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Full Length Research Paper

Effectiveness of motor intervention on children with Developmental Coordination Disorder (DCD): A systematic review

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The aim of this study is to determine the quality of evidence obtainable from published clinical trials on motor interventions, and assess whether the quality, in terms of methods and results, is sufficient to enable the development of evidence-based recommendations for clinical practice on children with Developmental Coordination Disorder (DCD). Here, a systematic review was conducted, with the addition of randomized controlled trials and quasi-randomized studies, with no language or time restrictions. Pre-school and school-aged children of both sexes, with DCD were considered for inclusion. As the primary outcome, the motor skills of the children were evaluated. Searches were conducted in the following databases: MEDLINE/PubMed, LILACS, SCOPUS, CENTRAL, CINAHL and PSYCINFO. Results revealed that 1002 studies were encountered. After screening, 21 studies were initially considered eligible. Finally, after analysing the full articles, 9 studies involving 339 children were selected, comprising 6 randomized controlled trials and three quasi-randomized studies. The quality of evidence of most of the included trials was sufficient to recommend motor interventions for clinical practice on children with DCD. Finally, more clinical trials would be needed so as to define the best intervention, since different interventions presented positive effects.

Key words: Disabled children, motor skills disorders, intervention

INTRODUCTION

Motor competence is a behavioural variable defined as the ability to execute motor acts at a sufficiently optimum level in order to solve motor problems (Keogh, 1977) and may be classified as low, adequate or high (Gallahue et al., 2013). In some cases, children present more pronounced motor coordination impairments, which cannot be attributed to any apparent neurological or physiological delays, and are thus characterized as children with Development Coordination Disorder – DCD (Bart et al., 2011). According to the Diagnostic and

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Statistical Manual of Mental Disorders (DSM-5) (American Psychiatric Association, 2013) children with DCD show acquisition and execution of motor skills below the expected range of age; motor skills deficit also interfere significantly with daily living activities appropriate to the child´s range of age, affecting school productivity, leisure and play. The estimated prevalence of DCD is around 6% between children from 5–11 years of age depending on case definition (American Psychiatric Association, 2013).

A recent study (Bieber et al., 2016) that aimed to provide a systematic review of clinical tools appropriate for manual function assessment in children with DCD within the International Classification of Functioning and Disability-Children Youth Version (ICF-CY) model found that manual dexterity skills are frequently impaired in children with DCD at different ICF-CY levels interfering with development and successful participation in everyday activities. The authors said that several clinical tools are available nevertheless there is no consistency in their use in clinical practice as well as limited application in research, what makes standardization difficult.

DCD has been related to a deficit in mapping visual and proprioceptive information (Mon-Williams et al., 1994; Sigmundsson, 1999). Researchers have also encountered abnormalities in the execution of movements, emphasizing the absence of any perceptual component (Hoare, 1994; Raynor, 2001). This disorder, which has been attributed to deficiencies in the sensory and perceptual domain, the motor domain, and sensorimotor integration, has proven to be a very widespread problem.

Motor intervention programs become crucial in assisting the motor development process, since they provide opportunities for both planned and systematic practices (Logan et al., 2011). The objectives of these interventions are: to enhance the construction of more advanced movement patterns, to develop new movement strategies, to understand child motivational factors that may influence practice, as well as remedy established difficulties (King-Thomas, 1987), as in the case of children with DCD.

However, although it may seem intuitive that motor intervention will bring about positive changes in the motor behaviour of children with DCD, some intervention studies have presented no improvement for motor competence (Iversen et al., 2005; Fong et al., 2013) and another has presented no significant differences between the interventions (Hung and Pang, 2010).

According to Miyahara et al. (2017) in the current Era of evidence-based medicine, systematic reviews and meta-analyzes sit at the top of the hierarchy of research designs employed to evaluate the strength of evidence in support of a particular intervention approach. Previous systematic reviews and meta-analyses on interventions that aim to improve motor performance of children (Pless and Carlsson, 2000; Morgan and Long, 2012; Smits-Engelsman et al., 2013) used rating scales as a method for assessing the quality of evidence, which may not adequately reflect the risk of bias contained within the articles, therefore its use is not recommended in the methodology for conducting systematic review (Greenland, 1994).

Miyahara et al. (2017) recently proposed a narrative meta-review of a series of systematic and meta-analytic reviews on the intervention outcome for children with developmental coordination disorder. The literature search yielded a total of four appropriate reviews published and the Assessment of Multiple Systematic Reviews percentage quality scores assigned to each review ranged from 0% (low quality) to 55% (medium quality). It was concluded that although the quality of the reviews progressively improved over the years, the shortcomings identified the need to be addressed before concrete evidence regarding the best approach to intervention for children with DCD can be specified.

Even though different strategies for motor intervention have been used, there is no available overview on the effectiveness of intervention programs on the motor skills of children with DCD. There are also few review studies that specify the methodological quality of the evidence on the subject. Therefore the aim of this study is to determine the quality of evidence in published clinical trials of motor interventions, using the Cochrane risk of bias tool, and assess whether the quality is sufficient in terms of methods and results, to enable the development of recommendations for evidence-based clinical practice on children with DCD.

METHODS

Eligibility criteria for studies

Types of studies

All randomized and quasi-randomized controlled trials, with no language or time restrictions, were considered for inclusion.

Types of participants

Preschool and school-aged children of both sexes, with Developmental Coordination Disorder (DCD). Obese children or those with physical and/or mental disabilities were not included, even if they presented with DCD.

Previous research has demonstrated that the motor performance of overweight and obese children is poorer when compared to their peers with normal weight (Vameghi et al., 2013; Khalaj and Amri, 2014), especially in skills such as climbing stairs, kicking a ball, fitting objects together (Vameghi et al., 2013), and motor competence in general (Khalaj and Amri, 2014).

A study by Nascimento et al. (2013), which aimed to characterize motor performance and nutritional status of schoolchildren with Attention Deficit and Hyperactivity Disorder (ADHD), encountered differences in balance skills and manual dexterity with a poorer motor performance presented by the group with ADHD. It was also found that balance skills were worse in children with ADHD presenting a higher BMI. Therefore, presenting ADHD or obesity,

Table 1. Search strategies for the databases: MEDLINE/Pubmed, LILACS, SCOPUS, CENTRAL, CINAHL and PSYCINFO.

Database	Search strategy
MEDLINE/Pubmed	((("Child"[Mesh] OR "Child, Preschool"[Mesh]) AND "Motor Skills Disorders/therapy"[Mesh])
LILACS	Child OR Preschool [Subject descriptor] and Motor skill disorders [Subject descriptor]
SCOPUS	TITLE-ABS-KEY (child) OR TITLE-ABS-KEY (child, preschool) AND TITLE-ABS-KEY (developmental coordination disorder) AND TITLE-ABS-KEY (motor activity intervention) OR TITLE-ABS-KEY (motor skills intervention)
CENTRAL	("Child") OR ("Child, Preschool") AND ("Motor Skills Disorders")
CINAHL	("Child") OR ("Child, Preschool") AND ("Motor Skills Disorders") AND ("Intervention") OR ("Therapy")
PSYCINFO	{Dyspraxia} AND motor intervention

for example, may further intensify the underperforming of children with motor difficulties and DCD.

Type of intervention

We considered any type of motor intervention, characterized by the practice of physical activities, except for motor intervention programs in the virtual environment.

Over recent decades, health professionals have increasingly included new technologies in therapeutic procedures. New interactive systems for physical activity, as well as being beneficial for the motor coordination and dynamic balance of children with DCD (Campelo, 2013), involve an environment in which it is possible to build different day-to-day experiences, that is, within a real environment. A study by Perez et al. (2014) in which the aim was to analyse the performance of a returning serve in table tennis in both a virtual and real environment, discovered that for this particular type of task, the performance of children who performed in a virtual environment was better. Therefore, seeking greater homogeneity within motor intervention programs, this review did not include interventions conducted in the virtual environment.

Outcomes evaluated

As a primary outcome, we evaluated the motor skills of children with DCD (motor performance).

Adverse effects

Tiredness and pain are possible adverse effects resulting from physical activity. However, because of the age group selected for the review, it was considered that the probability of occurrence of these adverse effects would be unlikely.

Search strategy to identify studies

Data bases and combinations

Searches were conducted with no language or time restrictions in the following databases: MEDLINE/Pubmed, LILACS, SCOPUS, CENTRAL, CINAHL and PSYCINFO. Table 2 shows Table of combinations.

Data collection and analysis

Study selection

From the combinations above in Table 1, studies that met the eligibility criteria were included. Two independent reviewers (I.O; D.O.) verified titles and abstracts of the search results and excluded any studies that did not meet the inclusion criteria. In this first analysis, articles with uncertain abstracts and a potential of entering the study were retained for further evaluation of the full text. When the two reviewers were unable to reach a consensus, a third reviewer was consulted (S. S.). The steps for the selection and exclusion of studies followed the flowchart proposed by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) (http://www.prisma-statement.org/).

Assessing the quality of evidence

The quality of evidence of the studies was assessed by using the Cochrane risk of bias tool, which considers the following items: randomization, allocation concealment, blinding, incomplete results (losses), selective description of the outcome and evaluation of results (Table 2).

RESULTS

A total of 1002 articles were identified according to the search strategy of the research. After screening, during which the articles were assessed by title and abstract, 21 studies were initially considered eligible. Finally, after analyzing the full articles, 9 studies were selected (Figure 1) involving 339 children, and 6 randomized studies (Fong et al., 2013; Hung and Pang, 2010; Leemrijse et al., 2000; Fong et al., 2012; Au et al., 2014; Giagazoglou et al., 2015) and 3 quasi-randomized studies (Iversen et al., 2005; Tsai, 2009; Bardid et al., 2013). The studies included are described and detailed in Table 2 and the results of information about the quality of evidence are described in Table 3.

DISCUSSION

The aim of this study was to determine the quality of evidence of published clinical trials on motor interventions using Cochrane’s risk of bias tool, and assess whether the quality is sufficient in terms of methods and results, to enable the development of evidence-based recommendations for clinical practice on children with DCD.

The results demonstrated a significantly positive effect

Table 2. Characteristics of the included studies.

Author (location) - Study design	Samples	Protocol	Study groups	
			Treatment group	Control group
Au et al. (2014) (China) - RCT[1]	22 DCD children (aged 6 to 9 years): 11 TG1[2] 11 TG2[2]	Intervention weeks: 8 Duration: 60 min Frequency: 1x/week	Intervention 1: Core stability program (exercises were performed in the supine, prone, sitting and standing positions). Children were instructed to co-contracting the abdominal and back muscles to maintain the spine in a neutral position.	Intervention 2: Task-oriented training – focus on training functional tasks, which included those that involved mainly body stability (e.g., standing) and those that required body transport (e.g., running, jumping).
Bardid et al. (2013) (Belgium) - RCT[1]	93 DCD children (aged 3.5 to 5.5 years): 47 TG[2] 46 CG[3]	Intervention weeks: 10 Duration: 60 min Frequency: 1x/week	Intervention: Developmentally appropriate motor program consisting of playful activities clustered around 6 themes (that is, locomotor skills, ball handling skills, jumping skills, postures and balance, play, rhythm and dance), each of which was practiced for approximately 10 min.	The control group continued with their usual programs, including 2 general PE-classes of approximately 60 min per week.
Fong et al. (2013) (China) - RCT[1]	44 DCD children (aged 6 to 9 years): 21 TG[2] 23 CG1[3] 18 normal children CG2[3]	Intervention weeks: 12 Duration: 60 min Frequency: 1x/week	Intervention: Taekwondo training (TKD) - apart from attending the face-to-face TKD training sessions, each participant in the DCD-TKD group was given a prescribed set of TKD home exercises.	Children in the DCD control and normal control groups received no training during the study period.
Fong et al. (2012) (China) - RCT[1]	44 DCD children (aged 6 to 9 years): 21 TG[2] 23 CG1[3] 18 typically developing children CG2[3]	Intervention weeks: 12 Duration: 60 min Frequency: 1x/week	Intervention: Taekwondo training (TKD) - apart from attending the face-to-face TKD training sessions, each participant in the DCD-TKD group was given a prescribed set of TKD home exercises.	The DCD-control and normal-control groups received no training during the study period.
Giagazoglou et al. (2015) (Greece) - QRCT[4]	20 DCD children (aged 8 to 9 years): 10 TG1[2] 10 CG1[3]	Intervention weeks: 12 Duration: 45 min Frequency: 3x/week	Intervention: Program-trampoline training (balance exercises in circuit training including a trampoline station, such as walking exercises, hopping on one foot, jumping and landing on one or both legs).	The control group adhered to their regular school schedule, which included participating in physical education activities at a frequency of 3 times per week for 40-45 min.
Hung and Pang (2010) (China) - RCT[1]	23 DCD children(aged 6 to 10 years): 12 TG1[2] 11 TG2[2]	Intervention weeks: 8 Duration: 45 min Frequency: 1x/week	Intervention 1: Group-based training (a variety of functional tasks and exercises were designed to address common motor difficulties faced by children with DCD, such as agility, balance, core stability, and movement coordination).	Intervention 2: Individual-based training (activities involved in the individual training and group training were essentially the same).
Iversen et al. (2005) (Norway) - QRCT[4]	30 DCD children (aged 7 to 12years): 15 TG1[2] 15 TG2[2]	Intervention weeks: Unclear (2-3 days or daily) Duration: undefined Frequency: 5x/week	Intervention 1: High-dosage (targeted motor skills approach with a high degree of parental involvement had been applied). Various in- and outdoor physical activities were practiced such as cycling, swimming, playing soccer, jumping and running.	Intervention 2: Low-dosage (basic motor skills approach with limited parental involvement). This intervention took place indoors, and the children mainly practiced skills such as climbing, jumping, running, hopping and catching).
Leemrijse et al. (2000) (Netherlands) - RCT[1]	6 DCD children (aged 6 to 8 years): 3 TG1[2] 3 TG2[2]	Intervention weeks: 12 to 18 Duration: undefined Frequency: 1x/week	Intervention 1: Le Bon Départ (LBD) is highly individualized and can be applied to address the specific problems of the child, for example writing or ball skills. Different musical instruments are used (drums, castanets, flutes), as well as materials such as ribbons, balls, sandbags and drawing utensils.	Intervention 2: Sensory integration (SI) is a noncognitive, movement-based therapy that enhances the brain's capacity to perceive and organize sensory information to produce a more normal adaptive response, and thus to provide the foundation for mastering academic tasks.

Table 2. Cont'd

Tsai (2009) (China) - QRCT[4]	57 children (aged 9 to 10 years): 14 DCD TG1² 14 DCD CG1³ 29 normal children CG1³	Intervention weeks: 10 Duration: 50 min Frequency: 3 x/week	Intervention: Table tennis training - the procedure structure for each single training session was as follows: warm-up, main part of table tennis training, playing table tennis with a partner, and cooling down at the end. The table tennis training program was aimed at improving general skills, and had seven main components over the whole training session (such as forehand and backhand driving, footwork etc).	The DCD non-trained group and the normal control group (typical development group) performed their regular classroom activities and did not participate in any training for the duration of this study.

[1]Randomized Clinical Trial; [2]Treatment group; ³Control group; [4]Quasi-randomized Controlled Trial; - not informed.

for most intervention studies (Hung and Pang, 2010; Leemrijse et al., 2000; Fong et al., 2012; Au et al., 2014; Giagazoglou et al., 2015; Tsai, 2009; Bardid et al., 2013). However, as a number of the studies presented different treatments, it was therefore difficult to establish one single recommendation for children with DCD. These results were similarly reported in the meta-review proposed by Miyahara et al. (2017), in which all included systematic reviews concluded that some kind of intervention was better than none at all, however they stated that concrete evidence regarding the best approach to intervention for children with DCD still needs to be specified.

Motor skill competence is defined as proficiency in fundamental motor skills (Stodden et al., 2008), including the categories of locomotor skills, object control and balance. Therefore, the form of assessing motor skills should be taken into consideration, since the result of the intervention depends on how the performance was assessed, e.g. focusing on one of the categories separately, or using an index of general motor competence (sum of categories).

An eight-week intervention with weekly one-hour sessions, involving 22 children with DCD aged from 6 to 12 years, demonstrated a significant improvement in motor skills in both the core stability group and the task-oriented group, and there was a significant increase in the overall balance score in the task-oriented group (Au et al., 2014).

Among 44 children with DCD (mean age 7.6 ± 1.3 years), 21 were randomly assigned to try a weekly, one-hour session of Taekwondo training for three consecutive months (approximately 12 weeks). The results revealed that Taekwondo training is able to remedy unilateral balance and deficiencies in the vestibular function of children with DCD. Their balance performance may achieve normal patterns after only three months of daily Taekwondo training (Fong et al., 2012). The same sample and methodology in a similar study revealed that children with DCD who were subjected to an intensive Taekwondo training program improved muscle strength around the knee and single-leg balance control, but there was no benefits to reactive balance control (Fong et al., 2013).

Twenty children with DCD, aged 8 and 9 years, were evenly divided into two groups (intervention and control). Results indicated that after 12 weeks (with 3 sessions per week), balance circuit training including a trampoline station program, may be an effective intervention for improving functional outcome, and may also be recommended as an alternative mode of physical activity (Giagazoglou et al., 2015).

Another study including 93 children with DCD aged between 3 and 5 years proposed a 10-week intervention program, with weekly one-hour sessions. Results demonstrated that the intervention group has been significantly benefited by the intervention, presenting a better performance in gross motor skills and in subcategories (locomotor and control objects) than the control group in the post-test. Furthermore, the intervention program was effective in helping 49% of the intervention group to reach an average level of motor skills, according to TGMD-2 standards, while a further decline of motor skills in the control group was observed (Bardid et al., 2013).

In a study by Hung and Pang (2010), 23 children with DCD (mean age 8.0 ± 1.2 years) were randomly assigned to participate in a motor training program (with collective or individual practice) for 8 consecutive weeks (one session per week). The results indicated that the collective and individual training produced similar gains to the motor performance (overall M-ABC score).

In another study, 30 children with DCD aged 7 to 12 years, were divided into two groups, both with an approach targeted to fundamental motor skills. However, group A received a high dose with a high degree of parental involvement, while group B received a low dose, with limited parental involvement. No significant differences were

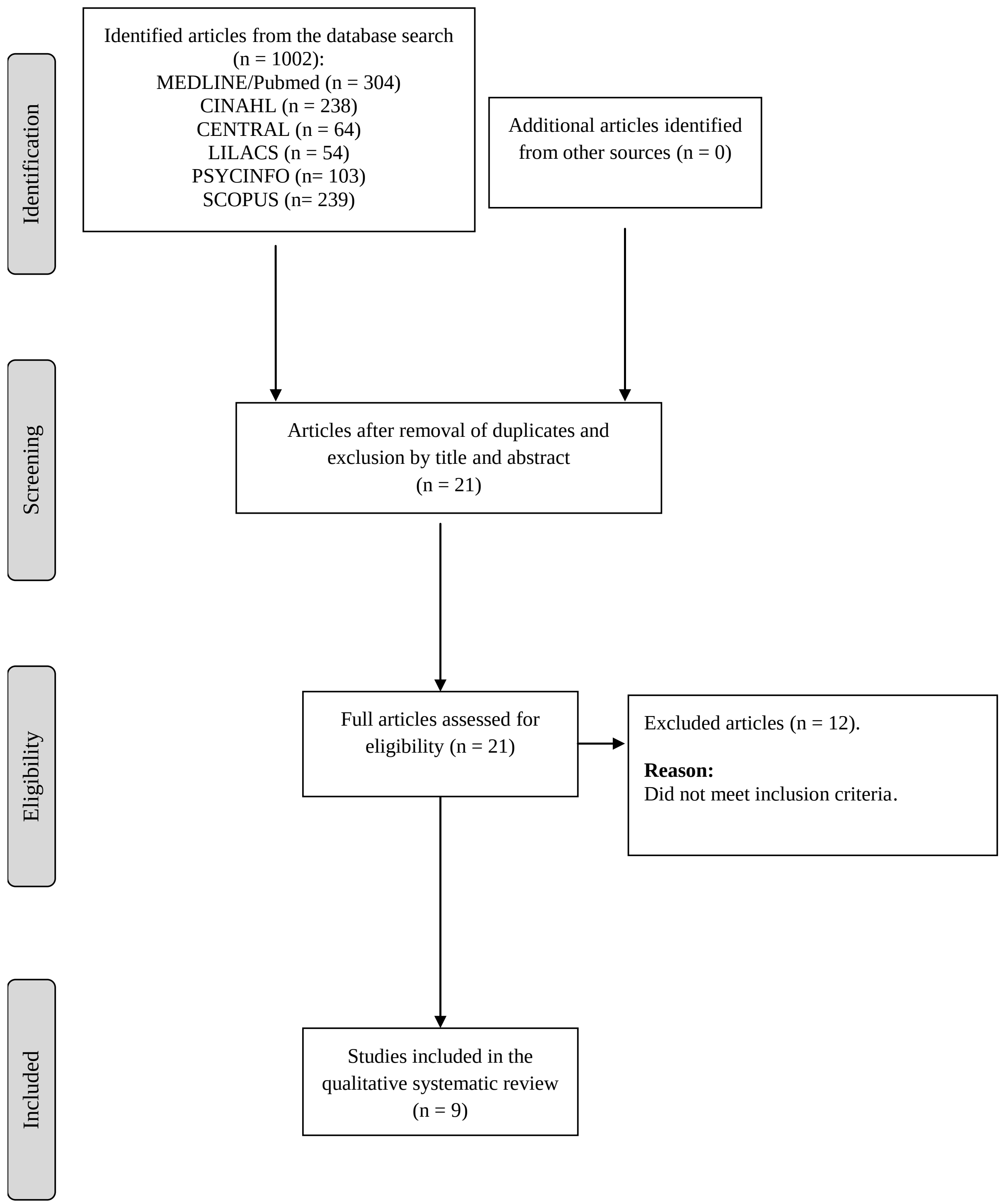

Figure 1. Flowchart of the steps to select the identified articles according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

encountered in relation to the overall M-ABC score, and most of the children in both groups presented comorbidities related to learning disabilities and attention deficits at follow-up (Iversen et al., 2005).

Six children with DCD aged 6 to 8 years experienced three conditions: initial, Le Bon Départ treatment and sensory integration treatment for a period of 12 to 18 weeks (one weekly session). While the motor performance (M-ABC score) of the children with DCD improved significantly after combination treatment, the

Table 3. Summary of the risk of bias in the included studies**.**

Study	Generating the random sequence (selection bias)	Allocation concealment (selection bias)	Blinding of the participants and researchers (performance bias)	Blinding the outcome assessments (detection bias)	Incomplete outcomes (attrition bias)	Selective reporting of the outcome (reporting bias)	Assessment of outcomes (performance bias)
Au et al. (2014)	+	+	+	+	+	+	+
Bardid et al. (2013)	?	+	+	+	+	+	+
Fong et al. (2013)	+	+	+	+	+	?	+
Fong et al. (2012)	+	+	+	+	+	+	+
Giagazoglou et al. (2015)	+	-	?	?	?	+	+
Hung and Pang (2010)	+	+	+	+	+	+	+
Iversen et al. (2005)	?	-	-	?	?	+	+
Leemrijse et al. (2000)	+	+	+	-	?	+	+
Tsai (2009)	-	-	+	+	?	+	+

benefits of the Le Bon Départ treatment were greater than the sensory integration treatment (Leemrijse et al., 2000).

Another study on 28 children with DCD, aged between 9 and 10 years, was almost randomly distributed into a DCD training group or a non-DCD training group. The intervention lasted for ten weeks and consisted of table tennis training (3 sessions per week). The table tennis training resulted in a significant improvement in motor performance (overall M-ABC score) for children with DCD (Tsai, 2009).

Summarily, the studies demonstrated that an intervention period of 8 weeks was sufficient to bring about positive changes in children's motor performance (Hung and Pang, 2010; Au et al., 2014). However, in most of the included studies, which presented significant effects, the intervention period was 12 weeks (Fong et al., 2013; Leemrijse et al., 2000; Fong et al., 2012; Giagazoglou et al., 2015). Most studies established that one weekly session was satisfactory (Hung and Pang, 2010; Leemrijse et al., 2000; Fong et al., 2012; Au et al., 2014; Bardid et al., 2013).

When investigating human motor behaviour, age should be considered. Childhood is a significant period for the acquisition and combination of movements, especially middle childhood (7-10 years), when children are able to process a wide range of cognitive and affective tasks, which provides them the conditions to participate in structured intervention programs. It is probably why almost all the included intervention studies focused on this particular stage, except for Bardid et al. (2013), who investigated younger children (3-5 years).

Although there are two systematic reviews with similar goals to the present study (verifying the effects of interventions on improving motor performance), the revision by Riethmüller et al. (2009) also conducted their search in controlled clinical trials, but their sample did not include children with DCD. Furthermore, they also only investigated children in early childhood (aged <5 years), thus limiting the range of intervention studies with older children.

While the review by Smits-Engelsman et al. (2013) assessed the effect of interventions on children with DCD, it contained time constraints (only studies published between 1995 and 2011), which may have restricted the inclusion of important former or current studies. On the other hand, the search was not limited to controlled clinical trials (it also included systematic reviews and crossover studies), thereby expanding the possibility of other eligible studies, but presented shortfalls in terms of accuracy. It should be noted that the risk of bias of the above review was not assessed by the Cochrane evaluation tool, which has proved to be appropriate for assessing the quality of evidence, and was used in this review.

With regard to methodological quality, some studies should be viewed with caution, since they presented some risk of bias. In terms of generating adequate random sequences, two studies did not provide any details concerning this process (Iversen et al., 2005; Bardid et al., 2013). Therefore, they were considered obscure and only one study was rated with a high risk of bias (Tsai, 2009).

With regard to random allocation, we considered that three trials presented a high risk of bias (Iversen et al., 2005; Giagazoglou et al., 2015; Tsai, 2009). Ideally, participants should be divided into groups without any influence; hence, all participants would have an equal chance of being allocated to either group or sequence (Jüni et al., 2001).

One of the included studies was considered at high risk of bias with regard to the blinding of participants and researchers (Iversen et al., 2005), and one as obscure (Giagazoglou et al., 2015). In blinding the outcome assessments, two studies were identified as obscure (Iversen et al., 2005; Giagazoglou et al., 2015) and at high risk of bias (Leemrijse et al., 2000). This type of bias may change the conduct of events and the intervention, and may directly interfere with the effects encountered.

There was no language or time constraints in the search process of this review, which was conducted by two independent researchers. However, although we used the main databases, there is the possibility that a database (e.g. Embase) or important descriptor was not included in this review. Thus, this factor may be considered as a possible limitation of the study.

CONCLUSION

With regard to methodological quality, most of the included trials enable us to recommend motor interventions for clinical practice on children with DCD, but some studies should be viewed with caution, since they presented some risk of bias. While the results of most intervention studies demonstrated a significant effect, the treatment in some of them was different, thus making it difficult to establish a single recommendation for children with DCD. More controlled clinical trials are needed in order to define which would be the best type of motor intervention for this population, since in general terms the positive effects of interventions have been proven.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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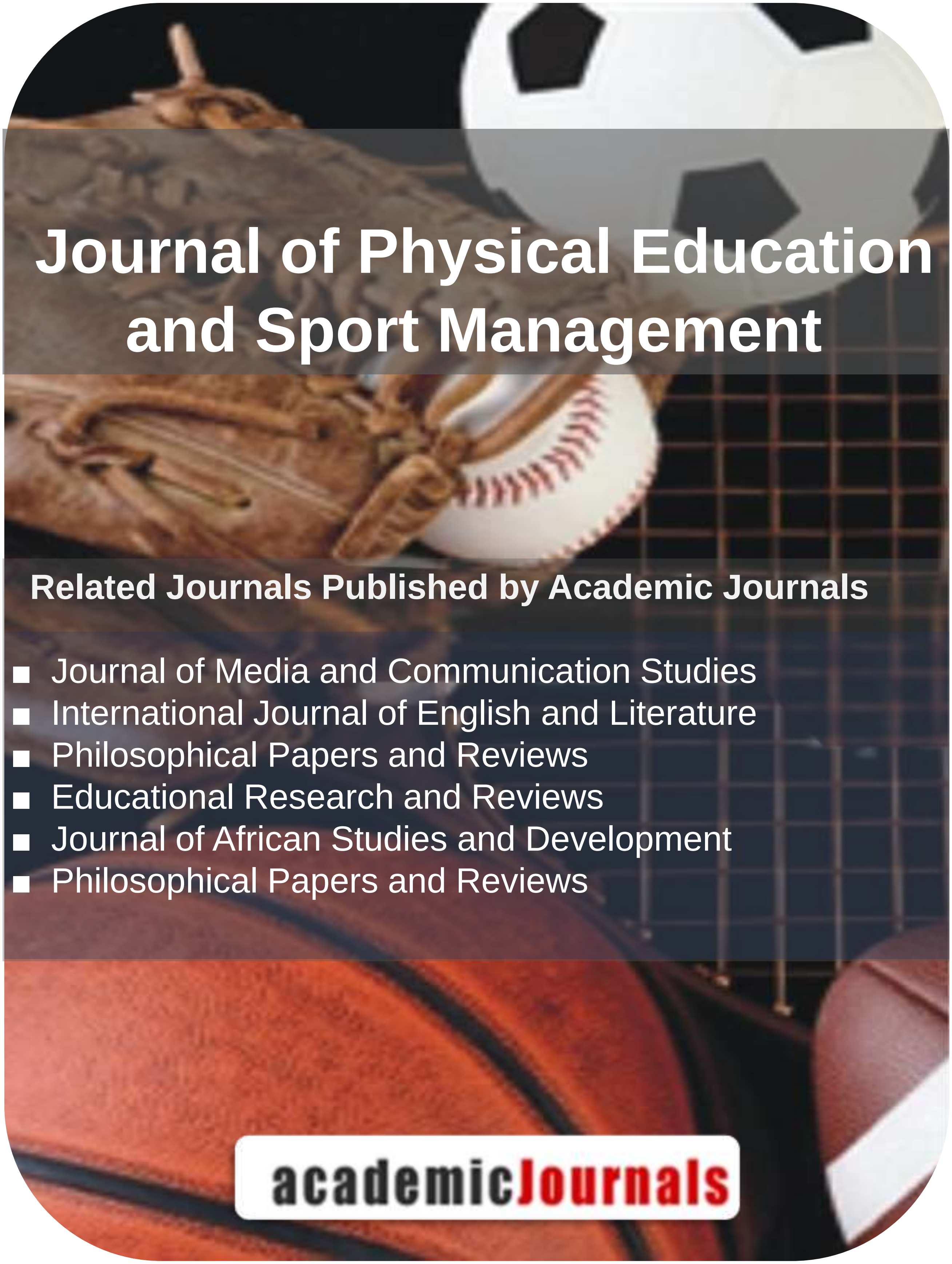

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