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ARTICLE

A core-stabilization program for motor performance in adolescents with motor difficulties

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Abstract

Background: Developmental coordination disorder (DCD) is a neurodevelopmental condition characterized by poor motor competence that affects negatively adolescents' activities of daily living, and also poses as an increased risk to their health, and psychosocial development. Core stability improves posture, balance, and proprioception, skills in which adolescents with DCD are deficient. A weak core is a fundamental problem in the inefficient production of motion, which can lead to incorrect motor patterns. **Purpose**: The aim of this study was to investigate the effectiveness of a core-stabilization functional exercise program on motor competence, health-related physical fitness, weekly physical activity, and health-related quality of life (HRQoL) in adolescents with motor difficulties. **Methods**: 24 adolescents (12.75±.74y) participated in a 12-weeks (3 sessions/week) core-stabilization functional exercise program. Two groups were formed: experimental group (DCDexp n=8), and control group (DCDcontrol n=16). Motor performance, balance, abdominal muscles strength, flexibility of lower back, and hamstrings muscles, BMI, weekly physical activity, and HRQoL were assessed pre, and post intervention. **Results**: There were significant improvements in motor performance, balance, in abdominal muscles strength/endurance, and in flexibility of the lower back, and hamstrings muscles flexibility. Also, HRQoL and functional status were improved, too. There were no statistically significant differences in physical activity, and or BMI. **Conclusion:** A core-stabilization functional exercise program seems to improve motor performance, health-related physical fitness, and HRQoL in adolescents with motor difficulties. This study provides evidence that processes-oriented approaches, such as a core-stabilization functional exercise program can improve motor performance and HRQoL in adolescents with poor motor competence. Further research is encouraged. **Health & Fitness Journal of Canada 2021;14(1):3-24.**
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Keywords: Developmental coordination disorder; Functional status; Movement Assessment Battery for Children – 2nd Edition; TNO-AZL Questionnaire for Children's Health-Related Quality of Life; Optimum Performance Training model

Introduction

Developmental Coordination Disorder (DCD) is a neurodevelopmental disorder characterized by lower acquisition and execution of coordinated motor skills than expected, given the individual's chronological age. It affects functional performance in activities of daily living, and health. Its prevalence in children ages 5-11 years is thought to be 5%-6%. It seems that motor difficulties, and accompanying problems continue through adolescence in an estimated 50%-70% of children with DCD (APA, 2013; Cermak & Larkin, 2002).

Adolescents and children with DCD when compared to typically developed peers, appear to be affected by secondary consequences in mental health, educational achievement (Harrowell, Hollén, Lingam, & Emond, 2017; Harrowell, Hollén, Lingam, & Emond, 2018), participation in physical, and leisure activities (Izadi-Najafabadi, Ryan, Ghafooripoor, Gill, & Zwicker, 2019; APA, 2013; Barnett & Hill, 2019), in physiological characteristics (Wright, Furzer, Licari, Thornton, Dimmock, Naylor, et al. 2019) such as poor physical fitness (Rivilis, Hay, Cairney, Klentrou, Liu, & Faught, 2011), and obesity (Hendrix, Prins, & Dekkers, 2014), and lower health-related quality of life (HRQoL), (Raz-Silbiger, Lifshitz, Katz, Steinhart, & Cermak, 2015; Zwicker, Missiuna, Harris, & Boyd, 2012; Zwicker, Harris, & Klassen, 2013). According to Katartzi & Vlachopoulos (2011), these combined factors engage adolescents in a negative cycle of physical inactivity. The lack of motor competence can lead to the adoption of a sedentary lifestyle, as adolescents avoid participating in physical activities. This, in turn, has negative consequences in physical fitness levels, an important health factor, and in overall health, well-being, and HRQoL, according to the activity-deficit hypothesis (Green, Lingam, Mattocks, Riddoch, Ness, & Emond, 2011; Schoemaker & Smits-Engelsman, 2015; Dewey & Volkovinskaia, 2018).

HRQoL is increasingly used as a health outcome among children and adolescents to assess their physical and social functioning, mental health, and well-being (Solans, Pane, Estrada, Serra-Sutton, Berra, Herdman et al., 2008). Studies have shown that DCD affects negatively children's (Karras, Morin, Gill, Izadi-Najafabadi, & Zwicker, 2019) and adolescents' HRQoL, which in turn, has a strong relationship with physical activity participation (Dewey & Volkovinskaia, 2018; Raz-Silbigeret al., 2015).

Monastiridi, Katartzi, Kontou, Kourtessis, and Vlachopoulos (2020) supported that negative consequences of the activity-deficit hypothesis (Green et al., 2011; Schoemaker & Smits-Engelsman, 2015) and also, the negative cycle of physical inactivity (Katartzi & Vlachopoulos, 2011) could be reversed, if appropriate exercise intervention programs, focusing on the reduction of individual constraints (coordination, balance, stabilization, posture, strength, flexibility etc.), (Newell, 1986) are implemented.

Hands and Parker (2019) suggested that a physical fitness education approach, as a part of the school based physical education curriculum, should provide knowledge, skills and motivation in adolescents with DCD, in a setting that is applicable for post-school participation, in sport clubs, or community based physical activity, and exercise settings. Given that, there is low recognition of this learning disability, and access and funding for individual therapy programs are scarce, school physical education, and physical fitness programs should be an ideal avenue to improve motor performance, foster participation, and prevent secondary consequences (Hands & Parker, 2019).

Intervention programs developed for DCD population, derived mainly from occupational therapy, physiotherapy, medicine, dietetics, and education (Bart, Podoly, & Bar Haim, 2010; Dunford, 2011; Peens, Pienaar, & Nienaber, 2008; Sugden & Chambers, 2003). To our knowledge, there are few research studies which examined the effect of a physical fitness, and exercise-based intervention, and more specifically the effect of a functional exercise program using core stabilization exercises for the improvement of motor performance and HRQoL, in adolescents with motor difficulties, related to DCD (Monastiridi et al., 2020). Functional exercise is defined as movements that improve a person's ability to complete their daily activities building appropriate muscle strength, joint integrity, balance, and flexibility (O'Sullivan, 2007). Core training is based on core stabilization which is consisted of core strength, endurance, power, balance, proprioception, coordination of the spine, abdominal, and hip musculatures (Hibbs, Thompson, French, Wrigley, & Spears, 2008), and improves performance, and prevents injuries. The strong, and endurable core muscles, stabilize the spine, providing passive support, neurological recruitment patterns, and appropriate activation of the muscles when forces and loads are applied (Akuthota, Ferreiro, Moore, & Fredericson, 2008; Barnet & Gilleard, 2005; Sugden & Chambers, 1998; Wilson, Patrick, Thomas, & Maruff, 2002), on the assumption that the correct motor function is the result of proper function of the neuromuscular system (Mandich, Polatajko, Macnab, & Miller, 2001). It may be considered as a process-oriented intervention method, as it is aimed to increase muscle strength (Smits-Engelsman, Blank, van der Kaay, Mosterdvan der Meijs, Vlugt-van den Brand, Polatajko, & Wilson, 2013). To our knowledge, only a few studies found that core, and strength training improved the muscle strength, proprioception, balance, motor functions and performance of motor skills in children, and adolescents with DCD (Kane & Bell, 2009; Fong, Tsang, & Ng, 2012; Fong, Chung, Chow, Ma, & Tsang, 2013; Kaufman & Schilling, 2007; Bhayani & Singaravelan, 2012; Menz, Hatten, & Grant-Beuttler, 2013; Au, Chan, Lee, Chen, Chau, & Pang, 2016; Kordi, Sohrabi, Kakhki, & Hossini, 2016; Hands, Chiversa, Gracea, & McIntyreb, 2019; Cacola, Romero, Ibana, & Chuang, 2016; Fong, Guo, Liu, Ki, Louie, Chung, & Macfarlane, 2016a; Fong, Guo, Cheng, Liu, Tsang, Yam, et al., 2016b; Giagazoglou, Sidiropoulou, Mitsiou, Arabatzi, & Kellis, 2015; Kane & Staples, 2016; Tsai, Chang, Chen, Hung, Pan, & Wang, 2014). There is a need for further research in adolescents with DCD in order to find a physical fitness and exercise-based intervention for this population that is applicable not only in school, but in post-school settings, too (Hand & Parker, 2019).

The main purpose of the current study was to investigate the effect of a 12-week core-stabilization functional exercise intervention program on motor performance, health-related physical fitness components, self-reported weekly physical activity and HRQoL in adolescents with motor difficulties. Another purpose was to examine if the effect of the intervention continued to be present in a 3-week retention period for motor performance and physical fitness. It is hypothesized that participation in such an intervention program would improve all the above variables which would help adolescents to manage their motor difficulties, in order to have a functional, adulthood in terms of motor performance and quality of life.

Methods

Participants

The initial sample consisted of 31 adolescents who met the Diagnostic, and Statistical Manual of Mental Disorders 5th Edition (DSM-5) criteria for DCD and were screened for motor difficulties using MABC-2 (scores below the 16th percentile).

They were randomly assigned to two groups, the experimental group (DCDexp, n=14), who participated in the intervention, and the control group (DCDcontrol, n = 17). During the study, 7 participants dropped out the study (refused to continue or missed some sessions), so they were rejected for not meeting the criteria for participation. The final sample consisted of 24 adolescents with motor difficulties (boys = 18, girls = 6): DCDexp, n=8, and DCDcontrol, n = 16 (Table 1).

The research study was approved by the Greek Ministry of Education and the Departmental Research Ethics Committee. All parents were informed about the research requirements and procedures. Prior to data collection, permission to conduct the study was obtained by the school head-master, where the research took place.

Table 1: Participant characteristics (Mean ± SD).

Groups	N	Age (yr)	Weight (kg)	Height (m)
DCDexp	8 Boys=6 Girls=2	12.9 ±.83	63.8 ±21.6	1.66 ±.14
DCDcontrol	16 Boys=12 Girls=4	12.6 ±.70	54.3 ±7.05	1.60 ±.08

Methods and materials

Movement Assessment Battery for Children, Second Edition (MABC-2), (Henderson, Sugden, & Barnett, 2007) was used for the identification of motor difficulties. In order for the effects of the core-stabilization functional exercise intervention program to be measured, both groups were pre-, and post-tested as follows. Motor performance assessment was evaluated by using total component, and standard scores in MABC-2 and high scores indicated improvements in motor performance. Balance measurements were derived from MABC-2 (two-board balance, heel-to-toe walking backwards, zigzag hopping), and high scores indicated better balance skill performance. The total, balance component, and standard scores (motor problem: scores <5, at risk: 6–7, average/normal performance >7) were used to measure the effect of the intervention. The MABC-2 test has acceptable validity, and reliability -inter-rater reliability .92 to 1.00 / test–retest reliability from .62 to .92 (Henderson et al., 2007).

For health-related physical fitness, the sit-up test was used to assess the abdominal and hip-flexors muscle strength and endurance. The score of this test was determined by the number of sit-ups in 30 seconds that an adolescent is able to execute (the maximum number of correctly performed sit-ups indicate better health-related physical fitness). This test formed part of the EuroFit Testing Battery (Council of Europe, 1983, 1993). The sit & reach test measured the flexibility of the lower back, and hamstrings muscles (high scores indicated better flexibility), (Wells & Dillon, 1952), and the Body Mass Index (BMI = kg/m^2) was calculated from body mass (M in kilograms) and height (H in meters). The higher the score, the higher levels of body fat and risk associated with obesity, according to the norms of ALPHA Fitness Test Battery for Children, and Adolescents (Ruiz, España, Castro, Artero, Ortega, Cuenca, Jiménez et al., 2011).

The Godin-Shephard Leisure-Time Physical Activity Questionnaire (Godin, 2011) was used to measure physical activity by reporting how many times the listed activities were performed for more than 15 minutes in a week (7 days), during free time. Its validity, and reliability was high (Godin & Shephard, 1985). The questionnaire's score was expressed in units: 24 units or more = active (*Substantial benefits*), 14 to 23 units = moderately active (*Some benefits*), less than 14 units = insufficiently active (*Less substantial or low benefits*), (Godin, 2011).

Finally, the TNO-AZL Questionnaire for Children's Health-Related Quality of Life (TACQOL), (Vogels, Verrips, Verloove-Vanhorick, Fekkes, Kamphuis, Koopman et al., 1998) was used to measure HRQoL, and functional status in adolescents with motor difficulties. It is a multidimensional instrument with 7 scales. As HRQoL is seen as a multidimensional construct, no total score is calculated. It assesses problems/limitations concerning, general physical functioning/complaints (BODY), motor functioning / performance (MOTOR), independent daily functioning (AUTO), cognitive functioning, and school performance (COGNIT), social contacts with parents, and peers (SOCIAL). It also contains two scales to evaluate occurrence of positive (EMOPOS), and negative moods (EMONEG). All questions relate to the occurrence of problems in performance over the past few weeks, and vary from never to sometimes or often. In the present study, the questions in each scale was summed, and the high scores of scales indicated better functional status. Internal consistency of domain-scores (*Cronbach a*) varied from 0.65 to 0.84.

A follow up study was conducted 3 weeks after the completion of the intervention program in MABC-2, sit-up, and sit & reach tests. Regarding weekly physical activity, and HRQoL, a retention measurement was not performed, due to the fact that the questionnaires give scores for the previous week/weeks (1-3), respectively, and the 3-week retention measurement was considered too short to have an effect.

The core-stabilization functional training intervention program

The exercise protocol was designed according to the Optimum Performance Training (OPT) model of the National Academy of Sports Medicine (NASM, 2107). The duration of the program was 12 weeks with 60min sessions conducted 3 times a week, and it took place in the context of extra-curricular organized sport clubs, immediately after the end of the daily school program. Each session began with a 10-minute warm-up, the main part lasted 45 minutes, and the recovery was 5-10 minutes. The 1st level of the OPT model (first 6 weeks) focused on the main adaptations of stabilization which were accomplished through low-intensity emphasizing core, and joint stabilization. It was designed to prepare the body for the demands of higher levels of the training that would follow, and incorporated exercises that progressively challenge the body's stability requirements (or proprioception). The primary means of progressing (or increasing the intensity of training) in those weeks was by increasing the proprioceptive demands of the exercises (the exercises became progressively more unstable, and challenge the adolescents' ability to maintain proper balance and posture (Table 2)). The 2nd level of the OPT model focused on the main adaptations of strength endurance, and promoted the increased stabilization from the previous level.

Acute variables were progressed, by increasing proprioceptive demand, volume (sets, reps), and intensity (load, exercise, selection, planes of motion), and by decreasing rest periods.

Table 2: OPT Model Level 1: stabilization endurance training.

	Reps	Sets	Tempo	% intensity	Rest	Exercise selection
Core	12-20	1-4	Slow 4/2/1	N/A	0-90s	1-4 core-stabilization
Balance	12-20 6-10 (SL)	1-3	Slow 4/2/1	N/A	0-90s	1-4 balance - stabilization
Resistance	12-20	1-3	4/2/1	50-70%	0-90s	1-2 stabilization progression

Note: N/A = not applicable; SL = single leg

This form of training entailed the use of a more stable exercise (such as a bench press) which was immediately followed by a stabilization exercise with similar biomechanical pattern (such as a stability ball push-up), (Table 3), (NASM, 2107). The exercises/tasks were: exercises with body weight, stability balls, bands, resistance bands, dumbbells, kettlebells, and medicine balls. The selected tasks included multi-joint exercises, with, and without equipment, and the involvement of many muscle groups. The workouts were executed in the form of circuit training, and each session included elements of balance, proprioception, strength, and flexibility aimed mainly at the core.

Data analysis

Descriptive statistics were obtained for all variables using SPSS (version 20.0) for Windows. Results were expressed as means (M), and standard deviations (SD). An independent samples t-test to examine differences in every dependent variable between the experimental and control group at the baseline (pre-intervention - T1), was conducted. A 2 (group) by 3 (time), repeated measures analysis of variance (ANOVA) to test both the main effects of group (DCDexp and DCDcontrol) and time [Time 1 (pre-intervention–T1), 2 (post-intervention-T2), and 3 (3-weeks follow up–T3)], and interaction between both, was performed only for motor performance, balance (MABC-2), sit-ups, and flexibility scores. Bonferroni's post hoc tests examined the difference of the above variables between T1, T2 and T3 within each group. In case significant differences in main effects were found, an independent samples t-test was conducted to analyze the differences of the above variables between both groups in Time 2 and Time 3.

Table 3: OPT Model Level 2: stabilization strength and endurance training.

	Reps	Sets	Tempo	% intensity	Rest	Exercise selection
Core	8-12	2-3	Medium	N/A	0-60s	1-3 core strength
Balance	8-12	2-3	Medium	N/A	0-60s	1-3 balance strength
Resistance	8-12	2-4	(str) 2/0/2 (stab) 4/2/1	70-80%	0-60s	1 strength with 1 stabilization

Note: N/A = not applicable; str = strength; stab = stabilization

A 2 (group) by 2 (time), repeated measures of analysis of variance (ANOVA) to test both the main effects of group (DCDexp and DCDcontrol), and time (T1 and T2, pre- and post- intervention, respectively), and interaction between both, was performed for BMI, physical activity, and HRQoL variables. In case significant differences in main effects were found, an independent samples t-test was conducted to analyze the differences of the above variables between both groups in Time 2. To calculate the strength of the results, partial-eta-squared were applied. These effect sizes were defined: η^2=.01 as small, η^2=.06 as medium and η^2=.14 as large (Field, 2010). Statistical significance in this study was set at the $p< .05$ level.

Results

Baseline (pre-intervention) scores

No statistically significant differences between groups were found at baseline. Only for MOTOR and COGNIT scores regarding HRQoL statistically significant differences were found ($p>.05$). For this reason, a univariate ANOVA with T1 score as covariate was conducted for these two variables between groups and because there were statistically significant differences these two dimensions of HRQoL were excluded (HRQoL MOTOR* & HRQoL COGNIT**), (Table 4).

The effect of the core-stabilization functional intervention program on motor coordination and balance (MABC-2)

The DCD, balance (MABC-2) component, and standard scores achieved by the experimental group in the post-test were improved from those on the pre-test, and this improvement maintained in the 3-week retention period, whereas those of the control group showed no significant progress. Repeated measures ANOVA showed a significant main effect of time on DCD (MABC-2) component, and standard scores. Bonferroni's post hoc comparisons showed statistically significant differences between T1 and T2 and T1 and T3 mean values for DCD component and standard scores (Figure 1). No main effects of group were found, but there were significant interaction-effects group x pre-post-follow up measures (Table 5). Repeated measures ANOVA showed a significant main effect of time on balance (MABC-2) component, and standard scores. Bonferroni's post hoc comparisons showed statistically significant differences between T1 and T2 and T1 and T3 mean values for balance component and standard scores (Figure 2). We also found main effects of group on balance scores, and there were significant interaction-effects group x pre-post-follow up measures (Table 5). Taken together, these results indicate a large intervention effect of the core-stabilization functional intervention on motor coordination, and balance and this effect maintained in a 3-week retention period.

Table 4: Baseline pre-intervention scores (mean, standard deviation - SD, significance) between two groups in motor coordination (MABC-2), physical fitness (PF), physical activity (PA) and HRQoL.

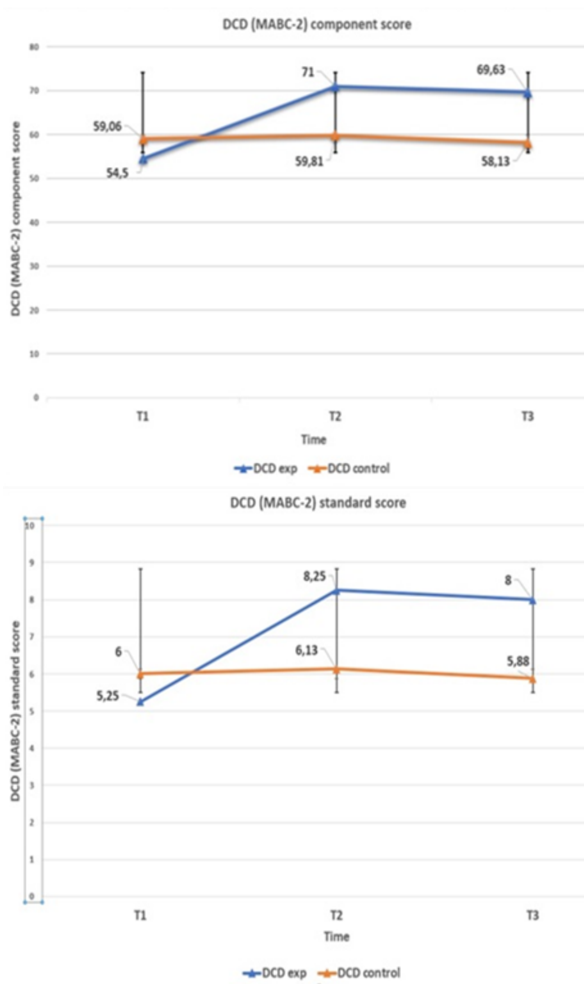
Dependent variables	DCDexp N=8	DCDcontrol N=16	t	p
	Time1 (T1) (Mean, ±SD)			
Age	12.91 ±.83	12.61±.70	.90	.37
Body weight	63.88±21.64	54.31±7.05	1.21	.25
Height	1.66 ±.14	1.60±.08	1.29	.20
MABC-2: DCD component score	54.50±9.33	59.06±8.94	-1.16	.25
MABC-2: DCD standard score	5.25±1.48	6.00±1.31	-1.26	.22
MABC-2: balance component score	21.0 ±6.43	20.00±6.67	.35	.73
MABC-2: balance standard score	6.50±2.13	6.00±2.09	.54	.59
PF Sit-ups	17.38 ±3.81	14.75 ±4.31	1.45	.15
PF Sit & reach	13.00 ±7.09	10.81±7.71	.67	.50
PF BMI	22.71±4.40	20.756±1.93	1.20	.26
PA strenuous	27.00±24.99	16.31±9.42	1.16	.27
PA moderate	11.25±11.57	10.31±6.18	.26	.79
PA mild	12.37 ±20.12	6.75±7.54	1.00	.32
PA total score	38.25 ±31.46	26.62±9.90	1.02	.33
HRQoL BODY	26.12±7.27	30.43±4.87	-1.73	.09
HRQoL AUTO	28.50 ±4.27	29.93±2.83	-.98	.33
HRQoL SOCIAL	26.75 ±3.88	25.43±4.66	.68	.50
HRQoL EMOPOS	8.87±3.31	10.68±2.18	-1.61	.12
HRQoL EMONEG	8.87 ±2.53	9.06±2.08	-.19	.84
ANCOVA				
HRQoL MOTOR*	29.75 ±3.41	28.81 ±3.65		.001
HRQoL COGNIT**	28.20 ±3.28	27.43 ±4.28		.000

Table 5: Mean, standard deviation, time-, group- and interaction-effects on motor coordination and balance scores for the DCD experimental and DCD control group at pre-, post and follow up tests (T1, T2 & T3).

MABC-2	DCDexp N=8			DCDcontrol N=16			Time effects (pre-post-follow up) df=2			Group effects (DCDexp-control) df=1			Interaction effects (between groups) df=23		
	T1 (SD)	T2 (SD)	T3 (SD)	T1 (SD)	T2 (SD)	T3 (SD)	F	p	η^2	F	p	η^2	F	p	η^2
DCD component	54.5 (9.33)	71 (13.25)	69.63 (11.14)	59 (8.94)	59.81 (8.52)	58.13 (8.76)	53.14	.00*	.70	2.22	.15	.09	52.92	.00*	.70
DCD standard	5.25 (1.48)	8.25 (2.6)	8 (2.13)	6 (1.31)	6.13 (1.45)	5.88 (1.54)	40.07	.00*	.64	2.78	.10	.11	39.18	.00*	.64
Balance component	21 (6.43)	29 (5.15)	29.75 (4.33)	20 (6.67)	21 (6.45)	19.87 (5.79)	35.06	.00*	.61	6.24	.02*	.22	29.59	.00*	.57
Balance standard	6.5 (2.13)	9.5 (2.33)	9.63 (2.2)	6 (2.09)	6.62 (2.18)	5.94 (1.84)	27.94	.00*	.56	7.48	.01*	.25	20.14	.00*	.47

Note: Statistically significant findings (*, p < 0.05).

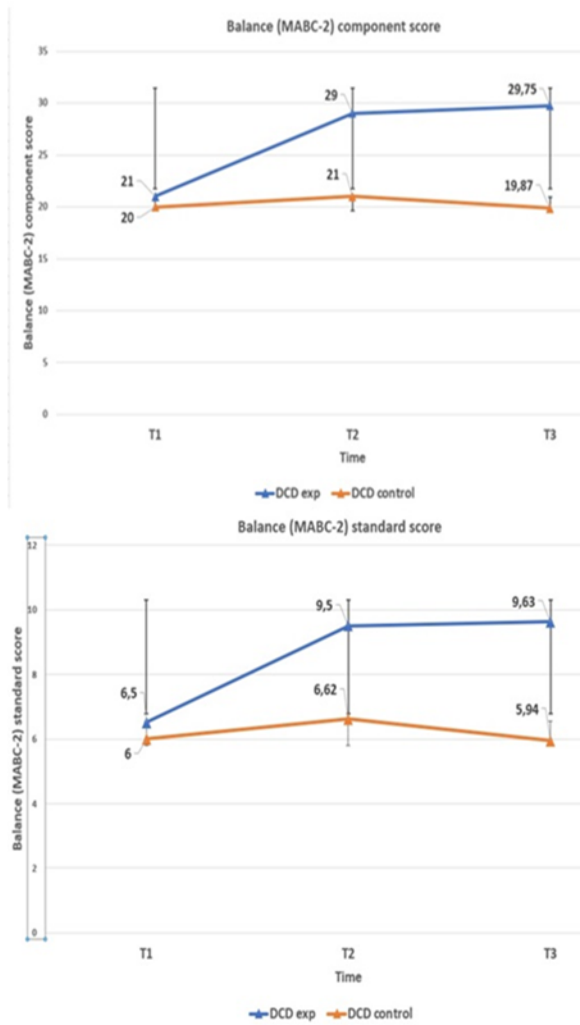
Figure 1: DCD (MABC-2) component and standard scores significant effects on time (T1, T2, T3) between groups according to post hoc tests (Bonferroni).



The effect of the core-stabilization functional intervention program on physical fitness (Eurofit)

The sit-up scores achieved by the experimental group on post-test were improved from those on the pre-test, and this improvement was maintained in the 3-week retention period, whereas those of the control group showed no significant progress. Repeated measures ANOVA showed a significant main effect of time in sit-up score. Bonferroni's post hoc comparisons showed statistically significant differences between T1-T2, and T1-T3

Figure 2: Balance (MABC-2) component and standard scores significant effects on time (T1, T2, T3) according to post hoc test (Bonferroni).



mean values for sit-up scores (p=.00). Main effects of group were also found and there were significant interaction-effects group x pre-post-follow up measures (Table 6). The sit & reach scores achieved by the experimental group in post-test were improved from those in the pre-test, and this improvement was maintained in the 3-week retention period, whereas those of the control group showed no significant progress. Repeated measures ANOVA showed a significant main effect of time on sit & reach score. Bonferroni's post hoc comparisons showed statistically significant differences between T1-T2, and T1-T3 mean values (p=.00), (Figure 3). No main effects of group and no interaction-effects group x pre-post-follow up measures were found on the sit & reach test (Table 6). No main effects of group and time and no interaction-effects group x pre-post measures were found on BMI. Taken together, these results indicated a large intervention effect of the core-stabilization functional intervention in muscle strength and endurance of the abdominals and hip-flexors muscles, a medium effect on flexibility of the lower back and hamstring muscles and these effects maintained in a 3-week retention period. On the contrary, no intervention effect was found on BMI.

The effect of the core-stabilization functional intervention program on self-reported weekly physical activity (Godin-Shephard's)

Repeated measures ANOVA showed no significant main effects of time, group, and interaction group x pre-post measures on self-reported weekly physical activity scores. These results revealed no intervention effect on self-reported weekly physical activity (Table 7).

Table 6: Mean, standard deviation, time-, group- and interaction-effects on physical fitness scores for the DCD experimental and DCD control group at pre-, post and follow up tests (T1, T2 & T3).

Physical fitness scores	DCDexp N=8			DCDcontrol N=16			Time effects (pre-post-follow up) df=2			Group effects (DCDexp-control) df=1			Interaction effects (between groups) df=23		
	T1 (SD)	T2 (SD)	T3 (SD)	T1 (SD)	T2 (SD)	T3 (SD)	F	p	η^2	F	p	η^2	F	p	η^2
Sit-up	17.38 (3.81)	21.75 (5.17)	22 (5.8)	14.75 (4.31)	14.56 (3.5)	14.13 (3.98)	8.96	.00*	.29	11.33	.00*	.34	13.04	.00*	.37
Sit & reach	13 (7.09)	15.38 (9.72)	15.25 (9.48)	10.81 (7.71)	12.63 (7.45)	12.25 (7.18)	8.97	.00*	.29	.61	.44	.02	.29	.64	.01
BMI	22.71 (4.4)	22.21 (3.9)	-	20.75 (1.93)	20.55 (2.24)	-	2.22	.15	.09	2.12	.15	.08	.38	.54	.01

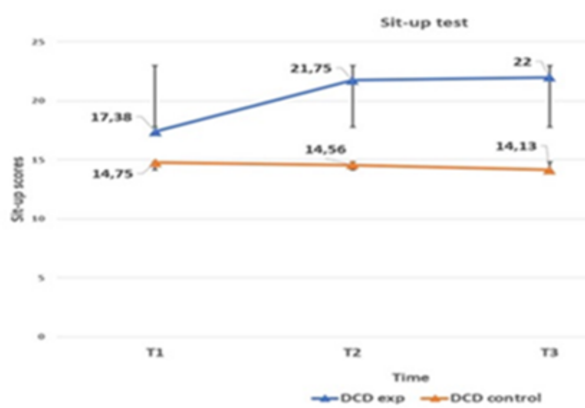
Note: Statistically significant findings (*, p < 0.05).

Table 7: Mean, standard deviation, time-, group- and interaction-effects on self-reported weekly physical activity scores for the DCD experimental and DCD control group at pre-, & posttests (T1 & T2).

Weekly physical activity scores	DCDexp N=8		DCDcontrol N=16		Time effects (pre-post-follow up) df=1			Group effects (DCDexp-control) df=1			Interaction effects (between groups) df=23		
	T1 (SD)	T2 (SD)	T1 (SD)	T2 (SD)	F	p	η^2	F	p	η^2	F	p	η^2
Strenuous	27 (24.99)	22.5 (20.96)	16.31 (9.42)	13.5 (13.14)	.97	.33	.04	2.78	.10	.11	.05	.82	.00
Moderate	11.25 (11.57)	11.87 (4.58)	10.31 (6.18)	10.31 (7.63)	.05	.82	.00	.17	.68	.00	.05	.82	.00
Mild	12.37 (20.12)	5.25 (4.74)	6.75 (7.54)	8.43 (8.35)	1.20	.28	.05	.10	.75	.00	3.16	.08	.12
Total	38.25 (31.46)	34.37 (24.14)	26.62 (9.90)	23.81 (16.61)	.62	.43	.02	2.32	.14	.09	.01	.90	.00

Note: Statistically significant findings (*, $p < 0.05$).

Figure 3: Sit-up scores significant effects on time (T1, T2, T3) according Bonferroni post hoc test.



The effect of the core-stabilization functional intervention program on reported HRQoL (TACQOL)

The TACQOL scales scores achieved by the experimental group in post-test were improved from those in pre-test, whereas those of the control group showed no significant progress. The results indicated a large intervention effect of the core-stabilization functional intervention on HRQoL, and more specifically on general physical functioning (BODY), independent daily functioning (AUTO), social contacts with parents, and peers (SOCIAL), on the occurrence of positive (EMOPOS), and the absence of negative moods (EMONEG). Taken together, in general there was an intervention effect on adolescents' health and functional status (Table 8).

Table 8: Mean, standard deviation, time-, group- and interaction-effects on self-reported HRQoL scores for the DCD experimental and DCD control group at pre-, & post-tests (T1 & T2).

HRQoL scores	DCDexp N=8		DCDcontrol N=16		Time effects (pre-post-follow up) df=1			Group effects (DCDexp-control) df=1			Interaction effects (between groups) df=23		
	T1 (SD)	T2 (SD)	T1 (SD)	T2 (SD)	F	p	η^2	F	p	η^2	F	p	η^2
BODY	26.12 (7.27)	30.87 (5.27)	30.43 (4.87)	31.87 (4.25)	15.84	.00*	.41	1.5	.2	.0	4.54	.04*	.17
AUTO	28.5 (4.27)	31.62 (1.06)	29.93 (2.83)	30.31 (2.35)	8.32	.00*	.27	.00	.95	.00	5.14	.03*	.18
SOCIAL	26.75 (3.88)	30.62 (1.5)	25.43 (4.66)	26.5 (4.13)	12.44	.00*	.36	2.9	.1	.1	4.03	.05*	.15
EMOPOS	8.87 (3.31)	12.87 (1.88)	10.68 (2.18)	11.37 (2.18)	14.36	.00*	.39	.03	.84	.00	7.17	.01*	.24
EMPONEG	8.87 (2.53)	11.5 (1.41)	9.06 (2.08)	9.56 (1.86)	9.55	.00*	.30	1.55	.22	.06	4.42	.04*	.16

Note: Statistically significant findings (*, $p < 0.05$).

Individual progress in motor performance (MABC-2) in both groups with DCD

Conclusive analysis of the individual results of the experimental, and control DCD group revealed great variations in progress. All adolescents in the experimental group showed individual progress on the MABC-2 total standard scores (motor performance / coordination), (Figure 4), and balance standard scores (Figure 5), but there was a considerable heterogeneity regarding these improvements. From the seven adolescents who had a clinical score (below the standard score 6) on the total score in the DCD experimental group, three adolescents moved to a score at risk (at, or above the standard score 6), and three to a score) that denotes no motor difficulty. One adolescent who had a very low clinical score (standard score 2) on the total score, moved to a higher, but still clinical score (standard score 4). One adolescent moved from a score at risk to a score that denotes no motor difficulty. The retention measurements results showed that the effect of the core-stabilization intervention was maintained 3 weeks after the end of the intervention, but scores tended to decline in some adolescents. The adolescents in the DCD control group showed a more irregular pattern (Figure 4). In this group one adolescent increased motor coordination scores, but fifteen did not establish any progress. Comparable results were found for the balance standard score (Figure 5). It is worth to mention that, figures 4 and 5 depict only the individual progress in motor performance, in each adolescent in both groups, as heterogeneity is a key factor in DCD.

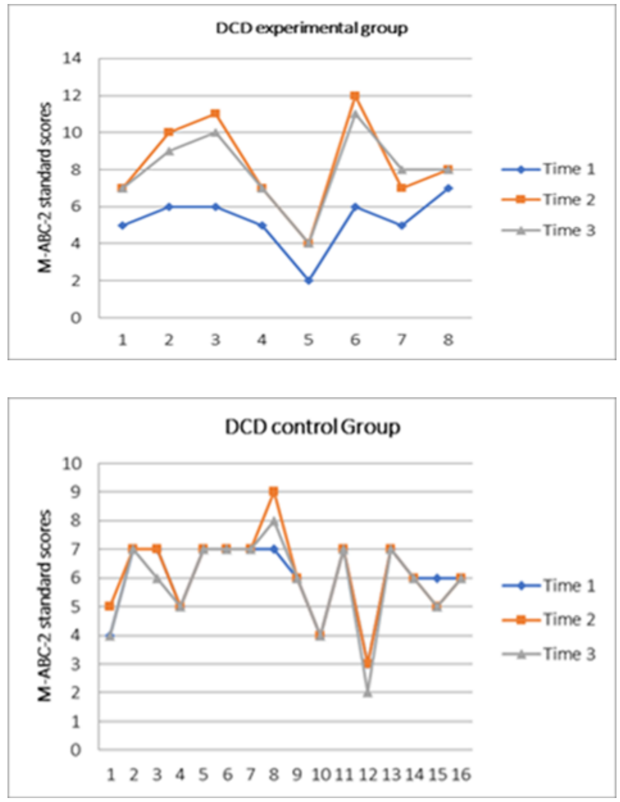
Discussion

As motor difficulties related to DCD continue to exist in adolescence, the findings of this study showed that a core-stabilization functional exercise intervention program had a significant positive effect on motor performance, health-related physical fitness, self-reported weekly physical activity, and HRQoL, in adolescents with motor difficulties. The most important was that some participants jumped from the category of severe motor difficulties, to the category of moderate, and typical motor coordination, after their participation in the intervention, according to MABC-2 assessment. The results will be discussed according to dependent variables examined.

Intervention effects on motor coordination and balance (MABC-2)

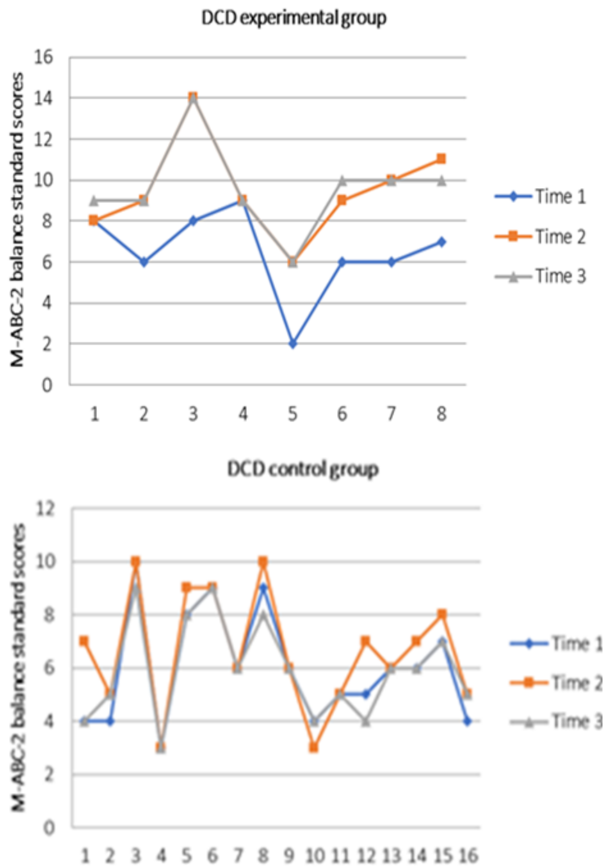
The eight adolescents who participated in the training program during the 12 weeks showed a significant increase on their MABC-2 total, and balance scores. The motor performance, and balance scores achieved by the experimental group at post-test were significantly improved from those at the pre-test, and maintained in the 3-weeks retention period, whereas those of the control group showed no significant progress.

Figure 4: Individual progress standard scores of MABC-2 total score on pre (T1), post (T2) and follow up (T3) test in the DCD experimental (n = 8) and DCD control groups (n = 16).



The functional exercise program included a training plan, and exercises with emphasis on stabilizing and strengthening the core, which aimed to improve motor performance in adolescents with motor difficulties. These findings are in accordance with the results of a study conducted by Au et al. (2014), who showed the effectiveness of a core stability program with a task-oriented motor training intervention, in improving motor proficiency in a child with DCD, Menz, Hatten, & Grant-Beuttler (2013), by examining gross motor function changes and improvements in manual coordination. Another study (Bhayani & Singaravelan, 2012) showed that a core

Figure 5: Individual progress standard scores of MABC-2 balance score on pre (T1), post (T2) and follow up (T3) test for the DCD experimental (n = 8) and DCD control groups (n = 16).



stabilization intervention program improved motor skills and increased participation in physical activity, in children and adolescents (6-16 years) with DCD. Accordingly, two studies by Kane and Bell (2009), and Kaufman and Schilling (2007) showed that strength training, and core stabilization programs improved fundamental movement skills and participation in physical activity, in children aged 5 and 9-11 years. Conclusively, in the present study the core-stabilization functional training program improved motor coordination and balance performance in adolescents with motor difficulties, and this result is in line with findings from other studies who conducted in children samples, but the most interesting was that these improvements were present in a 3-weeks follow up study.

Intervention effects on health–related physical fitness

Adolescents who participated in the training program showed a significant increase in abdominal, and hip-flexor muscle strength, and endurance, and in flexibility of the lower back, and hamstring muscles performance. The scores achieved by the experimental group at post-test were significantly improved from those at the pre-test, and maintained in the 3-weeks retention period, whereas those of the control group showed no significant progress. Similar studies, with different training approaches, and age of participants, showed that levels of physical fitness were improved (balance, strength, muscle endurance, motor coordination, body composition, flexibility, cardiorespiratory capacity, etc.), and the improvement of these abilities, led to a significant improvement in motor ability, and coordination in children with DCD (Au et al., 2014; Cacola et al., 2016; Fong et al., 2016a; Fong et al., 2016b; Giagazoglou et al., 2015; Kane & Staples, 2016; Kordi et al. 2016; Tsai et al., 2014). Studies which implemented an intervention training program based on Tae Kwon Do, in children aged 6-12 years with DCD (Fong, Tsang, & Ng, 2012; Fong, Chung, Chow, Ma, & Tsang, 2013), showed that this sport-based intervention improved their motor skills, and more specifically the ability of balance. Kane and Staples (2016) implemented a group training program for 5-7 aged children, including tasks focused on physical fitness, and found positive effects on motor skills. The study conducted by Giagazoglou et al. (2015), showed that a balance training program on a trampoline had adjustments, and improvements in balance ability in 8-9 aged children with DCD. Regarding BMI scores, no significant effects were shown in the present study. Evidence, indicated that children and adolescents with motor difficulties participate less in physical, and leisure activities (Raz-Silbiger, Lifshitz et al., 2015), so they have increased BMI values, and they are at higher risk for obesity-related chronic diseases (Hendrix, Prins, & Dekkers, 2014). The present study non-significant results regarding BMI may be explained by the fact that, adolescents in both groups were physical active before the intervention so their BMI was at normal levels already. Conclusively, in the present study the core-stabilization functional exercise program generally improved health-related physical fitness indexes, in adolescents with motor difficulties, and this result is in accordance with findings from other studies who conducted in children samples. Thus, the most interesting founding was that these improvements were present in a 3-week follow up study. However, there is a need for further research in this age group.

Intervention effects on self-reported weekly physical activity

Adolescents who participated in the training program showed no significant increase on their weekly physical activity. These results are not in accordance with the results from other studies in the literature (Rivilis et al., 2011). In the present study, the non-intervention effect in weekly physical activity may have been occurred due to the fact that, adolescents with motor difficulties were already physically active, and engaged in some extracurricular physical activity, before their participation in the intervention, and although the questionnaire was a valid and reliable instrument for use in adolescents, was not sensitive enough to detect small differences. Further research should focus on using a combination of self-reported questionnaires, and more objective instruments like pedometers, to record physical activity levels in adolescents with DCD.

Intervention effects on health-related quality of life (HRQoL) and functional status

Adolescents who participated in the training program showed a significant increase in their HRQoL, and functional status scores. Scores achieved by the experimental group at post-test were significantly improved from those at the pre-test, whereas those of the control group showed no significant progress. The results indicated a large intervention effect of the core-stabilization functional intervention program on HRQoL, and more specifically on general physical functioning, on independent daily functioning, on social contacts with parents, and peers, on the occurrence of positive, and the absence of negative moods. Taking together, in general there was an intervention effect on adolescents' health and functional status. To our knowledge, there are no studies that, examined any intervention effects on the improvement of HRQoL by improving motor ability in children, and adolescents with motor difficulties. In a review conducted by Monastiridi et al. (2020), most of the revised studies were descriptive and just recorded, and compared HRQoL in children with DCD, and their typically developing peers. In addition, Kane and Bell (2009) whose intervention program improved both motor ability, and participation in physical activity suggested that there had been a possible further improvement in HRQoL, in children and adolescents with motor difficulties.

Taking the findings together, the results of the present study was encouraging for further development and implementation of core-stabilization functional exercise programs, in adolescents with DCD. It is suggested that a physical fitness education approach, as a part of the school based physical education curriculum, should provide knowledge, skills, and motivation in adolescents with DCD (Hands & Parker, 2019). Moreover, combined this suggestion with the possibility to use a core-stabilization functional exercise program in a school setting that is applicable for post-school participation, in sport clubs, community based physical activity, and exercise settings, or home environments, provides a new solution for adolescents with a severe, or moderate delay in motor coordination. In this study, among the eight adolescents in the intervention group who had a clinical score on the total score, three adolescents moved to a score at risk, and three to a score that denotes no movement difficulty. One adolescent moved from a score at risk to a score that denotes no movement difficulty. A core-stabilization functional exercise program seemed to give adolescents with motor difficulties a better opportunity to improve their motor performance, their enjoyment and their participation in daily physical education lessons, and sport, preventing secondary consequences, given that, there is low recognition of this motor learning disability, and access, and funding for individual therapy programs are scarce (Hands & Parker, 2019). In general, this study provides additional evidence to the findings related to process-oriented interventions that a core-stabilization functional exercise program would be an important link in the positive cycle proposed by Monastiridi et al. (2020) that can inverse the negative cycle (Katartzi & Vlachopoulos, 2011), and reduces the activity-deficit hypothesis' (Green et al., 2011; Schoemaker & Smits-Engelsman, 2015) consequences, in adolescents with DCD.

Conclusions

Considering the limitations (participant drop outs), and merits, this research study showed that a core-stabilization functional exercise intervention program, as a process-oriented approach, had positive effects and improvements in most of the dependent variables in adolescents' motor competence, and overall performance. This means that the interventions, focusing on structural abilities (core stabilization, muscle strengthening, proprioception, balance, etc.) seemed to be effective in managing motor difficulties.

In conclusion, the physical education teacher is the one who, through daily contact with students, can observe all those "signs" that adolescents with motor difficulties show (motor and behavioral). Thus, physical education lessons should be adapted (Barnett & Hill, 2019) for encouraging effective participation not only in physical education classes, but in extracurricular sports programs, as well. However, there is a lack of intervention data in adolescents, so further research could contribute to the management of DCD difficulties, in this population.

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