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Can balance trampoline training promote motor coordination and balance performance in children with developmental coordination disorder?

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ABSTRACT

The present study aimed to examine movement difficulties among typically developing 8- to 9-year-old elementary students in Greece and to investigate the possible effects of a balance training program to those children assessed with Developmental Coordination Disorder (DCD). The Body Coordination Test for Children (BCTC; Körperkoordinationstest fur Kinder, KTK, Kiphard & Schilling, 1974) was chosen for the purposes of this study and 20 children out of the total number of 200, exhibited motor difficulties indicating a probable DCD disorder. The 20 students diagnosed with DCD were equally separated into two groups where each individual of the experimental group was paired with an individual of the control group. The intervention group attended a 12-week balance training program while students of the second – control group followed the regular school schedule. All participants were tested prior to the start and after the end of the 12-week period by performing static balance control tasks while standing on an EPS pressure platform and structured observation of trampoline exercises while videotaping. The results indicated that after a 12-week balance training circuit including a trampoline station program, the intervention group improved both factors that were examined. In conclusion, balance training with the use of attractive equipment such as trampoline can be an effective intervention for improving functional outcomes and can be recommended as an alternative mode of physical activity.

1. Introduction

A minimal level of competence in motor skills, ranging from fine coordination to gross motor coordination and balance skills, is necessary to participate in daily physical activities typical of young children. However, while some children execute a whole range of motor tasks easily, others experience considerable difficulties coordinating and controlling their body movements. The latter children are often diagnosed with Developmental Coordination Disorder (DCD) which has been described as one of the six most commonly occurring developmental disorders (Kwan, Cairney, Hay, & Faught, 2013). There is

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a debate in the literature regarding the prevalence of DCD, with estimates ranging from 1.8% (Lingam, Hunt, Golding, Jongmans, & Emond, 2009) to 5–6% of school-aged children (Missiuna et al., 2008).

According to the diagnostic criteria of DCD, the current diagnosis is applied to children who present marked impairment in the development of motor coordination that has negative impact on the child's academic achievement or the performance of everyday life tasks and is not due to any known medical condition (APA, 2013). Children with DCD require much more effort and take much longer than their peers to learn specific complex age-appropriate motor skills (Sylvestre, Nadeau, Charron, Larose, & Lepage, 2013). Without proper intervention, the problems that arise from DCD may persist into adolescence and adulthood (Losse et al., 1991; Fitzpatrick & Warkinson, 2003). A typical characteristic of children with DCD is poor postural control (Geuze, 2003). It has been reported that 73–87% of children with DCD actually display balance control problems (Macnab, Miller, & Polatajko, 2001). Postural control has been defined as the control of the body's position in space for the purpose of balance and orientation (Shumway-Cook & Woollacott, 2001). Children without static balance control lack the stabilizing framework that is necessary to develop normal functional activities. Since the development of the balance control is the base for development of all other skills, the ability to maintain postural stability in children with DCD is an important area that needs to be addressed. Any impairment in postural control may limit the children's activity participation (Fong, Lee, & Pang, 2011; Smyth & Anderson, 2001) increase their risk of falling and delay motor skills development (Grove & Lazarus, 2007).

Without proper intervention, the balance and motor deficits that arise from DCD may persist into adolescence and even adulthood (Fitzpatrick & Warkinson, 2003). Early intervention to enhance motor and balance performance is thus very important. Although many different intervention strategies have been used and studied, it remains unclear which best improve motor performance or activities in children with DCD and lighten the associated problems (Smits-Engelsman et al., 2013; Peens, Pienaar, & Nienaber, 2008).

To our knowledge there is no study that examined the effects of balance training with the use of trampoline in healthy children with DCD on variables of static balance and motor coordination. However, it has been suggested in recent studies that trampoline exercises consist of a multicomponent approach which are likely to affect many physical factors such as balance, flexibility, strength, body stability, muscle coordinative responses, joint movement amplitudes and spatial integration (Aragao, Karamanidis, Vaz, & Arampatzis, 2011; Giagazoglou et al., 2013).

Children with DCD have been reported to avoid physical activity due to poor self-efficacy (Cairney, Hay, Faught, et al., 2005; Engel-Yeger & Hanna Kasis, 2010). The most difficult part for children with DCD is to find an appropriate exercise program to keep their interest in taking part and continue participation for a long time. In this regard, it was hypothesized from the authors that balance training circuit including a station with a trampoline as an equipment promoting fun and enjoyment, would keep children's interest throughout the whole duration of the activity program. Therefore, the purpose of the present study was to assess the effect of a 12-week balance training intervention program with the use of a trampoline on motor coordination and balance ability of school aged children with DCD.

2. Methods

2.1. Participants

The children who participated in this study were sampled from various elementary schools in Thessaloniki, a big town of Northern Greece. There were 200 children (104 boys and 96 girls) 8–9 years old (mean age 8.43 ± 1.85 months). All children were tested using the tasks from the quantitative test of neuromuscular coordination of the whole body (*Body Coordination Test for Children BCTC*; Körperkoordinationstest für Kinder, KTK) (Kiphard & Schilling, 1974, 2007). It was found that 20 children (13 boys and 7 girls) out of the total number of 200 children participating in this study exhibited motor difficulties indicating a probable Developmental Coordination Disorder.

All children had normal-range IQs and no evidence of physical or neurological disorder. Children with a history of prenatal problems, neurological diseases, sensory disturbances, premature children and children with epilepsy or other chronic diseases were excluded from the study. Additionally, information such as motor skill delays and poor coordination interfere with the performance of self-care activities and academic achievement beyond what would be anticipated, given their age and intellectual ability was derived from children's school records and parent's reports according to APA (2000) recommendations.

The 20 students diagnosed with DCD were equally separated into two groups where each individual of the experimental group was paired with an individual of the control group in terms of gender, age and school placement to ensure that both groups started from the same reference point prior to intervention. The first – experiment-group (mean age = 8.80 ± 1.7 years, height = 1.39 ± 0.13 cm, body weight = 38.77 ± 12.88 kg) followed a 12-week balance training program while students of the second – control-group (mean age = 8.43 ± 1.85 years, height = 1.36 ± 0.12, body weight = 35.98 ± 11.61 kg) followed the regular school schedule. Independent *t*-tests indicated non-significant group differences in anthropometric parameters. The 20 participants were tested prior to the start and after the end of the 12-week period by performing static balance control tasks and structured observation of trampoline exercises while videotaping.

All parents or legal guardians provided written informed consent prior to participation approved by an Institutional Review Board for use of Human subjects, allowing children's involvement in the program and access to relevant information.

2.2. Testing procedures and instrumentation

2.2.1. Body Coordination Test for Children (BCTC; Körperkoordinationstest fur Kinder, KTK, Kiphard & Schilling, 1974)

Actual motor competence of the 200 students from the initial sample was measured by the Body Coordination Test for Children (BCTC; Körperkoordinationstest fur Kinder, KTK, Kiphard & Schilling, 1974), which is designed to evaluate the overall body co-ordination and control of children from 5 to 14.11 years old. It is appropriate for children with typical development, as well as for children with brain damage, behavioral issues or learning difficulties. This test measures the overall body coordination and control of children, through the measurement of four tasks: balance during walking backwards, obstacle jump on one foot, sideways movements with initial position and side jumps right-left of two trials, during which the children had to jump from side to side over a little beam with both feet together, as often as possible within a period of 15 s. The score is the total number of correct jumps in both trials. For each of the four items, a rawscore (RW) and a scaled score (Motor Quotient score) are recorded. A total Motor Quotient ($MQ = 100 \pm 15$) percentiles, and motor age can be estimated per item as well as for the global test. A score less than 85 in MQ indicates a serious co-ordination disturbance (Schilling & Kiphard, 1977). Internal consistency reliability based on test–retest reliability coefficients, for each item, ranges from .80 to .96. Data collection took approximately 20 min to complete for each child.

2.2.2. Trampoline body coordination test (TBCT; trampolin-körperkoordinations – test für Kinder, TKT)

Monitoring the progress in various aspects of motor ability and body co-ordination in DSD children was achieved using the Trampoline body coordination test (Trampolinkörperkoordinations test für Kinder, Kiphard, 1978). This is a structured observation test which is based on video analysis of children while perform jumps on the trampoline. Particularly, the observation sheet consists of 33 items in 9 different motor domains, namely: segmental movement flaw, body posture, level of muscular effort (contraction), muscle strength (force), rhythm, balance, side asymmetry, body stability and existence of redundant movements. Each of the 33 items takes a score of 0 or 1 and the whole score can range from 0 (indicating no faults) to 33 (indicating severe motor difficulties).

In this particular test, the trampoline is used as a diagnostic tool since the 33 different items of the 9 different domains are designed to ascertain the motor coordination and balance control of the participants that are observed while the participants jumping on the air (Kiphard, 2001, pp. 127–129; Kiphard & Schilling, 1974). The major advantage of the test is that through a careful observation of the film recorded, a clear diagnostic indication for movement difficulties can be provided. This test has proven to be reliable and valid (Kiphard, 1978; Neuhäuser, 1988; Wehhaus, 1973; Wehhaus & Lössl, 1974) with intra-class and inter-class reliability coefficients ranging from 0.55 to 0.93 (across the nine domains) and a reliability coefficient of the total score equal to 0.85 (Kiphard, 2001, pp. 127–129).

Each child was asked to perform free jumps on the trampoline according to the recommendation provided by Kiphard and Schilling (1974). Particularly, the children were instructed to jump, to make a 90 degree rotation and then return to the starting position. The instruction was to "jump as high as you can" and at least 10 free continuous jumps were performed. The examiner was positioned approximately 5 m from the wide side of the trampoline giving directions to the participants. A standardized camcorder, placed perpendicular to the plane of jumping motion, was used to record the whole sequence of movements in digital video format. Following data collection, the investigator carefully observed the video movement files and confirmed the score of all participants.

2.2.3. Balance testing

All balance tests were performed on an EPS pressure platform (Loran Engineering S.r.I., Bologna, Italy). The system uses 2304 force sensing resistors in an active area of 70 cm × 50 cm to record plantar pressure at 25 Hz. All the participants performed one-leg stance (OLS) with opened eyes and double-leg stance (DLS) with opened and closed eyes. During the DLS, the children were instructed to stand erect, as motionless as possible, on a normal comfortable posture, with opened eyes looking straight ahead at a cross marked at approximately eye level on a black board 3 m away and barefoot with feet shoulder width apart on the platform with the arms by their sides. Each child was requested to keep a quiet stance posture for 30 s. The assessment included three measurements, and a 5-min rest was provided between successive trials. The best trial was further analyzed (Ageberg, Roberts, Holmstrom, & Friden, 2003). The participants performed the same task with closed eyes. During OLS, the participants were instructed to stand on their dominant foot, which was placed pointing straight forward in relation to reference lines in the frontal and sagittal planes. The swinging leg was flexed 90° at the hip and knee joints with both arms hanging relaxed at the sides (Ageberg et al., 2003). The subjects were instructed to stand as still as possible, looking straight ahead at a point on the wall 65 cm away. The test order between legs was randomized. Data recording started once the subject was stable in the required posture. Ample time was provided for familiarization. If OLS balance was not maintained for 10 s, the trial was not recorded and the measurement was repeated. A computer program (Footchecker 3.2, Engineering S.r.I., Bologna, Italy) was used to compute peak-to-peak amplitude (CoPmax) and standard deviation of the COP from the mean value of COP in antero-posterior (SDy) and mediolateral (SDx) axis in mm, often defined as sway amplitude. Students executed the test by standing on the platform in a normal position with the hands next to the thighs and the feet slightly apart. The first test included the Normal Quite Stance for 30 s and the second test the OLS for 10 s. Through the screening process a group of 20 children exhibiting DCD was identified.

2.2.4. Intervention program-trampoline training

Two physical education teachers conducted the balance training program alternately. The intervention program included balance exercises in circuit training including a trampoline station. The training program was applied 3 times per week in the intervention group for 12 weeks and each training unit lasted approximately 45 min. Indicatively, the training included walking exercises, hops on one foot, jumps and landings in one or both legs, landings from heights with opened or closed eyes, and rotations in different directions. The participants followed circuit training in stations with the use of various portable or stable gym equipment. The trampoline was used from the students at least 15 out of 45 min of each session such that the interval time between exercise stations is minimal.

Exercises selected for each session were challenging and attractive to children and required their mind concentration. Various exercises were performed using assistive equipment (besides the trampoline), such as benches, game cones, ropes, bars, steps, balls, balloons, etc. while performed. The exercises on trampoline included: quiet stance with eyes closed and with one foot support, hopping with rotation or with legs opening and closing, with alternate front and back leg movements, one foot jumps, kicking a ball while hopping and association of different jump patterns with ball throwing, hooping and playing a balloon with the hands. As for the control group, participants adhered to their regular school schedule, which included participation in physical education activity at a frequency of 3 times per week for 40–45 min.

2.2.5. Statistical analysis

Data were checked for normality using the Kolmogorov–Smirnov test. The Mauchly's test of sphericity was used to examine whether the variability of the changes in dependent variable scores between the different measurement occasions was constant.

One-way multivariate analysis of variance (MANOVA) designs was calculated using as dependent variables participants' gender and each of the 9 TKT domains all assessed at pre-measurement with the two groups treated as the independent variable. A separate MANOVA was applied for Balance scores. Then, repeated measures MANCOVA (2 groups $\times$ 2 measurements) were computed, each for the TKT and Balance scores. Given significant interaction terms, the Student Neuman Keuls multiple comparison procedure was used to examine potential mean differences. Significance level was set at $p \leq .05$.

3. Results

The Kolmogorov–Smirnov test indicated that data were normally distributed. The one-way MANOVAs indicated a non-significant multivariate effect on TKT [Pillai's trace = .30, $F_{10,\ 8} = 0.97$, $p > .05$, partial eta squared (η^2) = .53] and balance scores [Pillai's trace = .87, $F_{16,\ 2} = 0.85$, $p > .05$, $\eta^2 = .87$]. The 2 $\times$ 2 MANCOVA revealed a significant multivariate interaction term for TKT [Pillai's trace = 0.98, $F_{10,\ 7} = 17.52$, $p < .05$, $\eta^2 = .97$] and balance [Pillai's trace = 0.98, $F_{10,\ 7} = 44.40$, $p < .05$, $\eta^2 = .99$] scores. The sphericity test results were statistically significant for all dependent variables allowing the use of the Greenhous–Geisser index to interpret the findings. Subsequently, the group $\times$ time interaction terms was examined for each set of dependent variables (TKT, Balance scores).

3.1. Trampoline body coordination test (TBCT; trampolin-körperkoordinations – test für Kinder'' (TKT)

A statistically significant univariate "group x time" interaction term was noticed in all 9 different motor domains and in total score. More specifically, there was a significant interaction on movement flaw ($F_{1,16} = 19.41$, $p = .000$, $\eta^2 = .548$), body posture ($F_{1,16} = 4.79$, $p = .044$, $\eta^2 = .230$), contraction ($F_{1,16} = 19.84$, $p = .000$, $\eta^2 = .554$), force ($F_{1,16} = 7.89$, $p = .013$, $\eta^2 = .330$), rhythm ($F_{1,16} = 19.89$, $p = .000$, $\eta^2 = .554$), balance ($F_{1,16} = 14.43$, $p = .002$, $\eta^2 = .474$), side asymmetry ($F_{1,16} = 24.40$, $p = .000$, $\eta^2 = .604$), body stability ($F_{1,16} = 11.47$, $p = .004$, $\eta^2 = .418$), redundant movements ($F_{1,16} = 7.01$, $p = .018$, $\eta^2 = .305$), and total score ($F_{1,16} = 96.86$, $p = .000$, $\eta^2 = .858$). No statistically significant differences were noted between the two groups or in the control group between measurements for each skill measured. The test descriptive results of the Trampoline Body Coordination Test (TBCT) are presented in Table 1.

3.2. Balance tasks

The means and SD values of balance tasks pre and posttraining for intervention and control group are represented in Table 2.

In the mediolateral (M/L) direction, a statistically significant univariate "group $\times$ time" interaction effect was found for CoPsd ($F_{1,16} = 4.62$, $p = .047$, $\eta^2 = .224$) but not for CoPmax ($F_{1,16} = 3.81$, $p = .069$, $\eta^2 = .192$) in double leg stance (DLS) task with eyes open. Similarly, at the eyes closed condition, interaction effect was noted for CoPsd ($F_{1,16} = 13.23$, $p = .002$, $\eta^2 = .453$), but not for CoPmax ($F_{1,16} = 1.45$, $p = .246$, $\eta^2 = .083$).

With regards to the anterior/posterior (A/P) direction in DLS with the eyes opened, the results showed a statistically significant "group $\times$ time" interaction term for CoPmax ($F_{1,16} = 47.46$, $p = .000$, $\eta^2 = .748$) but not for CoPsd ($F_{1,16} = 3.92$, $p = .065$, $\eta^2 = .197$). In the same task with eyes closed, the test revealed a statistically significant group $\times$ time interaction difference in CoPmax ($F_{1,16} = 15.40$, $p = .001$, $\eta^2 = .490$) and in CoPsd ($F_{1,16} = 10.85$, $p = .005$, $\eta^2 = .404$).

Table 1
The scores of the 9 different motor domains and the total score of the TBCT test means and SD values pre and post training for experimental and control group.

	Experimental group (n = 10)		Control group (n = 10)	
	Pre	Post	Pre	Post
Movement flaw	1.70 ± 0.48	0.70 ± 0.67*	1.90 ± 0.32	1.90 ± 0.57
Body posture	2.30 ± 0.68	0.70 ± 0.68*	1.90 ± 0.88	1.10 ± 0.97
Contraction	2.00 ± 0.82	0.60 ± 0.59*	1.70 ± 0.48	1.40 ± 0.52
Force	1.50 ± 0.53	0.30 ± 0.48*	1.30 ± 0.48	0.80 ± 0.63
Rhythm	1.40 ± 0.52	0.30 ± 0.68*	1.30 ± 0.48	1.20 ± 0.63
Balance	1.70 ± 0.48	0.20 ± 0.42*	1.80 ± 0.48	1.50 ± 0.85
Side asymmetry	3.00 ± 0.67	0.80 ± 0.91*	2.60 ± 0.84	2.50 ± 0.85
Body stability	2.10 ± 0.74	0.20 ± 0.42*	2.30 ± 0.68	1.60 ± 1.01
Redundant movements	1.60 ± 0.70	0.70 ± 0.94*	1.50 ± 0.71	1.20 ± 0.79
Total score	17.40 ± 1.84	4.50 ± 2.07*	16.95 ± 2.24	12.30 ± 2.45

* $p < .05$ pre to post test.

Table 2
Peak-to-peak amplitude of the center of pressure (CoP) displacement (CoPmax) and standard deviation of the CoP (CoPsd) in the anterior posterior (A/P) and in mediolateral (M/L) direction in 3 balance tasks; pre and post training for experimental and control group.

	Experimental group (n = 10)		Control group (n = 10)	
	Pre	Post	Pre	Post
Double leg stance with opened eyes (mm)				
CoPmax-M/L	27.07 ±11.13	12.55 ± 4.28	22.11 ± 10.48	17.52 ± 8.15
CoPsd-M/L	5.88 ± 2.05	3.27 ± 1.43*	5.62 ± 2.79	4.84 ± 2.61
CoPmax-A/P	20.35 ±4.65	10.16 ± 4.01*	15.67 ± 8.12	14.80 ± 7.71
CoPsd-A/P	6.19 ± 3.73	2.54 ±1.38	3.87 ± 1.82	2.53 ± 1.39
Double leg stance with closed eyes (mm)				
CoPmax-M/L	18.56 ± 4.64	16.24 ± 8.48	18.41 ± 4.84	19.50 ± 6.67
CoPsd-M/L	5.50 ± 1.74	3.08 ± 1.31*	5.09 ± 1.32	4.85± .71
CoPmax-A/P	20.08 ± 3.98	10.41 ± 3.99*	16.32 ± 4.14	18.00 ± 7.07
CoPsd-A/P	5.59 ± 3.25	2.75 ± 1.32*	2.88 ± 1.01	3.29 ± 1.50
Right one leg stance (mm)				
CoPmax-M/L	31.20 ± 8.45	24.59 ± 12.93*	29.53 ± 7.46	30.83 ± 4.61
CoPsd-M/L	12.60 ± 3.08	6.98 ± 4.19*	11.35 ± 2.76	10.38 ± 2.75
CoPmax-A/P	39.00 ± 5.16	21.03 ± 9.07*	38.82 ± 9.17	38.67 ± 9.17
CoPsd-A/P	8.82 ± 1.67	6.87 ± 1.87	7.94 ± 1.90	7.61 ± 1.83

* $p < .05$ pre to post.

With regards to one leg stance (OLS) task on dominant foot, the MANCOVA revealed a statistically significant group × time interaction difference in CoPsd ($F_{1,18}$ = 11.29, p = .004, η^2 = .414) in M/L direction and in CoPmax ($F_{1,16}$ = 6.01, p = .026, η^2 = .273). However, in A/P direction there was a statistically significant interaction in CoPmax ($F_{1,16}$ = 50.71, p = .000, η^2 = .760) but not in CoPsd ($F_{1,16}$ = 2.87, p = .110, η^2 = .152). Furthermore, no statistical significant differences were noticed between pre and post measurements of the control group.

4. Discussion

The present study aimed to examine movement difficulties among typically developing elementary students in Greece and to investigate the possible effects of a balance training program to those children assessed with Developmental Coordination Disorder (DCD). The Body Coordination Test for Children (BCTC; Körperkoordinationstest fur Kinder, KTK, Kiphard & Schilling, 1974) was chosen for the purposes of this study since it was considered an adequate test for the assessment of children's coordinative performance (Graf, Koch, Dordel, et al., 2004; Graf, Koch, Kretschmann-Kandel, et al., 2004).

Children with DCD judge themselves to be less competent than their peers, both physically, psychologically and socially (Cairney, Hay, Faught, & Hawes, 2005), and are likely to avoid participating in physical activities in order to avoid experiencing failure and sustaining injuries due to their difficulty in coordinating movements (Bouffard et al., 1996). In this regard, the current research examined whether motor coordination and balance abilities of children with DCD can be improved through an exercise program. To our knowledge, this is the first time a balance training circuit including a trampoline station was developed for this population in an attempt to parallely promote enjoyment of students with DCD participating in this program.

The results indicated that after a 12-week training program, implemented in regular PE lessons in healthy 8- to 9-year-old children with DCD, the intervention group improved both factors that were examined. 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 (Macnab et al., 2001). The problem requires special attention because poor balance ability may increase the risk of falls, limit activity participation, and affect motor skill development (Fong et al., 2011; Grove & Lazarus, 2007).

The present results showed a significant performance improvement in all balance post-tests that took place after the participation of individuals with DCD in a 12-week training program that included a variety of trampoline exercises. The results are in agreement with a recent study reporting an improved balance ability and motor performance of participants with intellectual disabilities (Giagazoglou et al., 2013) and of elderly participants (Aragao et al., 2011) after applying a training intervention with trampoline. The performance improvements in balance task may be due to alterations in the complex sensory motor stimulation of participants' efforts to adapt to the trampoline unstable surface and maintain balance.

Additionally, a previous study reported an improved balance ability of elementary students with DCD using a Taekwondo training (Fong, Tsang, & Ng, 2012). This finding suggests that many exercises (e.g., spinning, jumping), which are commonly used in Taekwondo training and are similar to those used in the present study, might facilitate the vestibular system to maintain postural equilibrium as reflected by a quicker stabilization after landing from an unexpected drop (Fong et al., 2012; Leong, Fu, Ng, & Tsang, 2011). This hypothesis could be also true for the present findings since repeatedly jumping on the trampoline, force the participants to make an effort to keep their balance after continuously landings on the trampoline unstable surface.

It should be noted that despite the fact that most exercises were performed with eyes open, balance of participants without visual control also improved significantly (Table 2). This is in agreement with the finding of a recent study (Giagazoglou et al., 2013) suggesting that exercises with the use of unstable surface of the trampoline improve deep sensibility in individuals with intellectual disabilities. Additionally, a recent study showed that Taekwondo training (TDK) may strengthen the ability to use visual input due to the control of posture while kicking (Fong et al., 2012). Similar to TKD training, trampoline training places high demands on visual system to help maintain body balance.

Difficulty tolerating or processing sensory information is a characteristic that may be seen in children with DCD and this reflects deficits in their proprioceptive system (Zimmer et al., 2012). This in turn affects adequate acquisition of information and reaction to visual and proprioceptive stimuli, leading to poor outcome in terms of balance ability and maintenance of good posture. Thus, training interventions for children with DCD should focus on sensorimotor organization including activities that are believed to organize the sensory system, by providing visual, proprioceptive, auditory, and tactile inputs.

The balance training program applied in the present study, included performance of various types of jumping exercises on the trampoline which were combined with various secondary movements (e.g., rotating, jumping) that are commonly used in sensory integration (SI) therapy. SI therapy is known to be effective in remediating sensory deficits and enhancing motor skill development in children with DCD (Ayres, 1979; Cermak & Larkin, 2002; Sugden, 2007). Similarly, Heitkamp, Horstmann, Mayer, Weller, and Dickhuth (2001) applied a balance training circuit including a mini-trampoline station in healthy adults and found that it was effective not only in balance and strength but also in motor coordination. Therefore, the improved performance of the intervention group could be due to a strong proprioceptive stimulation received during the trampoline training intervention. This might indicate that both balance and body coordination can potentially improve in children with DCD thus assisting them to prevent falls and improve the quality of daily life.

In the present study, a matched-paired experimental design was applied. This was appropriate given the practical difficulties in identifying children with DCD from various schools in this area. A fully randomized design, however, would allow safer conclusions regarding the efficacy of the experimental program for these children. In addition, in the present study, the intervention (trampoline-based) program was compared with standard physical education program, which did not include trampoline-based training. Although the two programs were matched based on the overall dosage, future studies are needed to compare the same exercise program, with and without the use of trampoline, under the same experimental conditions. Another limitation of this study was that the effectiveness of the exercise program was tested using the TBCT test, which is also based on trampoline performance. This indicates that the results of this study regarding improvements in motor skill and co-ordination are restricted to TBCT performance. However, the use of balance tests using a pressure platform provided an independent outcome measure regarding program effectiveness.

In conclusion, improvements in motor coordination and balance performance by intervention group who participated in the 12-week balance training circuit including a trampoline station program are apparent in our study. In balance training with attractive equipment such as trampoline, children could be active participants engaged in a variety of movement activities that can be both enjoyable and therapeutic. In this regard, it could be suggested that balance training with the use of trampoline can be an effective intervention for improving functional outcomes and it is clearly recommended as an alternative mode of physical activity for improving balance and motor coordination performance.

References

Ageberg, E., Roberts, D., Holmström, E., & Fridén, T. (2003). Balance in single-limb stance in healthy subjects: Reliability of testing procedure and the effect of short-duration sub-maximal cycling. *BMC Musculoskeletal Disorders, 4*, 14.

American Psychiatric Association (2000). *Diagnostic and statistical manual of mental disorders (4th text revision)*. Washington, DC: American Psychiatric Association.

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders: DSM-5*. Washington, DC: American Psychiatric Publishing Inc, Arlington, VA, USA.

Aragao, F. A., Karamanidis, K., Vaz, M. A., & Arampatzis, A. (2011). Mini-trampoline exercise related to mechanisms of dynamic stability improves the ability to regain balance in elderly. *Journal of Electromyography and Kinesiology, 21*(3), 512–518.

Ayres, A. J. (1979). *Sensory integration and the child*. Los Angeles: Western Psychological Services.

Bouffard, M., Watkinson, E. J., Thompson, L. P., Causgrove Dunn, J. L., & Romanow, S. K. E. (1996). A test of the activity deficit hypothesis with children with movement difficulties. *Adapted Physical Activity Quarterly, 13*, 61–73.

Cairney, J., Hay, J. A., Faught, B. E., & Hawes, R. (2005). Developmental coordination disorder and overweight and obesity in children aged 9–14 y. *International Journal of Obesity, 29*(4), 369–372.

Cairney, J., Hay, J. A., Faught, B. E., Wade, T. J., Corna, L., & Flouris, A. (2005). Developmental coordination disorder, generalized self-efficacy toward physical activity, and participation in organized and free play activities. *The Journal of Pediatrics, 147*, 515–520.

Cermak, S. A., & Larkin, D. (2002). *Developmental coordination disorder*. Albany, NY: Delmar Thomson Learning.

Engel-Yeger, B., & Hanna Kasis, A. (2010). The relationship between developmental co-ordination disorders, child's perceived self-efficacy and preference to participate in daily activities. *Child: Care, Health and Development, 36*, 670–677.

Fitzpatrick, D. A., & Warkinson, J. E. (2003). The lived experience of physical awkwardness: Adults' retrospective views. *Adapted Physical Activity Quarterly, 20*, 279–298.

Fong, S. S. M., Lee, V. Y. L., & Pang, M. Y. C. (2011). Sensory organization of balance control in children with developmental coordination disorder. *Research in Developmental Disabilities, 32*, 2376–2382.

Fong, S. S., Tsang, W. W., & Ng, G. Y. (2012). Taekwondo training improves sensory organization and balance control in children with developmental coordination disorder: A randomized controlled trial. *Research in Developmental Disabilities, 33*(1), 85–95.

Geuze, R. H. (2003). Static balance and developmental coordination disorder. *Human Movement Science, 22*, 527–548.

Giagazoglou, P., Kokaridas, D., Sidiropoulou, M., Patsiaouras, A., Karra, C., & Neofotistou, K. (2013). Effects of a trampoline exercise intervention on motor performance and balance ability of children with intellectual disabilities. *Research in Developmental Disabilities, 34*, 2701–2707.

Graf, C., Koch, B., Dordel, S., Schindler-Marlow, S., Icks, A., Schüller, A., et al. (2004). Physical activity, leisure habits and obesity in first-grade children. *European Journal of Cardiovascular Prevention and Rehabilitation, 11*.

Graf, C., Koch, B., Kretschmann-Kandel, E., Falkowski, G., Christ, H., Coburger, S., et al. (2004). Correlation between BMI, leisure habits and motor abilities in childhood (CHILT-Project). *International Journal of Obesity, 28*.

Grove, C. R., & Lazarus, J. A. C. (2007). Impaired re-weighting of sensory feedback for maintenance of postural control in children with developmental coordination disorder. *Human Movement Science, 26*, 457–476.

Heitkamp, H. C., Horstmann, T., Mayer, F., Weller, J., & Dickhuth, H. H. (2001). Gain in strength and muscular balance after balance training. *International Journal of Sports Medicine, 22*(4), 285–290.

Kiphard, E. J. (1978). Testanalysen zum trampolinkörperkoordinationstest (TKT). *Psychomotorik, 2*(3), 111–114.

Kiphard, E. J. (2001). *Motopädagogik. Psychomotorische Entwicklungsförderung, Band 1* Verlag mνdernes lernen, 9, unveränd. Aufl. Borgmann: Dortmund.

Kiphard, E. J., & Schilling, F. (1974). *Körperkoordinationstest für Kinder*. Weinheim, Germany: Beltz Test GmbH.

Kiphard, E. J., & Schilling, F. (2007). *Körperkoordinationstest für Kinder* (Uberarbeitete und erganzte Auflage) Gottingen, Germany: Beltz Test GmbH.

Kwan, M. Y., Cairney, J., Hay, J. A., & Faught, B. E. (2013). Understanding physical activity and motivations for children with developmental coordination disorder: An investigation using the theory of planned behavior. *Research in Developmental Disabilities, 34*(11), 3691–3698.

Leong, H. T., Fu, S. N., Ng, G. Y., & Tsang, W. W. (2011). Low-level Taekwondo practitioners have better somatosensory organisation in standing balance than sedentary people. *European Journal of Applied Physiology, 111*, 1787–1793.

Lingam, R., Hunt, L., Golding, J., Jongmans, M., & Emond, A. (2009). Prevalence of developmental coordination disorder using the DSM-IV at 7 years of age: A UK population-based study. *Pediatrics, 123*(4), 693–700.

Losse, A., Henderson, S. E., Elliman, D., Hall, D., Knight, E., & Jongmans, M. (1991). Clumsiness in children: Do they grow out of it? A ten year follow-up study. *Developmental Medicine & Child Neurology, 33*, 55–68.

Macnab, J. J., Miller, L. T., & Polatajko, H. J. (2001). The search of subtypes of DCD: Is cluster analysis the answer? *Human Movement Science, 20*, 49–72.

Missiuna, C., Gaines, R., McLean, J., DeLaat, D., Egan, M., & Soucie, H. (2008). Description of children identified by physicians as having developmental coordination disorder. *Developmental Medicine & Child Neurology, 50*, 839–844.

Neuhäuser, G. (1988). *Kinder- und Jugendpsychiatrie in Klinik und Praxis Band 1* Motoskopisches Beurteilen des Bewegungsverhaltens, Hrg. H. Remschmidt und M.H. Schmidt Georg Thieme Verlag.

Peens, A., Pienaar, A. E., & Nienaber, A. W. (2008). The effect of different intervention programmes on the self-concept and motor proficiency of 7- to 9-year-old children with DCD. *Child: Care Health and Development, 34*(3), 316–328.

Schilling, F., & Kiphard, E. (1977). Ziele und differentialdiagnostische Mφglichkeiten des Kφrper-Koordinationstests fốr Kinder (KTK) [Goals and differential – Diagnostic possibilities of KTK]. *Psychomotoric, 2*, 147–148.

Shumway-Cook, A., & Woollacott, M. (2001). Normal postural control. In A. Shumway-Cook & M. Woollacott (Eds.), *Motor control: Theory and practical applications* (pp. 117–137). Philadelphia, PA: Lippincott Williams & Wilkins.

Smits-Engelsman, B. C., Blank, R., van der Kaay, A. C., Mosterd-van der Meijs, R., Vlugt-van den Brand, E., Polatajko, H. J., et al. (2013). Efficacy of interventions to improve motor performance in children with developmental coordination disorder: A combined systematic review and meta-analysis. *Developmental Medicine & Child Neurology, 55*(3), 229–237.

Smyth, M. M., & Anderson, H. I. (2001). Football participation in the primary school playground: The role of coordination impairments. *British Journal of Developmental Psychology, 19*, 369–379.

Sugden, D. (2007). Current approaches to intervention in children with developmental coordination disorder. *Developmental Medicine & Child Neurology, 49*, 467–471.

Sylvestre, A., Nadeau, L., Charron, L., Larose, N., & Lepage, C. (2013). Social participation by children with developmental coordination disorder compared to their peers. *Disability and Rehabilitation, 35*(21), 1814–1820.

Wehhaus, B. (1973). *Untersuchungen zur Rehabilitäts und Validität des Trampolintests* (Diplomarbeit. Psycho.), Mannheim .

Wehhaus, B., & Lössl, E. (1974). Rehabilitäts und Validitätsstudie zur Verwendung des Trampolins bei der Diagnose von motorisch gestörten Verhalten bei Kindern. *Praxis der Kinderpsychologie und Kinderpsychiatrie, 23*, 73–80.

Zimmer, M., Desch, L., Rosen, L. D., Bailey, M. L., Becker, D., Culbert, T. P., et al. (2012). Sensory integration therapies for children with developmental and behavioral disorders. *Pediatrics, 129*(6), 1186–1189.