

Green, D., **Charman, T.**, Pickles, A., Loucas, T., Chandler, S., Simonoff, E. & Baird, G. (2009). Impairment in movement skills of children with autism spectrum disorders. *Developmental Medicine and Child Neurology*, 51, 311-316.

## **Impairment in movement skills of children with autism spectrum disorders**

Dido Green PhD<sup>1,6</sup>, Tony Charman PhD<sup>2</sup>, Andrew Pickles PhD<sup>3</sup>, Susie Chandler PhD<sup>2</sup>,

Tom Loucas PhD<sup>4</sup>, Emily Simonoff FRCPsych<sup>5</sup>, Gillian Baird FRCPCH <sup>1</sup>

1 Guy's & St Thomas' NHS Foundation Trust, London

2 UCL Institute of Child Health, London

3 Biostatistics Group, Division of Epidemiology & Health Sciences, University of Manchester

4 School of Psychology and Clinical Language Sciences, University of Reading

5 Department of Child and Adolescent Psychiatry, King's College London, Institute of Psychiatry

6 NIHR KCL/GSTT Biomedical Research Centre, Research Training Fellow

### **Correspondence to:**

Dido Green

Newcomen Centre

Guy's & St Thomas' NHS Foundation Trust

St. Thomas's Street

London, SE1 9RT, UK

Fax: 0207 7378 6994

Email: dido.green@gstt.nhs.uk

**Running head:** Movement impairment in ASD

**Text word count:** 3,367

## Summary

This study explored the degree of impairment in movement skills in a large, well-defined, **population-derived** group of children with childhood autism and broader autistic spectrum disorders (ASD, mean (SD) age = 11.4 (0.8) years; **89 male, 12 female**) with a wide range of IQ. Movement skills were measured using the Movement Assessment Battery for Children (M-ABC, N=101). Additionally, we tested whether a parent-completed questionnaire, Developmental Coordination Disorder Questionnaire (DCDQ), was useful as a screen children who for movement impairments (N=97 complete M-ABCs and DCDQs). Of the children with ASD, 79% had definite movement impairments on the M-ABC; a further 10% having borderline problems. Children with childhood autism were more impaired than children with broader ASD and children with an IQ <70 were more impaired than those with IQ>70. This is consistent with the view that the movement impairment may arise from a more severe neurological impairment that also contributes to intellectual disability and more severe autism presentation. Movement impairment was not associated with everyday adaptive behaviour once the effect of IQ was controlled. The DCDQ performed moderately well to screen children for possible motor difficulties. Movement impairments are common in children with ASD. Systematic assessment of movement abilities should be considered a routine investigation.

**Summary word count:** 199

Many empirical studies over the past two decades have confirmed that movement impairment is common in children with autism spectrum disorders (ASD). Manjiviona and Prior<sup>1</sup> found that 50% of children with Asperger syndrome and 67% of children with autism had a movement impairment as measured by the Test of Motor Impairment – Henderson (TOMI-H)<sup>2</sup>. Ghaziuddin and Butler<sup>3</sup> found that movement problems were common in children with Asperger syndrome, autism and PDD-NOS using the Bruininks Oseretsky Test of Motor Proficiency<sup>4</sup>. Miyahara et al.<sup>5</sup> reported that 85% of a sample of 26 children with Asperger syndrome were at least 2 SD below the mean of the Movement Assessment Battery for Children (M-ABC)<sup>6</sup>. Dewey et al<sup>7</sup> found that 59% of children with an ASD met criteria for a movement impairment on the Bruininks Oseretsky Test of Motor Impairment-Short Form (BOTMP-SF)<sup>4</sup>. Denkla and colleagues<sup>8</sup> explored basic motor actions (e.g. repetitive timed hand and feet actions) and ‘soft’ neurological signs (e.g. postures while walking on the outsides of the feet) in boys with ASD. They found impairment in balance and gait, slower speed of timed movements and greater ‘overflow’ movements in ASD compared with controls. This research group has also suggested an additional praxis (gesture/imitation) problem in ASD<sup>9</sup>. The movement impairments in ASD have been shown to be more similar than different to those found in Developmental Coordination Disorder (DCD) where praxis impairment is also suggested, except in the area of ball skills (throwing and catching) where children with ASD show greater impairment<sup>10</sup>.

Whilst movement impairments have been frequently identified in samples of children with ASD it remains to be established whether these findings apply to the broader population of children with an ASD. First, many studies have been conducted

with children with average or close to average IQ, often with a view to contrasting the performance of children with Asperger syndrome and ‘high functioning’ autism<sup>1,3,5,7,8,9</sup>. It is well-established that movement impairment is more common in children with intellectual disability (IQ<70)<sup>11</sup> yet few studies have contrasted the movement impairments in children with autism with and without intellectual disability. Second, with the exception of the recent studies by the Denkla group<sup>8,9</sup> (N=40 and N=47, respectively) and Dewey et al.<sup>7</sup> (N=49), many studies have had modest sample sizes only (e.g. Manjiviona & Prior<sup>1</sup>, N=21; Miyahara et al.<sup>5</sup>, N=26). Finally, in several previous studies<sup>3,7,10</sup> recruitment has been, at least in part, through hospital-based clinical services where children with more complex presentations, including comorbid neurological conditions and motor impairments, might be over-represented. **No previous studies have reported on motor abilities in a large, population-derived sample of children with ASD with a wide range of IQ.**

#### *The present study*

The first aim of the present study is to extend previous work by using a standardized clinical instrument (Movement Assessment Battery for Children; M-ABC)<sup>3</sup> to measure how common movement impairments are in a large (N=101), population-derived, well-defined group of school-aged children. The sample included children with a diagnosis of childhood autism and broader ASD and children with intellectual disability (IQ<70) as well as borderline and average IQ (IQ≥70). **This enabled us to examine whether motor impairment was more prevalent or more severe in children with autism (vs. broader ASD) and children with low IQ (vs. high IQ) which would be consistent with motor impairment being a sign of greater neurological compromise.** Second, although it

is well established that everyday adaptive behaviour is poor amongst children with ASD, even in those who score in the average range on IQ tests<sup>12</sup>, it has not been previously investigated whether movement impairment contributes to poor everyday adaptive skills. We will examine the association between severity of movement impairment and adaptive behaviour, independent of IQ, in our sample. Finally, we assessed the properties of the DCDQ, a parent questionnaire, in identifying children who were found to have impaired motor skills in the M-ABC. For 97 of the 101 children who completed M-ABC assessments we had parental reported motor abilities on the Developmental Coordination Disorder Questionnaire (DCDQ)<sup>13</sup>.

## Method

The study was approved by the South East Multicentre Research Ethics Committee (REC) (00/01/50). Parents of the child participants gave informed consent for them to take part in the study.

### *Participants*

The children in this study were a subsample of the Special Needs and Autism Project (SNAP) sample drawn from a total population cohort of 56,946 children in South East England<sup>14</sup>. All those with a current clinical diagnosis of Pervasive Developmental Disorder (PDD; N=255) or considered 'at risk' for being an undetected case by virtue of having a statement of Special Educational Needs (SEN; N=1,515) were surveyed (mean age=10.3, SD=1.1) using the Social Communication Questionnaire (SCQ)<sup>12</sup>. A stratified subsample (coincidentally also N=255; 223 boys, 32 girls) drawn from across the range of SCQ scores were seen for assessment as part of a prevalence study of autism and ASD<sup>14</sup>. Each received a comprehensive diagnostic assessment including standardized clinical

observation (Autism Diagnostic Observation Schedule - Generic (ADOS-G)<sup>15</sup>) and parent interview assessments of autistic symptoms (Autism Diagnostic Interview-Revised (ADI-R)<sup>16</sup>), adaptive behaviour (Vineland Adaptive Behavior Scale (VABS)<sup>17</sup>), language and IQ, psychiatric comorbidities and a medical examination. The team used International Classification of Diseases (ICD-10)<sup>18</sup> research criteria to derive a clinical consensus diagnosis of childhood autism and other ASDs (see Baird et al<sup>14</sup>; for details). For 36 randomly selected cases, project consensus diagnoses were compared to those of 8 internationally recognised experts using ICD-10 criteria (usually 2 experts independently rated ADI, ADOS, psychometric findings and a clinical vignette for each case). Quadratic weighted agreement between project consensus and expert autism/ASD/no-ASD diagnostic categories was 93% with kappa 0.77.

Of the children with an ASD diagnosis 101 completed **all items of** the M-ABC (45 autism, 56 other ASD; mean (SD) age = 11.4 (0.8); 89 male, 12 female). **From the larger sample of children with ASD (N=158; see Baird et al<sup>14</sup>), 7 children with ASD completed some but not all M-ABC items due to poor verbal understanding (N=3) refusal (N=1) and lack of time (N=3) and are not included in the current report. Fifty 50 children with ASD were not assessed on the M-ABC due either to time constraints (N=33) or were too low functioning to access the assessment (N=17, all IQ  $\leq$ 57).** A higher proportion of children with autism (44.4%) from the total sample of N=158 children with ASD assessed in the SNAP study vs. other ASD cases (27.3%) did not complete the M-ABC ( $\chi^2=5.05$ ,  $p=.03$ ) and children who did not complete the M-ABC had lower IQ (N=57; 61.2 (27.1) vs. N=101; 78.2 (20.8); [range 28 to 136];  $F(1,156)=19.0$ ,  $p<.001$ ). Two children had known genetic conditions (one fragile X; three with small chromosome

deletions (6p, 10q, 14.1p)). Ninety-seven of these 101 children had the DCD-Q completed by their parents (43 autism, 54 other ASD; mean (SD) age = 11.4 (0.8); 85 male, 12 female). IQ was measured using the Wechsler Intelligence Scale for Children (WISC-III-UK<sup>19</sup>), Raven's Standard or Coloured Progressive Matrices (SPM/CPM)<sup>20,21</sup>, depending on the child's ability. Where WISC full scale IQs were not available, imputed full-scale IQs were obtained using the regression relationship of full scale IQ to SPM/CPM IQ (N=12). For the 5 cases where no direct cognitive testing was possible all had VABS<sup>17</sup> Adaptive Behaviour Composites below 20 and these cases were assigned an IQ score of 19 to reflect their profound level of intellectual disability. On the M-ABC we compared the children with childhood autism (N=45) to those with broader ASD (N=56) and the children with an IQ<70 (N=35; mean (SD) = 56.5 (10.3) to those with an IQ≥70 (N=66; mean (SD) = 89.7 (15.0)).

### *Measures*

The *Movement Assessment Battery for Children (M-ABC)*<sup>3</sup> is a clinical assessment used to determine the extent of possible impairment in fine and gross motor skills. The 8 items are divided into three subtests; manual dexterity, ball skills, and static and dynamic balance. Point scores range from 0-5 with 5 indicating the highest level of impairment. Scores of 0 represent those achieved by 75% of the normative sample and scores of 5 indicative of the lowest 2%. A total impairment score is obtained from the sum of subsections and may then be converted to a percentile rank. A raw score of 0-9.5 is considered within the average range, a score of 10-13.5 (15-6%ile) is considered borderline, and scores of >13.5 (≤5%ile) are indicative of definite motor difficulties. Percentile cut-offs (15% and 5%) for the 3 subtests are also reported. Two of the four test

age bands [whereby children undertake different items dependent on age], corresponding to developmental attainments of children 9-10 years (N=31) and 11-12 years (N=70), were undertaken in this study. Only children who completed all items on the M-ABC for whom a total impairment score could be calculated are included in the analysis.

The *Developmental Coordination Disorder Questionnaire (DCDQ)*<sup>13</sup> is a 17-item parent survey of a broad range of gross and fine motor, ball skills and organisational/planning ability. The DCDQ discriminates between children with and without movement impairments in skills in naturalistic contexts, independent of instructional and test requirements. A total score is computed (with lower scores indicating more movement difficulties). Ten (10.3%) DCDQ total scores were pro-rated as fewer than 3 items were missing as per research administration guidelines<sup>13</sup>. Cut-off scores for determination of the risk for DCD are currently based on Canadian norms of children between the ages of 8-14 ½ years although good sensitivity has been shown in the screening of motor difficulties of children in the UK<sup>22</sup>. Scores below 58 represent probable motor difficulties (<25<sup>th</sup> percentile) and scores below 48 considered to represent more definite motor problems (<10<sup>th</sup> percentile). The DCDQ was completed by the child's parent(s) in advance of the clinical assessment that included the MABC.

#### *Statistical Analysis*

Chi-squared analysis was used to explore the proportion of children with definite movement impairment on the MABC in the autism vs. broader ASD subgroups and in the subgroups with IQ<70 and IQ≥70. The data met Levene's test for homogeneity of variance and a 2 (diagnosis: Autism or broader ASD) by 2 (IQ: <70 or ≥70) analysis of variance (ANOVA) assessed group differences and diagnosis-by-IQ interactions in M-



ABC total impairment score. A repeated measures multivariate analysis of variance (MANOVA) and a post-hoc series of paired t-tests (according to good practice without Bonferroni corrections; see Rothman<sup>23</sup>) assessed differences in the profile of fine and gross motor skills between the individual M-ABC subtests. We ran full and IQ partialled Pearson correlations to investigate whether movement impairment was associated with everyday adaptive behaviour as measured by the VABS. Analyses were carried out using the Statistical Package for Social Sciences (SPSS, v.15)<sup>24</sup>. Area-under-curve (AUC) and the sensitivity, specificity and positive predictive value (PPV) parameters were derived using the diagt procedure in Stata 9<sup>25</sup>. Confidence intervals for AUC estimates were obtained by bootstrap resampling (1,000 replication)<sup>26</sup> Receiver Operator Curve (ROC) procedures of Stata 9.

## Results

On the M-ABC, 80/101 (79.2%) children had definite movement problems (<5%ile), with a further 10 (9.9%) having borderline problems (5%ile to 15%ile) and only 11 (10.9%) having no movement problems (see Table 1). The proportion of children with autism (82.2%) and broader ASD (76.8%) with definite movement problems was similar ( $\chi^2(1)=0.45, p=.50$ ); although the proportion of all ASD children with low IQ who had definite movement problems (97.1%) was higher than that of children with high IQ (69.7%) ( $\chi^2(1)= 10.5, p=.001$ ). The 2 x 2 ANOVA for total impairment score indicated a main effect for diagnosis with children with autism scoring higher (indicating a greater degree of movement impairment) than children with broader ASD ( $F(1,97)=6.72, p=.01$ ) and a main effect of IQ with low IQ children scoring higher than higher IQ children

( $F(1,97)=46.5, p<.001$ ) but no diagnosis by IQ interaction (See Table 1). Although total impairment score on the M-ABC was significantly correlated with the VABS Adaptive Behavior Composite ( $r=-.37, p<.001, N=92$ ), when the effect of IQ was partialled out there was no significant association ( $r=.00, p=.98$ ).

The repeated measures MANOVA of M-ABC subtest scores indicated an overall significant within-subjects effect ( $F(1,100)=5.80, p=0.02$ ). Post-hoc analysis of the profile of movement impairments using pairwise t-tests showed that M-ABC impairment scores were significantly higher (poorer skill) on the timed pegboard activity and board balance tasks than all other tasks (all  $p<.001$ ) but these 2 tasks were not different from each other (see Figure 1). In addition, fine motor hand skills and ball catching impairment scores were higher than ball throwing impairment scores ( $p=.008$  and  $p=.004$ , respectively) and ball catching impairment scores were higher than balance ball/walk impairment scores ( $p=.04$ ).

<Table 1 approximately here>

<Figure 1 Approximately here>

The association between the DCDQ cut-points for ‘probable’ and ‘definite’ motor difficulties and movement impairment as assessed by the M-ABC is shown in Table 2. Comparing the proportion of the sample above the ‘definite motor problems’ cut point on the DCDQ to children identified as having a ‘definite movement impairment’ on the M-ABC yielded the following values: **AUC 0.71 (95% confidence intervals (CI) 0.59 to 0.80), Sensitivity 66.2% (95%CI 54.2% to 76.7%), Specificity 75.0% (95% CI 55.6% to 94.4%), PPV 91.1% (95% CI 82.3% to 98.1%)**. Comparing the proportion of the sample above the ‘probable motor problems’ cut point on the DCDQ to children identified as

having a 'borderline movement impairment' on the M-ABC yielded the following values:

AUC 0.66 (95CI 0.50 to 0.82), Sensitivity 86.0% (95%CI 76.9% to 92.6%), Specificity 45.5% (95% CI 16.7% to 76.6%), PPV 92.5% (95% CI 84.4% to 97.2%).

<Table 2 approximately here>

## Discussion

The primary purpose of this study was to measure the extent of impairments in fine and gross motor skills in a large, well-defined and population-derived (as opposed to a clinically referred sample where motor impairments might be over-represented due to referral bias) group of school-age children with autism or a broader ASD, including both children with intellectual disability ( $IQ < 70$ ) and children of low average to average cognitive ability ( $IQ \geq 70$ ). This enabled us to test whether movement impairments were more common or more severe in a diagnostic or IQ subgroup within the autism spectrum. The majority of children with ASD had a movement impairment as measured by the M-ABC. Unlike many previous studies, this large group of children with ASD was obtained from a population-derived sample<sup>15</sup> rather than a group of children referred for a neurodevelopmental assessment that may have included concerns over motor ability or clumsiness<sup>3,7,9</sup>.

The proportion of children with definite motor problems was similar in the childhood autism and broader ASD groups. However, whilst movement problems were near universal in the group with  $IQ < 70$  (only one child did not score in the definite problem range) they occurred in only two-thirds of children with  $IQ \geq 70$ . As regards the severity of movement impairments, scores were higher in children with autism compared to broader ASD and in children with intellectual disability ( $IQ < 70$ ) compared to low to

average IQ ( $IQ \geq 70$ ). These findings are consistent with previous findings<sup>1,3,5,7,9,10,27</sup> but also extend them, in particular in identifying that motor problems are more common and more severe in children with ASD with intellectual disability, and in children with autism as opposed to broader ASD.

Why might children with ASD with low IQ have a higher rate and severity of movement problems and children with childhood autism more severe motor impairment than children with broader ASD? This association might be due to the fact that children with autism and children with intellectual disability are more ‘neurologically compromised’ than children with broader ASD and those without an intellectual disability. We know that severity of autism and low IQ are associated, including in the population representative sample from which the current sample was drawn<sup>14</sup>. It appears that whatever perturbations in brain development and function underlie autism, they affect both motor and cognitive systems as well as the brain systems and developmental responses that lead to the characteristic symptoms of the disorder. There are other more artefactual potential explanations for the association between movement impairment and low IQ in children with ASD. The M-ABC tests fine and gross motor dexterity, ball skills and balance but also requires the child to follow and understand instructions. Therefore, some children may score poorly due to non-compliance or poor understanding of instructions. However, the children from the SNAP cohort with the lowest IQ did not complete the M-ABC (mean IQ 61.2) and the mean IQ of the children who did complete this assessment was on the border of the borderline/low average range (78.2). We think it unlikely that lack of understanding or non-compliance accounts for the very high rate of movement impairment identified, especially in the low IQ subgroup.

Contrary to our expectations, movement impairments were not associated with everyday adaptive behaviour once the effect of IQ was accounted for. Thus, there was no indication that motor skills *per se* contribute to poor adaptive outcome. Other studies have shown that social and communication impairments account for the very low adaptive skills in children with ASD, alongside IQ,<sup>12</sup> and the present findings suggest that there is no independent contribution from motor impairments.

The DCDQ performed moderately well as a screen of movement impairments as determined by the direct clinical assessment on the M-ABC, with acceptable specificity (75%) but somewhat low sensitivity (66%) at the ‘definite motor problems’ cut point. At the ‘borderline movement impairment’ cut-point the sensitivity was improved (86%) at the expense of reduced specificity (46%). The confidence intervals on these estimates were fairly wide, reflecting the relatively small sample. In a study of 5-to-15-year-old children referred to a UK Occupational Therapy service the DCDQ had a higher sensitivity in identifying children categorised with movement impairment on the M-ABC (93%) but very much lower specificity (19%), falsely classifying many children who did not have an impairment on assessment.<sup>22</sup> Screening instruments can never substitute for clinical assessment and the very high rate of movement disorder in this and previous studies suggests that a movement assessment should be considered part of routine investigation for children with ASD. However, there may be some clinical circumstances or research studies where a first-level screen is required and the DCDQ performed adequately as a screen in our sample.

None of the children in this study had an identified neurologically based motor disorder. Denkla and colleagues<sup>8,9</sup> have suggested that the movement problems of

children with ASD are greater than can be accounted for by a difficulty in motor actions (although in their study, children with ASD are impaired in basic motor actions compared with controls). These authors suggest a particular problem with praxis as do Rinehart et al.<sup>28</sup>. Our analysis does, however, show that it was the timed tasks of the M-ABC that were more impaired in ASD. Whether this represents a particular problem with speed of task or an indifference to time, or a failure of mental conception of time passing, is unknown. Moreover, our results show that children with ASD have greater difficulties in movement tasks that have an inherent or dual nature to them; that of accuracy and timing as seen in the timed peg-board tasks and standing on one-leg for as long as possible. This suggests that complexity of motor task may be the important feature affecting performance.

#### *Limitations and conclusions*

Although this was a large sample of children with ASD that was derived from a population cohort, as only two-thirds of the children assessed completed the M-ABC we have reported simple rather than the design adjusted estimates of the frequency and severity of movement impairments as we have reported elsewhere for psychiatric disorders<sup>29</sup>. Children with childhood autism and IQ<70 were less likely to complete the M-ABC so the present estimates of motor impairment might be considered minimum figures only. Whilst we felt that it was useful to use the DCDQ data that was available on the majority of the sample assessed, the content of the movement skills assessed by the direct assessment (MABC) and the parental questionnaire (DCDQ) do differ, likely reducing the latter's predictive power. Finally, the measures used in the current study do not allow separate assessment of praxis from other aspects of movement execution that

would better help us to understand the *nature* of movement impairments seen in children with ASD<sup>8,9,26</sup>. Notwithstanding these limitations, motor impairments are very common in children with ASD (both those with childhood autism and those with broader ASD and those with high IQ as well as those with low IQ) and the assessment and identification of movement impairments in children with ASD should be considered a routine investigation.

### **Acknowledgements**

We are grateful to the children and families who participated in the study and to the clinical teams in South Thames, whose collaboration made the study possible. We thank Iris Carcani-Rathwell, Caron Coleman, Rachael Fallows, Greg Pasco, David Meldrum, Amarlie Ousdine, Samantha Ross, Emma Rowley, Vicky Slonims and Martha Turner for their help with assessments.

**Funding:** The study was funded by the Wellcome Trust and the Department of Health.



## References

1. Manjiviona J, Prior M. (1995) Comparison of Asperger Syndrome and High-Functioning Autistic children on a test of motor impairment. *J Autism Dev Disord* **25**: 23-39.
2. Stott DH, Moyes FA, Henderson SE. (1972) *The Test of Motor Impairment*, Guelph, ON: Brook Education.
3. Ghaziuddin M, Butler E. (1994) Clumsiness in autism and Asperger syndrome: a further report. *J Intell Dis Research* **42**: 43-48.
4. Bruininks RH. (1978) *Bruininks Oseretsky Test of Motor Proficiency – Manual*, Circle Pines, MN: American Guidance Service.
5. Miyahara M, Tsujii M, Hori M, Nakanishi K, Kageyama H, Sugiyama T. (1997) Brief report: Motor incoordination in children with Asperger syndrome and learning disabilities. *J Autism Dev Disord* **27**: 595-603.
6. Henderson SE, Sugden DA. (1992) *The Movement Assessment Battery for Children*. London: The Psychological Corporation.
7. Dewey D, Cantell M, Crawford SG. (2007) Motor and gestural performance in children with autism spectrum disorders, developmental coordination disorder, and/or attention deficit hyperactivity disorder. *J Int Neuropsychol Soc* **13**: 246-256.
8. Jansiewicz EM, Goldberg MC, Newschaffer CG, Denckla MB, Landa RJ, Mostofsky SH. (2006) Motor signs distinguish children with high functioning autism and Asperger's syndrome from controls. *J Autism Dev Disord* **36**: 613-621.
9. Dziuk MA, Gidley Larson JC, Apostu A, Mahone EM, Denckla MB, Mostofsky SH. (2007) Dyspraxia in autism: association with motor, social, and communication deficits. *Dev Med Child Neuro* **49**: 734-739.

10. Green D, Baird G, Barnett AL, Henderson L, Huber J, Henderson SE. (2002) The severity and nature of motor impairment in Asperger's syndrome: a comparison with Specific Developmental Disorder of Motor Function. *J Child Psychol Psych* **43**: 655-668.
11. Lam Y, Henderson SE. (1987) Some applications of the Henderson Revision of the Test of Motor Impairment. *Brit J Educat Psychol* **57**: 389-400.
12. Klin A, Saulnier CA, Sparrow SS, Cicchetti DV, Volkmar FR, Lord C. (2007) Social and communication abilities and disabilities in higher functioning individuals with autism spectrum disorders: the Vineland and the ADOS. *J Autism Dev Disord* **37**: 748-759.
13. Wilson BN, Kaplan BJ, Crawford SG, Campbell A, Dewey D. (2000) Reliability and Validity of a Parent Questionnaire on Childhood Motor Skills. *Am J Occ Ther* **54**: 484-493.
14. Baird G, Simonoff E, Pickles A, Chandler S, Loucas T, Meldrum D, Charman T (2006), Prevalence of disorders of the autism spectrum in a population cohort of children in South Thames: the Special Needs and Autism Project (SNAP). *Lancet* **368**:210-215.
15. Lord C, Risi S, Lambrecht L, Cook E, Leventhal B, DiLavore P, Pickles A, Rutter M. (2000) The Autism Diagnostic Observation Schedule – Generic: a standard measure of social and communication deficits associated with the spectrum of autism. *J Autism Dev Disorders* **30**: 205-223.
16. Lord C, Rutter M, Le Couteur A. (1994) Autism Diagnostic Interview – Revised: a revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *J Autism Dev Disorders* **24**: 659-685.
17. Sparrow SS, Balla DA, Cicchetti D. (1984) *Vineland Adaptive Behavior Scales* Circle Pines, MN: American Guidance Service.
18. World Health Organisation (1993) *The ICD-10 classification of mental and behavioural*

*disorders. Diagnostic criteria for research.* Geneva: WHO.

19. Wechsler D. (1992) *Wechsler Intelligence Scale for Children-III<sup>UK</sup>* (3<sup>rd</sup> ed.) London: The Psychological Corporation.

20. Raven JC, Court JH, Raven J. *Coloured Progressive Matrices.* Oxford: Oxford University Press; 1990.

21. Raven JC, Court JH, Raven J. *Standard Progressive Matrices.* Oxford: Oxford University Press; 1990.

22. Green D, Bishop T, Wilson B, Crawford S, Hooper R, Kaplan B, Baird G. (2005) Is questionnaire-based screening part of the solution to waiting lists for children with Developmental Coordination Disorder? *British Journal of Occupational Therapy* **68**: 2-10.

23. Rothman KJ. (1990) No adjustments are needed for multiple testing. *Epidemiol* **1**: 43-46.

24. SPSS (2006) *Statistical Package for Social Sciences* Chicago Ill: SPSS Inc.

25. Stata (2005), *Stata Statistical Software Release 9.0: User's Guide.* College Station, TX: Stata Corporation.

26. Efron B, Tibshirani RJ. (1986) Bootstrap methods for standard errors, confidence intervals, and other measures of statistical accuracy. *Stat Sci* **1**: 54-77.

27. Gaziuddin M, Tsai L, Ghaziuddin N. (1992) Brief report: A reappraisal of clumsiness as a diagnostic feature of Asperger's syndrome. *J Autism Dev Disord* **22**:651-656.

28. Rinehart N, Bradshaw J, Brereton A, Tonge B. (2001) Movement preparation in High-Functioning Autism and Asperger Disorder. *J Autism Dev Disord* **31**:79-88.

29. Simonoff E, Pickles A, Charman T, Loucas T, Chandler S, Baird G. (2008)

Psychiatric disorders in children with autism spectrum disorders: Prevalence, comorbidity and associated factors in a population-derived sample. *J Am Acad Child Adol Psychiat* **47**: 921-929.

Table 1 – M-ABC and DCDQ total scores

|             | M-ABC <sup>a</sup><br>Mean (SD) | M-ABC<br>N (%) definite<br>problems |
|-------------|---------------------------------|-------------------------------------|
| Autism      | 25.5 (10.7)<br>N=45             | 37 (82.2%)                          |
| Broader ASD | 21.5 (10.4)<br>N=56             | 43 (76.8%)                          |
|             |                                 |                                     |
| IQ<70       | 31.3 (8.1)<br>N=35              | 34 (97.1%)                          |
| IQ≥70       | 19.0 (9.4)<br>N=66              | 46 (69.7%)                          |

a M-ABC = Movement Assessment Battery for Children – Total impairment score

Table 2 – Association between DCDQ cut-points and M-ABC impairment category

|                         | DCDQ No<br>difficulties | DCDQ<br>Probable<br>difficulties | DCDQ Definite<br>difficulties | Total |
|-------------------------|-------------------------|----------------------------------|-------------------------------|-------|
| MABC No deficit         | 5                       | 2                                | 4                             | 11    |
| MABC Borderline problem | 5                       | 3                                | 1                             | 9     |
| MABC Definite problem   | 7                       | 19                               | 51                            | 77    |
| Total                   | 17                      | 24                               | 56                            | 97    |

Figure 1 – Profile of motor impairment scores (mean (SE)) across the individual items of the M-ABC for the whole ASD group (N=101)

