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Development and Psychometric Properties of A Screening Tool for Assessing Developmental Coordination Disorder in Adults

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Abstract

Background: Developmental Coordination Disorder (DCD) is a neurodevelopmental disorder affecting motor coordination. Evidence suggests this disorder persists into adulthood and may be associated with biomechanical dysfunction and pain. We report on the development and initial validation of a questionnaire to assess for DCD in adults.

Methods: An initial item pool (13 items) was derived from the American Psychiatric Association criteria and World Health Organisation definition for DCD. An expert panel assessed face and content validity which led to a 9-item Functional Difficulties Questionnaire (FDQ-9) with possible scores ranging from 9-36 (higher scores indicating greater functional difficulties). The FDQ-9 was piloted on individuals recruited from convenience samples. The underlying factor structure and aspects of reliability, validity and accuracy were tested. The Receiver Operating Characteristic Curve was employed to evaluate the diagnostic accuracy of the test using self-reported dyspraxia as the reference standard.

Results: Principal Axis Factoring yielded a two factor solution relating to gross and fine motor skills; for conceptual parsimony these were combined. Internal reliability was high (0.81), the mean inter-item correlation was 0.51 and preliminary findings suggested satisfactory construct validity. The Area under the Curve was 0.918 [95% CI 0.84-1.00] indicating a diagnostic test with high accuracy. A cut-off score was established with a sensitivity and specificity of 86% [95% CI 78%-89%] and 81% [95 % CI 73%-89%] respectively. Test-retest reliability was good (ICC 0.96 [95% CI 0.92 to 0.98].

Conclusion: The psychometric properties of the FDQ-9 appear promising. Work is required to conduct further psychometric evaluations on new samples and apply the scale to clinical practice.

Keywords: Dyspraxia; Musculoskeletal pain; Reliability; Validity; Assessment Tool

Introduction

Developmental Coordination Disorder (DCD) is a term given to describe children who experience a range of difficulties with motor control affecting their functioning, in the absence of other medical conditions and not explained by intellectual delay [1]. Other terms also referred to, and still employed include: clumsy child syndrome [2]; perceptual motor dysfunction [3]; dyspraxia [4] and Specific Developmental Disorder of Motor Function (SDDMF) as defined by the International Statistical Classification of Diseases and Related Health Problems 10th revision (ICD 10) [5]. Motor coordination deficits were first discussed in the literature by Orton in 1937 and termed 'apraxia' [6]. The diagnostic criteria were introduced in the American Psychiatric Association (APA) Diagnostic and Statistical Manual for Mental disorders (DSM-III) in 1987 [7] and again, in subsequent editions and revisions of the DSM [8,9]. It is important to note that the DSM-IV-TR (APA 2000) diagnostic criteria do not include DCD in adulthood but motor difficulties first noted in childhood have been described as persisting into adolescence and adulthood [10-13].

The construct of DCD defined in the ICD-10 relates to impairment in motor coordination (in the absence of a congenital or acquired neurological disorder) occurring in childhood which may continue into adulthood in a milder form [5]. DCD manifests as difficulties in learning, planning and the execution of motor skills resulting in poor motor coordination. For movement to be coordinated requires the integration of sensory/perceptual information in the central nervous system (CNS) with cognition resulting in action or movement. Therefore the combination of cognition, perception and action contribute to motor control [14]. The underlying mechanisms are best understood using a theoretical framework described by Shumway-Cook and Woollacott [14] in which it is hypothesised that aspects of motor control arise though out the CNS [14]. This process is not linear but occurs on an multidimensional continuum. However, it is hypothesised that motor control difficulties in those with DCD may be predominantly cerebellar in origin [15]. In addition, there is a reliance on electrochemical information which is dependent on receptors, pathways and characteristics influencing input (i.e. frequency, duration and intensity). It might be hypothesised that integration takes place at varying degrees throughout the CNS resulting in action or execution of a movement – motor control. In spite of these complexities there are patterns of motor control impairment that have been recognised in those with DCD.

These impairments are summarized in criteria A and B of the diagnostic criteria for DCD (DSM-IV-TR) [9] and underpin the development of the screening tool discussed in this paper.

Motor skill difficulties can lead to substantial impairments in activities of daily living. These may be observed as 'clumsiness' and/or biomechanical dysfunction affecting domains such as gait, balance, and

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handwriting. It is reported that such biomechanical dysfunctions may contribute to musculoskeletal pain [16-20].

The assessment of DCD in adults is necessary as functional and environmental demands and coping strategies differ from those in childhood and need to be recognised if they are to be addressed. In addition there is evidence that DCD may be associated with other conditions contributing to impaired health and wellbeing [21].

There are standardized physical tests to assess motor difficulties in children and adolescents including: the Movement Assessment Battery for Children (MABC 2) [16]; and the Bruininks Oseretsky Test of Motor Proficiency - 2 (BOT - MP 2) [17]. Where participants are observed to have biomechanical dysfunction with accompanying musculoskeletal pain it is argued that physical tests may not be appropriate. This is because for those with musculoskeletal pain it is difficult to determine whether poor scores are related to coordination difficulties or due to pain. It might, therefore, be more appropriate to employ self-report questionnaires.

A number of questionnaires have been developed to screen for DCD in children but these are not suitable for identifying DCD in adults. This is because questionnaires developed as screening tools for children are generally either parent or teacher completed and include child specific activities [16,22-24]. Recently a couple of self-report questionnaires for adults have been developed; namely, the Adult Dyspraxia/ Developmental Coordination Disorder checklist (ADC) [13] and the Adolescent and Adults Coordination Questionnaire (AAC-Q) [25]. The former is a 40 item questionnaire and was developed for identifying DCD in young adults in higher education. This questionnaire, while important, is considered too long as a screening tool for clinical practice and, as the developers of the questionnaire acknowledge, is still in the early stages of development. The AAC-Q [25] is a 12-item questionnaire that has been developed using a large sample of participants for use in research and clinical practice. The psychometric properties of this tool look promising but the authors of the AAC-Q acknowledge a requirement to establish concurrent validity and it has been developed using adolescents and young adult samples only.

In the absence of a suitable method for identifying DCD in adults throughout adulthood, the aim of this study was to develop a brief screening tool to address this gap. The purpose of the FDQ-9 was twofold: firstly, to assess for DCD in adults with and without musculoskeletal pain and, secondly to be short enough for use in clinical practice and to act as a guide for intervention. This paper describes the development and initial validation of a screening tool called the Functional Difficulties Questionnaire-nine item (FDQ-9).

Methods

Development of the questionnaire

A literature search was undertaken (including MEDLINE, CINAHL, ASSIA, SPORTDiscus, PsychARTICLES and PsycINFO from 1989-2009) to identify existing questionnaires using the search terms 'DCD', 'dyspraxia' and 'questionnaires', 'screening tools' or 'checklists'. Four questionnaires were identified: the Movement Assessment Battery for Children - 2nd edition (MABC 2) [16]; the Developmental Coordination Disorder Questionnaire (DCDQ) [24]; the Developmental Coordination Disorder questionnaire devised for children with musculoskeletal pain [22] and the Children Activity Scales [23]. The latter questionnaire was not deemed relevant as it focuses on DCD in very young children. The 40 question Adult DCD/ Dyspraxia checklist (ADC) was also accessed [13].

Selection of items for the questionnaire

The development of the questionnaire was guided by: the definition of DCD in the ICD-10 [5], the diagnostic criteria for DCD in the DSM - IV TR (Table 1) [9] and the Leeds Consensus Statement (LCS) [26] which aims to standardize the diagnosis of DCD. Other relevant sources included the International classification of functioning, disability and health (ICF) which provides a standardized framework and language [27] and a cross-sectional observational study of adults with DCD in which perceptions of ability were correlated with observational findings [11].

From the sources discussed above [5,9,11,13,16,22,24,27] the researcher selected 13 items which encompassed the main areas of functional difficulties characterized by children and adults with DCD. Feedback from physiotherapists, occupational therapists and a rheumatologist led to the removal of 4 items. Examples of reasons for item removal include: non applicability to some (e.g. asking about driving when not everyone is a driver), duplication/overlap (two items asking about obstacle avoidance) and outdated terminology (asking about functional difficulties in relation to buttons and shoelaces when zips and Velcro are now common place).

Scale construction

The resulting scale, the Functional Difficulties Questionnaire-9 items (FDQ-9) (see appendices), incorporates a broad spectrum of items relating to organization and gross and fine motor difficulties set in the context of daily activities. A four-point Likert-type scale was used; for example 'AS AN ADULT how good are you at…' the response options were: 'Very good' "1", 'Good' "2", 'Poor' "3" and 'Very poor' "4". Total possible scores thus range from 9-36 with higher scores indicating greater functional difficulties.

Content and face validity

Face validity was considered by asking several individuals with different perspectives (three teachers, two researchers (one of whom had DCD) and three volunteers who had musculoskeletal pain) to examine and complete the FDQ-9 and provide feedback on clarity and relevance of the items to the construct of DCD. Respondents reported that they felt the scale adequately captured the construct of DCD and found the questions easy to understand. They reported being able to recount their abilities as a child with clarity. The scale took between one and two minutes to complete. Advice was sought from physiotherapists and occupational therapists working with children

Criterion	Description
A	Performance in daily activities requiring motor coordination is substantially below that expected.
B	Activities (that require motor coordination) significantly affect academic achievement and/or activities of daily living
C	Observed impairments (in activities) are not due to a general medical condition (for example hemiplegia, muscular dystrophy, cerebral palsy etc.).
D	If learning difficulties are present, that motor difficulties are in excess of those usually associated with them.
The Leeds Consensus Statement [26] suggests the assessment of these activities should be relevant and culturally sensitive and recommends that if IQ tests are not available, intellectual ability could be established through national tests.	

Table 1: Summary of the four criteria for the diagnosis of DCD in the DSM-IV-TR (APA) 2000.

with DCD throughout the development of the questionnaire content. The advice of these clinicians was sought as recognition of DCD in adulthood is a relatively new area and few clinicians have expertise in this field.

Participants

Participants were drawn from three convenience samples who met the following inclusion criteria: Aged 18-65 years, no previous neurological condition (excluding self-reported dyslexia, DCD or Attention deficit hyperactivity disorder) achieved a secondary school qualification.

Sample one (S1) was drawn from two groups i) general public; ii) hypermobility clinic. In total there were 257 participants (202 female and 55 male) with an age range of 18-63 years and mean age 35.7 [SD ± 12.20]. In the general public group potential participants were sent an email invitation. Of the 193 responses 26 did not meet the inclusion criteria. Thus there were 167 participants (119 female and 48 male) with an age range of 18-63 and mean age 36.7 [SD ± 13.19]. Group 2 comprised participants with a diagnosis of joint hypermobility syndrome attending a national hypermobility clinic in the United Kingdom over a 3 month period in 2009. Of the 114 participants attending the clinic 17 chose not to participate and 7 did not fulfill the inclusion criteria. This meant there were 90 participants (83 female and 7 male) with an age range of 18-61 and mean age 34.0 [SD ± 9.94].

Sample two (S2) comprised staff and students from a university who had responded to an email invitation. Of 177 responses, 25 did not meet the inclusion criteria. There were 152 participants (115 female and 37 male) with an age range of 18-63 and mean age 36.8, [SD ± 12.88].

Sample three (S3) was a separate sample recruited from the general public to explore test-retest reliability and consisted of 30 participants (26 females and 4 males) with an age range of 18-52 and mean age 31.9 [SD ± 12.25]. All met the inclusion criteria and none self reported DCD.

Procedure

All participants were sent an invitation, information about the study and questionnaire either by mail or by email with a link to the questionnaire on Survey Monkey (http://www.surveymonkey.com). It was explained that participation was voluntary and that by completing the questionnaire participants were giving informed consent to take part in the study. Participants were asked to report whether they had a known neurological condition and their highest academic achievement.

Participants were excluded if they reported a known neurological condition and if they were unable to report any secondary school qualifications, this was in fulfillment of criteria C and D of the diagnostic criteria for DCD, DSM - IV TR [9] and in consideration of the LCS [26].

Ethical approval was granted by the National Hospital for Neurosurgery and Neurology and the Joint Institute of Neurology Research Ethics Committee (ref 09/H0716/5) and internally from Bournemouth University. Permission was granted by Damascus Shell Club for the questionnaire to be sent out via an email distribution list to employees and their families.

Data suitability

The sample of 257 participants (S1) gave a participant-to-item ratio of almost 30:1, satisfying the criterion of Bryant and Yarnold [28] for factor analysis that the ratio should be no lower than 5:1. The Kaiser-Meyer Olkin measure of sampling adequacy (MSA=0.79) was well above the minimally accepted level and Barlett's test of sphericity was highly significant, indicating that items were interdependent (χ^2= 749.19, p <.001). Examination of individual item skew and kurtosis characteristics (mean skew = 0.44, SD =0.18, range = 0.20-0.78); (mean kurtosis = -0.31, SD =0.36, range=-0.81-0.16) confirmed the suitability of the principal axis factoring extraction method [29] to explore the dimensionality of the scale. An oblique rotation (Direct Oblimin) was chosen to allow for correlation between factors. The number of factors to retain was evaluated using: a) Kaiser-Guttman's eigenvalues exceeding unity extraction criterion [30,31]; b) Cattell's scree plot analysis [32]; c) Horn's parallel analysis [33] ; d) Velicer's minimum average partial (MAP) criterion [34]; d) the interpretability of the resulting factor structure [35].

Hayton et al. [36] have recommended the use of parallel analysis and MAP in addition to more conventional approaches for determining the number of factors to extract. Software programmes by Watkins [37] and Patil et al. [38] and syntax by O'Connor [39] were used to undertake the parallel analysis and MAP. In brief, parallel analysis involves generating a random dataset with the same numbers of observations as the original data. Eigenvalues are extracted from the random data and the means of these 'random eigenvalues' are compared with the eigenvalues from the actual data. If the eigenvalue from the actual data is greater than the eigenvalue from the random data the factor is retained. Glorfeld [40] has suggested a modification to Horn's parallel analysis in which the eigenvalue corresponding to a given percentile (typically 95th or 99th) of the distribution of random eigenvalues should be used [40].

While SPSS does not provide significance tests of factor loadings Stevens [41-45] has produced a table of critical values against which factor loadings can be compared. These values take into account sample size and are based on an alpha level of 0.01 (two tailed) allowing for several loadings to be tested. Based on Steven's critical values a cut off of 0.35 would be conservative based on our sample size of 257.

Statistical analyses

Data analysis was undertaken using SPSS Version 16. Critical p was set at 0.05. Cronbach's alpha was employed as a measure of internal consistency and average inter-item correlations were calculated. This was carried out using data from S1 (n=257).

Given the lack of a gold standard measure, construct validity of the FDQ-9 was explored using the known groups method. For this analysis, data from S2 (n=152) were utilised. It was expected that individuals from S2 who reported experiencing coordination difficulties in everyday life or who self-reported dyspraxia would score more highly on the FDQ-9 than those who reported never experiencing coordination difficulties or who did not self-report dyspraxia. Construct validity was evaluated using hypothesis testing. An independent samples t-test (with correction for unequal variance) was used to compare the mean FDQ-9 scores for the respective groups as well as the Mann-Whitney U test. A Receiver Operating Characteristic (ROC) curve was used to evaluate diagnostic accuracy [46,47]. For this analysis, data from S2 (n=152) were utilised with self-reported dyspraxia as the reference standard. A cut-off score was established and the sensitivity and specificity calculated.

Test-retest reliability used data from S3 (n=30). The FDQ-9 was administered twice to this sample over a period of six weeks. Intraclass correlation coefficients (ICC) [43,44] were computed and the Bland and Altman method [45] was used.

Results

Structure of the FDQ-9

Data from sample (S1) (n=257) were employed to explore the structure of the FDQ-9. Using the first two criteria described in the 'data suitability' section to guide the number of factors to retain a two factor solution emerged (Table 2) with two factors possessing eigenvalues >1 accounting for 57% of cumulative variance and two factors to the left of the inflexion point on the screen plot. The inflexion point is where the slope of the curve changes dramatically from being nearly vertical to being horizontal (Figure 1). The MAP criterion suggested retention of one factor only. In relation to the parallel analysis in the sample output, it can be seen that the first two eigenvalues from the actual data are larger than the corresponding first two 95th percentile and mean random data eigenvalues. However, the third eigenvalue from the actual data is lower than the third 95th percentile and mean random data eigenvalue, again suggesting retention of two factors.

A minimum factor loading of 0.35 was used as a selection criterion [41]. All items loaded on one factor ≥ 0.35. Two items (5 and 8) cross loaded (in each case only one loading was ≥ 0.35) (Table 3).

Major loadings for every item ≥ 0.35 are presented in bold typeface ($p<0.01$ according to Steven's [41] critical values table)

Exploratory factor analysis with Principal Axis Factoring extraction method with oblique rotation (Direct Oblimin (pattern matrix).

Inspection of the items indicated that Factor one (items 2, 3, 4, 6, 7) related to 'Gross motor skills' and explained approximately 41% of the variance and Factor two (Items 1, 5, 9) related to 'Fine motor skills with organisation' and accounted for approximately 16% of the variance. Item A8 (adult fine motor) cross loaded (0.35 on Factor one and 0.30 on Factor two).

Factor one related to gross motor skills, a subgroup previously identified in children [23] who may also have low postural tone and proximal joint instability [42]. Component two, related to fine motor and organisational skills (in particular, poor handwriting) [23,42].

Cronbach's alpha for Factor one was 0.83 (corrected item-total correlations range = 0.56-0.68 and mean inter-item correlation = 0.50). No items would improve Cronbach's alpha if deleted. Cronbach's alpha (excluding A8) for Factor two was 0.64 (corrected item-total correlations range = 0.34-0.55 and mean inter-item correlation = 0.37. No items would improve Cronbach's alpha if deleted.

Adding item 8 to Factor one reduced Cronbach's alpha marginally (0.82) whereas adding it to Factor two resulted in a marginal improvement (0.66).

Although Factor two had lower internal consistency it was retained as fine motor skills have been an important feature in identifying children with DCD [27]. Item 8 (***AS AN ADULT,*** *how good are you at using your hands i.e. to do jobs around the home, DIY, sewing or using scissors*) cross loaded reflecting the fact that such activities could challenge both gross and fine motor skills.

Although the factor analysis broadly indicated there were two factors a decision was made to combine the two factors based on the factor loadings and the underlying mechanisms of motor skill impairments for those with DCD. There was cross loading of item 8 addressing a functional skill involving either organisation and fine motor skills or organisation, gross and fine motor skills. In addition it is acknowledged that the underlying mechanisms of motor skill difficulties for those with DCD are generally multifaceted arising from a global impairment of organisation, fine and gross motor skills.

Internal consistency

The coefficient alpha for the nine-item scale was 0.81. This indicated an acceptable value for the alpha. The mean inter-item correlation was 0.51. Corrected item-total correlations ranged from 0.29-0.61 with 8 of the 9 items possessing corrected item-total correlations > 0.4. Item 1 was poorly correlated with the total score (0.29). However, deletion of this item resulted in only a marginal improvement of alpha.

Construct validity and between group differences

Participants from S2 were asked 'Have you ever considered yourself

Factor	Initial Eigen values		Mean Random Eigen values generated by Monte Carlo Analysis	95% Percentile
	Total	% of Variance		
1	3.67	40.82	1.30	1.39
2	1.46	16.21	1.19	1.26
3	0.90	10.04	1.12	1.17
4	0.74	8.17	1.05	1.10
5	0.65	7.24	0.99	1.03
6	0.54	5.98	0.93	0.98
7	0.39	4.30	0.87	0.92
8	0.34	3.76	0.81	0.86
9	0.31	3.48	0.73	0.80

Table 2: Factor loadings, total variance explained and parallel analysis results.

	Description	Factors	
		F1	**F2**
1	**AS A CHILD,** how good was your handwriting?	-0.04	**0.56**
2	**AS A CHILD,** how good were you at team games that involved balls? i.e. football, netball, basketball	**0.69**	-0.05
3	**AS A CHILD,** how did others rate your coordination?	**0.75**	-0.04
4	**AS AN ADULT,** how good are you at avoiding obstacles, like bumping into doors?	**0.60**	0.13
5	**AS AN ADULT,** how good are you at organising yourself? i.e. getting ready for work or for a meeting	0.22	**0.35**
6	**AS AN ADULT,** how good are you at catching a ball one handed?	**0.80**	-0.08
7	**AS AN ADULT,** how good are you at balancing on a bike, in a bus or train, or on skis?	**0.70**	0.01
8	**AS AN ADULT,** how good are you at using your hands i.e. to do jobs around the home, DIY, sewing or using scissors?	**0.35**	0.30
9	**AS AN ADULT,** how good is your handwriting now?	-0.08	**0.94**

Table 3: Factor loadings for each item of the Functional Difficulties Questionnaire (FDQ-9).

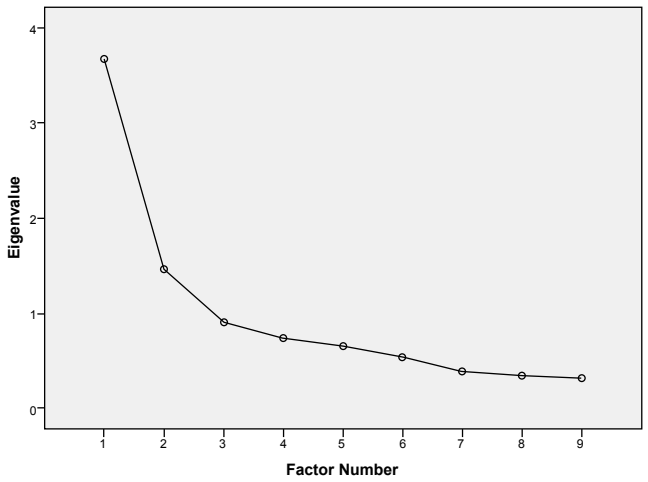

Figure 1: Screen plot showing eigen values plotted against factors in sample 1 (n=257).

to be 'clumsy' or uncoordinated in your everyday life?' Responses options were as follows:

- ✓ 'yes, both as a child and as an adult'(36/152, 23.7%);
- ✓ 'yes, but only as a child' (12/152 7.9%);
- ✓ 'yes, but only as an adult' (12/152 7.9%) or
- ✓ 'no' difficulties (92/152 60.5%).

It was expected that those who reported difficulties 'both as a child and as an adult' would have higher FDQ scores than those who reported having 'no' difficulties.

Participants were also asked if they had ever been diagnosed with dyspraxia. The term dyspraxia was employed instead of DCD as the term DCD has only been recognised relatively recently [1] and a diagnosis is usually confirmed in the first decade of life. It was expected that those who self-reported dyspraxia would have higher FDQ scores than those who did not self-report dyspraxia.

The mean total FDQ score (SD) of those reporting 'no' difficulties (mean=16.8, SD =3.10) was significantly lower than those who had reported difficulties 'yes, both as a child and as an adult' (mean = 22.2, SD = 4.52), $t(48.45) = -6.65$, $p<.001$(two tailed). The mean difference between the groups was -5.45 [95% CI - 3.80 to - 7.10]. This result was further confirmed by the Mann-Whitney U test. $U=531.00$, $p<0.001$(two tailed), indicating a statistically significant difference.

A total of 7/152 (4.6%) participants self-reported a diagnosis of dyspraxia and 145/152 (95.4%) reported not ever having received a diagnosis. The mean total FDQ scores (SD) of those self-reporting dyspraxia 25.9 (4.10) were significantly higher than those who did not report dyspraxia 18.1 (3.78), t (150) =4.93, p=0.02 (two tailed). The mean differences between the groups were 7.80 [95% CI 4.00 to 11.59]. A similar finding was obtained with the Mann-Whitney U test. U = 83.00, p < 0.001 (two tailed), indicating a statistically significant difference.

Diagnostic accuracy

Participants from sample S2 (n=152) were used of whom 7 self-reported dyspraxia. The Area Under the Curve (AUC) was 0.92 [95% CI 0.84 – 1.00], SE 0.04.This meant that a randomly selected individual who self-reported dyspraxia would have a test score on the FDQ-9 higher than that of a randomly chosen individual who did not self-report dyspraxia 92% [95% CI 84% - 100%] of the time. The AUC in this study indicated a diagnostic test with high accuracy [50] (Figure 2).

Sensitivity and Specificity

A cut-off score was calculated initially by finding the point on the curve closest to the (0,1) point which equates to a value in which sensitivity and specificity are balanced [48]. A minimal value was calculated which equated to a FDQ Score of 21.5 [95% CI 20.5 – 22.5].

The Youden index [49] maximum score was calculated which equated to a FDQ score of 21.5 [95% CI 19.5 – 22.5]. The sensitivity and specificity of a FDQ score of 21.5 would be 86% [95% CI 78% - 94 %] and 81% [95% CI 73% - 89%], respectively.

A cross tabulation of the index test and reference standard is presented (See Table 4). From which the sensitivity, specificity, prevalence, positive predictive value and negative predictive value were calculated.

In table 4 the prevalence was 7/152 (4.6% [95% CI 0% - 13%]). The positive predictive value (PPV) was 6/34 (18% [95% CI 10% - 26%]) and the negative predictive value was 117/118 (99% [95% CI 91% - 100%]). A low prevalence equates to a lower PPV and therefore the positive likelihood ratio (PLR) should be calculated which is independent of the prevalence. The PLR indicates the odds of a condition increase when the test is positive. In this study the odds of the condition increasing when the test was positive were 4.61 [95%CI 3.93 – 5.38], which indicates a high ratio. High ratios indicate that useful information is being provided by the test [50].

In Figure 3 we present the distribution of continuous data relating to participants' FDQ total scores (n=152) with seven self-reporting dyspraxia. FDQ total scores ranged from 11-30. An FDQ total score of 11 could indicate a participant reporting being 'very good' at 7/9 items and 'good' at 2/9 items. An FDQ score of 30 could indicate a participant reporting being 'very poor' at 3/9 items and 'poor' at 6/9 items. Participants who self-reported dyspraxia recorded FDQ total scores of ≥ 20 indicating difficulties in 2/9 items or more. There were a number of participants who did not self-report dyspraxia who had total FDQ scores >21.5. It is suggested that this group may be those who had functional difficulties in childhood which persisted into adulthood

FDQ Total Score	Self-reported dyspraxia	No dyspraxia reported	Total
>21.5	6	28	34
<21.5	1	117	118
Total	7	145	152

Table 4: Proportion reporting true positive, true negative, false positive and false negative results by employing a 21.5 cut-off on the Functional Difficulties Questionnaire (FDQ).

	Item Description	ICC Single Measure	95% CI
1	Child handwriting	1.00**	1.00-1.00
2	Child games	0.92**	0.84-0.96
3	Child co-ordination	0.86**	0.72-0.93
4	Adult obstacle avoidance	0.95**	0.89-0.97
5	Adult organisation	0.86**	0.71-0.93
6	Adult ball games	0.91**	0.83-0.96
7	Adult balance	0.85**	0.71-0.93
8	Adult DIY	0.75**	0.54-0.87
9	Adult handwriting	0.90**	0.81-0.95

Two way random effect model (absolute agreement)
**p < 0.001

Table 5: The intra class correlation coefficient (ICC) [ICC 95% C.I.] between individual items of the FDQ-9 (Sample 2, n=30).

but were not assessed for dyspraxia/DCD in their early years. This is a group that has been previously identified and the reasons discussed in a previous paper [59].

Test-retest reliability

Test-retest reliability was examined using data from sample S3 (n=30) (FDQ-9 was administered to the sample on two occasions with a 6 week interval). The mean total FDQ score (SD) for administration one was 16.17 (4.19) and for administration two (6 weeks later) 16.23 (3.82). The mean difference was -0.07 [95% CI -0.48 to 0.35].

The test-retest ICCs for each of the items ranged from 0.75-1.00 and are presented in Table 5. All ICCs were statistically significant across the two test administrations (all *ps* < 0.001). When the total scores were analysed, the ICC two way random effects (absolute agreement) model was 0.96 [95% C.I. 0.92 to 0.98]. Only one item (Item 8 - ***AS AN ADULT,*** *how good are you at using your hands i.e. to do jobs around the home, DIY, sewing or using scissors*) had an ICC that was less than 0.8. A perfect 1.00 was obtained for item 1 (***AS A CHILD,*** *how good was your handwriting?*).

The limits of agreement (calculated using the mean difference ± 1.96 SDs) were -2.2 [95% CI -2.10 to -1.60] units to 2.1 [95% CI 1.80 to 2.70] units with a total width of 4.3 units. To check that the assumptions of the limits of agreement were met (i.e. mean and SD constant through range of total scores and that differences were approximately normally distributed) two charts were produced: i. A scatter plot of the difference (FDQ score test 2- FDQ score test 1) plotted against the mean of the two measurements with the limits of agreement depicted (Figure 4) and ii. a histogram of the difference (Figure 5).

In the scatter plot (see Figure 4) approximately 95% of the points should lie within the limits of agreement. In this plot there are some overlapping points and 96.7% of the cases lie within the limits of agreement and equal divergence is observed. From the histogram the differences in the means were noted to be from an approximately normal distribution. Test-retest total scores are assumed to be from the same distribution when the differences have a mean of zero and 95% of

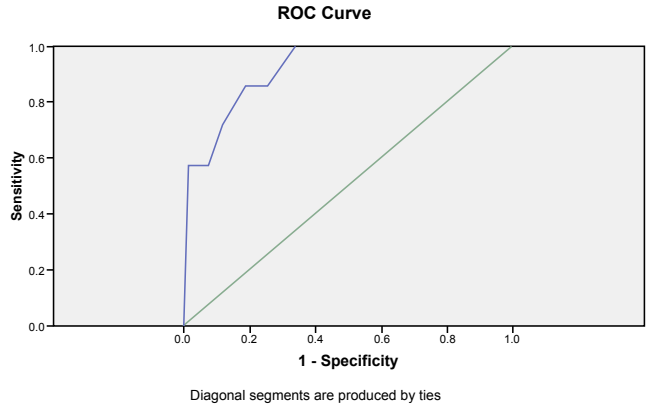

Figure 2: Receiver Operating Characteristic (ROC) curve using the total scores of the FDQ-9 and those who self-reported a previous diagnosis of dyspraxia (n=152).

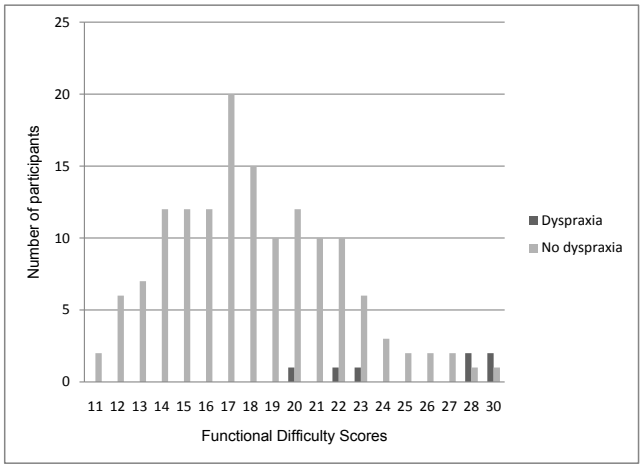

Figure 3: Distribution of the Functional Difficulties Total Scores (FDS) of participants with reference standard self-reported dyspraxia (n=7) and those with no dyspraxia reported (n=145).

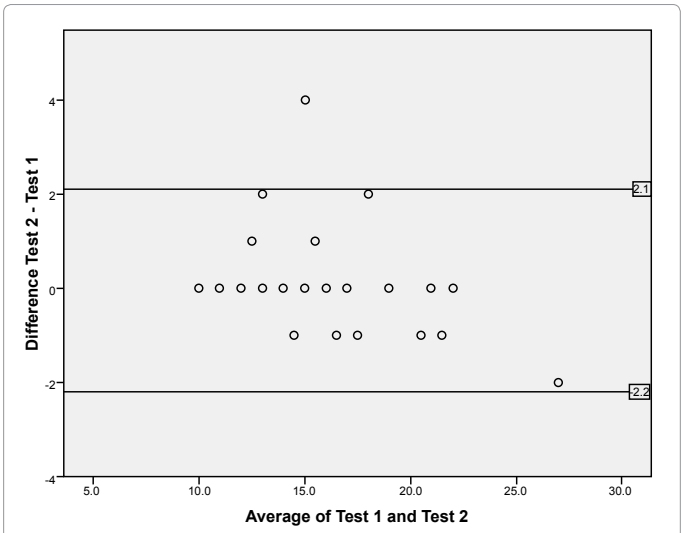

Figure 4: Simple scatter diagram of the difference between the scores from the first and second tests versus the averages of the scores for the two tests of the Functional Difficulties Questionnaire (FDQ-9). Limits of agreement set -2.2 and 2.1. Sample 2 (n=30).

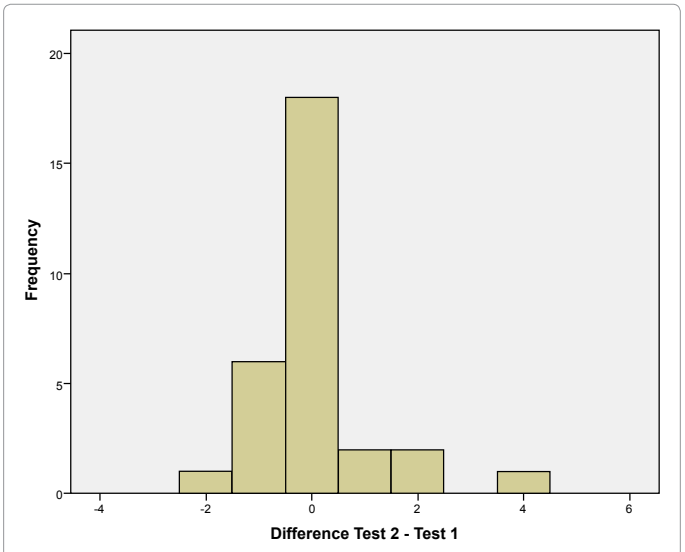

Figure 5: Distributions of the difference between the second and first administrations of the Functional Difficulties Questionnaire (FDQ-9) (n=30).

the differences lie within the 95% limits of agreement [45]. In this study the mean difference of the FDQ scores was 0.07 [95% CI -0.35 to 0.48] which implies that a person with a test score of 16 might score 15 on re-testing. This difference is unlikely to be clinically significant. The range reported for the limits of agreement is likely to be clinically significant.

Discussion

The aim of this study was to develop a questionnaire to assess for DCD in adults and to undertake a preliminary validation of the questionnaire. The Functional Difficulties Questionnaire-9 (FDQ-9) is a nine-item questionnaire that requires respondents to rate their functional abilities of gross and fine motor skills and organisation during childhood and adulthood.

Development of the FDQ-9 drew upon a variety of sources which included: (i) ICD-10; (ii) DSM - IV TR; (iii) LCS; (iv) ICF; (v) existing questionnaires to assess for coordination difficulties in children; observational studies [5, 9, 11, 13, 16, 21, 23, 25] and expert opinion. Experts and respondents reported that the FDQ-9 was simple, easy to understand, comprehensive, and experts felt that it adequately captured constructs central to DCD.

The exploratory factor analysis indicated a two factor solution related to two theoretical constructs of DCD; namely, gross and fine motor activities. One item cross loaded which was not unexpected given the fact that motor skills often require an integration of these domains: for example, a complex task such as handwriting requires the integration of gross (proximal stabilization for the position of the upper limb) and fine motor control (manipulation of the pencil) and planning to form the letters and shapes. A decision was made to combine the two factors based on the factor loadings and current understanding of the mechanisms of DCD in which difficulties relating to motor control are considered to be of a global nature. Thus all items were included to form a single FDQ score.

Internal consistency of the FDQ-9 was high (Cronbach's alpha = 0.81) and item-total and inter-item correlations acceptable. As there was no available reliable and valid tool to assess for DCD in adults at the time of this research the known groups procedure was employed to explore construct validity. The FDQ-9 distinguished between subgroups in expected ways - participants reporting coordination difficulties both as a child and in adulthood scored significantly more highly on the FDQ-9 than those who reported no such problems. Similarly, participants who self-reported a diagnosis of dyspraxia scored significantly more highly than those who did not self-report dyspraxia. It is appreciated that one of the limitations in this study in relation to construct validity was the small number of those self-reporting a previous diagnosis of dyspraxia. Nevertheless these results highlight between group differences in motor abilities that are likely to be clinically important and that are well established in children with DCD [23,51,47]. This corroborates the work of Cousins and Smyth [11], Kirby et al. [13] and Tal Saban et al. [25].

The diagnostic accuracy of the FDQ-9 was assessed by employing a ROC curve. The AUC reflects how good the test is at distinguishing between those with or without a condition and in this study the AUC indicated high accuracy. Two methods were employed to establish a cut-off score. Applying a cut-off score of 21.5, the sensitivity and specificity were 86% [95% CI 78% - 92%] and 81% [95% CI 73% - 89%], respectively. The recommendations of the APA (1985) are for a test to achieve a sensitivity of 80% and a specificity of 90% but this may not always occur in practice. A variety of tools are employed for assessing DCD/dyspraxia in children. The Developmental Coordination Disorder Questionnaire (DCDQ) [24] is one which has been referenced against the McCarron Assessment of Neuromuscular Development (MAND) [52] and the Movement Assessment Battery for Children (MABC) [16]. When the DCDQ was referenced against the MAND sensitivity and specificity of 55% and 74% respectively were recorded [53]. When the revised DCDQ was referenced against the MABC sensitivity and specificity of 85% and 71% respectively were recorded [54]. It is suggested that when publishing the results of sensitivity and specificity the readers should be made aware of the limitations of a tool. Where a condition is treatable a higher sensitivity is important, if the specificity is low, this limitation should be acknowledged.

Test re-test was analysed using two methods; calculating the ICCs and using the Bland and Altman method. ICCs were found to be high for each of the items and for the overall scale. There was a perfect ICC between the test-retest responses for item A1 which related to handwriting as a child. This may be because a significant emphasis is placed on handwriting as a child and so difficulties in relation to this activity are well remembered. However, we acknowledge that as a test for stability ICCs can be inflated by sample heterogeneity, thus in the future test-retest reliability should be carried out in samples with more homogeneous FDQ scores for example those with DCD. In addition the Bland and Altman method [45] was employed. Using this method to test for stability of the test re-test required the assumption that the mean and standard deviation of the differences were constant through range (heterogeneous sample). The Bland and Altman method suggested good test-retest reliability with over 95% of cases lying within the limits of agreement [45].

In clinical practice it is anticipated that higher total scores of the FDQ-9 would enable clinicians to recognise global functional difficulties and that the identification of specific functional impairments could be used to guide intervention.

Limitations of this study include the fact that convenience samples were used and females were over-represented. While DCD is thought to be more prevalent in male than female children [53,54] two studies have shown gender prevalence to be reversed or similar [55,56].

A further limitation is a failure to report concurrent validity. At the time of the data collection for this study there was no 'gold standard'. Accumulation of evidence relating to validity is a continuous process [57,58] and future studies are required to address this aspect.

Conclusion

This paper describes the development and initial psychometric validation of the FDQ-9. Satisfactory face, content validity and internal consistency were obtained. The sensitivity of the FDQ-9 which is the ability of the test to identify those with DCD is adequate. The specificity which is the ability of the test to identify those without DCD is below the recommended threshold and this should be acknowledged when employing this test. Test-retest reliability was good. The FDQ-9 provides a simple and quick method to assess for DCD in adults. These findings need to be explored in larger samples.

There is a requirement to identify DCD in adults and in particular those with long term musculoskeletal pain, where biomechanical dysfunction may result from coordination impairment. There are currently no 'gold standard' methods for assessing DCD in adults. This means that adults with DCD will be missed and strategies to minimise the effects of DCD will not be implemented. This preliminary psychometric evaluation suggests that the FDQ-9 is a promising assessment tool for the identification of DCD in adults. It requires further validation in the clinical setting and further studies are required

to continue testing the validity and reliability of the FDQ-9 in other sample groups (Appendix).

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