Motor impairment among different psychiatric disorders : can patterns be identified?

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Motor impairment among different psychiatric disorders: Can patterns be identified?

Abstract

Objective: The aim of this study was to explore the type and severity of motor impairment in male adolescents suffering from a range of psychiatric conditions. In addition, the motor profiles of distinctive diagnostic groups were evaluated, while taking into account the heterogeneity of a clinical population. The question of whether of not motor ability discriminates between several diagnostic categories was addressed.

Method: The Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) was administered to examine a detailed motor profile. The motor abilities of a clinical population (n=144) were compared to those of typically developing peers (n = 87), using independent t-tests. Additionally, a one-way ANCOVA was performed to examine group differences, while accounting for differences in intellectual functioning. In order to investigate the extent to which a specific diagnosis contributes to variation in motor scores a stepwise linear regression approach was applied.

Results: The results indicated that the clinical group performed significantly worse in comparison to the control group on all BOT-2 subscales and composite scores, even after controlling for IQ. The constructed models indicated that diagnostic categories accounted for a significant amount of the variance in motor ability scores.

Conclusion: The results of this study imply that motor ability of adolescents with a psychiatric disorder is in need of attention, regardless of the diagnosis. Additionally, the results support the notion that objective motor assessment should be part of routine clinical practice.

Keywords: motor ability; psychiatric disorder; adolescent; BOT-2

Motor impairment among different psychiatric disorders: Can patterns be identified?

1. Introduction

It is well recognised that co-occurring motor problems are common in children and adolescents with a psychiatric disorder. Several studies indicate that motor impairment is a feature of various child psychiatric disorders, including developmental disorders, emotional disorders and behavioural disorders (Emck, Bosscher, Beek, & Doreleijers, 2009). In general, these individuals perform worse on standardised motor assessment instruments in comparison to typically developing peers or norm populations (Emck, Bosscher, Van Wieringen, Doreleijers, & Beek, 2011; Simons, Vanderheyden, Nilius-Hoffman, & Vandenbussche, 2011; Simons, Verscheure, Vandenbussche, Adriaenssens, & Delbroek, 2013).

Given the continuous interaction between different developmental domains, it is not surprising that the presence of motor impairment has a significant impact on mental as well as on physical health. Quite a number of studies have shown that motor impairment in childhood predisposes for a range of social, emotional, physical and academic problems (Dewey, Kaplan, Crawford, & Wilson, 2002; Piek, Bradbury, Elsley, & Tate, 2008; Rivilis, Hay, Cairney, Klentrou, Liu, & Faught, 2011; Schoemaker & Kalverboer, 1994; Skinner & Piek, 2001). For instance, motor ability plays an important role in establishing an individual's reputation among peers and in the development of self-esteem (Piek, Baynam, & Barrett, 2006; Simons, Capio, Adriaenssens, Delbroek, & Vandenbussche, 2012). This is particularly relevant for individuals with a psychiatric condition, as they demonstrate a high incidence of motor problems that are serious enough to interfere with daily life. The combination of behavioural and emotional problems with motor problems makes these children especially vulnerable and can result in a negative outcome on participation and activity level (Iversen, Knivsberg, Ellertsen, Nødland, & Larsen, 2006).

Previous research has investigated the motor abilities of children and adolescents with psychiatric disorders. There is an increasing body of literature, demonstrating the high prevalence of motor impairment in individuals with Attention Deficit Hyperactivity Disorder (ADHD) (Fliers et al., 2009; Piek, Pitcher, & Hay, 1999; Pitcher, Piek, & Hay, 2003) and Autism Spectrum Disorders (ASD) (Downey & Rapport, 2012; Fournier, Hass, Naik, Lodha, & Cauraugh, 2010). In contrast, evidence regarding other child psychiatric disorders, such as

Disruptive Behaviour Disorders (DBD) and depression, continues to be limited in scope. Moreover, the interest of prior research is mainly directed towards children.

Apart from the fact that motor impairment has repeatedly been shown to be associated with ADHD and ASD, the results are inconsistent. The discrepant findings can be explained, at least in part, by the use of different motor assessment instruments and conceptualisations of motor impairment. Typically, a rather poor agreement between different standardised motor assessment instruments has been established, indicating that they measure different aspects of a similar concept (Logan, Robinson, Rudisill, Wadsworth, & Morera, 2014; Spironello, Hay, Missiuna, Faught, & Cairney, 2010). Consequently, directly comparing the results across studies that use different assessment instruments would be incorrect. In addition, the use of different cut-off points results in highly variable prevalence rates of motor impairment and complicates generalisation of findings (Geuze, Jongmans, Schoemaker, & Smits-Engelsman, 2001).

Because motor impairment is seen in the majority of individuals with a psychiatric disorder, there is a need to compare the motor profiles of several diagnostic groups. These kinds of comparisons can possibly provide evidence for specific areas of impairment that may occur with a certain diagnosis. In addition, the association of specific motor profiles related to a diagnosis, may lead to the identification of clinically relevant endophenotypes. Although motor impairment has repeatedly been associated with psychiatric disorders, the underlying and contributing neurobiological aspects are incompletely understood. A detailed examination of motor profiles is an inexpensive and non-invasive method that possibly can provide further insight into the neurobiological underpinnings of these disorders (MacNeil & Mostofsky, 2012). Despite being valuable, previous research tended to focus on comparing motor abilities of individuals with a psychiatric disorder to typically developing peers or norm populations, rather than investigating differences among distinctive diagnostic groups. So far, only a handful of studies made comparisons across different clinical groups (Dewey, Cantell, & Crawford, 2007; Emck et al., 2011; Kooistra, Crawford, Dewey, Cantell, & Kaplan, 2005; Kopp, Beckung, & Gillberg, 2010; Pan, Tsai, & Chu, 2009; Skirbekk, Hansen, Oerbeck, Wentzel-Larsen, & Kristensen, 2012). Occasionally, limited comparisons were made, addressing only differences in the total motor score on a given motor assessment instrument. In order to examine a detailed motor profile that enables to identify possible differences across several motor areas, a comprehensive motor assessment instrument that covers a wide variety of skills across the full range of ability should be administered.

Another topic of considerable importance is the comorbidity issue. As the overlap between different child psychiatric disorders is substantial, it is extremely difficult to obtain an adequate number of participants with only one diagnosis of interest. Part of the difficulty with past research is the failure to adequately control for co-occurring disorders. The fact that uncomplicated conditions are hard to find puts a challenge to the field of motor ability research.

One objective of this study is exploring the type and severity of motor impairment in male adolescents with a psychiatric condition. In order to do so, the detailed motor profile of male adolescents, suffering from a range of psychiatric conditions will be investigated. Based on previous research, it is hypothesised that the clinical population will exhibit motor impairment in comparison to typically developing peers. An additional objective of this study is to examine the extent to which a specific diagnosis contributes to variation in motor scores. Therefore, a stepwise linear regression approach will be applied. This approach provides the opportunity to address the question of whether or not motor ability discriminates between several diagnostic categories, while taking into account the heterogeneity of the clinical population in terms of co-occurring disorders.

2. Methods

2.1 Participants

A total of 245 male adolescents aged 12-18 years participated in the study. The total sample encompassed a control population (n = 89) and a clinical population (n = 156).

Participants from the clinical population were recruited from the University Centre for Child and Adolescent Psychiatry in Antwerp (Belgium). Many health care providers from all over Flanders (Dutch speaking part of Belgium) make referrals to this clinic. Participants were enrolled through consecutive sampling and were diagnosed according to the DSM-IV-TR criteria (American Psychiatric Association, 2000) by experienced psychiatrists. The standard assessment protocol from the centre includes parent and child interviews, parent and child questionnaires, clinical observations made by the multidisciplinary staff and neuropsychological testing.

Participants from the clinical population were referred to the clinic and recruited for this study based on the presence of emotional, behavioural and/or developmental problems. As can be expected in a clinical population, the comprehensive assessment protocol resulted in frequently occurring comorbid disorders. Therefore, distinctive subgroups were created,

allocating all participants in one or multiple groups. According to this strategy, each time a certain diagnosis was present, an individual was assigned to the group. In total, six diagnostic categories were identified, namely DBD, ASD, Depression, ADHD, Substance Abuse and Reactive Attachment Disorder (RAD). Although some individuals sporadically presented themselves with other psychiatric conditions, such as reading disorder or obsessive-compulsive disorder, they were not taken into account. Due to the low occurrence rate of these disorders, it would be impossible to make meaningful inferences.

The control group comprised 89 typically developing adolescents. Subjects were recruited through schools and participated on voluntary basis. Exclusion criteria were communicated prior to participation in the study and were defined as follows: (a) a history of psychopathology, (b) receiving interventions by a physiotherapist addressing motor abilities, (c) physical disability that hampers motor assessment. To ensure that no characteristics of mental health disorders were present in the control group, all participants and parents completed the Dutch version of the Strength and Difficulties Questionnaire (SDQ) (Goedhart, Treffers, & van Widenfelt, 2003). Participants who obtained a total SDQ-score within the clinical range, either self-reported or reported by the parents, were excluded from the study.

Depending on age, the Wechsler Intelligence Scale for Children (WISC-III-NL) or Wechsler Adult Intelligence Scale (WAIS-III-NL) was administered by an experienced psychologist. In order to maintain homogeneity in the sample, all adolescents with a Full Scale Intellectual Quotient (FSIQ) ≤70 were excluded from the study. Two control participants were excluded from the study, based on scores within the clinical range on the SDQ. Another 12 participants from the clinical population were excluded, due to low intellectual functioning. Consequently, the final sample contained 231 participants. The sample characteristics are presented in Table 1 [Insert Table 1].

2.2 Motor Assessment

The Bruininks-Oseretsky Test of Motor Proficiency, Second Edition (BOT-2) (Bruininks & Bruininks, 2005) was used in order to examine a detailed motor profile. The BOT-2 is an individually administered test that uses goal-directed activities to measure a wide range of motor abilities in individuals aged 4-21 years. In contrast to other standardized motor assessment instruments, the BOT-2 provides gender-specific scores across a full range of ability, measuring variation from well below to well above average performance. The BOT-2 consists of eight subscales, thus providing a detailed motor profile. The performance on a subscale is converted into a standardized scale score (mean = 15 ±5). Subscales that

assess related aspects of a motor area are combined into a composite score. In total the BOT-2 generates four composite scores (Fine Manual Control, Manual Coordination, Body Coordination, Strength and Agility) and a Total Motor Composite, representing the overall motor abilities. According to the norms that are based on the American population, all composite scores have a mean of 50 (±10). According to the manual, the BOT-2 has established reliability and validity (Bruininks & Bruininks, 2005). Because normative values for the BOT-2 have not been developed on a Dutch population, a control group of typically developing Dutch adolescents was included in the study.

2.3 Procedure

Ethics approval was granted by the Ethics Committee of the University of Antwerp, Faculty of Medicine and the local Ethics Committee of the clinic (Ziekenhuis Netwerk Antwerpen). The study was explained orally and in writing to parents and participants. All participants signed informed consents forms, in addition to their parents or caregivers.

In line with the testing procedure from the BOT-2, each participant was tested individually and regular breaks were proposed, whenever desirable. All test instructions were followed precisely. To ensure a full understanding and a correct performance of the motor tasks, the administrator gave verbal instructions and physical demonstrations of all items, as permitted by the manual guidelines.

The adolescents from the clinical populations were assessed in the clinic where they resided and the infrastructure of the local schools was used for the test administration of the control group. A psychologist evaluated the intellectual functioning of the participants, whereas an experienced psychomotor therapist administered the BOT-2. While participants from the control group were assessed in a single session, adolescents from the clinical population were tested on two occasions. For practical reasons, a separate session took place for the administration of the BOT-2 and the evaluation of intellectual functioning. Because prior research has demonstrated a potential beneficial effect of stimulant medication on motor ability and cognitive functions, stimulant medications were discontinued on the day of the assessment (Brossard-Racine, Shevell, Snilder, Belanger, & Majnemer, 2012; Pietrzak, Mollica, Maruff, & Snyder, 2006).

2.4 Statistical Analysis

All analyses were run using SPSS, Version 22. Statistical significance was set at $p < .05$. There were no missing data for any of the variables.

The analyses were conducted in two phases. Prior to these phases, sample characteristics were compared in order to identify potential confounding variables, including age and FSIQ. In the first phase, the detailed motor profile of the clinical group and the control group was explored, using descriptive measures of the eight subscales, the four composite scores and the total motor composite (TMC) of the BOT-2. Group comparisons on the BOT-2 composite scores and subscales were conducted, using independent t-tests. As FSIQ differed significantly between the clinical and control population, a one-way ANCOVA was performed to examine group differences, while accounting for FSIQ. Bonferroni corrections were applied in order to account for an inflated type I error by multiple testing. Effect sizes estimates were calculated as Eta Squared. In accordance with the guidelines from Cohen (1988), the effect size was interpreted as follows: .01 = small effect, .06 = moderate effect, .14 = large effect.

The second phase involved a stepwise linear regression approach to examine the extent to which diagnostic category contributes to variation in motor scores. A multiple regression analysis was conducted to predict the total motor composite and the four composite scores of the BOT-2, while controlling for FSIQ. The analysis started from a regression model with only FSIQ as predictor. In the second step of the analysis, six indicator variables that indicated all six diagnostic categories (DBD, ASD, Depression, ADHD, Substance Abuse and Reactive Attachment Disorder) were simultaneously added to the model. Each time, we recorded the percentage of variance explained by the newly added variables in terms of the R^2 change with regard to the model with only FSIQ. The significance of the change in model fit was tested using an F-test. To ensure no assumptions were violated, the following model checks were performed: normality of the residuals, linearity of continuous variables, multicollinearity and homoscedasticity.

3. Results

3.1 Sample characteristics

The sample characteristics are outlined in Table 1. There were no significant differences between the clinical population and the control population in terms of age ($t(229) = -.260$, $p = .795$). In contrast, a significant difference in FSIQ emerged between the two groups ($t(229) = 6.330$, $p = .000$), with the clinical group obtaining significantly lower FSIQ-scores in comparison to the control group.

3.2 Comparison between clinical population and control population

The detailed motor profile of both groups, represented by the eight subscales of the BOT-2, is illustrated in Figure 1 [Insert Figure 1]. In general, Figure 1 indicates that the clinical group performed significantly worse in comparison to the control group on all BOT-2 subscales. With regard to the type of impairment, it is evident that the largest impairment is situated in the subscales Fine Motor Integration and Bilateral Coordination.

The results of the group comparisons on the BOT-2 motor composites and TMC are presented in Table 2 [Insert Table 2]. Means, standard deviations, t-test or F-test results, effect size estimates and mean differences are reported. Each variable takes up two rows. In the first row, the results of the independent *t*-tests are presented. The second row contains the results of the one-way ANCOVA, thus statistically controlling for group differences in FSIQ. In comparison to the control group, the clinical group performed significantly worse on all composite scores of the BOT-2. In accordance with the guidelines from Cohen (1988), effect size estimates are situated in the moderate to large range. Even when accounting for initial differences in FSIQ, the results continue to yield significant p-values.

3.3 Stepwise linear regression

To examine the extent to which a diagnostic category contributes to variation in motor scores, a stepwise linear regression analysis was performed. The results for the TMC of the BOT-2 and its four composite scores are presented in Table 3 [Insert Table 3]. We started with a simple linear regression model with only FSIQ as predictor. Subsequently, six indicator variables for the six diagnostic categories (DBD, ASD, Depression, ADHD, Substance Abuse and Reactive Attachment Disorder) were added to the model. All predictor variables were indicator variables, indicating the presence or absence of a certain diagnosis. Thus, the B-coefficients in Table 4 refer to the difference in motor score between individuals diagnosed with a disorder relative to individuals without the disorder, keeping FSIQ constant.

3.3.1 Total Motor Composite

FSIQ explains 23% of the variance in the BOT-2 Total Motor Composite. Upon adding the diagnostic categories to the model, the total variance explained increased to 44.4% with group membership accounting for a significant amount of additional variance, compared to the model with FSIQ alone (R^2 Change = .215; $p \leq .0001$). Thus, above and beyond the effect of FSIQ, four diagnostic categories were identified as significant predictors of the Total Motor Composite, namely DBD, ASD, ADHD and RAD.

3.3.2 Composite Fine Manual Control

FSIQ has a significant effect on the composite Fine Manual Control and accounts for 16.4% of the variance. Adding the six diagnostic categories produced a model that explained 34.5% of the variance and the change in R^2 with regard to the initial model was significant (R^2 Change = .181; $p \leq .0001$). Above and beyond the effect of FSIQ, four diagnostic categories (DBD, ASD, ADHD and RAD) were significant predictors of Fine Manual Control.

3.3.3 Composite Manual Coordination

FSIQ explains 10.5% of the variance in the Manual Coordination composite. Adding the diagnostic categories, the model explains a total of 21.3% of the variation in Manual Coordination. The change in R^2 was significant (R^2 Change = .107; $p \leq .0001$). Above and beyond the effect of FSIQ, the diagnostic category ASD was a significant predictor of Manual Coordination.

3.3.4 Composite Body Coordination

FSIQ has a significant effect on the composite Body Coordination, explaining 18.4% of the variance. Upon adding the diagnostic categories, the model explains a total of 35.3% in variance and the change in R^2 was significant (R^2 Change = .169; $p \leq .0001$). Above and beyond the effect of FSIQ, the diagnostic categories DBD, ASD and ADHD were identified as significant predictors of Body Coordination.

3.3.5 Composite Strength and Agility

FSIQ has a significant effect on the composite Strength and Agility and explains 11.5% of the variance. Upon adding the diagnostic categories, the model explains 29.3% of the variance in Strength and Agility. The change in R^2 was significant (R^2 Change = .178; $p \leq .0001$). The diagnostic category ASD was a significant predictor of the composite Strength and Agility.

4. Discussion

One objective of this study was to explore the type and severity of motor impairment in male adolescents with a psychiatric condition. Consistent with our hypothesis and prior research, participants from the clinical population performed worse in comparison to typically developing peers (Emck et al., 2011; Simons et al., 2011; Simons et al., 2013). Significant differences emerged on all BOT-2 subscales and composite scores, indicating a mixed motor impairment profile. Whereas the clinical group obtained a TMC slightly below -

-1 SD from the mean population norm, the control group obtained a mean TMC close to the population norm.

Another objective of this study was to evaluate to what extent a certain diagnosis contributes to variation in motor scores. In order to account for co-occurring disorders, a stepwise linear regression was performed. The BOT-2 allowed studying various motor areas, which were investigated separately to determine any distinct performance profiles. The constructed models indicated that FSIQ and diagnostic categories accounted for a significant amount of the variance in motor ability scores. Whereas ASD was identified as a significant predictor for all BOT-2 composite scores, Depression and Substance Abuse did not have a predictive value for any of the composites. Moreover, DBD and ADHD were significant predictors of the Total Motor Composite, Fine Manual Control and Body Coordination. Reactive Attachment Disorder was a significant predictor of the Total Motor Composite and Fine Manual Control. While causality cannot be inferred from these analyses, the results show a direct association between diagnostic groups and motor ability.

The results from this study should be interpreted within the context of some strengths and limitations. One of the strengths is the accuracy of diagnostic categories, which resulted from a comprehensive screening by an experienced and multidisciplinary team. Additionally, a careful approach with regard to possible co-occurring disorders was applied. Furthermore, the results from the regression analyses emphasize the importance of controlling for potential differences in intellectual functioning. Another strong feature of this study is the use of the BOT-2 across different psychiatric populations. Not only are the items from this instrument the same across all ages; the BOT-2 also provides a comprehensive assessment of motor ability, which allows detailed comparisons.

However, some important limitations of this study should be recognised. First, participants from the clinical group were recruited from a specialist clinic. Therefore, our sample might not be directly representative of male adolescents diagnosed with these disorders in the general population. Second, some diagnostic categories were quite small; hence generalisation of the findings is restricted. Furthermore, it is suggested by some researchers that it is of interest to study groups of individuals with certain combinations of problems (Biederman, Newcorn, & Sprich, 1991; Kadesjo & Gillberg, 1998). For instance, a group of individuals with DBD and ADHD might be more homogeneous, than the entire DBD group. Such groups may respond differentially to therapies and may turn out to have variable outcomes. Unfortunately, we were unable to address this issue; as larger sample sizes would have been required to investigate potential meaningful relations between several

combinations of diagnostic categories. Third, the BOT-2 is not validated in a Dutch population. However, this issue was mainly compensated by the inclusion of a typically developing Dutch control group. Moreover, the same trained therapist conducted the motor assessment in all participants. Consequently, potential inter-rater bias was avoided.

Clinical implications

For clinicians, the results of this study imply that motor ability of adolescents with a psychiatric disorder is in need of attention, regardless of the diagnosis. Additionally, these results support the notion that objective motor assessment should be part of routine clinical practice. However, motor impairment is not a critical diagnostic feature of any of the discussed psychiatric conditions. As a result, motor assessment it is easily overlooked in a diagnostic process. Nevertheless, unrecognised motor problems might lead to withholding intervention and failure to adequately adapt the context according to the needs of each individual.

References

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (4th ed., text rev.). Washington, DC: Author.

Biederman, J., Newcorn, J., & Sprich, S. (1991). Comorbidity of attention deficit hyperactivity disorder with conduct, depressive, anxiety, and other disorders. *The American journal of psychiatry, 148*(5), 564-577.

Brossard-Racine, M., Shevell, M., Snider, L., Belanger, S. A., Majnemer, A. (2012). Motor skills of children newly diagnosed with Attention Deficit Hyperactivity Disorder prior to and following treatment with stimulant medication. *Research in Developmental Disabilities, 33*(6), 2080-2087.

Cohen, J. (1988). *Statistical power analysis for the behavioural sciences (2nd ed.)*. Hillsdale, NJ: Lawrence Erlbaum.

Dewey, D., Cantell, M., & Crawford, S. G. (2007). Motor and gestural performance in children with autism spectrum disorders, developmental coordination disorder, and/or attention deficit hyperactivity disorder. *Journal of the International Neuropsychological Society, 13*(2), 246-256.

Dewey, D., Kaplan, B. J., Crawford, S. G., & Wilson, B. N. (2002). Developmental coordination disorder: associated problems in attention, learning, and psychosocial adjustment. *Human Movement Science, 21*(5), 905-918.

Downey, R., & Rapport, M. J. K. (2012). Motor activity in children with autism: a review of current literature. *Pediatric Physical Therapy, 24*(1), 2-20.

Emck, C., Bosscher, R. J., Beek, P., & Doreleijers, T. (2009). Gross motor performance and self-perceived motor competence in children with emotional, behavioural, and

pervasive developmental disorders: a review. *Developmental Medicine & Child Neurology, 51*(7), 501-517.

Emck, C., Bosscher, R. J., Van Wieringen, P. C., Doreleijers, T., & Beek, P. J. (2011). Gross motor performance and physical fitness in children with psychiatric disorders. *Developmental Medicine & Child Neurology, 53*(2), 150-155.

Fliers, E., Vermeulen, S., Rijsdijk, F., Altink, M., Buschgens, C., Rommelse, N., . . . Franke, B. (2009). ADHD and poor motor performance from a family genetic perspective. *Journal of the American Academy of Child and Adolescent Psychiatry, 48*(1), 25-34.

Fournier, K. A., Hass, C. J., Naik, S. K., Lodha, N., & Cauraugh, J. H. (2010). Motor coordination in autism spectrum disorders: a synthesis and meta-analysis. *Journal of Autism and Developmental Disorders, 40*(10), 1227-1240.

Geuze, R., Jongmans, M., Schoemaker, M., & Smits-Engelsman, B. (2001). Clinical and research diagnostic criteria for developmental coordination disorder: a review and discussion. *Human Movement Science, 20*(1), 7-47.

Goedhart, A., Treffers, F., & van Widenfelt, B. (2003). Vragen naar psychische problemen bij kinderen en adolescenten: de Strengths and Difficulties Questionnaire (SDQ). *Maandblad Geestelijke Gezondheid,* 58, 1018-1035.

Iversen, S., Knivsberg, A. M., Ellertsen, B., Nødland, M., & Larsen, T. B. (2006). Motor coordination difficulties in 5-6-year-old children with severe behavioural and emotional problems. *Emotional and Behavioural Difficulties, 11*(3), 169-185.

Kadesjo, B., & Gillberg, C. (1998). Attention deficits and clumsiness in Swedish 7-year-old children. *Developmental Medicine and Child Neurology, 40*(12), 796-804.

Kooistra, L., Crawford, S., Dewey, D., Cantell, M., & Kaplan, B. J. (2005). Motor correlates of ADHD: contribution of reading disability and oppositional defiant disorder. *Journal of Learning Disabilities, 38*(3), 195-206.

Kopp, S., Beckung, E., & Gillberg, C. (2010). Developmental coordination disorder and other motor control problems in girls with autism spectrum disorder and/or attention-deficit/hyperactivity disorder. *Research in Developmental Disabilities, 31*(2), 350-361.

Logan, S. W., Robinson, L. E., Rudisill, M. E., Wadsworth, D. D., & Morera, M. (2014). The comparison of school-age children's performance on two motor assessments: the Test of Gross Motor Development and the Movement Assessment Battery for Children. *Physical Education and Sport Pedagogy, 19*(1), 48-59.

MacNeil, L.K., Mostofsky, S.H. (2012). Specificity of dyspraxia in children with autism. *Neuropsychology, 26*(2), 165-171.

Pan, C. Y., Tsai, C. L., & Chu, C. H. (2009). Fundamental movement skills in children diagnosed with autism spectrum disorders and attention deficit hyperactivity disorder. *Journal of Autism and Developmental Disorders, 39*(12), 1694-1705.

Piek, J. P., Pitcher, T. M., & Hay, D. A. (1999). Motor coordination and kinaesthesis in boys with attention deficit-hyperactivity disorder. *Developmental Medicine and Child Neurology, 41*(3), 159-165.

Piek, J. P., Baynam, G., & Barret, N. (2006). The relationship between fine and gross motor ability, self-perceptions and self-worth in children and adolescents. *Human Movement Science, 25*(1), 65-75.

Piek, J. P., Bradbury, G. S., Elsley, S. C., & Tate, L. (2008). Motor coordination and Social–Emotional behaviour in Preschool- aged children. *International Journal of Disability, Development and Education, 55*(2), 143-151.

Pietrzak, R. H., Mollica, C. M., Maruff, P., Snyder, P. J. (2006). Cognitive effects of immediate-release methylphenidate in children with attention-deficit/hyperactivity disorder. *Neuroscience and Biobehavioral Reviews, 30*(8), 1225-1245.

Pitcher, T. M., Piek, J. P., & Hay, D. A. (2003). Fine and gross motor ability in males with ADHD. *Developmental Medicine and Child Neurology, 45*(8), 525-535.

Rivilis, I., Hay, J., Cairney, J., Klentrou, P., Liu, J., & Faught, B. E. (2011). Physical activity and fitness in children with developmental coordination disorder: A systematic review. *Research in Developmental Disabilities, 32*(3), 894-910.

Schoemaker, M. M., & Kalverboer, A. F. (1994). Social and affective problems of children who are clumsy: How early do they begin? *Adapted Physical Activity Quarterly, 11*, 130-140.

Simons, J., Vanderheyden, V., Nilius-Hoffmann, E., & Vandenbussche, I. (2011). Bewertung der allgemeinen Körperkoordination bei Patienten einer Kinder-und Jugendpsychiatrie anhand des Körperkoordinationtests für Kinder [Assessment of general body coordination of patients in child- and adolescent psychiatry by means of the Körperkoordinationtest for children]. *Ergotherapie – Zeitschrift für angewandte Wissenschaft, 12*(1), 28-41.

Simons, J., Capio, C., Adriaenssens, P., Delbroek, H., & Vandenbussche, I. (2012). Self-concept and physical self-concept in psychiatric children and adolescents. *Research in Developmental Disabilities, 33*(3), 874-881.

Simons, J., Verscheure, B., Vandenbussche, I., Adriaenssens, P., & Delbroek, H. (2013). Motorische ontwikkeling bij kinderen en adolescenten met een psychiatrische stoornis [Motor development of children and adolescents with a psychiatric disorder]. *Tijdschrift voor Ortho-pedagogiek, Kinderpsychiatrie en Klinische Kinderpsychologie, 38*(2), 75-83.

Skinner, R. A., & Piek, J. P. (2001). Psychosocial implications of poor motor coordination in children and adolescents. *Human Movement Science, 20*(1), 73-94.

Skirbekk, B., Hansen, B. H., Oerbeck, B., Wentzel-Larsen, T., & Kristensen, H.. (2012). Motor impairment in children with anxiety disorders. *Psychiatry Research, 198*(1), 135-139.

Spironello, C., Hay, J., Missiuna, C., Faught, B. E., & Cairney, J. (2010). Concurrent and construct validation of the short form of the Bruininks-Oseretsky Test of Motor Proficiency and the Movement-ABC when administered under field conditions: implications for screening. *Child: Care, Health and Development, 36*(4), 499-507.

Table 1

Sample characteristics

Group	n	Age			FSIQ		
		M	SD	Range	M	SD	Range
Control group	87	15.33	1.50	12.25-18.50	104.57	11.69	78-127
Clinical group							
Total	144	15.38	1.44	12.08-17.75	93.74	13.13	70-126
DBD	99	15.33	1.41	12.08-17.75	90.41	11.67	71-126
ASD	53	15.46	1.45	12.08-17.67	99.09	14.35	70-124
Depression	33	16.07	1.30	13.92-17.67	91.27	12.09	70-121
ADHD	70	15.09	1.40	12.08-17.58	93.04	14.17	70-126
Substance Abuse	16	16.15	1.06	14.58-17.67	90.31	13.46	70-115
Reactive Attachment Disorder	13	15.35	1.36	13.33-17.58	98.54	15.44	76-126

Note. DBD = Disruptive Behaviour Disorder; ASD = Autism Spectrum Disorder; ADHD = Attention Deficit Hyperactivity Disorder; FSIQ = Full Scale Intelligence Quotient

Table 2

BOT-2 composites: Comparisons between clinical and control population

	Clinic (n=144)		Control (n=87)		T or F value	P value	η^2	Mean difference
	M	SD	M	SD				
Total Motor Composite								
Without controlling	39.89	6.44	51.06	8.09	11.57	.000	0.37	11.17
Controlling for IQ	40.67		49.79		85.34	.000	0.27	9.12
Fine manual control								
Without controlling	37.78	6.95	46.07	7.78	8.39	.000	0.24	8.28
Controlling for IQ	38.42		45.02		40.81	.000	0.15	6.60
Manual coordination								
Without controlling	43.08	7.56	49.95	8.84	6.28	.000	0.15	6.88
Controlling for IQ	43.62		49.06		21.87	.000	0.09	5.44
Body coordination								
Without controlling	38.69	7.11	47.91	7.02	9.60	.000	0.29	9.22
Controlling for IQ	39.34		46.83		55.99	.000	0.20	7.49
Strength and agility								
Without controlling	50.99	8.76	60.24	7.52	8.19	.000	0.23	9.25
Controlling for IQ	51.51		59.39		42.83	.000	0.16	7.88

Table 3

Multiple linear regression with six diagnostic categories

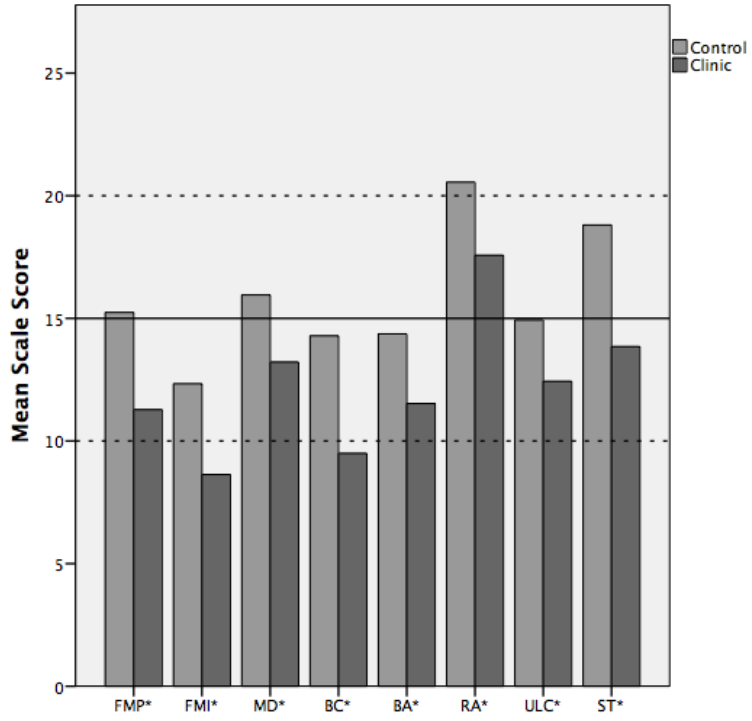
	R^2	Adjusted R^2	R^2 change	B	SE	β
Total Motor Composite						
Step 1	.23	.23***				
FSIQ				.31	.04	.48***
Step 2	.44	.43***	.22***			
FSIQ				.24	.04	.36***
DBD				-3.60	1.17	-.20*
ASD				-7.35	1.09	-.35***
Depression				-2.51	1.32	-.10
ADHD				-2.35	1.11	-.12*
Substance abuse				1.63	1.82	.05
Reactive Attachment Disorder				-4.53	2.03	-.12*
Fine Manual Control						
Step 1	.16	.16***				
FSIQ				.25	.04	.41***
Step 2	.35	.32***	.18***			
FSIQ				.16	.04	.27***
DBD				-4.10	1.18	-.25**
ASD				-5.51	1.10	-.28***
Depression				-1.42	1.33	-.06
ADHD				-2.46	1.12	-.14*
Substance abuse				1.34	1.84	.04
RAD				-2.88	2.05	-.08
Manual Coordination						
Step 1	.11	.10***				
FSIQ				.21	.04	.32***
Step 2	.21	.19***	.11***			
FSIQ				.16	.04	.26***
DBD				-2.26	1.36	-.13
ASD				-5.74	1.27	-.28***
Depression				-1.76	1.53	-.07
ADHD				-.97	1.29	-.05
Substance abuse				.53	2.12	.02
RAD				-2.45	2.36	-.07
Body Coordination						
Step 1	.18	.18***				
FSIQ				.26	.04	.43***
Step 2	.35	.33***	.17***			
FSIQ				.17	.04	.28***
DBD				-3.70	1.19	-.22**
ASD				-3.30	1.10	-.17**
Depression				-.83	1.33	-.04
ADHD				-4.25	1.12	-.23***

Substance abuse				1.17	1.84	.04
RAD				-2.61	2.06	-.07
Strength and Agility						
Step 1	.12	.11***				
FSIQ				.24	.04	.34***
Step 2	.29	.27***	.18***			
FSIQ				.23	.05	.34***
DBD				-.11	1.40	-.01
ASD				-8.30	1.30	-.37***
Depression				-2.88	1.57	-.11
ADHD				-1.11	1.32	-.05
Substance abuse				3.41	2.17	.09
RAD				-4.72	2.42	-.12

Note. *p<.05, **p<.01, ***p<.001. FSIQ = Full Scale Intelligence Quotient; DBD = Disruptive Behaviour Disorder; ASD = Autism Spectrum Disorder; ADHD = Attention Deficit Hyperactivity Disorder; RAD = Reactive Attachment Disorder.

Figure 1

Mean BOT-2 scale scores of the clinical and control population



Note. FMP = Fine Motor Precision; FMI = Fine Motor Integration; MD = Manual Dexterity; BC = Bilateral Coordination; BA = Balance; RA = Running Speed and Agility; ULC = Upper-Limb Coordination; ST = Strength. * $p < .000$.