Impairment in movement skills of children with autistic spectrum disorders

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AIM We undertook this study to explore the degree of impairment in movement skills in children with autistic spectrum disorders (ASD) and a wide IQ range.

METHOD Movement skills were measured using the Movement Assessment Battery for Children (M-ABC) in a large, well defined, population-derived group of children (n=101: 89 males, 12 females; mean age 11y 4mo, SD 10mo; range 10y–14y 3mo) with childhood autism and broader ASD and a wide range of IQ scores. Additionally, we tested whether a parent-completed questionnaire, the Developmental Coordination Disorder Questionnaire (DCDQ), was useful in identifying children who met criteria for movement impairments after assessment (n=97 with complete M-ABCs and DCDQs).

RESULTS Of the children with ASD, 79% had definite movement impairments on the M-ABC; a further 10% had borderline problems. Children with childhood autism were more impaired than children with broader ASD, and children with an IQ less than 70 were more impaired than those with IQ more than 70. This is consistent with the view that movement impairments may arise from a more severe neurological impairment that also contributes to intellectual disability and more severe autism. Movement impairment was not associated with everyday adaptive behaviour once the effect of IQ was controlled for. The DCDQ performed moderately well as a screen for possible motor difficulties.

INTERPRETATION Movement impairments are common in children with ASD. Systematic assessment of movement abilities should be considered a routine investigation.

Many empirical studies over the past 2 decades have confirmed that movement impairment is common in children with autistic spectrum disorders (ASD). Manjiviona and Prior found that 50% of children with Asperger syndrome and 67% of children with autism had a movement impairment on the Henderson Test of Motor Impairment. Ghaziuddin and Butler found that movement problems were common in children with Asperger syndrome, autism, or pervasive development disorder not otherwise specified, using the Bruininks–Oseretsky Test of Motor Proficiency. Miyahara et al. reported that 22 of 26 children with Asperger syndrome were at least 2SD below the mean of the Movement Assessment Battery for Children (M-ABC). Dewey et al. found that 59% of children with ASD met criteria for a movement impairment on the Bruininks–Oseretsky Test of Motor Proficiency (short form). Jansiewicz and colleagues 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 males with ASD. They found impairment in...
balance and gait, slower speed of timed movements, and greater ‘overflow’ movements in the children with ASD, than in the controls.\(^8\) That research group has also suggested an additional praxis (gesture/imitation) problem in ASD.\(^9\) The movement impairments in ASD have been shown to have more similarities to than differences from those found in developmental coordination disorder, where praxis impairment is also suggested, except in the area of ball skills (throwing and catching), where children with ASD show greater impairment.\(^10\)

Although movement impairments have been frequently identified in samples of children with ASD, the applicability of these findings to the broader ASD population remains to be established. 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.\(^1,3,5,7–9\) Movement impairment is known to be more common in children with intellectual disability (IQ<70),\(^11\) yet few groups have compared the movement impairments in children with autism with and without intellectual disability. Furthermore, with the exception of the studies by Denckla’s group (involving 40 and 47 children, respectively)\(^8,9\) and Dewey et al. (n=49),\(^7\) many studies have had only modest sample sizes (e.g. Manjiviona and Prior n=21,\(^1\) Miyahara et al. n=26\(^6\)). Finally, in several previous studies\(^5,7,10\) 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 group has reported on motor abilities in a large, population-derived sample of children with ASD with a wide range of IQ levels.

The first aim of the present study was to extend previous work, using a standardized clinical instrument (the M-ABC\(^6\)) to measure how common movement impairments are in a large, well-defined, population-derived group of school-aged children. The sample included children with a diagnosis of childhood autism or broader ASD and children with intellectual disability (IQ<70) as well as borderline and average 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 as a sign of greater neurological compromise. Second, although it is well established that everyday adaptive behaviour is poor in children with ASD, even in those who score in the average range on IQ tests,\(^12\) the contribution of movement impairment to poor everyday adaptive skills has not previously been investigated. We, therefore, examined the association between severity of movement impairment and adaptive behaviour, independent of IQ. Finally, we assessed the properties of the Developmental Coordination Disorder Questionnaire (DCDQ) for parents\(^13\) in identifying children found to have impaired motor skills on the M-ABC.

**METHOD**

The South East Multicentre Research Ethics Committee approved this study (00/01/50). Parents gave informed consent for their children 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 aged 9 to 10 years in southeast England.\(^14\)

From this total population, all children with a current clinical diagnosis of pervasive developmental disorder (n=255) or who were considered to be at risk for being an undetected case, on the basis of a statement of special educational needs (n=1515), were surveyed using a social communication questionnaire.\(^12\) A stratified subsample drawn from across the range of scores from this questionnaire were assessed as part of a prevalence study of autism and ASD (n=255; 223 males, 32 females).\(^14\) Each child received a comprehensive diagnostic assessment including standardized clinical observation (Autism Diagnostic Observation Schedule-Generic (ADOS-G)),\(^15\) and parent interview assessments of autistic symptoms (Autism Diagnostic Interview-Revised (ADI-R)),\(^16\) adaptive behaviour, language, and IQ, psychiatric comorbidities and a medical examination. The team used International Classification of Diseases (ICD-10)\(^17\) research criteria to derive a clinical consensus diagnosis of childhood autism and other ASDs (see Baird et al.\(^14\) for details). From this subsample of 255 children, 158 were diagnosed with ASD (autism n=81, other ASD n=77).\(^14\) These 158 children were considered for inclusion in the present analysis, depending on their completion of the M-ABC.

**Movement Assessment Battery for Children**

The M-ABC\(^6\) is a clinical assessment used to determine the extent of impairment in fine and gross motor skills. It includes eight items divided into three subtests; manual dexterity, ball skills, and static and dynamic balance; the tests are also divided into four age bands, with children undertaking different activities depending on their age. Two of the four test age bands, corresponding to developmental attainments of children aged 9–10 years (n=31) and 11–12 years (n=70), were used in the present study.

M-ABC scores range from 0 to 5, with 5 indicating the highest level of impairment. Scores of 0 are achieved by 75% of the normative sample, and scores of 5 by the
lowest 2%. A total impairment score is obtained from the sum of subsections and may then be converted to a centile rank. A raw score of 0 to 9.5 is considered to be within the average range, a score of 10 to 13.5 (5th–15th centile) is considered borderline, and scores of more than 13.5 (<5th centile) are indicative of definite motor difficulties. Centile cut-offs (15% and 5%) for the three subtests are also reported.

Of the 158 children with autism or ASD from the SNAP subsample,14 101 completed all items of the M-ABC (autism n=45, other ASD n=56; 89 males, 12 females; mean age 11y 4mo, SD 10mo; range 10y–14y 3mo). Seven children with ASD completed some but not all M-ABC items, because of poor verbal understanding (n=3), refusal (n=1), or lack of time (n=3), and 50 children with other ASD were not assessed on the M-ABC, because of time constraints (n=33) or inadequate functional abilities (n=17, all IQ<57). A higher proportion of children with autism than other ASD cases did not complete the M-ABC (autism group 44.4%, other ASD group 27.3%, χ² 5.05, p=0.03), and children who did not complete the M-ABC had lower IQ (incomplete M-ABC n=57, mean IQ 61.2, SD 27.1; complete M-ABC n=101, mean IQ 78.2, SD 20.8; range 28–136; F(1,156)=19.0, p<0.001). Only children who completed all items on the M-ABC and for whom a total impairment score could be calculated are included in the present analysis.

**Developmental Coordination Disorder Questionnaire**

The DCDQ13 is a 17-item parent survey of a broad range of gross and fine motor function, ball skills, and organizational and planning ability. The DCDQ discriminates between children with and without movement impairments in naturalistic contexts, independent of instructional and test requirements. A total score is computed, with lower scores indicating more movement difficulties. Scores below 58 represent probable motor difficulties (<25th centile), and scores below 48 are considered to represent more definite motor problems (<10th centile). Cut-off scores for determination of the risk for developmental coordination disorders are currently based on Canadian norms of children between the ages of 8 years and 14 years 6 months, although good sensitivity has been shown18 in the screening of motor difficulties of children in the UK.

The DCDQ was completed by the parents before the clinical assessment that included the M-ABC. Ninety-seven of the 101 children with a complete M-ABC had the DCD-Q completed by their parents (autism n=43, other ASD n=54; 85 males, 12 females; mean age 11y 4mo, SD 9mo; range 10y–13y 8mo). Ten DCDQ total scores were pro-rated because fewer than three items were missing, in line with research administration guidelines.13

**IQ assessment**

IQ was measured using the Wechsler Intelligence Scale for Children (WISC-III-UK)19 or Raven’s Standard or Coloured Progressive Matrices,20,21 depending on the child’s ability. Where WISC Full-scale IQs were not available (n=12), imputed Full-scale IQs were obtained using the regression relationship of Full-scale IQ to Raven IQ. No direct cognitive testing was possible in five children, all of whom had Vineland Adaptive Behaviour scores below 20; these children were assigned an IQ score of 19 to reflect their profound intellectual disability. For the M-ABC analysis, the children were stratified by IQ score (<70 or ≥70). In the children with an IQ of less than 70 (n=35), the mean IQ was 56.5 (SD 10.3); in the children with an IQ of 70 or more (n=66), the mean IQ was 89.7 (SD 15.0).

**Statistical analysis**

χ² analysis was used to explore the proportion of children with definite movement impairment on the M-ABC in the autism versus broader ASD subgroups and in the subgroups with IQ below 70 versus 70 or greater. The data met Levene’s test for homogeneity of variance. A 2 × 2 analysis of variance (ANOVA; autism or broader ASD by IQ<70 or ≥70) was used to assess group differences and diagnosis-by-IQ interactions in M-ABC total impairment score. A repeated-measures multivariate ANOVA and a post-hoc series of paired t-tests (according to good practice without Bonferroni corrections; see Rothman)23 were used to assess differences in the profile of fine and gross motor skills between the individual M-ABC subscales. We ran full IQ-partialed Pearson’s correlations to investigate whether movement impairment was associated with everyday adaptive behaviour as measured by the Vineland Adaptive Behaviour Scale.22 Analyses were carried out using the Statistical Package for Social Sciences version 15 (SPSS Inc., Chicago, Illinois, USA). Area under the curve (AUC), sensitivity, specificity, and positive predictive values were derived using the ‘diagt’ procedure in Stata 9 (Stata Corporation, College Station, Texas, USA). Confidence intervals for AUC estimates were obtained by bootstrap resampling (1000 replication)24 receiver operator curve procedures of Stata 9.

**RESULTS**

On the M-ABC, 80 of the 101 children with complete assessment (79.2%) had definite movement problems (<5th centile), with a further 10 (9.9%) having borderline problems (5–15th centile), and only 11 (10.9%) having no movement problems (Table I). The proportion of children with definite movement problems was similar between the autism group (82.2%) and the broader ASD group (76.8%; χ²(1)=0.45, p=0.50). By contrast, the proportion of children...
with low IQ who had definite movement problems (97.1%) was significantly higher than that of children with high IQ (69.7%; $\chi^2(1)=10.5$, $p=0.001$). The $2 \times 2$ 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 ($F(1,97)=6.72$, $p=0.01$), and a main effect of IQ, with low IQ children scoring higher than higher IQ children ($F(1,97)=46.5$, $p<0.001$), but no diagnosis by IQ interaction was seen (Table I). Although total impairment score on the M-ABC was significantly correlated with the Vineland Adaptive Behaviour Composite score ($r=-0.37$, $p<0.001$, $n=92$), when the effect of IQ was partialled out, there was no significant association ($r=0.00$, $p=0.98$).

The repeated-measures multivariate ANOVA of M-ABC subtest scores indicated an overall significant within-participant 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 (indicating poorer skill) on the timed pegboard activity and board balance tasks than all other tasks (all $p<0.001$), but these two tasks were not different from each other (Fig. 1). In addition, fine motor hand skills and ball catching impairment scores were higher than ball throwing impairment scores ($p=0.008$ and $p=0.004$ respectively), and ball catching impairment scores were higher than balance ball/walk impairment scores ($p=0.04$).

The association between the DCDQ cut-offs for ‘probable’ and ‘definite’ motor difficulties and the movement impairment assessed by the M-ABC is shown in Table II. The primary purpose of the present study was to measure the extent of impairments in fine and gross motor skills in a large, well-defined, population-derived group of school-aged children with autism or a broader ASD, including children with a broad range of cognitive ability. This enabled us to test whether the frequency or severity of movement impairments was affected by autistic diagnosis or IQ level. The majority of children with ASD had a movement impairment according to the M-ABC. Unlike many previous studies, this large group of children with ASD was obtained from a population-derived sample.
The proportion of children with definite motor problems was similar in the childhood autism and broader ASD groups. By contrast, movement problems were nearly universal in the subgroup of children with an IQ below 70 (only one child did not score in the definite problem range), but they occurred in only two-thirds of children with an IQ of 70 or more. As regards the severity of movement impairments, scores were higher in children with autism than in those with broader ASD and in children with intellectual disability (IQ<70) than in those with higher IQ (IQ≥70). These findings are consistent with previous findings, 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 rather than broader ASD.

Why might children with ASD with low IQ have a higher rate and severity of movement problems and children with childhood autism have more severe motor impairment than children with broader ASD? These associations might be because 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 subsample was drawn. 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 it also requires the child to understand and follow instructions. Therefore, some children may score poorly because of 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, and the present findings suggest that there is no independent contribution from motor impairments.

The DCDQ performed moderately well as a screen for movement impairments 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-off. At the ‘borderline movement impairment’ cut-off, 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 categorized 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. 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. Denckla and colleagues 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 studies, children with ASD were impaired in basic motor actions compared with controls). These authors suggest a particular problem with praxis, as do Rinehart et al. Our analysis does, however, show that the timed tasks of the M-ABC were more impaired in ASD. Whether this represents a particular problem with speed of task, 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 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**

Although this study included a large sample of children with ASD that was derived from a population cohort, only two-thirds of the assessed children completed the M-ABC, so we have reported simple estimates rather than the...
design-adjusted estimates of the frequency and severity of movement impairments as we have reported elsewhere for psychiatric disorders. Children with childhood autism and an IQ below 70 were less likely to complete the M-ABC, so the present estimates of motor impairment might be considered minimum figures only.

We felt that it was useful to use the DCDQ data that were available from the majority of the sample assessed; however, the content of the movement skills assessed by the direct assessment (M-ABC) and the parental questionnaire (DCDQ) do differ, probably 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.\(^8\,9\,26\)

**CONCLUSION**

Notwithstanding these limitations, motor impairments are very common in children with ASD (those with childhood autism as well as 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.

**REFERENCES**