risk of falls, limit activity participation, and affect motor skill development.

Objective: The purpose of this study was to investigate the effect of isokinetic training on knee muscle strength and functional activities in children with developmental coordination disorder.

Design: Randomized controlled trial.

Subjects: Sixty children with DCD from both sexes with age ranged from eight to 12 years were randomly assigned to either the isokinetic training intervention group or the control group. In addition to the DCD children, the study included thirty typically developing children who received no training as normal controls.

Methods: Patients in the isokinetic group (n=30) participated in the isokinetic training program for 12 weeks for quadriceps femoris and hamstring muscles, 3 times per week. Each set consists of 10 repetitions concentric contraction at an angular velocity of 150º/s and patients were allowed 3min of rest between sets.

Main Measures: Isokinetic peak torques of quadriceps femoris and hamstring muscles at two test speeds (60º/s) and balance control were assessed before isokinetic training and again within two weeks of its completion using an isokinetic machine and Bruiniks-Oseretstity test of motorproficiency, respectively.

Results: Patients in isokinetic group showed a significant improvement in quadriceps femoris and hamstring muscles strength specifically at 60º/s and was as high as that of the normal control children. Moreover, balance control in isokinetic group was better and was comparable to that of the normal control group after training.

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Conclusions: Children with DCD who undergo a 3-month program of isokinetic training experience improvements in isokinetic knee muscle strength at 180º/s and balance control.

Key Words: Developmental coordination disorder – Isokinetic muscle strength – Balance.

Introduction

DEVELOPMENTAL coordination disorder (DCD) is one of the most common pediatric sensorimotor disorders, affecting approximately six percent of typically developing children worldwide. Children diagnosed with DCD present a number of motor problems including marked delays in achieving motor milestones and poor coordination and body balance [1].

Among the many sensorimotor problems found in children with DCD, poor postural control is the most common, demonstrated in 73-87% of the DCD-affected population [2]. The problem requires special attention because suboptimal balance ability may increase the risk of falls, limit activity participation, and affect motor skill development [3,4].

Postural stability requires the optimal reception, processing, and integration of sensory inputs from somatosensory, visual, and vestibular systems along with proper muscle responses and execution of movement strategies such as ankle and hip strategies [5,6].

It has been well documented that children with DCD have widespread impairment in their sensory organization that is associated with greater standing postural sway [3,4,7]. Moreover, it has been reported that younger children with DCD have lower knee muscle strength [8] and altered timing of postural muscle contraction [9].
It is well-known that strengthening the lower limb muscles can improve standing balance control and thus prevent falls in older adults [10,11]. Similar to older adults, children with DCD have weaker lower limb muscles (e.g., lower isokinetic peak torque during knee extension and flexion at moderate to fast angular velocities) than their typically developing peers. This may predispose them to instability and falls [8].

Because postural control is essential for many daily activities and is the first line of defense against a fall following unexpected external disturbances to balance, it is important to investigate functional balance ability in children with DCD after an isokinetic strength training program in children with DCD [12,13].

This randomized controlled trial was aimed at (1) Identifying the developmental status of balance control and isokinetic knee muscle strength in children with DCD in comparison with children with normal motor development; and (2) Investigating the effect of intensive isokinetic knee muscle strength training on balance control in children with DCD compared with non-trained DCD-affected children and typically developing children.

Material and Methods

Subjects:

Sixty children diagnosed with DCD from both sexes with age ranged from eight to 12 years were recruited from the Primary School Giza from April 2014 – August 2014.

Children with DCD were randomly assigned to either the isokinetic training intervention group or the control group. In addition to the DCD children, the study included thirty typically developing children who received no training as normal controls.

Participants with DCD were chosen based on meeting the following inclusion criteria: (1) A formal diagnosis of DCD according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV-TR) [1]; (2) Aged between eight and twelve years; and (3) Were functionally independent, cooperative, and can understand and follow instructions.

Individuals with any of the following were excluded from this study: (1) A significant congenital, musculoskeletal or cardiopulmonary condition that might influence postural control; (2) Intellectual impairment; (3) Receiving physical or occupational therapy; (4) Unable to follow instructions. Children with normal development were recruited from the community through a convenience sampling method adopting the same inclusion and exclusion criteria, although they could not have any history of DCD.

Design overview:

The study consisted of a randomized, controlled trial. Children with DCD were randomly assigned to either the 3-month isokinetic training intervention group or the control group.

On the day of testing, the subjects completed a questionnaire that inquired about their medical history (primarily musculoskeletal injuries), exercise activity level, and lower extremity limb dominance. Limb dominance was defined as the preferred kicking leg. The subjects were then measured for height and weight. Lower extremity musculoskeletal examination were performed that composed of inspection, palpation, ligamentous examination of the knee, range of motion measurements, and a manual muscle test of the quadriceps femoris and hamstring muscles.

Randomization:

To ensure that the DCD-isokinetic training and DCD control groups both contained approximately equal numbers of males and females, all participants with DCD were stratified by sex before being randomly assigned to either group. This randomization procedure was performed by drawing dots, and was carried out by a person independent of the study. The 30 children with DCD who were assigned to the DCD-isokinetic training group received the 3-month course of isokinetic training. Another 30 children with DCD were assigned to the DCD control group. This DCD control group was included to account for the effect of maturation and possible spontaneous improvement over time. In addition, 30 children with normal motor development were allocated to the normal control group (a comparison group, no randomization) to provide a norm for later comparison of outcomes [14].

Intervention:

Isokinetic training protocol:

The isokinetic training protocol was started after the initial evaluation and was performed 3 times a week for 12 weeks (36 sessions). Each session included a 5-min warm-up period on a treadmill at a velocity of 4km/h, followed by five sets of quadriceps stretching.

Fifty percentages of average peak torque were selected as the initial dose of isokinetic exercise, and an increasing dose program was used in the
first to fifth sessions (one set to five sets), and a
dose of six sets was applied from the sixth to the
24th session and, finally, a dose of 10 sets was
applied from the 25th to the 36th sessions. Each
set consists of 10 repetitions concentric contraction
at an angular velocity of 150º/s and patients were
allowed 3min of rest between sets [15].

Verbal encouragement, as well as visual feedback
from the equipment, was given in an attempt to achieve a maximal voluntary effort level during all the contractions that each participant was asked to perform. Values of peak torque were calculated by the Biodex software system [15,16].

**Measurement of outcomes:**

All participants were assessed before the start of
the isokinetic training intervention (pre-test) and again within two weeks of its completion (post-test). Each participant, regardless of group assign-
ment, underwent the following assessments.

**Quadriceps and hamstring muscle isokinetic performance:**

Concentric isokinetic muscle strength and the
time taken to reach peak torque of both knee exten-
tors and flexors were evaluated using Biodex
isokinetic dynamometer (Biodex Medical System,
Shiley, NY, USA, linked to IBM PC-computer
software) because isokinetic measurements have
been found to be valid and reliable in young indi-
viduals [17,18]. Calibration of the Biodex for torque
and angular velocity was performed according to
the manufacturer’s instructions prior to each re-
cording session.

The subjects were asked to complete the per-
sonal data that included the subject’s name, age,
address and telephone number. The height and
weight of each subject were recorded from the
height and weight scale. Each child was allowed
to ask any question about any part of the study;
thus, the idea and the testing procedures of the
study became clear for all subjects.

Only the dominant leg (i.e., the leg that the
participant used to kick a ball) was tested, as there
is nosignificant side-to-side difference in knee
muscle peak torques [19] and the time taken to
achieve peak torque in children [20].

After a 5-min warm-up on the treadmill without
resistance, hot packs were applied for 15min to
the quadriceps; the participants stretched the quad-
riceps muscles of both limbs. Each muscle group
was stretched 5 times for 30 s alternately for 5min
[15,16].

The whole assessment was conducted while
participants were sitting with their hips flexed to
85º and trunk and ipsilateral thigh stabilized by
straps. The rotational axis of the dynamometer was
aligned with the knee joint axis (i.e., lateral femoral
epicondyle), and the shin pad of the adaptor was
placed just above the lateral malleolus of the tested
leg [21].

Each participant performed a full range of knee
flexion and extension at test speeds (60º/s). Before
the test, all participants were asked to perform
three sub-maximal and three maximal concentric
knee extensor and flexor contractions as familiar-
ization trials [22]. After correcting the gravitational
effect on knee torque, the participants performed
five knee flexion and extension movements con-
secutively at maximal effort throughout the range
as a test ensemble [21].

To facilitate the comparison of knee muscle
strength between the two groups, the average body-
weight- adjusted isokinetic peak torques of the
five trials of both knee extensors and flexors were
documented and used for analysis. In addition,
average “time to peak torque” (i.e., the duration
from the beginning of muscle torque development
until the point at which peak torque was first
developed) of the five trials of both knee extensors
and flexors were analyzed [21].

**Postural control assessment:**

Bruininks-Oseretsky test of motor proficiency
was chosen as a functional scale for evaluation.

Balance evaluation: Eight items ranging in diffi-
culty fromstanding on one leg to stepping over on
a balance beam [23].

**Bruininks-osereetsky test for motor proficiency
(balance test). General directions:**

1- The subjects were required to wear crepe-soled
shoes.

2- Prepare the target (big colored circle) and a
walking line.

a- Fasten the target to the wall with masking
tape so that the lowest point on the circum-
ference is at the subject’s eye level.

b- Make a walking line by taping an 8-foot
(2.4m) piece of masking tape to the floor in
front of the target, about 3m from the wall.
The walking line should be as straight as
possible.

3- For all items, therapist must stand next to the
subject to observe performance most efficiently.
4- For all items, administer a second trial only if the subject does not achieve a maximum score on the first trial. When a second trial is necessary, the subject’s errors should be pointed out before the second trial is administered.

Item (1): *Standing on preferred leg on floor:* Each subject was asked to stand on preferred leg on the walking line, looking at the target with hands on hips, and with other leg bent so that it is parallel to the floor. The subject must maintain the position for 10 s to achieve a maximum score.

Item (2): *Standing on preferred leg on a balance beam:* Each subject was asked to stand on preferred leg on the balance beam, looking at the target with hands on hips, and with other leg bent so that it is parallel to the floor. The subject must maintain the position for 10 s to achieve a maximum score.

Item (3): *Standing on preferred leg on a balance beam-eye closed:* Each subject was asked to stand on preferred leg on the balance beam, with eyes closed, hands on hips, and with other leg bent so that it is parallel to the floor. The subject must maintain the position for 10 s to achieve a maximum score.

Item (4): *Walking forward on walking line:* Each subject was asked to walk forward on the walking line in a normal walking stride with hands on hips. The subject must walk forward six steps to achieve a maximum score.

Item (5): *Walking forward on balance beam:* Each subject was asked to walk forward on the balance beam in a normal walking stride with hands on hips. The subject must walk forward six steps to achieve a maximum score.

Item (6): *Walking forward heel-to-toe on walking line:* Each subject was asked to walk forward on the walking line heel-to-toe, with hands on hips. The subject must make six consecutive steps correctly to achieve a maximum score.

Item (7): *Walking forward heel-to-toe on balance beam:* Each subject was asked to walk forward on a balance beam heel-to-toe, with hands on hips. The subject must make six consecutive steps correctly to achieve a maximum score.

Item (8): *Stepping over response speed stick on balance beam:* Each subject was asked to walk forward on the balance beam stepping over the response speed stick held at the middle of the beam by the examiner. The subject walks in a normal walking stride with hands on hips. The score is recorded as a pass or a fail.

**Results**

Results revealed that there were non-significant statistical differences between all groups regarding the demographic characteristics including (age, gender, height, weight, body mass index), where ($p > 0.05$), as shown in Table (1).

Body-weight-adjusted isokinetic peak torque of knee flexors at 60°/s for all groups:

<table>
<thead>
<tr>
<th>Variables</th>
<th>DCD-Isokinetic group (n=30)</th>
<th>DCD-Control group (n=30)</th>
<th>Normal control group (n=30)</th>
<th>$p$-value*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean±SD</td>
<td>Mean±SD</td>
<td>Mean±SD</td>
<td></td>
</tr>
<tr>
<td>Age (year)</td>
<td>10.6±2.50</td>
<td>10.5±3.10</td>
<td>10.2±3.00</td>
<td>0.793 **</td>
</tr>
<tr>
<td>Gender (B, G)</td>
<td>19B,11G</td>
<td>18B,12G</td>
<td>20B,10G</td>
<td>0.935 **</td>
</tr>
<tr>
<td>Height (m)</td>
<td>126.3±8.80</td>
<td>122.1±11.2</td>
<td>122.7±10.10</td>
<td>0.394 **</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>28.10±9.31</td>
<td>26.50±9.8</td>
<td>26.80±8.40</td>
<td>0.873 **</td>
</tr>
<tr>
<td>BMI (Kg/m$^2$)</td>
<td>16.80±1.2</td>
<td>17.10±3.10</td>
<td>17.3±2.70</td>
<td>0.873 **</td>
</tr>
</tbody>
</table>


Table (1): Demographic data of all participants in the three groups, (Mean ±SD).
Table (2): Body-weight-adjusted isokinetic peak torque of knee flexors at 60°/s for all groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>DCD-Isokinetic group (n=30)</th>
<th>DCD-Control group (n=30)</th>
<th>Normal Control group (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre training</td>
<td>Post training</td>
<td>Pre training</td>
</tr>
<tr>
<td>Mean</td>
<td>56.14 ±31.09</td>
<td>64.12 ±22.62</td>
<td>55.35 ±21.78</td>
</tr>
<tr>
<td>Percentage of Change</td>
<td>14.46%</td>
<td>14.46%</td>
<td>3.21%</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.05</td>
<td>&lt;0.05</td>
<td>&gt;0.05</td>
</tr>
</tbody>
</table>

SD=Standard deviation. * = Significant. ** = Non-significant.

Comparison between groups regarding the Body-weight-adjusted isokinetic peak torque of knee flexors at 60°/s:

Table (3) revealed the ANOVAs test results for Body-weight-adjusted Isokinetic Peak Torque of Knee Flexors at 60°/s pre and post training between groups. There was no significant difference in post training values where the p-value was (0.782). However, there was a significant difference in the pre training values (p<0.05) where the p-value was (0.008). Results are illustrated in Fig. (2-A,B).

Bruininks-oservertsky test of motor proficiency for all groups:

Table (4) shows the Bruininks-Oseretsky Test of Motor Proficiency Pre and post treatment for all groups, concerning the DCD-Isokinetic Group, there was a significant difference in the paired t-test between pre and post training as the mean value of pre training was (44.80) and for post training was (68.42) where the p-value was (0.0072). The percentage of improvement was 52.72%. Results are illustrated in Fig. (2-A).

However, while regarding the DCD-Control Group and the Normal Control Group, There was a non significant difference in the paired t-test between pre and post training as the mean values of pre training were (43.52 & 87.40) and for post training were (47.20 & 88.23) respectively, where the p-values were (0.245 & 0.136). The percentage of improvement was 8.45% & .940%. Results are illustrated in Fig. (2-B).
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Comparison between groups regarding the Bruininks-Oseretsky test of motor proficiency:

Table (4) revealed the ANOVAs test results for the Bruininks-Oseretsky Test of Motor Proficiency pre and post training between groups. There was no significant difference in posttraining values where the $p$-value was (0.0962). However, there was a significant difference in the pre training values ($p<0.05$) where the $p$-value was (0.0075). Results are illustrated in Fig. (2-A,B).

Table (3): Comparison between groups regarding the body-weight-adjusted isokinetic peak torque of knee flexors at 60°/s.

<table>
<thead>
<tr>
<th>Groups</th>
<th>DCD-Isokinetic group</th>
<th>DCD-Control group</th>
<th>Normal control group</th>
<th>DCD-Isokinetic group</th>
<th>DCD-Control group</th>
<th>Normal control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre training</td>
<td>56.14 ± 31.09</td>
<td>55.35 ± 21.78</td>
<td>71.17 ± 13.98</td>
<td>64.12 ± 22.62</td>
<td>57.13 ± 24.86</td>
<td>73.28 ± 19.92</td>
</tr>
<tr>
<td>Post training</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$\text{SD}=\text{Standard deviation. } \ast=\text{Significant. } \ast\ast=\text{Non-significant.}$

![Fig. (2-A)](image1)

![Fig. (2-B)](image2)

Table (4): Bruininks-osereotsky test of motor proficiency pre and post treatment for all groups.

<table>
<thead>
<tr>
<th>Groups</th>
<th>DCD-Isokinetic group (n=30)</th>
<th>DCD-Control group (n=30)</th>
<th>Normal control group (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre training Post training</td>
<td>Pre training Post training</td>
<td>Pre training Post training</td>
</tr>
<tr>
<td>Mean BOTMP</td>
<td>44.80 ± 3.30</td>
<td>43.52 ± 4.21</td>
<td>87.40 ± 2.43</td>
</tr>
<tr>
<td>$\pm$SD</td>
<td>±68.42 ±4.20</td>
<td>±47.20 ±3.53</td>
<td>±88.23 ±3.45</td>
</tr>
<tr>
<td>Percentage of Change</td>
<td>52.72%</td>
<td>8.45%</td>
<td>.940%</td>
</tr>
<tr>
<td>$p$-value</td>
<td>0.0072 *</td>
<td>0.245 **</td>
<td>0.136 **</td>
</tr>
</tbody>
</table>

$\text{SD}=\text{Standard deviation. } \ast=\text{Significant. } \ast\ast=\text{Non-significant.}$
Table (5): Comparison between groups regarding the Bruininks-Oseretsky test of motor proficiency.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Pre training</th>
<th></th>
<th>Post training</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DCD-Isokinetic group</td>
<td>DCD-Control group</td>
<td>Normal control group</td>
<td>DCD-Isokinetic group</td>
</tr>
<tr>
<td>Mean</td>
<td>44.80</td>
<td>43.52</td>
<td>87.40</td>
<td>68.42</td>
</tr>
<tr>
<td>±SD</td>
<td>±3.30</td>
<td>±4.21</td>
<td>±2.43</td>
<td>±4.20</td>
</tr>
<tr>
<td>p-value</td>
<td>0.0075 *</td>
<td></td>
<td></td>
<td>0.0962 **</td>
</tr>
</tbody>
</table>

SD=Standard deviation. *=Significant. **=Non-significant.
Discussion

The purpose of this study was to investigate the effect of isokinetic training on knee muscle strength and functional activities in children with developmental coordination disorder.

This study revealed that measures of Body-weight-adjusted Isokinetic Peak Torque (at 60º/s) of knee extensors and flexors increased in children with DCD following isokinetic training. At posttest, the peak torque of their knee muscles was comparable to that of typically developing children, and was significantly higher than that of children [24].

Isokinetic training had a combination of resistance and endurance characteristics, imposed under constant speed throughout the whole range of motion [28]. The mechanisms underlying muscular adaptations involve many factors, that is, mechanical, metabolic, endocrine and neural factors, of these factors; training-induced muscular hypertrophy might be at least partially related to the secretions of endogenous anabolic hormones such as growth hormone (GH) and testosterone (TES) [26]. The normal physiological response to resistance training is reported to be increased neural activation and muscle hypertrophy. Suman et al., (2001) believed that neural adaptation predominates in the early phase of training and hypertrophy in the later phase [27,28].

Isokinetic training protocol increases the mean peak torque output of skeletal muscle group. The significant improvement in strength obtained following training protocol is the result of neural adaptations by allowing better activation of the motor neuron pool and decrease fatigue of muscle, so the isokinetic training program leads to significant increase in muscle performance [29].

The torque gains in response to training are caused by adaptive changes in muscle or neural control. Muscle can adapt to a strength training program with hypertrophy or adequate stimulant for increase enzyme activity of glycolytic and mitochondrial enzymes [30].

Isokinetic training protocols induce skeletal muscle hypertrophy on three types of muscle fibers I, Ila and Iib also it increase the functional capacity of the all skeletal muscles fibers with significant increase in peak torque of skeletal muscle after training protocols [29] this is supported by Myer et al., (2006) who reported that neuromuscular training protocols by using isokinetic that include both plyometrics and dynamic balance exercises can significantly improve biomechanics and neuromuscular performance and reduce ligamentous injury [31].

Our results were consistent with the results of Dragana et al., (2011) who reported that the implemented isokinetic training protocols significantly improved the strength of the thigh muscles measured isokinetically and decreased the degree of muscle strength asymmetry. It is clear that the isokinetic training protocol evoked greater changes in thigh muscle strength compared with isotonic training protocol, which is reflected in greater changes in the ipsilateral concentric ratio [32].

Increases in strength after heavy-resistance training are due to muscular and/or neural adaptations. Muscular adaptations include an increase in the Cross Sectional Area (CSA) of the prime movers (muscle hypertrophy) or adaptations that increase specific tension (force per unit CSA). Neural adaptations include increased prime mover motor unit activation, increased activation of synergistic muscles, or decreased activation of antagonistic muscles [33].

Results also revealed significant improvement in the mean value of Bruininks-Oseretsky Test of Motor Proficiency concerning the DCD-Isokinetic Group at the end of treatment as compared with the corresponding mean value before treatment (0.0072) that denotes an improvement of functional activities and postural control.

Concurring with several previous reports [3, 4,14], children with DCD were less able to rely on visual and vestibular inputs to maintain standing balance than their typically developing counter parts. Dysfunction of the parietal cortex may explain the visual-motor (e.g., visual-postural control) deficits [34], and inadequate vestibular stimulation during development may explain the lower vestibular function [35].

In line with the findings of Fong et al., [3] and Fong et al., [14,35], this study provides supplemental evidence that standing balance control is inferior in children with DCD, this could be attributed to the fact that DCD-affected children are less reliant on visual and vestibular inputs to maintain balance, and may be over reliant on the hip strategy to achieve balance [3,14,35].

Both knee flexor and extensor play a crucial role in maintaining standing balance and postural control. The major knee flexor muscles, hamstrings, are also important hip extensors because they cross both hip and knee joints [36]. The hamstring muscle
group is thus particularly important in controlling the forward sway of the body (i.e., hip flexion) in balance strategies showed that hamstring muscle reflex contraction latency can be as short as 100-150ms in response to a forward postural disturbance. This hints that when the hamstring muscles cannot produce enough torque within a short period to control forward sway, the result might be excessive hip flexion (hip sway) as observed in the children with DCD [37].

Weakness of the hamstring muscle leads to loss of its counter balancing action to Ground Reaction Force (GRFV) extension movement, this leads to hyperextension of the knee joint (genu recurvatum).

Quadriceps weakness diminishes the knee control and so the deficit in stance are most pronounced and compensations begin prior to weight acceptance at late swing and continue through the supporting activity of that limb. At terminal swing, the hip flexion leads to passive knee extension through the momentum transfer. Further more the weakness of the quadriceps makes child leans by the trunk forward at initial contact, to increase the moment arm of the GRFV and so increase the extension moment created by it to compensate the loss of extension due to quadriceps weakness [38].

Moreover the weakness of the quadriceps leading to loss of its role which start from terminal swing and continue till initial contact this role at terminal swing is to extend the knee for creating a new step, so loss of this role makes the child forcibly extend the knee joint using the momentum leading to hyperextension of the knee joint.

References


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