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Original Article

Design and Validation of a Motor Intervention Regime for Managing Co-Morbid ADHD and Developmental Co-ordination Disorder (DCD): A Descriptive Study

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Abstract

Background: Attention Deficit and Hyperactivity Disorder (ADHD) is a common neurobehavioral disorder. Children with ADHD, frequently experience motor difficulties. ADHD is treated with neuro-pharmacological medication and psycho-therapy; this seems to have little effect on the motor symptoms. Studies have investigated managing comorbid ADHD and Developmental Co-ordination Disorder (DCD), using neuro-motor treatments. However, a "gold standard" treatment, for managing co-morbid ADHD and DCD, is non-existent. This study fills this gap in the knowledge. Physical exercises have significant somatic benefits but equally important; cognitive, educational and behavioural benefits; which are produced by the increase in the cerebral blood flow and the increased release of endorphins, which in turn stabilize other neurotransmitters, such as dopamine, which enhance cognition and other executive functions. **Objectives:** To design and validate a motor intervention, that addresses both motor and cognitive symptoms of co-morbid ADHD and DCD. Intervention consists mainly of motor co-ordination exercises and balance exercises, which stimulate focus, attention and planning; hence also enhancing the cognitive. **Methods:** A motor intervention was designed, based on 5 conceptual frameworks: 1. International Classification of Function, Disability and Health (ICF). 2. Symptoms of co-morbid ADHD and DCD. 3. Neuroanatomy and neurophysiology affected in both conditions. 4. Effect of Physical exercises. 5. Motor Interventions previously administered to children with cognitive and motor deficits. Literature and clinical experience were also considered in the design of the prototype of the motor intervention. This was validated by a three-phase, modified Delphi process (Using Likert scales and polar questions), by a total of 17 experts, namely: neuro-paediatricians, educational psychologists, physiotherapists and Occupational Therapists (OT). **Results:** Consensus on structure and content of the motor intervention was achieved. A well-designed, motor intervention (content, structure, frequency, duration, repetitions and equipment needed) was the result. This intervention carries clinical significance, in the management of comorbid ADHD and DCD. **Conclusion:** A motor intervention is presented, which is innovative (the first of its kind) and useful (a "gold-standard" treatment for comorbid ADHD and DCD, which at present, is non-existent).

Keywords: Attention Deficit and Hyperactivity Disorder (ADHD), Developmental Co-ordination Disorder (DCD), Co-morbidity, Motor Intervention, Enhancing Quality of Care.

Introduction

ADHD is one of the most common neurobehavioral disorders, affecting children and adults, with persistent core symptoms of inattention, impulsivity and hyperactivity. Additionally, academic achievement, general well-being, executive functions and social interactions are affected. It is reported that worldwide prevalence figures range between 3.55 and 10%, contingent on what literature is consulted. There are 3 subtypes of ADHD: 1. Predominantly inattentive. 2. Predominantly impulsive and/or hyperactive. 3. Combined subtype. ADHD is diagnosed at any age, but symptoms should have appeared before age 12. (Barkley, 2015; DSM V, 2013; Pranjic et al; 2023). Treatment of ADHD is predominantly using neuro-pharmacological medication. It has been reported that the medication produces both short-term and long-term side effects, such as: nausea, gastro-intestinal symptoms, headaches, loss of appetite, disturbance of sleeping patterns, liver damage, cardiac complications, substance abuse, psychological mood disturbances and suicidal ideations (Barkley, 2015; Banaschewski et al, 2010; Breytenbach, 2013).

DCD is a discrete neuro-developmental disorder, consisting of 3 core symptoms: severe difficulty in performing motor tasks at age-appropriate levels, clumsiness and reduced motor speed. This delay cannot be explained by any other physical, sensory or intellectual impairment. Activities of daily living (ADL), academic achievement and participation in sport and leisure are also adversely affected. It has been reported that worldwide figures range between 5 to 8%, within the age-group 6 to 8 years. Symptoms of DCD include but are not limited to: Reduced muscle tone, decreased muscle power, impaired gross and fine motor co-ordination, visual-motor integration problems, reduced balance, core stability issues, bilateral and sensory integration deficits, postural deviations and motor planning difficulties. DCD is a diagnosis of exclusion, in that all other mental, medical and neuromuscular impairments need to be excluded for a DCD diagnosis to be made (Missiuna et al, 2008/2009; Pearsall-Jones et al, 2010; Vaivre-Douret et al, 2011; Smits-Engelsman et al, 2018; Biotteau, 2020; Lino, 2022). Commonly used interventions for DCD, take one of two forms: Deficit/process-orientated, where the deficit is remediated or task-specific. For example: bead-threading remediates fine motor co-ordination and visual motor integration, and the task is the number of beads successfully threaded. Task specific interventions are more commonly administered and seem to yield the better results (Zwicker et al, 2012; Smits-Engelsman, 2018).

Studies reveal that children with ADHD frequently experience motor impairment, with prevalence figures ranging from 30 to 50%, although little attention is given to comorbid ADHD and DCD, in clinical practice (Zwicker, 2012). Considering the association between motor and attentional deficits, especially seen in DCD and ADHD; the concept of "Deficit of attention, motor control and perception syndrome" (DAMP) was created (Lino; 2022). Treatment of ADHD is commonly with neuro-pharmacological medication, which seems to have little or no effect on the motor impairment. The reason for this could possibly be due to neuro-pharmacological medication having an effect mainly on the inferior frontal cortex, which controls cognition, emotions and behaviour and does not address motor difficulties. Motor difficulties significantly impact ADL and thus need to be addressed, to ensure functional independence in children, with such impairments (Barkley, 2015; Fliers, 2010). Physical exercises have commonly known effects of improving general fitness, reduction of obesity, cardiovascular enhancement, prevention of demineralisation, improvement of muscle strength and co-ordination and general feeling of well-being. The less commonly known effects of physical exercises are that they regulate the levels of neurotransmitter substances, such as dopamine, serotonin, norepinephrine and endorphins; which, in turn, have the effect of enhancing focus, attention, memory, balance and co-ordination (Den Heijer et al, 2017; Pienaar et al, 2017; Rowland, 2016).

It thus follows, that physical exercises, should be used as an adjunct, in the management of co-morbid ADHD and DCD. In most studies found, investigating the effects of physical exercises on the comorbidity of ADHD and DCD; the design of the motor intervention was not fully described, and all facets of the intervention were not comprehensively outlined (Den Heijer et al, 2017; Pienaar et al, 2017; Visniauske et al, 2020; Zierus, 2015). This gap in the literature, provides impetus for this study, which describes the design of the motor intervention, how this intervention was validated and fully describes the final draft of the intervention. The validation process ensures the inclusion of clinical expert opinion, which reduces all possibility of author bias, in the design process (Skulmaski et al, 2007). This study replies to the study question: "Does a gold standard motor intervention exist, for use as an adjunct to the management of comorbid ADHD and DCD?"

Methodology

The study design followed a three-round hybrid Delphi process; in the development and validation of a motor intervention, for managing comorbid ADHD and DCD. A systematic sampling method was used to identify paediatric neurologists, educational psychologists, occupational therapists and physiotherapists as these are clinicians mostly involved in the management of both ADHD and DCD. This was done by using Medpages (Neuburger, 2014), the Internet and by word-of-mouth.

Ethical clearance was obtained from Biomedical Research Ethics Committee (BREC): BFC 397/16, in 2016.

Round 1

In the first round, the inclusion criteria required participants to have at least 10 years of knowledge and/or clinical experience in neuro-pediatrics, ADHD, or DCD. They also needed to be willing and available to participate, with effective communication skills and access to suitable communication facilities. Those with less than 10 years of experience, unwilling or unable to participate, or lacking the necessary communication skills and facilities were excluded.

Fifteen professionals meeting these criteria were identified and each received an email containing a concise explanation of the study requirements along with a consent form, carefully designed to ensure clarity while minimizing potential participation bias. Once informed consent was obtained, these professionals were formally enrolled in Round 1 of the study.

The initial draft of the motor intervention was generated; taking all 5 conceptual frameworks, described below, into careful consideration; drawing on clinical experience and considering motor interventions designed, in previous, similar studies.

The International Classification of Function, Disability and Health (ICF) describes how the body structure/s involved, affect the condition; the symptoms of the condition/s and the implications of these symptoms on limiting activity and restricting participation (Mahdi et al, 2017).

Symptoms experienced in comorbid ADHD and DCD are summarised as follows: Inattention; impulsivity; hyperactivity; deficits in executive function; impaired muscle tone and muscle power; impaired gross and fine motor co-ordination; balance deficits; visual-motor problems; sensory integration problems; postural and core stability issues; motor planning deficits and secondary manifestations on areas such as academic, sport and leisure and ADL (Missiuna et al, 2008/9; Biotteau et al, 2020).

In several neurological studies (structural and functional) undertaken on children with ADHD and children with DCD, similar abnormalities were detected in both conditions. Furthermore, reduced concentrations of certain neurotransmitter substances (dopamine, norepinephrine, serotonin, endorphins), in blood and brain metabolites were found in children with ADHD and in children with DCD. This shows the link between the two conditions, which provides the rationale for treating both conditions, simultaneously. Exercises regulate the concentration of the neurotransmitter substances, which enhance the executive functions (focus, attention, memory, inhibition, planning) and improve movement and co-ordination (Kasperek et al, 2015; Curatolo et al, 2010; Mandal, 2015).

Effects of physical exercises: Better known effects and less well-known effects of exercises as previously described, were carefully considered in the initial design of the motor intervention. Increased blood flow to the brain, may also lead to cognitive enhancement. Long term exercises improve cognitive function through "morphological brain changes and improved cardio-respiratory functioning" and were also found to promote cerebellar development and hence improvement in balance and co-ordination (Best et al, 2010; Den Heijer et al, 2017).

Motor interventions previously administered to address cognitive and motor difficulties in comorbid ADHD and DCD: The literature review revealed many, varying motor interventions, administered to children having cognitive and motor deficits. These are summarized in Table 1.

Table 1. illustrates the Summary of the Publications Reviewed in the Development of the Prototype of the Motor Intervention, for use in the Management of co-morbid ADHD and DCD.

Author details	Exercises	Duration and frequency of exercises	Age group in years.	Outcomes: (E: excellent, M: moderate, P: poor, U: undocumented)
Smith et al. USA, 2013.	Vigorous hopping and running.	30 minutes daily for 8 weeks.	5 to 9	E (Motor and inhibition improved.)
Ziereis and Jansen. Germany, 2015.	Moderately vigorous ball skills, balance and manual dexterity.	60 minutes, once per week, for 12 weeks.	7 to 12	E (Motor and executive functions improved.)
McKune Australia, 2003.	Vigorous running and jumping.	60 minutes, 5 times per week, for 5 weeks.	5 to 13	E (Motor and attention improved.)
Kang et al. Korea, 2011.	Running, rope-jumping, goal-directed throwing.	90 minutes, twice per week, for 6 weeks.	7 to 9	M (Only motor improvement.)
Verret et al. Canada, 2014.	Aerobic motor and muscular skills.	45 minutes, 3 times per week, course duration unspecified.	7 to 12	E (ADHD symptoms improved.)
Pienaar et al. South Africa, 2017.	Vestibular and kinaesthetic input, balance exercises, eye-hand co-ordination exercises, fine motor activities.	37-minute sessions, for 9 weeks, number of sessions per week not recorded.	7 to 12	E (Significant improvement in visual-motor integration)
Kolesky South Africa, 2017.	Cardiovascular training, strengthening, balance, bilateral co-ordination, visual-motor.	30 minutes, 3 times per week, for 8 weeks.	4 to 14	E (Significant improvement in BOT-2 # scores.)
Maharaj and Lallie South Africa, 2016.	Trampolining, ball skills, core strengthening (push-ups, sit-ups), throwing and catching, balance (wobble board), jumping in and out, bilateral co-ordination (star-jumps), large ball activities.	30 minutes, once per week, 8 weeks.	6 to 12	U (6 to 46% improvement in MABC** scores)
Peens et al. South Africa, 2008.	Vestibular and kinesthesis (rolls, jumps, toe-walking, skipping, hopping, balance on 1 leg), ball skills, fine motor activities, eye control exercises. + psycho-motor intervention. +self-concept enhancing.	30 minutes, 3 times per week, 8 weeks.	7 to 9	E (31 % improvement in MABC scores) This seems unusually high
Morton, Dublin, 2015.	Balance, ball skills, throw and catch, gross motor (line-walking, hopping), ball rolling up the wall, strengthening (wheelbarrows, crab-walking).	1 hour, once per week, for 10 weeks.	7 to 10	U (5 to 7 % improvement in MABC**)

#BOT-2: Bruninks Oseretsky Test 2nd version; **MABC: Motor Assessment Battery for Children

The prototype of the motor intervention was sent to each participant, together with a questionnaire, with fifteen statements pertaining to content and structure of the motor intervention. The participants were requested to rate each statement, on a nine-point Likert scale, with three descriptive levels. They were given one week by which to return the responses. The prototype and the intervention and the questionnaire are available from the author on request, this is too lengthy to be included in this manuscript.

Once responses were all received, the results were collated and coded by 2 trained assistants, to eliminate possibility of errors. Consensus was determined by a 70% a-priori threshold, for example: If 70% or more of the participants agreed to the exercise described (execution of the exercise, number of repetitions and other details), the exercise was kept, as it had been described. If less than 70% agreed, appropriate changes to the exercise were made, by the primary investigator, as suggested by the participants, for example: if consensus was that more repetitions of abdominal crunches, were needed; repetitions of crunches were increased from 5 to 7, appropriate to what was suggested. The second draft of the motor intervention was created, and this was used in Round 2 and Round 3.

Round 2 and 3

In Rounds 2 and 3, participants were selected through systematic sampling from medical professionals working at special needs schools in and around Durban, South Africa. To be included, they needed at least three years of experience in the pediatric field, clinical experience in treating ADHD and/or DCD, a willingness and availability to participate, and effective communication skills and facilities. Anyone with less than three years of pediatric experience, insufficient clinical experience with ADHD and/or DCD, a lack of willingness or time to participate, or inadequate communication resources or skills was excluded. Two schools for special needs were identified and informed consents to participate in these rounds, were received from 5 occupational therapists and 5 physiotherapists.

The second draft of the motor intervention, providing the name of each exercise and a full description of each exercise was delivered to the participants. It consisted of 10 exercise items and an additional five items, pertaining to structure of the exercise programme. One or more polar questions were asked on each item and "yes", "no" and "comments" columns were provided. Once again, this document is available on request from the author, as this is too lengthy to be included in this manuscript.

Responses were collected after a week and the results were collated and coded, by 2 trained study assistants. Items on which consensus was not reached, were amended, as described in Round 1, above. These were highlighted and forwarded to the experts, who were encouraged to re-evaluate and re-rate these items. The final draft of the motor intervention was compiled. This is illustrated in Table 3.

Statistical Analysis

Data were pooled and was analysed, by data analysts, who were blinded to the objectives of the study. Consensus was determined by a 70% a-priori threshold. Cronbach's alpha was utilised as a measure of reliability of the result. Alpha = 0,802; close to 1.0; illustrating consistency and reliability of the responses of the medical professional panel. Items on which consensus was not reached, were amended, as described above.

RESULTS

Participant Demographics

Table 2: Participant Demographics for Round 1 and Rounds 2 and 3

Round	Experts	Location	No	Experience (average in years)
1	Neuro-paediatricians	Durban, South Africa.	1	12
1	Educational Psychologists.	Durban, South Africa.	2	11
1	Physiotherapists.	Durban, South Africa.	2	13
1	Occupational Therapists.	Durban, South Africa.	2	12
2 and 3	Physiotherapists.	Durban, South Africa.	5	**5**
2 and 3	Occupational Therapists.	Durban, South Africa.	5	4

Validation

Consensus was NOT reached on the following items, in Round 1:

Two-point kneel walking: Not an effective balance exercise: Was altered to Half-kneeling, balance. Diadochokinesis (DDK): Not a fine motor exercise. Another fine motor activity was incorporated, that is opposition of fingers to thumb. Tandem Walking and Hopping: Could not be part of the intervention, as these were tests on the Movement Assessment Battery for Children (MABC), used frequently, to test DCD. These were replaced with Toe walking, Jumping/Hopping over something such as a hoop, exercises. The exercise intervention was not administered frequently enough. This was increased from once per week to twice per week.

Consensus was not reached on the following items, in Round 2 and Round 3:

Abdominal Crunches: Only rectus abdominus was catered for. Exercises were altered, to cater for the straight and oblique abdominals. Half kneeling balance: Insufficient repetitions. These were increased from 3 on each lower limb to 5 on each lower limb. The final draft of the motor intervention is illustrated in Table 3.

Table 3. illustrates the Summarized version of final draft of the Motor Intervention, for use in the Management of co-morbid ADHD and DCD.

Exercise	Repetitions	Effect/s
Abdominal Crunches with knees flexed. Hold for 10 seconds.	2 repetitions straight abdominals. 2 repetitions oblique abdominals to the right. 2 repetitions oblique abdominals to the left.	Builds core stability. Enhances posture.
Bridges with knees flexed. Hold for 10 seconds.	7 repetitions.	Builds core stability. Enhances posture. Influences muscle tone.
Superman: Four-point kneeling. Raise opposite upper limb and lower limb. Hold for 10 seconds.	3 repetitions right upper limb left lower limb. 3 repetitions left upper limb, right lower limb.	Builds core stability. Improves balance. Enhances proprioception and bilateral integration. Influences muscle tone. Improves focus/attention/concentration. Calming effect of improved proprioception.
Crawling forwards, backwards and sideways.	4 meters in each direction.	Builds core stability. Enhances proprioception and bilateral integration. Influences muscle tone. Improves gross motor co-ordination. Facilitates the ability of motor planning. Calming effect of improved proprioception.
Ball throwing and catching (23 cm size ball), whilst in half-kneeling.	10 throws and catches in the air. 10 throws and catches, with a bounce of the ball.	Improves balance. Enhances posture. Optimizes eye-hand co-ordination. Facilitates the ability of motor planning. Improves focus/attention/concentration.
Half-kneeling balance. Each time leg is lifted and placed anterior, the hip and knee should be flexed to 90 degrees.	5 repetitions with the right leg anterior. 5 repetitions with the left leg anterior.	Improves balance. Enhances posture. Optimizes gross motor co-ordination. Improves focus/attention/concentration. Enhances function.
Wheelbarrow activity. Children work in pairs, child A holds child B at the ankles, while child B puts his/her hands down on the floor and walks on his/her hands. The children then swap duties.	4 meters forwards. 4 meters backwards.	Builds core stability. Influences muscle tone. Weight on the shoulder girdle, improves fine motor co-ordination.
Walking on toe-tips forwards and	4 meters forwards.	Improves balance.

backwards, with good posture.	4 meters backwards.	Enhances posture. Facilitates gross motor co-ordination.
Jumping and/or hopping over an object, such a s a hoop or a rope.	6 hoops or 6 ropes. Different combinations. 3 repetitions of each combination.	Improves balance. Optimizes gross motor co-ordination. Enhances eye-foot co-ordination. Improves the ability of motor planning. Facilitates sensory integration.
Star-jumps/jumping jacks: Jump to a position with legs apart and arms overhead then return to a position with feet together and arms at the side.	10 repetitions	Builds endurance. Enhances motor planning and bilateral integration. Improves timing and sequencing. Facilitates eye-hand and eye-foot co-ordination. Optimizes gross motor co-ordination.
Diadochokinesis: Rapid, alternating movements, with the upper limbs, pronation (palm down) then supination (palm up).	10 repetitions. Repeat set twice.	Enhances eye-hand co-ordination. Improves fine motor co-ordination.
Opposition of thumb to each finger.	2 repetitions with right hand. 2 repetitions with left hand. 2 repetitions with both hands together.	Enhances eye-hand co-ordination. Improves fine motor co-ordination. Facilitates focus/attention/concentration.
General Rules	Motor intervention should be done for an hour, twice per week.8 weeks. In groups.	

Discussion

The primary purpose of this paper was to design, validate and present a motor intervention, to be used specifically in the management of comorbid ADHD and DCD. A motor intervention such as this one, does not exist at present and this study will assist in filling this gap. A large number of studies were reviewed, during the initial drafting process of this motor intervention. The description of these studies is summarised and illustrated in Table 1. Some of the interventions in these studies were not specifically designed to cater for the symptoms of both ADHD and DCD (Smith et al, 2013; McKune et al, 2003; Kang et al, 2011; Verret et al, 2014) whereas others were (Ziereis et al, 2015; Pienaar et al, 2017; Kolesky, 2017; Maharaj and Lallie, 2016; Peens et al, 2008; Morton, 2015). The studies that were designed to cater for both conditions resembled the motor intervention designed in this study. A full description of the exercises and execution thereof, as well as number of repetitions of exercises, that needed to be performed, was not always provided. In a systematic review completed (Smits-Engelsman et al, 2018), duration of sessions ranged from 20 minutes to 1 hour. The average duration was an hour, which is in support of the motor intervention designed in this study. The average number of sessions administered were 1.5 per week, for an average of 9 weeks; whereas it is suggested that the motor intervention in this study, is administered twice per week, for an 8-week period. Most interventions were administered to a group, as opposed to individual therapy; the benefits of group therapy being physical and psycho-social (Smits-Engelsman, 2018). This is in support of the intervention designed and presented in this study.

The strengths of this study are as follows: The motor intervention in this study, is the first of its kind, which has involved a multi-disciplinary team approach in both design and in validation thereof. It is one of very few interventions, which lists the exercises/activities, provides a description of how each of these are performed, how many repetitions should be performed, what equipment is needed, and it provides the effect that each exercise produces. The clinical significance of this intervention is that, in providing a new clinical pathway to the management of comorbid ADHD and DCD, it will have an impact on public health, on children with ADHD, with associated motor impairments.

Limitations to the study, were as follows: replies to questionnaires, from medical professionals, were not always timeously received. The number of participants were too few, namely 7 in Round 1 and 10 in Round 2 and 3. All the experts/professionals came from the same area, namely Durban, South Africa. This could impact negatively on generalization of the intervention, for use on other populations. The changes were made by the primary investigator, which might have resulted in bias. It is suggested that further studies involve testing the efficacy of this intervention in improving symptoms of comorbid ADHD and DCD.

Conclusion

This paper highlights the design/development and validation, of a motor intervention, which is targeted at addressing the symptoms of co-morbid ADHD and DCD.
The motor intervention in this study brings new perspective to the management of co-morbid ADHD and DCD, in that it is designed with rigor, using theory, literature and clinical experience. It has been critically validated by a multi-disciplinary, team; their clinical opinion being taken into careful consideration. Its content, structure and all administrative details have been fully described. The motor intervention designed in this study, could thus have an effect on the clinical pathway utilized in the management of co-morbid ADHD and DCD as well as it possibly being a useful tool in research on co-morbid ADHD and DCD.

Author Contributions

All authors significantly contributed to the work reported, including conception, study design, execution, data acquisition, analysis, and interpretation. They actively participated in drafting, revising, or critically reviewing the manuscript, provided final approval of the version to be published, agreed on the journal submission, and accepted accountabilities for all aspects of the work.

Data Availability Statement

The authors will transparently provide the primary data underpinning the findings or conclusions of this article, without any unjustified reluctance. If need from editorial team.

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Conflicts of Interest

The authors declare no potential conflicts of interest related to the research, writing, or publication of this work.

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