

# **A SYSTEMATIC REVIEW ON THE EFFECTIVENESS OF PERCEPTUAL MOTOR TRAINING ON IMPROVEMENT IN MOTOR PERFORMANCE IN INDIVIDUALS WITH DEVELOPMENTAL COORDINATION DISORDER**

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## **Abstract**

**Purpose:** To systematically review published research literature to identify and evaluate the effectiveness of perceptual motor training on improvement in motor performance in individuals with Developmental Coordination Disorder (DCD). **Methods:** Multiple databases were methodically searched for articles related to Developmental Coordination Disorder; only descriptive, intervention or qualitative articles were retained. **Results:** A generalized performance deficit may be observed in majority of the children with DCD. Pronounced difficulty in internal (forward) modeling, rhythmic coordination, executive function, gait and postural control, catching and interceptive action, and aspects of sensoriperceptual function were observed in most of the individuals diagnosed with DCD. Research indicates that poor motor co-ordination has far-reaching implications for social and emotional wellbeing. DCD occurs not only in children, as motor difficulties are retained in adulthood. **Conclusions:** The perceptual motor training approach may result in positive outcomes in motor performance in individuals with DCD. Cognitive orientation to daily occupational performance was observed to be a superior alternative to contemporary coordination treatment approach. Furthermore, psychomotor therapy placing emphasis on music rhythm and sensory integration therapy was observed to have a sustainably facilitative impact.

*Keywords:* DCD, perceptual motor training, coordination

## **Introduction**

Dyspraxia, or Developmental Coordination Disorder (DCD), refers to the impairment in the ability to plan and carry out sensory and motor tasks. Generally, individuals with DCD are considered to be "out of sync" from their surroundings and environment. There are various types of indications that can denote DCD in people; which may include poor balance and coordination, clumsiness, vision problems, perception difficulties, emotional and behavioral problems, difficulty with reading, writing, and speaking, and poor social skills, posture, and short-term memory (Doherty, 2004). Although individuals with the disorder may be of average or above average intelligence, they may behave immaturely (National Institute of Neurological Disorders and Stroke, 2011). The motor skill deficit in DCD individuals persistently interferes with the activities of daily life (e.g., self-care and self-maintenance) and hampers academic/school productivity, prevocational and vocational activities, and leisure and play (Criterion A, American Psychology Association, Diagnostic and Statistical Manual of Mental Disorders, 2013).

Dyspraxia can affect children in various ways and to different degrees, ranging from mild problems with coordinating their movements up to severe impairment. The problems may initially interfere with a child's ability to perform daily activities and in day-to-day life skills, including education. It is imperative to understand that

dyspraxia does not mean that a child is less intelligent but it means that their learning ability is affected (Albaret & de Castelnau, 2007). The issue of major concern here is that for many of the affected children, dyspraxia continues into adulthood, which in turn may affect their working environment.

Outside the cognitive domain, dyspraxia is essentially characterized by a marked impairment in the performance of motor skills, which may have a significant negative impact on daily activities (National Health Service, UK 2014). As Audiffren (2009) pointed it out, DCD however has an impact not only on all of the areas of motor performance, but can also have inhibitive impacts on academic achievement (Barnett & Henderson, 2005; Chen, Tseng, Hu, & Cermak, 2009); social development (Tseng, Howe, Chuang, & Hsieh, 2007; Chen et al., 2009) and on health parameters in the long run (Cairney, Veldhuizen, Wade, Kurdyak, & David, 2007).

In cases of persons with motor function disabilities, some inherited qualities have been observed to be inhibited by accidents, motor function disorders or diseases, or genetic errors. Hence those may act upon as constraints for successful motor activation and performance. Thus acquisition and mastery over those skills become harder to achieve through traditional instructions and practice strategies. Perceptual–motor intervention is a systemic instruction or therapeutic intervention that uses the combined processes of sensation, perception and movement to enhance the basic determinants of the movement skills depicted.

## **Objectives**

The objective of this review is to assemble existing literature assessing the effectiveness of perceptual motor training to improve the performance of individuals with dyspraxia or developmental coordination disorder.

## **Methods**

A systematic review of the published literatures was conducted to identify the articles providing authentic information on the effectiveness of perceptual motor training aiming at the population diagnosed as having DCD. A PRISMA flow diagram (Moher, Liberati, Tetzlaff, & Altman, 2009) was used to depict the selection of articles included in this study (Figure.1).

## **Search Strategy**

A literature search was conducted using databases available from Medline, PubMed, Google Scholar, Scopus and Science Direct. The literature search included terms commonly used by researchers and service providers working with children with DCD: clumsy; clumsiness; developmental coordination disorder (DCD); incoordination; motor-impairment; motor skills disorder; minimal brain dysfunction; minor neurological dysfunction; motor delay; perceptual motor difficulties; dyspraxia; dysgraphia; developmental right hemisphere syndrome; movement disorders; non-verbal learning disability; sensory integration; sensory integrative dysfunction; sensorimotor difficulties; physical awkwardness; and psychomotor disorders. Articles dating from January 1995 to July 2013 were considered for inclusion. In addition to the electronic search, a manual search was completed in order to ensure that the search was exhaustive and not subject to search bias.

## **Selection Criteria and Screening Process**

The selection criteria for this review specified four characteristics for studies. First, the studies needed to analyze the effectiveness of perceptual motor training on improvement in motor performance in individuals with DCD. Second, the interventions were carried out or focused only on to the young adults (20-24 years). Third, the studies were conducted to measure the level of performance of the DCD individuals. Finally, only articles

published in English, with a year of publication between 1993-2013, and which were peer-reviewed and published in authentic citation-indexed journals were included in this systematic review.

The screening process was carried out in four stages. Firstly, articles were screened based on the titles and abstracts. At the second phase, the studies were screened to ensure that those are randomized control trials(RCTs). Thirdly, reference lists of the short listed articles were also examined. In the fourth step, based on the afore-mentioned selection criteria, final screening from the short listed articles was done.

## Data Extraction

At first studies were separated for compatibility with the aforesaid selection criteria by their key words, titles and abstracts. After that full texts of the studies were reviewed at length. A standard review form was used to extract data from those studies, including country of origin, methodology including type of evaluation, comparators used, outcome measures, settings and participants and results.

## Results

The wide-ranging and thorough search altogether produced 120 abstracts (see Figure 1). After removing the duplicates, 74 abstracts were reviewed, and full-length articles were also procured. Among those 74 studies, 28 studies met the data extraction requirements and had sufficient information to include for this review. As a result, the rest of the studies (n = 46) were excluded from the review process. After that, the selected 28 experimental studies were thoroughly assessed based on the eligibility criteria, and out of those studies only 18 were selected for conclusion in the review. Table 1 summarizes the characteristics of the included studies.

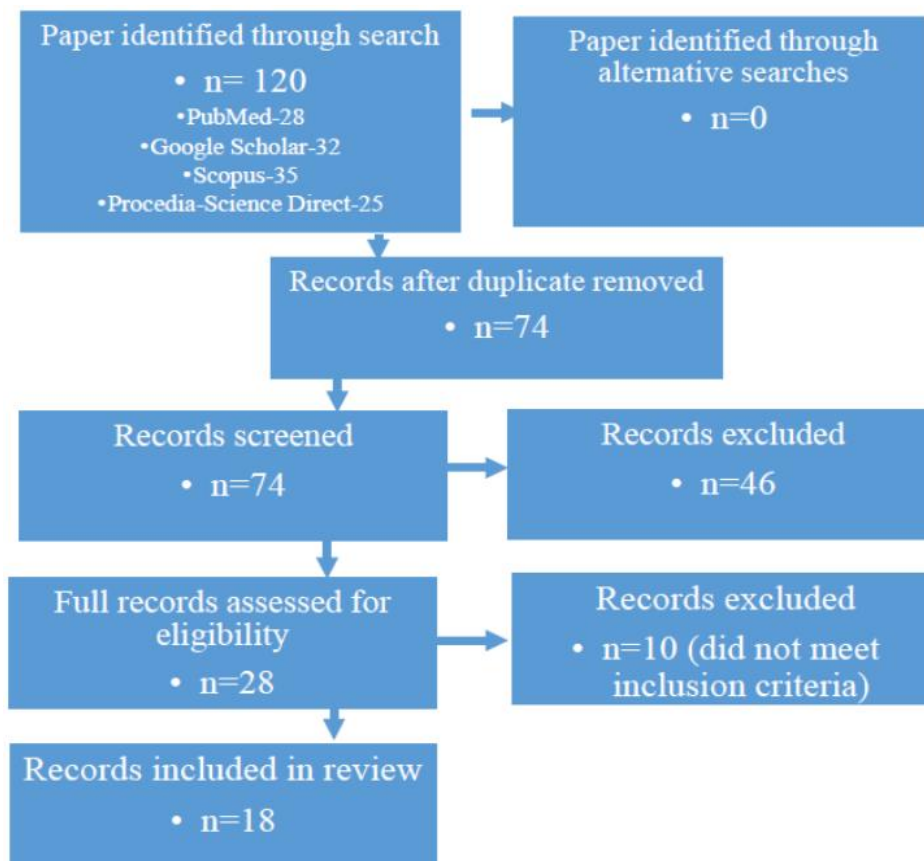


Figure 1: Prisma Flow Chart

### **Country of Origin**

One meta-analytical review was carried out jointly by the authors in Australia, Canada, Belgium and the Netherlands, and another systematic review study was performed by the collaboration between the Brazilian and Canadian authors. Apart from these two studies, three experiments were conducted in Australia (n = 3); two in Canada (n = 2); and three others in Netherlands (n = 3). Further to that, one systematic review was carried out in New Zealand, while two other meta-analytical studies were carried out in Sweden (n = 2). Besides those, a few more RCTs were reportedly carried out, viz., two studies in Sweden (n = 2); one in Taiwan (n = 1) and two others were carried out in the United Kingdom (n = 2).

### **Comparators Used**

In determining effectiveness of a specific intervention, choice of comparator plays a vital role. In this review, studies may be categorized based on emphasis on visuomotor integration as comparator or any other factors considered to be potential comparators. Based on the assessment protocols and inclusion of the independent variables, six of the studies evidently assessed effectiveness of intervention provided against visuomotor integration along with level of self-esteem in behavioral and academic aspects. Apart from that, five other studies were observed to consider visuomotor integration only as a comparator. Another study considered level of self-esteem in behavioral and academic aspects as potential comparator. In two studies, comparison between interventions and spatiotemporal control enhancing activities were observed, while usual care given to the participants by the general trainers was also observed for use as a comparator in three of the aforementioned studies. The remaining studies compared the effectiveness of intervention in an alternative intervention scenario in which participants would be required to obtain intervention through an alternative procedure.

**Table 1:** List of Intervention Studies

Authors, Date	QS/11	Cohort (N)	Country	Comparators Used	Outcome Assessment	Intervention	Findings
Johnston, Burns, Brauer et al., 2002	(4)	DCD (64)	Netherlands	Usual Care	M-ABC Manual dexterity Ball skills Balance Total impairment	Movement Skill training Movement activity in Muscles Movement Control Activities	For DCD children altered postural muscle activity may contribute to poor proximal stability and consequently poor arm movement control
Tsai, 2009	(6)	DCD (43)	Taiwan	Regular classroom activity	M-ABC Visuospatial Attention	Table tennis training – a. serving; b. forehand bouncing, backhand bouncing, and alternate bouncing, c. smashing, d. forehand and backhand driving, e. footwork	The study revealed that, exercise intervention employed within the experimental setting may facilitate in the inhibitory control and motor performance in children with DCD
Magalhaes, Cardoso, & Missiuna, 2011	*	DCD	Brazil, Canada	Self-care, as well as involvement in play, sports and classroom tasks	Assessment of strength, movement patterns, balance, muscle tone, cognition, attention and visual perception Bruininks Ozeretsky Test of Motor Proficiency (BOTMP)	Conventional coordination training and regular play activities	Most frequently cited issues were poor handwriting, difficulties playing ball games, getting dressed and participating in organized sports. Impact of children’s motor impairments on function
Smits-Engelsman, Blank, Van-der, et al., 2012	*	DCD	Belgium, Netherland, Canada, Australia	Spatial and temporal control of gait pattern Spatiotemporal control	Bimanual (auditory–motor) timing; Visuospatial attention Overt orienting of attention (without cues) Manual pursuit tracking control and dynamic coordination associated with catching Pre-cued response time Both unilateral and bilateral movement time	(1) task-oriented intervention, (2) traditional physical therapy and occupational therapy, (3) process-oriented therapies, and (4) chemical supplements.	(1) Internal (forward) modeling, (2) Rhythmic coordination, (3) executive function, (4) Control of gait and posture, (5) control of reaching, (6) catching and manual interception, and (7) aspects of sensory-perceptual function.
Hillier, Turner, Yang, et al., 2007	*	DCD	Australia	Visuomotor integration; Behavioural academic self-esteem	Varied amongst studies M-ABC, TOMI, COPM, PQRS, VABS, BOTMP, VMI, SPPC, SC-SIT, KST	General vs SI vs Specific Skills; SIT vs PMT vs nil/tutoring; CO-OP vs CTA; Task-oriented vs Process-oriented;	21 articles: 13 for meta-analyses supports: specific skill interventions at >5yrs old, delivered 2 articles

						MI vs PM vs nil; Group motor skills vs nil	All groups receiving intervention improved, no one more than another CO-OP+ > CTA (COPM, PQRS, VABS) CO-OP = CTA (BOTMP) Gains maintained at follow-up (COPM not blind tested, some pre differences between groups) 4 articles: motor intervention per se is better than no Rx, but no differences between types
Rasmussen & Gillberg, 2000	(4)	Predominantly ADHD Candidates having DCD as co-morbidity (Longitudinal Cohort study for 15 years) Initially N was 5114, final N was 101.	Sweden	Usual Care	Neuropsychiatric Assessment. Versions I and II DSM-III-R algorithm diagnoses (APA, 1987); Modified version of the Asperger Syndrome Diagnostic Interview (ASDI) and Current ADHD Symptoms Interview (CASI).	Regular Motor activities in School set up	Childhood ADHD and DCD appears to be a most important predictor of poor psychosocial functioning in early adulthood.
Wilson, Ruddock, Smits-Engelsman et al. 2012	*	DCD	Australia	Usual Care	Motor measures (i.e. M-ABC; MAND; BOTMP)	Motor Coordination Activities Physical activity Movement Skills	Reviewed 129 articles, which confirmed - Generalized performance deficit in children with DCD. Pronounced difficulty in internal (forward) modeling, rhythmic coordination, executive function, gait and postural control, catching and interceptive action, and aspects of sensoriperceptual function.
Pless & Carlsson, 2000	*	DCD	Sweden	Visuomotor integration;	Various in studies	General vs SI vs Specific Skills	21 articles: 13 for meta-analyses supports: specific skill

				Behavioural academic self- esteem			interventions at >5yrs old, delivered
Kaplan, Strawbridge, Camache et al., 1993	*	DCD	Sweden	Visuomotor integration; Behavioural academic self- esteem	Various academic tests BOTMP	SIT vs PMT vs nil/tutoring	2 articles All groups receiving intervention improved, no one more than another
Miller, Benson & Galbraith, 2001	(6)	DCD (20)	Canada	Visuomotor integration; Behavioural academic self- esteem	COPM, PQRS, VABS, BOTMP, VMI, SPPC	CO-OP vs CTA	CO-OP+ > CTA (COPM, PQRS, VABS) CO-OP = CTA (BOTMP) Gains maintained at follow-up (COPM not blind tested, some pre differences between groups)
Miyahara, Mizunuma, Hirata et al., 1996	*	DCD	New Zealand	Visuomotor integration; Behavioural academic self- esteem	Various in studies (M-ABC, TOMI etc)	Task-oriented vs Process- oriented	4 articles: motor intervention per se is better than no Rx, but no differences between types
Polatajko, Fox, & Missiuna, 1995	(9)	DCD (76)	Canada	Behavioural academic self- esteem	SC-SIT, KST, VMI, TOMI	PO vs traditional (sensory- motor) vs nil	Mixed results Po = traditional PO + (KST) ? very severe group need repetition
Wilson, Thomas, & Maruff, 2002	(5)	DCD (54)	Australia	Visuomotor integration;	M-ABC	MI vs PM vs nil	PM = MI +, nil 0
Pless, Carlsson, Sundelin et al., 2000	(5)	DCD (37)	Sweden	Visuomotor integration	M-ABC	Group motor skills vs nil	Intervention = nil ? borderline subgroup did gain with intervention
Sims, Hinderson, Morton et al., 1996	(6)	DCD (20)	United Kingdom	Visuomotor integration; Behavioural academic self- esteem	TOMI, KST, PEST, Shape copying, handwriting	KT vs nil (then cross over)	Both groups + (all tests) ? PEST produced change in itself
Schoemaker, Niemeijer, Reynders et al., 2003	(3)	DCD (15)	Netherland	Visuomotor integration;	M-ABC CAMCH	NTT vs nil	NTT +, nil 0 (all tests)
Leemrijse, Meijer, Vermeer et al., 2000	(9)	DCD (6)	Netherland	Visuomotor integration;	M-ABC, Praxis test, Rhythm test, VAS for parents	LBD vs SIT (crossover)	LBD = SIT+ (all tests) after combination of Rx: LBD > SIT on some

Sugden & Chambers, 2003	(7)	DCD (31)	United Kingdom	Visuomotor integration	M-ABC	Guided teacher/ parent intervention	Intervention + (M-ABC) In 27 out of 31 children
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**Explanatory Notes & Abbreviations used in this Table:**

QS/11 – PEDRO Scale Quality of the Experiments out of total 11 marks

(\*) Denoted Meta analytic systematic review literatures

ADHD – Attention-Deficit Hyperactivity Disorder

ASDI – Asperger Syndrome Diagnostic Interview

BOTMP – Bruininks–Oseretsky Test of Motor Impairment

COPM – Canadian Occupational Performance Measure

DCD – Developmental Coordination Disorder

KST – Kinesthetic Sensitivity Test

M - ABC – Movement Assessment Battery for Children,

MAND – McCarron Assessment of Neuromuscular Dysfunction,

PQRS – Performance Quality Rating Scale

SC-SIT – Southern Californian Sensory Integration Tests

SPPC – Self Perception Profile for Children

TOMI – Test of Motor Impairment

VMI – Visual Motor Integration

VABS – Vineland Adaptive Behavior Scale

CAMH - Concise assessment measure for children’s handwriting (1).

COPM - Canadian occupational performance measure (1)

SC-SIT – Southern Californian sensory integration tests (5)

**Interventions, with frequency of investigation in parenthesis:**

CA – Cognitive affective – task (draw, mime, visual) with emphasis on experiencing success and self-monitoring (1)

CO-OP – Cognitive orientation to daily occupational performance (1)

CTA - Contemporary treatment approach (1)

Effort training – based on training the specific movement qualities proposed by Laban (1)

Ex – exercises – see more specific forms

Fine/gross work – not specified (1)

Gp – group program (2)

Guided teacher/parents – intervention prescribed by therapists for teachers/parents to conduct (1)

Home Ex – home exercises prescribed by PT (1)

Indiv PT/OT – individual physio and occupational therapy

Indiv tutoring – provided 1:1 teaching (1)

KT – Kinesthetic training – process oriented approach proposed by Laszlo (4)

KT/S/T – kinesthetic training with spatial and temporal programming (2)

LE – lower extremity (see WB)



LBD – Le Bon Depart – psychomotor therapy, includes emphasis on music and rhythm (1)  
Mastery – training paradigm that complies with requirements for high autonomy level versus low autonomy/mastery (2)  
MI – Motor imagery – training in visual., predictive timing, relaxation, mental preparation, modeling, mental rehearsal etc. (1)  
NTT – Neuromotor task training – task oriented, based on recent motor learning/control research (1)  
Parent assisted – home Ex prescribed by therapist and conducted by parents (1)  
PE – physical education; (RPE- regular physical education) (1)  
PMT or PM – perceptual –motor (therapy) “doing”, based on Bobath etc. (9)  
Psychomotor training – gross motor, ball skills and body awareness. (1)  
PO – Process oriented – based on kinesthetic training proposed by Laszlo (1)  
PT – physical therapy or physiotherapy (2)  
SIT or SI – Sensory integration (therapy); based on Ayres (7)  
Spatial training – based on Laszlo (1)  
Task specs reps – repetitive training or practice that is specific to a task (2)  
Traditional – sensory – motor – not specified (1)  
UE – upper extremity (see WB)  
Usual sport – participation in usual school based sporting activities (1)  
WB – weight bearing (kinesthetic training) (1)  
Writing – high motor content (1)

**Results:**

(See outcome assessment and interventions lists for most abbreviations)

+ - positive effect

0 – no effect/equivocal effect

= - one intervention had same as other (either + or 0).

## **Discussions**

Based on the outcomes represented in this systematic review (refer to Table 1), it is evident that out of the studies included, seven were based on extensive literature reviews (Magalhaes, Cardoso, & Missiuna, 2011; Smits-Engelsman et al., 2012; Hillier, Turner, Yang, & Park, 2007; Wilson et al., 2012; Pless & Carlsson, 2000; Kaplan Strawbridge, Camache, & Cohen, 1993; Miyahara, Mizunuma, Hirata, Tsuchiya, & Miyakawa, 1996). Out of these studies, three studies (Wilson et al., 2012; Pless & Carlsson, 2000; Miyahara et al., 1996) were meta-analytic reviews, which included more than 150 studies, carried out world-wide, wherein M-ABC; MAND & BOTMP along with various other methods were employed to measure the outcomes of interventions introduced to the DCD participants. Similarly, systematic reviews carried out by Magalhaes and co-researchers (2011); Smits-Engelsman and colleagues (2012); Kaplan and co-authors (1993) and Hillier along with his co-researchers (2007) reported on outcome assessments carried out in numerous studies, mostly considered M-ABC, TOMI, COPM, PQRS, VABS, BOTMP, VMI, SPPC, SC-SIT, KST alongside assessment of strength; movement patterns; balance; muscle tone; cognition; attention and visual perception; bimanual (auditory-motor) timing; visuospatial attention; pre-cued response time and both unilateral and bilateral movement time.

Identical scenario with regard to the utilization of the assessment tools were observed in the RCTs carried out on dyspraxia individuals (Johnston, Burns, Brauer, & Richardson, 2002; Tsai, 2009; Rasmussen & Gillberg, 2000; Miller et al., 2001; Polatajko, Fox, & Missiuna, 1995; Wilson, Thomas & Maruff, 2002; Pless, Carlsson, Sundelin, & Persson, 2000; Sims, Henderson, Morton, & Hulme, 1996; Schoemaker, Niemeijer, Reynders, & Smith-Engelsman, 2003; Leemrijse, Meijer, Vermeer, Ader, & Diemel, 2000; Sugden & Chambers, 2003), which however confirmed that, most of the experiments were carried out incorporating M-ABC, TOMI, COPM, PQRS, VABS, BOTMP, VMI, SPPC, SC-SIT, KST. Further to that, assessment of shape copying, handwriting (Sims et al., 1996); CAMCH (Schoemaker et al., 2003); praxis test, rhythm test (Leemrijse et al., 2000); manual dexterity, ball skills, balance (Johnston et al., 2002) and visuospatial attention (Tsai, 2009), were also given adequate attention in most of the recent experimental studies carried out all over the world. Apart from all these aforementioned assessment protocols, in one longitudinal cohort study for 15 years, which was carried out with predominantly ADHD candidates diagnosed as having DCD as co-morbidity (Rasmussen & Gillberg, 2000), along with neuropsychiatric assessments, a modified version of the Asperger Syndrome Diagnostic Interview (ASDI) and Current ADHD Symptoms Interview (CASI) was also carried out. Thus, according to our understanding about the assessment protocols for the DCD candidates goes, studies carried out in last two decades revealed that regardless of the types of studies (RCT or systematic reviews) carried out, M-ABC; BOTMP; and visuospatial attention were evidenced as the most important tools of assessment, while based on population-specific requirements other kinds of assessment tools such as pre-cued response time and both unilateral and bilateral movement time (Smits-Engelsman et al., 2012); shape copying and handwriting (Sims et al., 1996); CAMCH (Schoemaker et al., 2003); praxis test and rhythm test (Leemrijse et al., 2000) and so on were also administered to evaluate specific potential limitations in DCD individuals.

In terms of the intervention regimes incorporated, studies were generally observed to have a wide range of variation, by introducing more traditional approaches such as subjecting the DCD participants in conventional coordination training and regular play activities (Magalhaes et al., 2011); traditional physical therapy and occupational therapy (Smits-Engelsman et al., 2012); and in task-oriented intervention and process-oriented therapies (Miyahara et al., 1996; Smits-Engelsman et al., 2012; Hillier et al., 2007). Additionally, few researchers cited numerous studies carried out incorporating motor coordination activities; physical activity and movement skills and General vs SI vs Specific Skills training (Wilson et al., 2012; Pless & Carlsson, 2000 and Magalhaes et al., 2011), whereas others cited introduction of more structured and systematic intervention protocols, such as SIT vs PMT vs nil/tutoring; CO-OP vs CTA (Kaplan et al., 1993; Hillier et al., 2007).

As with the other studies reviewed, the RCTs were also observed to incorporate both traditional and systematic methods of intervention protocols. The RCTS reportedly incorporated conventional interventions, were mostly evidenced to consider motor skills training in differential regimes and modalities, such as movement skill training and muscles movement control activities (Johnston et al., 2002); regular motor activities in school set up (Rasmussen & Gillberg, 2000); group motor skills (Pless et al., 2000); kinesthetic training based process oriented

therapy compared with traditional sensory-motor training (Polatajko et al., 1995) and guided teacher/parent intervention (Sugden & Chambers, 2003). Contrary to that, a few other authentic research was carried out, considering contemporary and diversified intervention strategies, such as cognitive orientation to daily occupational performance (Miller et al., 2001); motor imagery compared with perceptual – motor therapy (Wilson et al., 2002); kinesthetic training (Sims et al., 1996); neuromotor task training (Schoemaker et al., 2003) and Le Bon Depart – psychomotor therapy, which includes emphasis on music and rhythm compared with sensory integration therapy (Leemrijse et al., 2000). A more recent study by Tsai (2009) incorporated table tennis training, in which he included – a. serving; b. forehand bouncing, backhand bouncing, and alternate bouncing, c. smashing, d. forehand and backhand driving, and e. footwork and so on for training elderly children suffering from DCD.

Here we would like to raise a question pertaining to the quality of the systematic reviews as well as the RCTs we included in this review study. For this analysis, based on the guidelines of National Health and Medical Research Council (NH & MRC Australia, 1999), the reported studies could be categorized and identified as having insufficient or satisfactory level or strong evidence. Based on NH & MRC (1999) criteria of demarcation, both the systematic reviews and RCTs included in this study were evaluated to observe authenticity of the evidence provided in the studies included. For analyses of the systematic reviews and meta-analyses, strength of the studies was demarcated based on whether the studies included were properly designed and whether relevant RCTs carried out following rigorous methodology or not. In addition, experimental studies included in this study were checked with the criterion based on whether they were non-randomized clinical trials (NRCT); or controlled clinical trials (CCT); or pseud-randomized controlled trials (PRCT); or properly controlled randomized controlled trials (RCT). This evaluation on experimental trials was also conducted for the trials included in systematic reviews and the experimental trials, we included in this study. Based on the grade of evidences, the best evidence synthesis technique (adapted from van Tulder, Cherkin, Berman, Lao, & Koes 1999) was followed to evaluate authenticity of the studies included. Criterion for grading of evidences were done following the standardized format of analysis (PEDro Scale – Physiotherapy Evidence Database, 2016) of quality of RCTs, as earlier employed by Hillier and colleagues (2007) in their study to evaluate the quality of RCTs and as they proposed, any RCTs scoring more than 4 points out of 11 (based on PEDro Scale scores), were considered to be high quality experimental studies.

Finally, following NH & MRC (1999) criteria of demarcation; best evidence synthesis technique (adapted from van Tulder et al., 1999); and PEDro Scale (2016) evaluations, out of 18 studies which were included for meta-analytic review, accepting only one study (Magalhaes et al., 2011), all other studies (Pless & Carlsson, 2000; Smits-Engelsman et al., 2012; Hillier et al., 2007; Wilson et al., 2012; Kaplan et al., 1993; Miyahara et al., 1996) were observed as having either Grade I or Grade II category of strong evidence (NH & MRC, 1999). Similarly, amongst the experimental trials included, the study of Schoemaker and co-researcher (2003) received a PEDro Scale quality score 3 out of 11 and hence was considered as having moderate strength of evidence (van Tulder et al., 1999), 4 studies had strong evidence scores (Johnston et al., 2002; Rasmussen & Gillberg, 2000; Wilson et al., 2002; Pless et al., 2000) at either 4 or 5 (refer to Table – I). All other RCTs (for instance, Tsai, 2009; Miller et al., 2001; Polatajko et al., 1995; Sims et al., 1996; Leemrijse et al., 2002; Sugden & Chambers, 2003) were observed to achieve PEDro scores more than 6 or 7 and even up to 9 out of 11, which revealed higher authentic quality of those studies (refer to Table – I). In sum, however, it may be postulated that the outcomes of this study indicated differential efficacy of both the conventional and process-oriented perceptual and motor skill training regimes in modification of the visuomotor, spatiotemporal, and sensory-perceptual motor coordination ability of children and young adult individuals diagnosed as having Dyspraxia or DCD.

### **Limitations of this review and included studies**

This study suffers from a few limitations, as only a few studies were included and as all of the RCTs and systematic reviews did not provide the mean differences, meta-analytic Forest-plot evaluation could not be performed. Thus it was difficult to analyze the efficacy of the interventions in reducing or minimizing the problems of DCD. Owing to our strict inclusion criteria, we had to exclude some of the studies and articles.

Since the search was restricted to articles published in English only, the activity and participation issues reported here may not be universal.

## **Conclusions**

Though scanty, a group of authentic systematic reviews and good number of RCTs with strong evidence have revealed that many individuals studied achieve neuromuscular mediated perceptual and motor skill enhancements, which would lead to major gross-motor functional improvements. We hope that the findings of this study will be useful to psychologists, teachers, and therapists of DCD children in improving the quality of their performances, as well as encourage future researchers to carry out more systematic reviews and RCTs to enrich this field of study.

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