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POSITIVE RELATIONS OF PHYSICAL FITNESS AND EXERCISE INTERVENTION PROGRAMS WITH MOTOR COMPETENCE AND HEALTH-RELATED QUALITY OF LIFE IN DEVELOPMENTAL COORDINATION DISORDER: A SYSTEMATIC REVIEW

Sofia G. Monastiridi[1],
Ermioni S. Katartzi[2],
Maria G. Kontou[3],
Thomas Kourtessis[4],
Symeon P. Vlachopoulos[5]
[1]BSc, MSc, PhD Student,
Department of Physical Education & Sport Science at Serres,
Faculty of Physical Education & Sport Sciences,
Aristotle University of Thessaloniki,
Greece
[2]Assistant Professor,
Department of Physical Education & Sport Science at Serres,
Faculty of Physical Education and Sport Sciences,
Aristotle University of Thessaloniki,
Greece
[3]Specialized Educational Staff,
Department of Physical Education & Sport Science at Serres,
Faculty of Physical Education and Sport Sciences,
Aristotle University of Thessaloniki,
Greece
[4]Professor,
Department of Physical Education and Sport Science, Komotini,
Faculty of Physical Education and Sport Sciences,
Democritus University of Thrace,
Greece
[5]Professor,
Department of Physical Education & Sport Science at Serres,
Faculty of Physical Education and Sport Sciences,
Aristotle University of Thessaloniki,
Greece

Abstract:
Developmental Coordination Disorder (DCD) is an impairment in the development of motor coordination creating varied problems and difficulties in children's and adolescent's daily life activities. As a result, the avoidance of participating in physical activity leads in low levels of fitness and also in secondary social and emotional problems.

Fitness levels in children and adolescents with DCD have been recognized as an important factor which influences their performance in daily activities and has a positive impact on their health-related quality of life (HRQOL). Surveys showed that every domain in HRQOL (motor, cognitive, emotional, social) is significantly lower in children with DCD compared to their peers. These data showed that intervention is very important for improving motor skill performance and HRQOL, too, in children and adolescents with DCD. The present study aimed to systematically review the literature published in peer reviewed journals and to summarize information about possible relationships between intervention approaches focused on physical fitness and exercise, participation in physical activity and HRQOL, in children and adolescents with DCD. Studies which examined the effect of fitness and exercise intervention programs on motor competence and HRQOL in children and adolescents with DCD were also, included. The review of the literature has shown that several intervention programs developed for DCD population, focusing to improve motor ability, derived from occupational therapy, physiotherapy, medicine, dietetics and education scientific areas. Generally, the present review focused on two basic approaches in clinical practice regarding intervention programs for DCD individuals: task-oriented and process-oriented approach. The task-oriented approach aims to improve the performance of a specific skill and on the other hand the process-oriented approach aims to identify the underlying processes or dysfunctions which the individual has not developed adequately according to his/her age, although they are considered to be necessary for successful performance and acquisition of motor skills. Children and adolescents with DCD seemed to report poorer HRQOL than their typically developing peers. However, HRQOL in children and adolescents with DCD needs further investigation. In addition, there is a need of research in interventions focused on fitness and exercise programs with an ultimate goal to improve motor ability and HRQOL too; through participation in such interventions children and adolescents with DCD, may be possible to break the negative cycle of physical activity avoidance, reversing it to a positive one. It is concluded that, there are possible positive relationships between fitness and exercise intervention programs, motor competence and HRQOL in children and adolescents with DCD. Future research should focus on examining whether and how such interventions may eliminate functional constraints leading to an engagement in the positive cycle of physical activity, with a further improvement in HRQOL in DCD population.

Keywords: motor ability, physical activity, process-oriented intervention

1. Introduction

Developmental coordination disorder (DCD) is a neurodevelopmental motor disorder, which leads to impaired functional performance in activities of daily living and moreover the impairment is increased with co-occurring conditions such as dyslexia and ADHD. Consequences of DCD include reduced participation in team play and sports, poor self-

esteem, and sense of self-worth, emotional or behaviour problems, impaired academic achievement, poor physical fitness and reduced physical activity and obesity (DSM-5, 2013).

Studies have shown that children with DCD have lower levels of participation in physical activity than their peers without DCD (Cairney, Hay, Faught & Hawes 2005; Cairney, Hay, Faught, Mandigo & Flouris, 2005; Watkinson, Dunn, Cavaliere, Calzonetti, Wilhelm & Dwyer, 2001). This is due to their reduced motor ability level and negative judgments about their motor performance by their parents, teachers, and peers. As a result, they tend to avoid participating in team play and sports, which in turn leads to social isolation and failure to develop the skills necessary for successful interpersonal relationships (Smoll, 1974). Motor competence has been recognized as a factor that may determine the social status of children among their peers (McMath, 1980). Children with DCD tend to have low social status that may become evident through situations such as not being selected or being the last one to be selected to participate in sports teams by their peers. As a result, they tend to avoid participating in team games and physical activities. Avoiding sport participation may lead not only to a decrease in children's perceived competence, but also to a deterioration of motor performance due to a lack of practice (Cermack & Larkin, 2002; Katartzi & Vlachopoulos, 2011). These factors lead to a negative cycle of physical activity avoidance which may also lead to negative consequences in terms of children's physical fitness (Katartzi & Vlachopoulos, 2011). This negative cycle leads to lower physical fitness levels and this has been shown in several studies in which children with DCD display low levels in components such as, cardiorespiratory fitness, muscular strength and endurance, anaerobic capacity, power, flexibility, balance, coordination, and body composition (Cairney, Hay, Veldhuizen & Faught, 2010; Cantell, Crawford & Doyle-Baker, 2008; Haga, 2009; Li, Wu, Cairney & Hsieh, 2011; Rivilis, Hay, Cairney, Klentrou, Liu & Faught, 2011). This poor physical fitness status moreover reduces their participation in physical activity and this could have a negative consequence in children's health, well-being and health-related quality of life (Zwicker, Harris & Klassen, 2012).

Quality of life (QOL) is a global assessment of life as a whole, and reflects an overall sense of well-being including positive and negative feelings. Health-related Quality of Life (HRQOL) includes a set of concepts and personal perceptions according to physical, psychological, and social functioning (Meciejwski, Patrick & Williamson, 2005). The notion of HRQOL has been described as an exclusive personal perception and represents the way that individuals understand physical status, recruiting physical, emotional, and other dimensions (Fayers & Sprangers, 2002).

Physical activity has been found to decrease psychological and physiological stress indices, increase self-efficacy, and has been associated with mood benefits, and positive self-concept and self-esteem (Raustorp, Pangrazi & Stahle, 2004; Rubin & Coplan, 2004). Health-related Quality of Life depicts the health enhancement model of physical activity, such as increases in the vitality, enhanced mood states, and personal enjoyment (Singer, Hausenblas & Janelle, 2001). The campaign of World Health Organization has recognized

physical activity as a significant key to change HRQOL (WHO, 2018). In addition, various studies have shown that DCD affects negatively children's HRQOL (physical, motor, cognitive, mental, social, and emotional domains) (Caçola & Killian, 2018; Dewey & Volkovinskaia, 2018; Engel-Yeger & Hanna Kasis, 2010; Flapper & Schoemaker, 2008; Karras, Morin, Gill, Izadi-Najafabadi & Zwicker, 2019; Raz-Silbiger, Lifshitz, Katz, Steinhart, Cermak & Weintraub 2015; Stephenson & Chesson, 2008). The research of HRQOL in children and adolescents with DCD is of great importance, and there is a need for more targeted intervention programs for improving every domain in HRQOL.

Over the past 40 years, several intervention programs developed for DCD population, focusing to improve motor ability, derived from occupational therapy, physiotherapy, medicine, dietetics and education scientific areas (Bart, Podoly & Bar-Haim, 2010; Dunford, 2011; Peens, Pienaar & Nienaber, 2008; Sugden & Chambers, 2003). However, there is a lack of interventions focused on exercise and physical fitness.

Generally, there are two basic approaches in clinical practice on motor intervention: *task-oriented* and *process-oriented approach*. A *task-oriented approach* basically aims to improve the performance of a specific skill, behavior, or task without an emphasis on underlying processes; rather, using a variety of practices to promote skill generalization (Schmidt, 1975; Sugden & Chambers, 2003). On the other hand *process-oriented approach*, is another approach used in children and adolescents with DCD and basically aims to identify the underlying processes (or dysfunctions) which the child has not developed adequately for his/her age and are deemed necessary for successful performance and acquisition of motor skills (Polatajko & Cantin, 2005; Sugden, 2007; Sugden & Chambers, 1998; Sugden & Wright, 1998; Wilson, Patrick, Thomas & Maruff, 2002). The process-oriented approach is based on the assumption that ideal motor functioning is the result of proper function of neuromuscular system (Mandich, Polatajko, Macnab & Miller, 2001; Mathiowetz & Haugen, 1995). As for children with DCD, the improvement of body function, such as sensory integration, kinaesthetic perception, muscle strength, core stability, visual-motor perception and functions similar to them, leads to better skill performance (Barnhart, Davenport, Epps & Nordquist, 2003; Polatajko, Kaplan & Wilson, 1992; Sugden, 2007). For example, a strength training program may be considered as a process-oriented intervention method, if it is aimed to increase involved muscle strength (Smits-Engelsman, Blank, van der Kaay, Mosterdvan der Meijs et al., 2013). It has been claimed that, identifying the dysfunctional processes as children use them in a variety of ways to perform fundamental and sport-specific motor skills, will allow the development of intervention programs appropriate to improve the basic deficit (Sveistrup, Burtner & Woollacott, 1992). Regarding both approaches, study findings have strongly supported the effectiveness of them, but the reasons for such effectiveness remain unclear

The aim of the present study was to systematically review the literature published in peer reviewed journals and to summarize information about possible relationships between intervention approaches focused on physical fitness and exercise, participation in physical activity and HRQOL, in children and adolescents with DCD. This review

should provide valuable insight on the implementation of appropriate intervention strategies, focused on enhancing physical fitness, and physical activity participation, targeting to reverse the negative cycle and further improvement in HRQOL aspects, among children and adolescents with DCD.

2. Material and Methods

The systematic search strategy used in this review included an electronic data-based search of MEDLINE, PUBMED, and SCOPUS. Studies, which included, examined the effect of physical fitness intervention programs that aimed to increase motor competence in children and adolescents with DCD. Keywords used to perform the literature search included terms commonly used by researchers and service providers working with children with DCD: clumsy, developmental coordination disorder (DCD); motor impairment; motor skills disorder; intervention; physical fitness; physical activity; health-related quality of life (HRQOL); motor skill training; exercise training; exercise program. The following information was extracted from each study: study design, sample source, terms and definitions of DCD, mean age or age range of participants in DCD and control groups, outcome measures relevant to HRQOL, physical fitness, physical activity, intervention programs, and variables measured.

2.1 Data Extraction and Synthesis

One author extracted data which included study types, participant characteristics, group size, intervention characteristics, and outcome characteristics, while another reviewer checked the extracted data.

3. Results

3.1 Description of studies

A total of 22 studies were included in this systematic review regarding interventions focusing on improving physical fitness, physical activity, and HRQOL. Results are presented shown in Tables 1 and 2. More specifically, Table 1 depicts studies that implemented intervention programs to improve physical fitness and physical activity variables in children with DCD.

Table 1: Physical fitness and physical activity intervention programs in children/adolescents with DCD

Authors	Study design	Sample	Aim	Assessment tools	Measure(s) / Interventions	Outcomes
Smits-Engelsman et al., 2017	Pre-post experimental design	6–10 years old children with lower levels of motor coordination (n =17) and typically developing peers (TD) (n = 18)	The effect of a 5-week training program using Wii Fit games on physical fitness	DSM-5 criteria MABC-2 Functional Strength Measurement (FSM) anaerobic fitness, balance, running speed and agility (BOTMP-2) Enjoyment rating scale	20 min of active Nintendo Wii Fit gaming on the balance board, twice a week for a period of 5 weeks (10 training sessions) Choice of ten games aiming to functional strength, anaerobic fitness, balance skills and agility	Both groups improved functional strength and anaerobic fitness DCD group benefited more in balance skills, while the TD group benefitted in running speed and agility
Kordi et al., 2016	Randomized controlled clinical trial, single-blind, pre-post-test assessment	7-9 years old children with DCD (n = 30), assigned to two groups (experimental /control)	The effects of a strength training program on static and dynamic balance	Hand held Dynamometer BOTMP-2 MABC-2	Experimental group: A 60 min session of strength training program (core and lower limb muscles through static and dynamic balance tasks -12 weeks /24 session) Control group: ordinary physical education class	The experimental DCD group significantly increased muscle strength and improved static balance
Fong et al., 2016	Randomized single-blinded, parallel group controlled trial	6–10 years old children with DCD (n = 161) assigned to three groups (two experimental/ FMT & FMPT) and a control)	Comparison of the effectiveness between functional movement power training (FMPT) and functional movement training (FMT) in improving neuromuscular and balance performance and balance strategies in children with DCD	DSM-5 criteria BOTMP-2 FMPT FMT	FMT group received task-specific training concurrent with electromyographic (EMG) biofeedback. FMPT group received power/resistance training after the FMT Both groups attended 2 training sessions per week (1.5 hours per session for 12 weeks) The control group continued their usual daily activities	The FMPT program was more effective than the conventional FMT program in improving balance strategies and neuromuscular performance in children with DCD A retention effect was recorded, too

					Measurements were taken pre, post, and 3 months after the end of the intervention period (retention)	
Authors	**Study design**	**Sample**	**Aim**	**Assessment tools**	**Measure(s) / Interventions**	**Outcomes**
Farhat et al., 2015	Intervention study	Boys (n=41), assigned to three groups: 14 DCD training-group (mean=8.8 years), 13 DCD non training-group (mean age 8.5 years) & 14 typically developing (TD) children (mean age 8.6 years)	The effect of motor skill training on exercise tolerance and cardiorespiratory fitness in children with DCD	SM-IV criteria MABC-2 6-min walking test (6MWT) Pictorial Children's Effort Rating Table (PCERT) Cardiopulmonary exercise test (CPET)	60 min sessions, 3 times a week for 8 weeks skill and agility training A variety of functional tasks (agility, balance, core stability and movement coordination)	Increase in cardiorespiratory performance at both anaerobic threshold (AT) and maximal intensity Improvement in walking distance, in aerobic endurance and exercise tolerance in DCD training group
McIntyre et al., 2015	Pre-Post-Intervention study	35 adolescents with low motor competence Boys (n=25) and girls (n=10) 13 to 17 years No control group.	The effect of an exercise intervention program to improve aerobic fitness, strength, and self-perceptions in the physical domain.	Physical Self Perception Profile and Perceived Importance Profile McCarron Assessment of Neuromuscular Development (MAND)	Resistance exercises (leg press, chest press, bridge, curl-ups and ankle raises) 5-minute aerobic exercise (bike ergometer, rowing ergometer, cross trainer or recumbent bike) Two sessions per week for 13 weeks	The intervention program improved adolescent physical self-perceptions, in particular males, with improvements in those sub domains specifically related to the exercise program (Sport competence, Physical condition, Physical strength, Attractive body)
Au et al., 2014	Randomized controlled pilot trial	6-9 years old DCD children (n = 22). DCD core training group (n=11).	Comparison of the effectiveness between a core stability training program and a task-oriented motor training program in improving	Short Form of the BOTMP-2 Sensory Organization Test at pre- and post-intervention	Both groups underwent a face-to-face training session once per week for 8 weeks They were also instructed to carry out home exercises on a daily basis during the intervention period	Both training groups improved motor proficiency

		DCD task-oriented group (n=11)	DCD children's motor proficiency			
Authors	**Study design**	**Sample**	**Aim**	**Assessment tools**	**Measure(s) / Interventions**	**Outcomes**
Jelsma et al., 2014		28 children with balance problems (BP) and 20 typically developing (TD) children (6-12 years old) BP/experimental group- TD / control group	To examine differences in dynamic balance control, motor skills and Wii Fit scores on a Wii Fit game between BP and TD children To evaluate children's enjoyment	MABC2 BOT2 Wii Fit ski slalom test Enjoyment scale	The intervention consisted of practicing the Wii Fit Plus Balancing Games in a 30-min session, 3 times a week for 6 weeks	BP children were less proficient than TD children in playing the Wii Fit game. Wii Fit improved BP group's motor performance The improvement was larger after intervention than after a period of non-intervention Both groups enjoyed participation
Mombarg et al., 2013	Randomized controlled trial	29 children (23 boys, 6 girls) aged 7–12 years Control group with typically developing children (TD), (n=14) and experimental group with motor delays (n=15)	The effect of a Wii-balance board training on balance performance The effects of the Wii-intervention on balance related skills	M-ABC-2 BOT-2	Experimental group trained on the Wii-balance board with the Wii-fit-plus1 software for 6 weeks Three training sessions of 30 min per week	The M-ABC-2 and the BOT-2 total balance-scores of the experimental group improved significantly The Wii-balance board is an effective intervention for children with poor balance skills No effect in running speed and agility was recorded
Menz et al., 2013	Case study	A 6 year & 11months old girl, with apraxia, hypotonia, & demonstrating motor delays	To examine gross motor function changes following strength training	Canadian Occupational Performance Measure (COPM) DCDQ'07	Intervention: twice a week for 12 weeks - 24 strength training sessions were completed using Universal Exercise Unit	Significant improvement on BOTMP-2 and the COPM scores and a rise in DCDQ'07scores above the range where DCD is suspected

		consistent with DCD		TGMD-2 BOTMP-2		No significant changes in strength
Authors	**Study design**	**Sample**	**Aim**	**Assessment tools**	**Measure(s) / Interventions**	**Outcomes**
Fong et al., 2013	Randomized controlled trial	Children with DCD (n=21) experimental group Children with DCD (n=23) control group Typically developing (TD) children (n=18). Mean age: 7.6 ± 1.3 years	Identifying the developmental status of reactive and static balance control and isokinetic knee muscle strength in children with DCD The effect of short-term intensive Tae Kwon Do (TKD) training on isokinetic knee muscle strength and reactive and static balance control The association between knee muscle strength and balance performance in children with DCD after short-term TKD training	Isokinetic machine (with low moderate and high movement velocities) a Motor Control Test (MCT) a Unilateral Stance Test (UST)	DCD-TKD training group attended one-hour TKD training session for 12 consecutive weeks Each participant in the DCD-TKD group prescribed TKD home exercises Pre-Post assessment one month before the TKD intervention and again within two weeks of its completion	The TKD training program in children with DCD showed improvements in isokinetic knee muscle strength at 180°/s and static single-leg standing balance control, but no benefit from improved reactive balance control
Bhayani & Singaravelan, 2012	Randomized Control Trial	Children with DCD (n=27) Intervention group (n=13) Control group (n=14) 6-16 years	The effect of a core stability training program in children with DCD to promote and improve task specific physical activity	BOTMP CSAPPA A five-point facial hedonic scale	Intervention group: core stability training program and task specific physical activity (3 session for 6 weeks – 60-min each) Control group: only task specific physical activity (3 session for 6 weeks – 20-min each)	Statistically significant difference was found in the average scores of BOTMP and CSAPPA in the intervention group In Five Point Facial Hedonic scale there was an

						improvement in the intervention group
Authors	**Study design**	**Sample**	**Aim**	**Assessment tools**	**Measure(s) / Interventions**	**Outcomes**
Winnie et al., 2010	Randomized controlled pilot intervention study	23 children (19 boys - 4 girls) with DCD -Mean age 8 years assigned to 2 groups Group-based training group (n=12) Individual-based training group (n=11)	The effect of group-based & individual-based motor skill training program in motor performance in children with DCD	MABC-2 Parental satisfaction questionnaire	Group-based training: a motor training program once a week/8 weeks in a group setting Individual-based training: the same training program on an individual basis Each child was also instructed to perform home exercises on a daily basis. Functional tasks & agility, balance, core stability & movement coordination exercises	Significant reduction in MABC-2 total impairment score in both groups The change in total impairment score did not differ significantly between the 2groups Parents perceived the training programs to be beneficial, not only for the children but also for themselves
Kane & Bell, 2009	Case reports documents	3 children, 9–11 years old with DCD	The effect of a program on motor skills, self-perceived adequacy for physical activity, balance, strength & core stability activities	DCDQ COPM BOTMP-SF CSAPPA	6-week group exercise program/ twice a week & a home program included core stability, fitness activities & task-specific intervention	Each child improved in one or more areas of motor skill, self-efficacy for physical activity, and core stability outcome measures Physical activity promotion in this population can improve Health Related Quality of Life and reduce health risks
Kaufman & Schilling, 2007	Case report	A 5-year-old child with poor body awareness and DCD	The effect of a strength training program in muscle strength, gross motor function, and proprioceptive position sense	BOTMP Proprioceptive tests Physical therapy testing	A 12-week strength training program/twice a week for 20-30 min	Improvements in muscle strength, gross motor function, and proprioception

Based on the literature's review regarding physical fitness and physical activity intervention programs in children/adolescents with DCD (Table 1), it was found that there is a limited number of studies aiming to improve motor coordination in children and adolescents with DCD, through intervention approaches based on exercise and physical fitness programs.

The results have shown that, exercise intervention programs can improve both health-related and performance-related physical fitness and motor competence in children with DCD. There are intervention approaches based on physical fitness which focused on children with DCD and included the assessment of strength training, core stability, fitness activities, balance and task-specific interventions, aiming to improve muscle strength, gross motor function, proprioception and physical activity promotion with likely positive effects on health-related quality of life and a reduction of health risks. Moreover, the reviewed studies focused mainly on school-aged children and only two studies included adolescents. Some of the studies did not use a control group and in some studies the control group was typically-developing children who did not participate in the intervention program compared to DCD children. Regarding interventions, only two studies consisted of task-specific (oriented) procedures and most of them consisted of process-oriented procedures such as, physical fitness both health and performance-related (strength training tasks, core stability exercises, balance, motor coordination, agility, anaerobic performance).

In addition, one study, examined the effect of a short-term intensive Tae Kwon Do program and two studies examined the effect of a Nintendo Wii Fit training program on balance and physical fitness indexes. The frequency of all these interventions varied from one to three sessions per week, with a duration of twenty to ninety minutes per session. Program duration varied from five to thirteen weeks and/or eight to twenty-six consecutive sessions. In addition, only two studies examined the retention effect of the above interventions, in a period of three months the one study, and two weeks the other one, respectively. In conclusion, the review of the above studies highlights the need for further research on process-oriented interventions in children and especially adolescents, because DCD is a lifelong situation for most of the children, aiming not only to examine their effect on physical fitness variables, and physical activity participation, but their relationship with perceived health related quality of life.

Table 2: Health related quality of life in children and adolescents with DCD

Authors	Study design	Sample	Aim	Assessment tools	Measure(s) Interventions	Outcomes
Karras et al., 2019	Cross-sectional design	50 children (8–12 years) with DCD and their parents Compared to normative KidScreen-52 data	Description of health-related quality of life (HRQOL) in children with DCD compared to typically-developing children (TD) HRQOL perspectives of children with DCD and their parents Predictors of HRQOL for children with DCD	MABC-2 DCDQ KidScreen-52 Strength and Difficulties Questionnaire (SDQ)	-	DCD contribute to lower perceived HRQOL Children with DCD and their parents report significantly lower HRQOL across numerous domains Findings inform therapeutic targets for children with DCD, beyond motor skill intervention
Dewey & Volkovinskaia, 2018	Pilot study	Adolescents with DCD (n=9), ADHD (n=9), DCD and ADHD (n=10), and typically developing adolescents (TD), (n=16)	A better understanding of HRQOL and peer relationships in adolescents with DCD and ADHD, using both quantitative and qualitative data	KIDSCREEN-52 Health-Related Quality of Life Questionnaire Peer Relations Questionnaire for Children (PRQ) Semi-structured interview	-	DCD and ADHD was associated with poorer HRQOL Adolescents with DCD and ADHD experience significantly higher levels of peer victimization than TD adolescents HRQOL and peer relationships are significantly associated in adolescent respondents
Caçola & Killian, 2018		96 children with reported DCD (6 to 12 years old) and their parents	The comparison of HRQOL in a DCD sample with normative sample of typically developing children, and a sample of children reported to be living with a chronic health condition, using two standardized parent reports for evaluation of HRQOL	PedsQL Measurement Model KIDSCREEN	-	Scores on both instruments state that children with DCD have lower overall HRQOL and moreover lower than HRQOL of a sample of children experiencing chronic illness

Authors	Study design	Sample	Aim	Assessment tools	Measure(s) Interventions	Outcomes
Raz-Silbiger et al., 2015	Correlative study	Parents of 22 children with DCD and parents of 55 typically developing (TD) children, aged 6-11 years old	The relationship between motor skills, participation in leisure activities and quality of life (QOL) within a temporal context (school year vs. summer vacation and school days vs. weekends) among children with and without DCD	MABC-2 Medical and Motor Questionnaire Participation in Physical Activity and Sedentary Behavior Questionnaire (PQ) PedsQL 4.0 Generic Core Scales	-	In DCD group, positive correlations of balance scores with participation in sedentary activities. In both groups, balance, aiming and catching skills were related to the physical and school aspects of QOL Positive correlation of participation in vigorous activities in the summer with social and school QOL In TD group, negative correlation of participation in vigorous activities during the school year with school QOL In both groups, negative correlation of participation in sedentary activities during school days with school QOL Parents' perceptions of their children's QOL related to the level of activeness of the leisure activities
Flapper & Schoemaker, 2013		N=65 children with specific language impairment (SLI), 5-8 years old, assigned to two groups: SLI-no DCD (n=44) SLI-DCD (n=21)	The exploration of DCD co-morbidity in children with SLI The assessment of which motor skills are most affected The investigation of the impact of SLI on QOL and the additional impact of comorbid DCD	MABC-2 DCDQ and/or MOQ-T TNO-AZL-Child-Quality-Of-Life Questionnaire (TACQOL)	-	SLI-DCD group showed lower mean overall-, motor-, autonomy-, and cognitive domain-QOL scores Assessment of QOL is warranted, in order to assess which domains are affected in children with SLI with or without DCD

						About one third of children with SLI can also be diagnosed with DCD
Authors	**Study design**	**Sample**	**Aim**	**Assessment tools**	**Measure(s) Interventions**	**Outcomes**
Wuang et al., 2012		A convenience sample of 369 children with DCD (144 girls; mean age: 11.2 ± 3.66 years) and 360 children with typical development (TD), (146 girls; mean age: 11.4 ± 4.09 years)	This study measured health-related quality of life (HRQOL) in children with DCD and their parents	The Bruininks—Oseretsky Test of Motor Proficiency Child Health Questionnaire-Parent Form 50 12-Item Short Form Health Survey (SF-12) Beck Depression Inventory (BDI) Beck Anxiety Inventory (BAI)	-	Although the two groups had comparable physical health, the DCD group had significantly lower HRQOL in all psychosocial domains Parents of children with DCD had significantly lower HRQOL for both SF-12 and BAI HRQOL of the parents was unassociated with the motor proficiency of the children DCD significantly affected multiple HRQOL domains in both the child with DCD and parents
Flapper & Schoemaker, 2008	Pilot study	Healthy children (n=23) ADHD/DCD with methylphenidate (MPH) (n=23) ADHD/DCD without MPH control group (n=23) Mean age 8.6 years Child/parent perceived HRQOL	Investigate the impact of the combined diagnoses of DCD and ADHD on HRQOL The effectiveness of methylphenidate (MPH) on HRQOL	Dutch-Child-AZL-TNO-Quality-of-Life (DUX-25) TNO-AZL-Child-Quality-of-Life (TACQOL) questionnaire	4-week, open-label MPH study, after MPH-sensitivity was established, in a double-blind, placebo-controlled trial	ADHD/DCD group improved HRQOL scores and also demonstrated a significant improvement in ADHD symptoms and motor functioning Additional motor therapy will still be needed in about half of the children with ADHD/DCD receiving MPH, within multimodal treatment including educational and psychosocial assistance

The reviewed studies focusing on the assessment of HRQOL and the implementation of intervention programs in improving HRQOL in children with DCD are depicted in Table 2. However, only one study aimed to improve HRQOL using an intervention program based on a pharmaceutical approach, in children with a diagnosed comorbidity of ADHD and DCD. Most of the reviewed studies were descriptive and they compared HRQOL in children with DCD and their typically developing peers using child and parent reports. It was demonstrated that DCD is a situation that contributes to lower levels of HRQOL not only in children, but in their parents, as well. In addition, it was found that perceived HRQOL in DCD children is even poorer than that in children experiencing chronic illness. Only one study examined the relationship between participation in leisure activities, motor skills, and HRQOL and found positive correlations between them. Parents' perceptions of their children's HRQOL were also found to be related to objective measurements of physical activity during participation in leisure-time activities. Moreover, most of the above research was focused on children.

In conclusion, there is a need for further research to examine process–oriented interventions (e.g. physical fitness programs), aiming to improve the individual constraints, in an attempt to reverse the negative cycle of physical activity avoidance, and increase lifelong physical activity engagement, leading to reduction of health risks, and improvement in HRQOL aspects, in children and especially adolescents with DCD.

4. Discussion

The purpose of the study was to conduct a systematic review of the literature published in peer reviewed journals aiming to summarize information about possible links between intervention approaches targeting to the enhancement of physical fitness and exercise behavior in children and adolescents with DCD.

A perusal of the findings of the present review reveals that physical fitness and exercise-related interventions that included strength training, core stability, fitness activities, balance and task-specific programs improved physical fitness (muscle strength, balance, aerobic capacity) both health-related and performance-related, and motor competence, mainly in children with DCD, aiming to improve muscle strength, gross motor function, proprioception, and physical activity promotion with likely positive effects on health-related quality of life, and a reduction of physical health risks.

However, very few studies including adolescents revealed that DCD is a situation that persists in adolescence, affecting, not only performance in motor and perceptual tasks, but social and academic aspects as well (Cantell, Smyth & Ahonen, 1994). In the study conducted by Cantell et al., (1994), it was found that adolescents with DCD had fewer social hobbies and pastimes, had lower academic achievements, and lower academic ambitions for their future, and believed they were less physically and scholastically competent than their typically developing peers. However, they did not report low evaluations of their social acceptance or self-worth. Hence, it seems that there is a need to conduct intervention studies in adolescents in an attempt to reverse the

negative effects of the DCD condition and their negative impact on psychosocial aspects and HRQOL.

Moreover, it was presently shown that among children with DCD and based on parents' reports on their children's HRQOL there was a relationship between HRQOL, participation in leisure physical activities, and motor abilities (Raz-Silbiger, Lifshitz, Katz, Steinhart, Cermak & Weintraub, 2015). Health Related Quality of Life in DCD individuals was mainly measured by the TACQOL instrument which assesses physical, psychological, social, autonomy and cognitive health of the child. There is a strong consensus that physical activity is associated with health-related quality of life (HRQOL) (Brown, Bowling & Flynn, 2004; De Vreede, Van Meeteren, Samson, Wittink, Duursma & Verhaar, 2007; Mitchell & Barlow, 2011; Tessier, Vuillemin, Bertrais, Boinia, Le Bihana et al., 2007; Vuillemin, Boini, Bertrais, Tessier, Oppertnb et al., 2005). Studies have indicated that physical activity can enhance overall HRQOL and also influences individual dimensions that compose the construct concept of HRQOL (Rejeski & Mihalko, 2001; Spirduso & Cronin, 2001).

Physical activity can improve HRQOL through social interaction, substantial time use and empowerment (Alexandratos, Barnett & Thomas, 2012). Although individuals who participated in regular physical activities showed high level of perceived HRQOL, greater improvement was observed in the social functioning domain (Wendel-Vos, Schuit, Tijhuis, Kromhout et al, 2004). Similarly, the benefits of physical activity on components of HRQOL were associated with increased general health, vitality, physical functioning, and psychological health even more with a decrease in body bodily pain, depression, and stress (Atlantis, Chow, Kirby & Fiatarone-Singh, 2004). The fact that, only one study examined the relationship between physical activity and HRQOL in children with DCD, stresses the need for further research in the domain of HRQOL, focusing on the implementation of interventions using physical fitness programs aiming to an improvement in all aspects of HRQOL, not only in children, but also in adolescents with DCD.

According to Katartzi and Vlachopoulos (2011), children with DCD tend to avoid participation in team games and physical activities, because of their low perceived motor competence, or negative judgments by their parents, teachers, and peers. Avoiding sport participation may lead not only to a decrease in children's perceived competence, but also to a deterioration of motor performance, due to a lack of practice and as a result, they are engaged in a negative cycle, which may also have negative consequences in children's physical fitness. However, there is a number of other mediating factors such as individual factors (e.g., genetic predisposition or psychological such as self-perception and motivation), and environmental factors (e.g., physical constraints) that may influence the development of physical fitness in children with DCD through active participation in physical activity by reversing the negative cycle of physical activity avoidance, with positive effects on HRQOL.

In addition, based on Newell's constraints model (1986), there are factors that either facilitate or restrict motor development and behaviour. According to Newell

(1986), the development of new motor behaviours emerges as a result of changing individual constraints, environmental restrictions, and task constraints. Environmental constraints can be related to the physical environment, or sociocultural factors, such as terrain, surface, space, temperature and characteristic of the home and family. Individual constraints refer to organismic/physical factors and divided into two categories: structural and functional constraints such as weight, height, body composition (structural constraints) and speed, coordination, postural stability, strength, balance, flexibility (functional constraints), (Gabbard, Caçola & Bobbio, 2009).

Based on previous knowledge as depicted in Newell's (1986) theory and the negative cycle of physical avoidance stated by Katartzi and Vlachopoulos (2011), it seems that DCD children have to cope with their functional constrains like motor coordination, in order to develop new motor behaviours. The implementation of an intervention program aiming to eliminate individuals' functional constraints, in order to improve motor ability in children/adolescents with DCD, and further increase their participation in physical activity, it is imperative as children/adolescents with DCD lack physical movement opportunities. Based on Newell's theory, an intervention program, aiming to eliminate functional constraints of the individual, such as speed, coordination, postural stability, strength, balance, flexibility (Gabbard et al., 2009), constraints that have been reported in the literature for DCD individuals (Cairney, Hay, Veldhuizen & Faught, 2010; Cantell et al., 2008; Haga, 2009; Li, Wu, Cairney & Hsieh, 2011; Rivilis et al., 2011), could interrupt the negative cycle or reverse it as depicted in Figure 1.

This positive cycle stresses the effect of physical fitness intervention programs in eliminating individual's functional constraints in adolescents and children with DCD and thus increasing physical fitness and motor competence aspects, which in turn improve participation in physical activity. Such participation may further eliminate individuals' functional constraints, leading to increased physical fitness and motor competence.

As HRQOL is an aspect that has a strong relationship with physical activity participation in adolescents and children with DCD (Caçola & Killian, 2018; Dewey & Volkovinskaia, 2018; Engel-Yeger & Hanna Kasis, 2010; Flapper & Schoemaker, 2008; Karras et al., 2018; Raz-Silbiger et al., 2015; Stephenson & Chesson, 2008), the combination of all these aspects regarding physical fitness intervention programs, aiming to improve the aspects that constitute the constraints referred by Newell (1986), may also increase participation in physical activity and also improve HRQOL in adolescents and children with DCD, too.

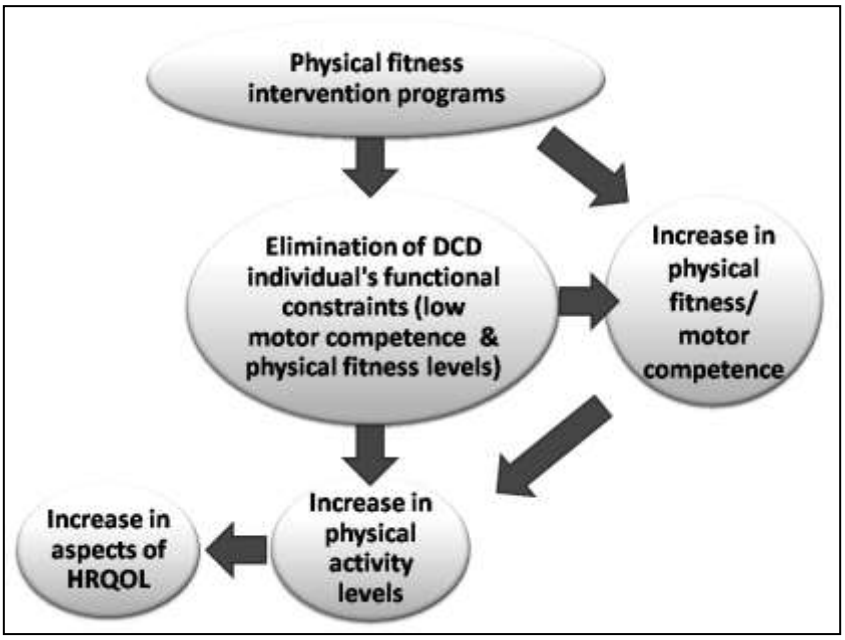

Figure 1: The positive cycle, depicting the possible effect of fitness intervention programs in increasing motor competence - physical fitness levels, physical activity participation and HRQOL in adolescents and children with DCD

5. Conclusion

It is concluded that, there are possible positive relationships between physical fitness and exercise intervention programs, motor competence, and HRQOL in children and adolescents with DCD. Future research should focus on examining whether and how these interventions may eliminate functional constraints leading in an engagement in the positive cycle of physical activity, with further improvements in HRQOL in DCD population. In addition, researchers should be encouraged to incorporate HRQOL measures into their protocols to achieve a better understanding of the impact of DCD, and physical fitness and exercise intervention programs on HRQOL in children and adolescents with this condition disorder.

About the Author(s)

Sofia G. Monastiridi is a PhD student at Aristotle University of Thessaloniki at Serres, Greece and her research area is motor development, motor coordination difficulties and fitness in school and sports. She has a degree in Physical Education & Sport Science, and a master's degree in Kinesiology. She is also a strength and conditioning coach, swimming coach and lecturer at Hellenic Network of Fitness Certifications (HNFC) by National Academy of Sports Medicine (NASM).

Ermioni S. Katartzi is an assistant professor in motor development and motor coordination difficulties, at Aristotle university of Thessaloniki, Dept. Of Physical Education and Sport Science at Serres. Her research area includes the assessment of motor abilities, skills and motor coordination difficulties and the implementation of

intervention programs in promoting participation in physical activity for children with motor coordination difficulties. He also teaches motor learning. and indoor fitness programs.

Maria G. Kontou is a specialized educational staff, at Aristotle university of Thessaloniki, Dept. Of Physical Education and Sport Science at Serres, Laboratoty of Social Research on Physical Activity. Her research area includes sport psychology and health-related quality of life in special populations. She is also teaching planning school physical education programs in elementary and secondary typical schools and special education schools.

Thomas Kourtessis (PhD, Democritus University of Thrace, Komotini, Greece, MA, McGill University, Montreal Canada, BSc, Aristotle University of Thessaloniki, Thessaloniki, Greece), is a Professor of Motor Coordination Disorders at the School of Physical Education & Sport Science at the Democritus University of Thrace, Komotini, Greece. His research interests are identification, assessment and interventional management of Developmental Coordination Disorder. He also teaches Research Methods and Motor Learning.

Symeon P. Vlachopoulos is a professor in sport and exercise psychology, at Aristotle university of Thessaloniki, Dept. Of Physical Education and Sport Science at Serres, and director of the Laboratoty of Social Research on Physical Activity. His research areas include, psychological factors related to the promotion and maintenance of exercise and physical activity. Evaluation of interventions to promote exercise and physical activity in adults, older adults, and individuals with chronic diseases.

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