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Manual function outcome measures in children with developmental coordination disorder (DCD): a systematic review

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Abstract

This study systematically reviewed the clinical and psychometric properties of manual function outcome measures for children with developmental coordination disorder (DCD) aged 3 to 18 years. Three electronic databases were searched to identify manual function tools at the ICF-CY body function, activity and participation level. Search strategy included terms identifying childhood, children with DCD and manual function tools. Study selection was conducted by two blind assessors. CanChild Outcome Measures Rating Form was used as a data report sheet. Seven clinical tests, three naturalistic observations and six questionnaires were identified. The fine-motor subdomain of the Movement Assessment Battery for Children, of the Bruininks-Oseretsky Test of Motor Proficiency-2 and of the Functional Strength Measurement, with adequate reliability and validity properties, might be useful for manual function capacity assessment. Naturalistic observations and questionnaires, whose psychometric properties have been investigated into limited extent, offer an assessment of the daily performances.

This review shows that a combination of different tools might be useful for a comprehensive assessment of manual function in children with DCD including the three levels of the ICF-CY. Further investigation of psychometric properties of those tools in children with DCD is warranted. Tests validated in other populations should be explored for assessing manual function in children with DCD.

What this paper adds

This is the first systematic review on manual function outcome measures in children with DCD.

Manual skills are frequently impaired in children with DCD at different ICF-CY levels interfering with their development and successful participation in everyday activities. Therefore it is important to assess manual function in children with DCD for diagnosis and treatment planning.

Several clinical tools are available nevertheless there is no consistency in their use in clinical practice as well as limited application in research.

A combination of different tools (tests, naturalistic observations and questionnaires) should be used for a comprehensive assessment of manual function in children with DCD, considering the ICF-CY framework. The present review offers a road map in choosing these tools for a comprehensive assessment of manual function in children with DCD.

Keywords

Developmental Coordination Disorder, systematic review, manual function, outcome measures

Words count

7531 plus tables

1. Introduction

DCD is classified in the fifth revision of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) (American Psychiatric Association, 2013) in the category of neurodevelopmental disorders. Children with DCD show (1) acquisition and execution of motor skills below what would be expected at a given chronological age and opportunity for skill learning and use; (2) motor skills deficit significantly interfering with activities of daily living (ADL) appropriate to the chronological age, impacting school productivity, leisure and play; (3) early development onset of symptoms; (4) motor skills deficits that cannot be explained by intellectual disability, visual impairment and not attributable to neurological condition. The estimated prevalence of DCD is around 6% of children aged 5-11 years depending on case definition (American Psychiatric Association, 2013). Since children with DCD can be recognized as having a heterogeneous condition with different functional manifestations, the International Classification of Functioning and Disability-Children Youth Version (ICF-CY) (World Health Organization, 2007) can be considered perfectly applicable to describe the clinical features of the disorder. The ICF-CY framework is based on a multifactorial and interactional model of disability and consists of two mains sections. While the first classifies functioning and disability with components of body structure and function (BF), activity and participation (A/P), the second refers to contextual factors (environment and personal factors). Within this framework, activity is defined as 'the execution of a task or action by an individual', and participation as 'the involvement in a life situation'. This domain is further delineated by two qualifiers known as capacity and performance. 'Capacity' describes an individual's ability to execute a task or an action describing highest probable level of functioning that a person may reach in a given domain at a given moment, while 'performance' describes what an individual does in his or her current environment. Children with DCD face motor problems which are essentially represented at BF level, such as strength problems, impairments of target-directed reaching, slowness, and deficits in visual proprioceptive and kinesthetic perception(Raynor, 2001; Schoemaker et al., 2001). At activity level, children with DCD face problems with motor planning (Adams, Lust, Wilson, & Steenbergen, 2014;Noten, Wilson, Ruddock, & Steenbergen, 2014) and execution of fine motor skills, such as manual dexterity, in-hand manipulation and bimanual coordination (Raynor, 2001). These manual function deficits contribute to poorer participation at school and weaker performance of ADL compared to typically developing (TD) children (Smits-Engelsman, Wilson, Westenberg, & Duysens, 2003). Secondary to the motor problems, children with DCD can experience significant emotional and mental health concerns (Summer, Larkin, 2008).

The ICF-CY framework is dynamic as components are related and influence one another (G. D. Ferguson, Jelsma, Versfeld, & Smits-Engelsman, 2014). These authors underline the importance of understanding the interaction between individual and contextual factors for maximizing the impact of the interventions in children with DCD. Thus even if the relationship between ICF-CY levels is not linear, it is fundamental that manual function assessment used for the diagnosis and for the treatment planning of children with DCD should tap into all domains of the ICF-CY.

Although insights in the problems of manual function within the ICF-CY framework are important, the development of specific testing of manual skills has been studied to a limited extent. Also, despite different treatment approaches in DCD, intervention studies specifically addressing manual function are sparse (Blank, Smits-Engelsman, Polatajko, & Wilson, 2012). To advance our understanding of manual function deficits and to plan targeted interventions in children with DCD, knowledge of the available measurement tools already used in this clinical population is indispensable. Previous systematic reviews on outcome measures in children with DCD have focused on gross motor function or on motor function in general (Blank et al., 2012;Missiuna, Rivard, & Bartlett, 2006). Also the EACD guidelines for DCD present an overview of the available tools for motor function assessment according to the different levels of the ICF-CY, but do not offer a differentiation among different motor domains (Blank et al., 2012). To the best of our knowledge, no investigation of a manual function assessment tools has been undertaken so far. Nevertheless, several clinical measures

are available and new tools have been developed, there is no consistency in their use in clinical practice as well as limited application in research.

Therefore, the aim of this study was to provide a systematic review of clinical tools appropriate for manual function assessment in children with DCD within the ICF-CY model. This should offer a framework in choosing the appropriate assessment for different aspects of manual function.

2. Materials and methods

2.1. Search strategy

A systematic search (March-September 2014) of electronic bibliographic databases (PubMed, CINAHL, MEDLINE) was performed by a single reviewer (EB). Search terms included keywords referring to "assessment" AND "children" AND "manual function" AND "developmental coordination disorder". All searches were limited to full-papers published in English, from 1980 to 2014, and performed on human participants from 3 to18 years old.

2.2 Study selection

A first selection was based on study titles by one reviewer (EB). Secondly, abstracts were independently screened for eligibility by two authors (KK and EB). The full texts of potentially relevant papers were read to ascertain whether the study met all selection criteria. Inclusion criteria for the outcome assessments were (1) an evaluative clinical tool for manual function at the ICF-CY level of BF and/or A/P, (2) previously used in studies including children with DCD, (3) available for children aged 3-18 years. Tools were excluded if they were (1) not directly linked with aspects of motor function but assessing cognitive, visual or sensory functions, (2) developed before 1980, (3) experimental conditions, (4) measures of manual function used in other pathologies; (5) of handwriting, (6) of handedness, (7) of ball-catching, (8) of gross motor functions. Additionally reference lists and citations of key articles were hand-searched.

2.3 Data extraction and quality assessment

Full texts of the selected papers, assessment manuals if available and related papers were retrieved for analysis of included measures. Two authors (KK and EB) completed a data extraction sheet based on the CanChild Outcome Measure Rating Form (Law, 2004) for extracting and evaluating (1) descriptive information, (2) clinical utility and (3) psychometric properties. Descriptive information was extracted for each tool to determine the focus of the measure (body function, activity and participation) according to the definitions of the ICF-CY, publication year, target population, information on norm values and description of content, domains and number of items specifically related to manual function. Discrimination was made between norm-referenced and criterion-referenced tests. Norm-referenced tests yield an estimate of the position of the tested individual in a predefined population. In contrast, criterion-referenced tests translate test scores into a statement about the behavior to be expected of a person with that score or the relationship to a specified subject (Nunnally, 1978).

The section on clinical utility entailed general duration and scoring information, required equipment and need for rater training. The section on psychometric properties addressed the analysis of reliability, responsiveness and validity of the outcome measures. Reliability was defined as the process of determining that the test has homogeneity of its items to the attribute being measured at one point in time (internal consistency); that the test is measuring something reproducible on repeated administration (test-retest); when used by the same rater (intra-rater) or when used by different raters (inter-

rater) (Portney 2009). Internal consistency was evaluated with Cronbach's alpha reliability coefficient in which values of . >.9 were considered excellent, >.8 good, >.7 acceptable, >.6 questionable, >.5 poor, <.5 unacceptable (George & Mallery, 2003). Cronbach's alpha reliability coefficient normally ranges between 0 and 1. However, there is actually no lower limit to the coefficient. Interrater and test-retest reliability were judged using intraclass correlation coefficients (ICC) and Kappa coefficients. The CanChild Outcome Measure Rating Form describes ICC's of 0.80 or above as excellent; from 0.60-0.79 adequate; and below 0.60 as poor. Kappa coefficients between 0.81 and 1.00 were considered as an almost perfect agreement, 0.61-0.80 as a substantial agreement and 0.41-0.60 as a moderate agreement (Street & Room, 2004; Landis, 1977).

Validity is the extent to which an evaluation tool measures what it purports to measure. Content, construct and criterion validity were reviewed. The CanChild Outcome Measure Rating Form refers to content validity when "the instrument is comprehensive and fully represents the domain of the characteristics it claims to measure". It can be qualitatively obtained with a judgment of experts, or quantitatively determined through a statistical analysis (e.g. factor or Rash analysis). Construct validity is described when "the measurements of the attribute conform to prior theoretical formulations or relationship among characteristics or individuals" Criterion validity is reported when "the measurements obtained by the instrument agree with another more accurate measure of the same characteristic, that is, a criterion or gold standard measure" (Street & Room, 2004; Nunnally, 1978). While concurrent validity refers to the ability of a test to predict an event in the present, predictive validity refers to the ability of a test to measure some event or outcome in the future (Drost, 2011).

Responsiveness is the ability of an instrument to detect changes over time in the construct to be measured. The minimal clinically important difference (MCID) and the smallest detectable difference (SDD) are frequently reported indices of responsiveness. MCID is defined as the smallest difference in scores that would mandate a change in patient's management (Cook, 2008). However, since there is no consensus regarding the optimal technique to calculate the MCID, it should be interpreted with caution. SDD equals the standard error of measurement (SEM) x 1.96 x $\sqrt{2}$ (Weir, 2005). This index is used to define whether the subjects show a real improvement rather than a difference in score that could be due to a measurement error.

3. Results

3.1 Study Selection

The selection process of the studies is outlined in the flowchart (see Figure 1). A total of 13 studies involving 16 assessment tools were identified, including seven clinical tests, three naturalistic observations and six questionnaires.

The tests measure the capacity of manual function in standardized conditions. Two assessments focused on strength, in static and dynamic conditions: the Hand-Held Dynamometer (HHD) (Van den Beld, van der Sanden, Sengers, Verbeek, & Gabreëls, 2006) and the Functional Strength Measurement (FSM) (Smits-Engelsman & Verhoef-Aertssen, 2012;.G.D. Ferguson, Aertssen, Rameckers, Jelsma, & Smits-Engelsman, 2014). The five other tests assess the performance on a series of standardized tasks. They included the In-Hand Manipulation Test (IHM) (Exner, 1993; Breslin & Exner, 1992), the McCarron Assessment Neuromuscular Development (MAND)(Brantner, Piek, & Smith, 2009;Hands, Larkin, & Rose, 2013), the Zurich Neuromotor Assessment (ZNA)(Rousson, Gasser, Caflisch, & Largo, 2008; Kakebeeke et al., 2014) the Bruininks-Oseretsky Test of Motor Proficiency-2 (BOT-2)(Deitz, Kartin, & Kopp, 2007; Wuang & Su, 2009) and the Movement Assessment Battery for Children-2 (MABC-2) (Henderson, Sugde & Barnett, 2007).

A naturalistic observational approach attempts to capture a child's real-life skill performance allowing an objective assessment in common childhood activities. Instruments of naturalistic observation included the Daily Functioning in

Children with Developmental Coordination Disorder (DCDDaily) (Van der Linde et al., 2013), the Assessment of Children's Hand Skills (ACHS) (C. W. Chien, Brown, & McDonald, 2011a; C. W. Chien, Brown, & McDonald, 2011b) and the "Do-Eat" (Josman, Goffer, & Rosenblum, 2002).

Questionnaires provide a subjective assessment of the child's performance by the parents/caregiver, teachers or other professionals. The seven questionnaires were the Little Developmental Coordination Disorders Questionnaire (LittleDCDQ)(Rihtman, Wilson, & Parush, 2011; Wilson et al., 2015), the Developmental Coordination Disorder Questionnaire'07 (DCDQ'07)(Parmar, Kwan, Rodriguez, Missiuna, & Cairney, 2014; Wilson & Crawford, 2012)', the Daily Functioning in Children with Developmental Coordination Disorder Questionnaire (DCDDaily Q)(Van der Linde et al., 2014), the Movement Assessment Battery for Children-2 Checklist (MABC-2 Checklist) (Henderson, Sugden & Barnett, 2007;' Schoemaker, Niemeijer, Flapper, & Smits-Engelsman, 2012), the Children Activity Scale–Parents/Teachers (ChAS-P/T)(Rosenblum, 2006), and the Children' Hand Skill Ability Questionnaire (CHSQ) (Chien & Brown, 2012).

[Figure 1. here]

3.2 Studies Characteristics

3.2.1 Descriptive Information

The descriptive information of the outcome measures is presented in Table 1.

Tests have been developed in different countries most of them in the last 15 years. The age range varied from 2/3 years up to 18 years. According to the ICF-CY framework (World Health Organization, 2007), only the HHD specifically refers to BF level. Other outcome measures are combining aspects of BF and A/P level in unimanual and bimanual tasks (except for the HHD and the ZNA which assess only unimanual tasks). More detailed information is reported below.

[Table 1. here]

3.2.1.1 Tests

Muscle power outcome measures included the HDD and FSM. The HHD is used to measure isometric muscle power for upper and lower limbs muscles with separate and related normative data. The FSM provides an indication about the functional muscle power real life situations. Norm references are specifically available for upper and lower limb functional activities separately. Four out of the five functional tests (BOT-2, MABC-2, MAND, ZNA) target children with motor difficulties for both gross and fine motor domains. These are all norm-referenced while the IHM is a criterion-referenced test and exclusively aims to assess fine motor problems. The MABC-2 has only three items on the domain of manual dexterity. They differ according to the age band. The complete form of the BOT-2 provides 15 items for fine manual control split into items for fine motor precision and for fine motor integration. Also this test includes a manual coordination subtest with components of manual dexterity and bilateral coordination tasks. The MAND includes the assessment of qualitative and quantitative performances in five fine-motor tasks. The ZNA is a standardized test for assessing the speed of several motor tasks and the quality of the movement. Finally, the IHM provides 60 items assessing quality and efficiency of in-hand manipulation skills.

3.2.1.2 Naturalistic observations

The DCDDaily is purposely developed for children with DCD with an age range of 5-8 years. The instrument assesses several tasks within three ADL domains. The ACHS is designed for use in children between 2 and 12 year old with or at risk for fine motor problems. It includes 20 representative hand skill items based on 22 activities representing typical childhood occupations. The “Do-Eat” is specifically developed for children with DCD aged 5-6.5 years. It consists of three main tasks, for each of it the child receives a score about the way of performing the task, the analysis of the sensory-motor skills and of the executive function.

All the naturalistic observation approaches have been developed in parallel with a caregiver questionnaire. However while for the DCDDaily and the ACHS the related questionnaires can be also stand alone, the “Do-Eat” questionnaire is strictly related to the performance of the naturalistic observation and therefore will not be considered as an outcome measure itself.

3.2.1.3 Questionnaires

The purpose of four out the seven questionnaires (LittleDCDQ, DCDQ’07,(B.N. Wilson & Crawford, 2012)(B.N. Wilson & Crawford, 2012) DCDDailyQ, ChAS-P/T) is to identify children at risk of DCD, while the MABC-2 Checklist and the CHSQ are addressed to a broad population of children with motor disabilities. The LittleDCDQ (3-4 years old) and the DCDQ’07 (5-15 years old) have been developed along the same structure, including items on control during movement, fine motor

skill and handwriting, and general coordination. The DCDDailyQ is just recently published and investigates ADL activities for children aged 5-8 years old. The ChAS-P/T addresses five items of fine motor skills, but also focuses on gross motor skills, ADL and on the children's organization in space and time. It also provides a specific version for teachers. The MABC-2 Checklist is developed as a complement to the MABC-2 test. It is based on three sections, subdivided into three parts and containing items referring to self-care skills, class-room skills and physical/recreational skills. Finally, the CHSQ is developed as a parallel assessment of the ACHS naturalistic observation used to obtain caregivers' perceptions specifically on the children's manual ability in three domains. It is the only questionnaire that can be used for children from two years old onwards.

3.2.2 Clinical Utility

The clinical utility for the outcome measures is summarized in Table 2.

[Table 2. here]

3.2.3 Psychometric Properties

The values reported for the test specifically refer to the fine-motor subdomain. Evidence for reliability (internal consistency, test-retest reliability, inter-rater) and responsiveness of the selected outcome measures is presented in Table 3.

The manual dexterity domain of the MABC-2 represents the tool with the best and more complete psychometric properties. Reliability values were less investigated for naturalistic observations and questionnaires.

Table 4 summarizes evidence for content, construct, criterion and predictive validity of each selected outcome measure. Compared to reliability more validity results are reported for the whole outcome measures.

[Table 3. here]

4. Discussion

This study aimed to identify different outcome measures that could be used for the assessment of manual function in children with DCD according to the ICF-CY framework: 16 assessments were identified of which seven tests, three naturalistic observations and six questionnaires.

4.1. Tests

The seven tests that came up from this review offer the assessment of different categories of ICF-CY framework namely the body function domain -muscle power- and activities domain -fine hand use.

All tests can be used in children with a broad spectrum of motor difficulties, which means that they are not specifically developed for use but can also be used in children with DCD.

The HHD and the FSM assess the category of muscle power in static or dynamic conditions respectively. The HHD is a measure of muscle power and allows examination of the more proximal upper limb muscles. Considering the specific difficulties in hand-manipulation of children with DCD, it might be more useful to assess grip strength using a Jamar dynamometer (Ploegmakers, Hepping, Geertzen, Bulstra, & Stevens, 2013) as suggested in the general NIH toolbox (Wang, Bohannon, Kapellusch, Garg, & Gershon, 2014) as well as in the EACD guidelines for children with DCD (Blank

et al., 2012). However, so far this measurement has not yet been applied in this target group. The FSM represents the first tool for measuring functional muscle power. Specific norm references are available (Smits-Engelsman & Verhoef-Aertssen, 2012). So far the instrument has been used in to two studies in DCD (Ferguson, Aertssen, Rameckers, Jelsma, & Smits-Engelsman, 2014).

The MABC-2, the BOT-2, the MAND, the ZNA and the IHM all analyze different aspects of the fine hand use category of the ICF-CY activity domain such as performing the coordinated actions of handling objects, picking up, manipulating and releasing them using one's hand, fingers and thumb.

The MABC-2 and the BOT-2 are broad scales also capturing gross motor function but have specific norm-referenced subdomains for fine-motor function. Both scales have been validated in a large sample of TD children, respectively from UK and US and recently from Netherlands(Niemeijer, Van Waelvelde, & Smits-Engelsman, 2015). The debate about the possible effect of testing procedures in different countries, and/or cultural influence, supports the necessity to have different normative samples (Niemeijer et al., 2015). While the MABC-2 provides only three items for the manual dexterity domain, the BOT-2 includes 27 fine motor tasks. However, the clinical relevance and diagnostic purpose of some of the BOT-2 items included in the subtest of fine motor integration (for instance, copying a circle or a square) and in the bilateral coordination subtest (such as touching nose with index finger with eye closed or tapping feet and fingers) might be criticized because of their pertinence, respectively, to writing tasks or neurological examination's tasks. Consequently manual dexterity subtests (e.g. transferring pennies or sorting cards) and fine-motor precision subtests (e.g. folding paper, cutting out a circle) could be the main interesting tasks to be used (Deitz et al., 2007) .

The MABC-2 and the BOT-2 can already be used from the age of 3 and 4 years respectively, which is helpful for an early detection of clinical symptoms of DCD (Blank et al., 2012). The MABC-2 is quick to set up, administer and score and requires minimal training, while the scoring process of BOT-2 is time intensive. Difficulties in the scoring of the BOT-2 have also been statistically confirmed by a lower inter-rater reliability of these tests, compared to the gross motor subtests (Deitz et al., 2007). In contrast, excellent inter-rater reliability has been reported for the manual dexterity domain of the MABC-2 in the 4-6 years age band (Chow & Henderson) Further studies on the inter-rater reliability on manual dexterity subdomain of the MABC-2 in the other age bands should be conducted. According to the EACD guidelines, most validity results from the MABC first version may be valid for the MABC-2 as the construct has remained the same (Blank et al., 2012). However, since the MABC first version did not provide specific subdomains norm references, studies on validity of the manual dexterity subdomain for every age bands are needed, specifically for children with DCD.

The ZNA and the MAND are also general tests including a section on fine hand use activities. Several studies have been published which assessed the reliability and the validity of the ZNA presented age-related normative values for its different fine hand use activities for children from 6 to 18 years (Rousson, Gasser, Caflisch, & Jenni, 2009; Jenni et al., 2011). Also, Kakkebekke found a good correlation between the fine motor adaptive task of the ZNA, which is a 12-hole pegboard test, and the manual dexterity subdomain of the MABC-2 (Kakebeeke et al., 2014). As such this particular subtest may be of added value for use in children with DCD, as centile curves and normative data are available in children from 5 to 18 years old. On the contrary, the MAND does not provide separate results or norm values for fine motor function. Based on these limitations, we would not recommend this test for assessing manual function in children with DCD.

The In-hand manipulation test (IHM) considers that a performance of complex fine motor tasks in an effective and efficient manner requires the use of in-hand manipulation skills (Exner, 1993). However, the test has not often been studied and lacks evidence of psychometric properties. Furthermore, it does not consider performance of functional activities. However, in-hand manipulation skills represent an important aspect of fine hand use. Based on the framework

of Exner (1993), another test assessing in-hand manipulation has been developed, the Test of In-Hand Manipulation revised (TIHM-R) (Pont, Wallen, Bundy, & Case-Smith, 2008).It has adequate construct validity and excellent inter-rater reliability for TD children between the ages of 5.5 and 6.5 years (Pont et al., 2008). However, no normative data are available and the test needs to be validated in a wider age range before the use in children with DCD can be explored. Furthermore, in-hand manipulation might be considered as a manual function component already included in some tasks of the MABC-2, the BOT-2 and the pegboards tools, such as turning pegs tasks.

Speed and accuracy, are two quantitative aspects of fine hand use that are often present in the tests affirming their importance within an assessment of manual function.

Still, these tests are usually limited to unimanual dexterity. Through the examination of tools for manual dexterity used in children with other clinical populations, interesting tests were found such as the Purdue Pegboard Test (Pitcher, Piek, & Hay, 2003;Wilson, Iacoviello, Wilson, & Risucci, 1982), the Tyneside Pegboard test (Basu Kirkpatrick, Pearse, Boundford E., Gibson M., 2012), the Nine-Hole pegtest of the NIH toolbox (Reuben et al., 2013; Wang et al., 2011). The Purdue Pegboard Test (PPT) and the Tyneside Pegboard Test (TPT) may be of particular interest as these tests include also a bimanual task. The PPT has evidence of reliability and has norm references for children (Wilson et al., 1982;'Buddenger, 2000). The TPT is an electronically instrumented test which is an extra asset, but as it has just recently been developed its psychometric properties still need to be published (Basu, Kirkpatrick, Pearse., Boundford, Gibson, 2012).

All the tests of capacity identified in this systematic review assess different aspects of body function and the activity domain of ICF-CY. A comprehensive assessment of manual function in children with DCD might need to include different categories related either to the ICF-CY body function and activity domain such as muscle power and fine hand use and this varying from simple unimanual to more complex bimanual tasks.

Most tests also need further validation in children with DCD, and especially construct and concurrent validation of fine motor domains are needed.

4.2 Naturalistic Observations

Three naturalistic observations, such as the DCDDaily, the ACHS and the “Do-Eat” assess the spontaneous performance of a child in ADL. The DCDDaily specifically targets children with DCD and covers the three main domains of ADL. However, criterion scores for each subdomain are not provided. The ACHS, on the other side, is developed for a broad population of children with and without disabilities and it specifically refers to hand skills in ADL. The “Do-Eat” is developed for children with DCD or other disorders, such as ADHD and learning disabilities. It is limited to three manual tasks but providing a standardized toolbox optimizes its standardization. Interestingly, the scoring system provides a section about planning action sequences.

According to their target population, both the DCDDaily and the “Do-Eat” can be used from 5 years old, age mostly identified for the diagnosis of DCD according to the DSM-5 (American Psychiatric Association, 2013), while the ACHS provides a utilization for children aged 2 years. Studies on early application of the ACHS in children at risk of DCD might be useful to screen for difficulties in ADL tasks.

Inter-rater reliability has been investigated in all three naturalistic observation measures with higher values for the DCDDaily and the “Do-Eat” (Van der Linde et al., 2013;Chien, Brown, & McDonald, 2010; Josman et al., 2002). On the other hand the ACHS was constructed using a Rash analysis model (Chien et al., 2011b). The DCDDaily and the “Do Eat” have been used in a specific sample of children (Dutch and Hebrew speakers, respectively), while the ACHS has cross-cultural validity for Australia and Taiwan (Chien et al., 2011a).

The naturalistic observations are interesting instruments as they provide an assessment of child's ADL performance, which are well known to be impaired in this population. All instruments can be used in combination with a subjective assessment of child's performance made by the parents through the filling of the related questionnaires to offer a comprehensive assessment of the child's ADL. Another asset is that these naturalistic observations can be used for planning and evaluating the effect of task-oriented interventions such as Neuromotor Task Training (NTT)(Ziviani & Poylsen, 2007) or Cognitive Orientation to Daily Occupational Performance (CO-OP)(Polatajko HJ et al.,2001; Polatajko HJ et al., 2001a; Polatajko HJ et al., 2001b) which are considered to be efficacious treatment approaches for children with DCD (Smits-Engelsman et al., 2013).Still the instruments depend on the perception of professionals on an ordinal scale, thus representing more subjective outcomes.

4.3 Questionnaires

Questionnaires focus on subjective ratings of ability and activity levels, helping clinicians to gain a more complete picture of child's everyday activities at home or in school and can thus be used complementary to manual function tests and naturalistic observation. The main strength of four out of six questionnaires emerged from this systematic search (LittleDCDQ, DCDQ'07, DCDDailyQ, ChAS-P/T) is that they specifically target children with DCD. However, these questionnaires do not address directly fine motor activities apart from writing skills. On the other hand, several questionnaires include activities, which belong to the self-care/ADL domain, which could be considered as mainly manual function. Still they do not provide separate criterion-referenced scorings for this subdomain. Evidence of construct and concurrent validity specifically related to the fine motor subdomains is also lacking. Only the LittleDCDQ reports concurrent validity between its fine motor domain and the manual dexterity domain of theMABC-2 with a fair correlation value (Wilson et al., 2014). Further studies on the validity are needed. Future work should also provide reliability evidence since only test-retest reliability for the LittleDCDQ and the DCDQ'07 has been investigated (Wilson, Crawford, Green, Roberts, Aylott, 2009).

On the contrary, the CHSQ specifically addresses fine motor activities in the domains of leisure and play, school education and ADL and seems to be more appropriate for a comprehensive evaluation of performance manual abilities. Its content and construct validity have been evaluated in children with disabilities supporting its clinical utility for assessing manual function performance (Chien & Brown, 2012) However, evidence for reliability is missing and it would be interesting to explore its feasibility specifically for children with DCD (Chien & Brown, 2012).

Since questionnaires deal with activities that are related to the habits of a specific country, the evidence of cross-cultural adaptations is an important aspect that might be taken into consideration for the use of a questionnaire. Up to now, the DCDQ'07 (B.N. Wilson & Crawford, 2012) and the LittleDCDQ (Rihtman et al., 2011) are the only ones that have been adapted in different countries. Further the MABC-2 Checklist targets a broad population of children with movement difficulties, but used together with the MABC-2 test, can be predictive and helpful for the screening of school aged children with DCD (Schoemaker et al., 2012). Psychometric properties have been widely investigated (Henderson, Sugden & Barnett, 2007; Schoemaker et al., 2012). Still, data on the inter-rater reliability is lacking.

4.4 Limitations

The findings of this review should be interpreted in light of its limitations. We only included measures that were in English. Secondly, tests used in other populations than DCD have been excluded. Still, tools used in other patient groups might be considered for future use if they have good psychometric properties, especially good responsiveness and if they are norm referenced. In addition, several studies assessed experimental conditions within the ICF-CY category of fine

hand use. Future study could examine these experimental conditions in more details to see if they could also be valuable as a clinical tool (Smits-Engelsman, Bloem-van Der Wel, & Duysens, 2006;Williams, Thomas, Maruff, Butson, & Wilson, 2006). Furthermore we have excluded tests of handwriting and ball catching which could be debated.

However, handwriting as brain-hand language is a complex human activity, compounded of cognitive, kinaesthetic, perceptual and motor components that requires organization of continuous hand movements in space and time while controlling a tool on a given page space, and investing cognitive resources while considering linguistic content (Bonny, 1992; Reisman, 1993). Ball-catching, on the other hand, even though involves the use of the upper limbs, can be considered as a gross motor activity performance (Williams, 1983) as it also includes components such as postural control and reactive balance. Since the aim of this review was to focus on the motor aspects of manual function assessment, we decided to exclude handwriting and ball catching. However, we acknowledge that these skills are commonly impaired in children with DCD and thus they need further study.

5. Conclusions

Manual skills are essential for children's development and successful participation in everyday activities and therefore it is important to assess manual function in children with DCD for diagnosis and treatment planning. Identified from this review were seven tests, three naturalistic observations and seven questionnaires. A combination of different tools should be used for a comprehensive assessment considering the ICF-CY framework.

The tests provide a measure of capacity of manual function in a standardized condition. At BF level, we recommend measuring muscle power in static or dynamic conditions, using the upper limb section of the FSM and the Jamar dynamometer (Bell, 1994). We further recommend evaluating different aspects of fine hand using the MABC-2 and the BOT-2 related fine-motor subdomains, and additionally the pegboards tools such as the Purdue Pegboard Test, which has norms and evidence of reliability'.

These assessments could be complemented with performance measures of everyday life using an objective perspective of professionals with naturalistic observation tools such as the "Do-Eat" or through a subjective perspective (parents/caregiver or teacher). Here, DCD questionnaires can be used of which the DCDQ'07 and LittleDCDQ'07 specifically target children with DCD from different countries, but do not offer specific information on manual function; or the CHSQ which specifically targets manual function, but does not consider cultural adaptations and, till now, has been used in a broad population of children with disabilities

Despite the available tools for manual function, future research is clearly warranted to further investigate the specific psychometric properties of assessment tools for hand skills (especially construct and concurrent validity) and their use in children with DCD. Additionally, development of a new comprehensive tool including all different aspects of manual function might be a focus for future research.

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Figure captions and legends

Figure 1. Flowchart of the selection of the outcome measures

OP, other populations; DCD, developmental coordination disorders

Tables captions and legends

Table 1. Descriptive Information of the selected outcome measures

C, children; BF, body function; A/P, activity/participation; MD, motor difficulties; CF, criterion referenced; NF norm referenced; x, description applicable for the instrument; UL, upper limbs; LL lower limbs; L and P, leisure and play; FM, fine motor; GM, gross motor; SC and SM, self-care and self-maintenance; FSM, Functional Strength Measurement; HHD, Hand-Held Dynamometer; IHM, In-Hand Manipulation;MAND, McCarron Assessment Neuromuscular Development; ZNA, Zurich Neuromotor Assessment; BOT-2, Bruininks-Oseretsky Test of Motor Proficiency-2; MABC-2, Movement Assessment Battery for Children-2; DCDDaily, Daily Functioning in Children with Developmental Coordination Disorder; ACHS, Assessment of Children's Hand Skills; "Do-Eat" Activity of Daily Living Performance Test for Children; LittleDCDQ, Little Developmental Coordination Disorders Questionnaire; DCDQ'07, Developmental Coordination Disorder

Questionnaire'07; DCDDailyQ, Daily Functioning in Children with Developmental Coordination Disorder Questionnaire; MABC-2 Checklist, Movement Assessment Battery for Children-2 Checklist; ChAS-P/T, Children Activity Scale P/T;CHSQ,Children's Hand Skills Ability Q.

Table 2. Clinical Utility of the selected outcome measures

See Table 1 for definitions of outcome measures; CF, complete form; SF, short form; x, description applicable for the instruments; P, purchasable on-line; R, require from the authors; F, free download; Required/Not required: mandatory for the utilization of the measure; Recommended: possibility to have an examiner qualification nevertheless the measures can be used by a professional without any qualification; Not addressed: not specified.

Table 3 Reliability and Responsiveness of the selected outcome measures

See Table 1 for definitions of outcome measures; Rc, Cronbach correlation; Rp, Pearson correlation; Rs, Spearman correlation ICC, intraclass correlation coefficient; SEM, standard error measurement

Table 4: Validity of the selected outcome measures

See Table 1 for definitions of outcome measures; UL, upper limb; FM, fine motor; +, judgmental; -, not established in children; SA, statistical analysis; FA, factor analysis; RA, Rash analysis; FM, fine motor; VMI, Beery visual motor integration.