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Motor difficulties in children with neurodevelopmental conditions: A report from a cross-national study in Belgian and Italian children

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Contributions

- EV: conception of the study, writing – original manuscript, formal data-analysis, data curation, interpretation data-analysis, visualization.
- CJ: data collection, data processing, writing – review and editing
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- MM: oversight for the research activity planning and execution, writing – review and editing.
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Abstract

Purpose: Motor behavior alterations are common in neurodevelopmental disorders (NDDs), including autism, developmental coordination disorder (DCD) and attention deficit hyperactivity disorder (ADHD), but the extent of motor impairment remains unclear. In autism and ADHD, motor difficulties may be linked to co-occurring DCD, which often goes unrecognized. We aimed to map the prevalence of DCD in autism and ADHD, and to explore motor skill difficulties using the Movement Assessment Battery for Children-2 (MABC-2), by comparing children with typical motor development (TMD) with those who have NDDs, and by identifying specific profiles among NDDs.

Methods: A combined sample of participants (n=215), including autistic children with(out) intellectual disability (ID), children with ADHD, DCD and TMD, performed the MABC-2. Depending on co-occurring DCD/ID, subgroups were composed: autism-only (n=17), autism+ID (n=17), autism+DCD (n=40), ADHD-only (n=14), ADHD+DCD (n=12), DCD (n=25), TMD (n=59). MABC-2 differences between TMD/NDDs (Mann-Whitney U test) and among NDDs (Kruskal-Wallis test) were assessed.

Results: DCD occurred in 70.2% of the autistic children without ID and in 46.2% of those with ADHD. Children with NDDs performed significantly worse than the TMD ($p<0.001$). Manual dexterity skills, aiming and catching, and balance were significantly different across the NDD subgroups ($p \leq 0.001$). Particularly children with (+)DCD and autism+ID performed worse on manual dexterity skills. Children with (+)DCD were outperformed on aiming and catching. All subgroups, except the ADHD-only group performed poorly on balance.

Conclusion: Distinct motor difficulties were identified across various NDDs. Children with co-occurring ID or DCD exhibit unique challenges, stressing the importance of motor profile subgrouping.

Keywords: neurodevelopmental disorders, autism, attention deficit hyperactivity disorder, developmental coordination disorder, motor skills, motor competence

Introduction

Neurodevelopmental Disorders (NDDs) refer to a heterogeneous group of conditions with onset in the developmental period [1]. NDDs include developmental coordination disorder (DCD), autism spectrum disorder (autism), and attention deficit hyperactivity disorder (ADHD). While DCD is characterized, by definition, by core motor skills disturbances [2], altered motor behavior is also reported in 50-85% of autistic children [3-8] and in 30-60% of children with ADHD [9-14] even after their ADHD symptoms are managed [12]. Despite these high occurrence rates, motor difficulties in specific NDD groups often go unrecognized, leaving families struggling to obtain adequate support.

Early emergence of motor impairments impacts social and communicative development by limiting a child's ability to gesture and interact with other children [15-17]. Inadequate motor skill acquisition may lead to low self-esteem and participation avoidance, causing a vicious cycle of sedentary behavior, low physically fitness, and eventually overweight and noncommunicable diseases [4; 18-21].

A recent systematic review and meta-analysis confirmed the high prevalence of motor skill difficulties in autistic children without intellectual disability (ID) when using the *Movement Assessment Battery for Children, second edition (MABC-2)* [22]. Indeed, although autistic children with ID generally present greater motor difficulties compared to those without ID (e.g. Bhat 2023 [23]), cognitive abilities are not reported to be a significant moderator of these motor alterations [24], suggesting that gross motor difficulties could be cardinal features of autism rather than simply effects of developmental delays. Children with ADHD also tend to have difficulties with a large variety of motor skills, such as handwriting, ball skills, (bimanual) coordination tasks, balance, gait, and motor planning [12; 25; 26]. Previous research has described a significant overlap between these motor profiles across conditions, but also difficulties specific to each condition [27-29].

Given the fact that co-occurring disorders are the rule rather than the exception in NDDs, it remains the question whether the motor difficulties in children with autism and ADHD are a distinct feature belonging to the disorders or a result of co-occurring DCD. The actual prevalence of co-occurring DCD in autism or ADHD varies depending on the source, but seems to be at least 50%, and tends to remain undiagnosed [22; 30]. Furthermore, the presence of ID in autistic children may mask specific motor profiles.

The purpose of this study is threefold. We aimed to: 1) explore motor skill difficulties using the MABC-2 by comparing TD children with a mixed group of children with NDDs, including autism, ADHD and DCD, 2) examine the prevalence of DCD among children with autism and ADHD, and 3) explore the motor profiles among NDD subgroups with(out) DCD or additional ID. We hypothesize that the presence of DCD or ID will result in worse performances compared to the subgroups that do not have these co-occurrences. We also expect that the children with autism or ADHD with co-occurring DCD will have similar results as the DCD group. Lastly, we anticipate that the children who have co-occurring ID will have the poorest results.

Methods

Participants

We performed a secondary analysis retrospectively on data collected in two research facilities [29; 31; 32]. The sample included 215 children (age 3-13). The Italian cohort included children with autism (n=74), ADHD (n=26), and from the general population (n=90). The Flemish cohort consisted of children with DCD (n=25). Exclusion criteria were using any medication affecting the central nervous system, having a well-defined genetic disorder, the presence of significant sensory impairment or neuroanatomical alterations.

Autistic and ADHD children were recruited at the Scientific Institute, IRCCS Eugenio Medea (Bosisio Parini, Italy). Autistic children had a DSM-5 based diagnosis, informed by, but not dependent on, scores on the Autism Diagnostic Observation Schedule-Second Edition ([33]). Seven autistic children (9%) also had an additional diagnosis of ADHD. Children with ADHD received a DSM-5 based diagnosis by a child neuropsychiatrist with experience in ADHD, independently confirmed by a psychologist through the administration of the Development and Well-Being Assessment [34] interview. No ADHD children presented with co-occurring autism.

Children from the general population were recruited by local pediatricians or schools. They had no developmental concerns nor family history of neurodevelopmental conditions. They were included as controls if they had an intelligence quotient (IQ)>70 and typical motor development (TMD). For children below age 5, TMD was assumed if the MABC-2 total score was above the 16th percentile (P16) and the parental questionnaire and anamnesis did not reveal any underlying disorders impeding motor development.

For children aged 5 and older, the same criteria were applied and supplemented with the Developmental Coordination Disorder Questionnaire (DCD-Q).

Children with DCD were clinically referred and had to meet the DSM-5 diagnostic criteria to be included [1]. In the DCD group , three children had a diagnosis of ADHD and three had a diagnosis of autism.

All the parents signed written informed consent before participation and the children provided their assent. The study was approved by the local ethical committees (Italy: Prot. N.33/18—CE; Belgium: B300201941833).

Measures

IQ assessment

IQ level was determined for ADHD and autistic children, and for controls with the following scales: Griffiths Mental Development Scales (Griffiths, 1970), Wechsler Preschool and Primary Scale of Intelligence (Wechsler, 2002), and Wechsler Intelligence Scale for Children–IV (Wechsler, 2012).

Movement Assessment Battery for Children, second edition (MABC-2)

The MABC-2 assesses motor skill competence in children aged 3-16, comprising of eight age-specific items divided over three age bands (ABs): 3–6 years (AB1), 7–10 years (AB2), 11–16 years (AB3) [35]. **Table 1** provides an overview of the item content per age band. Each item provides a raw score that is converted into an item standard score (ISS) [35]. The ISS are summed to calculate the domain and total standard scores (SS), which can also be converted into percentiles. According to children's cultural reference, we used the Dutch [36] or the Italian normative data [37]. The ISS, domain scores, and total scores are interpreted with a traffic light system: the red zone indicates a severe motor impairment (ISS≤5; percentile rank, P≤5), the orange zone indicates being at risk for a motor impairment (ISS=6-7; P=6-16), and the green zone indicates normal motor development (ISS>7; P>16). We used the total score (P), domain scores (P) and the item scores (ISS) to examine DCD criterion A [2] and to compare the motor profile between children with TMD and NDDs, and among NDDs.

Developmental Coordination Disorder Questionnaire (DCD-Q)

The DCD-Q is a parent questionnaire developed to identify motor problems in children (age 5-15) suspected of DCD [38], consisting of 15 items. Each item is rated on a 5-point Likert scale. The item scores are summed to calculate the total score. Lower scores indicate worse performance. Scores <47 (age 5-7), <56 (age 8-9) and <58 (age 10-15) indicate a suspicion of DCD [38]. The test has good sensitivity and specificity in clinically referred samples and good specificity in population-based samples. The scores were used to examine DCD criterion B [2].

Screening for DCD in other NDDs and the general population group

All participants with autism and ADHD were assessed with the DCD-Q [38] and the MABC-2 [35]. The age at symptom onset (criterion C) was also confirmed through a parent interview. To comply with DCD criterion D, we excluded from the screening for DCD the children with an IQ score below 70, who formed a separate group labelled as '+ID'. Other medical diagnoses that could better explain the motor difficulties were ruled out during the diagnostic process. The children that fulfilled all DCD criteria and presented an IQ>70 were labelled as '+DCD'.

Data analysis

All analyses were performed with the Statistical Package for Social Sciences (SPSS 29.0). Non-parametric statistics were applied because of lacking normal data distribution (TMD versus NDDs) and small sample sizes of NDD subgroups. Between-group (TMD/NDD) differences in MABC-2 scores (total PR score) and the DCD-Q (total score) were assessed with the Mann-Whitney U test. Motor profiles across the NDD subgroups were examined with the Kruskal-Wallis test (domain PR scores and ISS). Multiple comparisons were corrected for with Bonferroni corrections.

Results

Participants

The records of 215 children were screened. Thirty-one children in the general population group did not fulfill all TMD criteria (**Fig. 1**) and were excluded because of no age-appropriate motor skills (n=26), motor difficulties impacting daily activities (n=1) and both (n=4). Fifty-nine children served as TMD controls (mean age (SD): 7.4 (2.5); 79.7% males). One hundred twenty-five children with NDDs were included (mean age (SD): 8.7 (2.1); 83.2% males).

Prevalence of DCD among children with autism and ADHD

Seventeen of the 74 autistic children presented with ID (autism+ID) and were therefore not screened for DCD. Of the remaining 57 autistic participants, 40 fulfilled the DCD criteria (autism+DCD, 70.18%) and 17 children had no ID/DCD (autism-only, 29.82%). Of all children with ADHD, 12 met the DCD criteria (ADHD+DCD, 46.15%) and 14 had no co-occurrence (ADHD-only, 53.85%). None of the children with ADHD had ID. ***Fig. 1*** depicts the identification of DCD among NDDs.

Motor skills in children with NDDs versus TMD

The children with NDDs performed significantly worse on the MABC-2 (median (IQR): 2 (8.9)) than the TMD group (median (IQR): 50 (26); p<0.001, ***Fig. 2***) and also on the DCD-Q (NDD: median (IQR): 43 (17); TMD: median (IQR): 65 (14); p<0.001). In the NDD group, 107 children (85.60%) were at risk for motor impairment (≤P16), 77 of them (71.96%) had severe motor impairment (≤P5). ***Table 2*** summarizes the distribution across the traffic light zones for the NDD subgroups.

Motor skill profiles in children with NDDs

The total score was significantly lower for children with autism+ID compared to those with autism-only (p<0.001) and ADHD-only (p<0.001), as well as for children with autism+DCD compared to autism-only (p=0.013) and ADHD-only (p<0.001) and for children with DCD compared to ADHD-only (p=0.005).

The NDD subgroups demonstrated difficulties in different domains (**Fig. 3**). The item performances are depicted in ***Fig. 4***.

Manual dexterity skills were significantly different across NDD subgroups (p<0.001). More than half of the children in the ADHD-only group performed in the green zone, which was applicable for only half of the autism-only group. The vast majority of the (+)DCD groups was at risk for motor impairment (≤P16), with more than half having a severe motor impairment (≤P5). All children with autism+ID had severe motor impairments. Post-hoc comparisons showed significantly lower scores in autism+ID compared to all other groups (p<0.025), except for ADHD+DCD (p=0.413). Children with autism+DCD also performed worse than the ones with autism-only (p=0.021). At item level, significant differences were identified across groups for

item 2 (p<0.001), and ***item 3*** (p=0.008). The autism+ID group performed significantly worse on ***item 2*** compared to the autism-only group (p=0.010), the ADHD-only group (p<0.001), autism+DCD (p=0.019), and ADHD+DCD (p=0.041). Children with autism+DCD performed worse on ***item 3*** than the autism-only group (p=0.006).

Aiming and catching skills were significantly different across NDD subgroups (p<0.001). The vast majority of the children with ADHD-only and more than half of those with autism-only and ADHD+DCD performed in the green zone. Overall, performances were worse in the DCD group compared to all other NDDs (p<0.01), except for the autism+DCD (p=0.073), who in turn performed worse than children with ADHD-only (p=0.001). Both items were significantly different across NDD subgroups (p<0.001). Children with ADHD-only outperformed those with autism+DCD (p=0.001), autism+ID (p=0.001), and DCD (p<0.001) on ***item 4***. Children with DCD performed significantly worse than those with ADHD-only (p<0.001), ADHD+DCD (p=0.014), and autism+ID (p=0.003) on ***item 5***.

Balance was significantly different across NDD subgroups (p=0.001). Most children with ADHD-only performed in the green zone. Half of the children in the autism-only and ADHD+DCD groups were at risk for motor impairment (≤P16). The performances were poorer in the autism+DCD (p=0.003), DCD (p=0.048), and autism+ID (p=0.002) groups compared to the ADHD-only group. At item level, significant differences across NDD groups were found for ***item 7*** (p=0.007), with the DCD group performing worse than the ADHD-only group (p=0.008).

Discussion

The aims of this study were to compare motor skill competence in children with NDDs to TD peers, to examine the prevalence of DCD among children with autism and ADHD, and to explore motor profiles among NDD subgroups with(out) DCD/ID. Our results confirmed the hypothesis that children with NDDs perform significantly worse than their TD peers. Compared to normative data, 61.6% in the NDD group have a severe motor impairment, and 24% are at risk of having a motor impairment. Only a small minority performed within the typical range (14.4%). Among the children with NDDs, DCD co-occurred in 70% of autistic children without ID, which was substantially higher than the 46.2% in the ADHD group. The MABC-2 domain and item scores revealed that children with ADHD-only have the highest rates of typical motor performances, followed by the autism-only group. Children with co-occurring ID tend to perform worse on manual dexterity tasks, whereas aiming and catching tasks are indicative of (autism+)DCD. Balance problems appear to be a common feature, except for ADHD-only.

Despite the increasing knowledge about the motor difficulty prevalence in children with autism and ADHD, and the fact that both groups clearly benefit from motor-based training interventions, motor problems are still not considered a cardinal feature of those conditions [21; 39-41]. Ever since the DSM-5 allowed dual diagnosis of autism and DCD, investigations into the co-occurrence rates among different NDDs have increased drastically. However, not all DCD criteria are systematically checked, leaving room for interpretation [6; 22; 26]. We did not find any significant differences between the DCD group and the '+DCD' groups, indicating that the co-occurring DCD explains in part the variability of the motor skill deficits in autism and ADHD. Nevertheless, the autism and ADHD groups have distinct profiles, which have also been indicated by previous research [27-29].

Motor difficulties in autistic children

Our autistic participants with co-occurring DCD/ID performed worse than those in the autism-only group. However, almost half of the autism-only group still presented with deficient motor skills (≤P16), confirming that motor skill difficulties are a fundamental characteristic in autism [3; 6; 15; 22; 42-46]. Still, these difficulties are more severe in the presence of DCD [42]/ID [4], underlining the importance for awareness towards these co-occurring disorders [4; 42].

Particularly, fine motor skills and balance skills were most affected. [22]. Fine motor skills are crucial for participation at home and school. Prior works reported bradykinesia [47], weaker fine motor precision [48], and poor eye-hand coordination [47-49] in autism. Here we found that those skills are affected in autism+DCD and severely affected in autism+ID. The balance difficulties we documented are mainly caused by poor standing balance on an altered base of support, which requires adequate sensory integration. Peculiarities in the sensory domain are among the core features of autism [50] and may explain why most autistic children, regardless of their subgroup, tend to struggle with this item [51; 52]. Lastly, autism+ID presented a specific motor profile that highlights the importance of considering cognitive functioning in autism subgrouping.

Motor difficulties in children with ADHD

Approximately half of children with ADHD presented with motor difficulties, which fits nicely with previous literature [3; 9-14]. All children without motor skill difficulties belonged to the ADHD-only group. Nonetheless, even more than in autism, motor difficulties in children with ADHD go unnoticed, potentially caused by the general positive effect of medication [12; 26]. The remaining motor skill deficiencies can be attributed to the presence of DCD. In a small subset of our ADHD-only group, particularly manual dexterity items were difficult. Since items like drawing paths are much more influenced by impulsivity and attention, those differences may be an expression of the core ADHD features [53]. Practice guidelines do not suggest any form of motor skill intervention in ADHD, despite its clear positive effects also on the core features of ADHD [54-60] and executive functioning [58; 61-63]. However, to better understand the difficulties encountered by children with ADHD and facilitate appropriate assessment and intervention, attention to the co-occurrence of DCD is needed but also awareness of motor skill deficits unrelated to DCD.

Strengths and limitations of the study

Despite the available previous studies [3; 7; 8; 64], this is the first study to our knowledge to compare clinically referred groups with autism and ADHD, after controlling for co-occurring DCD, to a DCD group. Notwithstanding the small subgroup sample sizes, this study provides novel insights into the impact of co-occurring DCD/ID to the motor profile at a domain and item level. Since the included samples were clinically referred, the different NDD subgroups were predominantly male [22; 26; 65]. Future extensions of this work should also consider including participants with either ADHD+ID or ID-only.

Recommendations for future research

We retrospectively explored the motor profiles based on the test results that were also used to check DCD criterion A but those profiles should preferably be unrelated to the diagnostic tools in future research. Due to the impact of other NDD co-occurrences on functioning, clearly defined groups are imperative for future work, considering the entire spectrum of functioning [65]. Neural correlates could help gain more in-depth insights into the causes of the different motor profiles among NDDs and help us disentangle which type of intervention is more appropriate for each individual child.

Conclusion

This cross-national study confirms the extent of motor difficulties in various NDDs and highlights the importance of recognizing motor profiles in all NDD subgroups. While children with ADHD exhibit the fewest difficulties, almost half of them present a co-occurring DCD. In autistic children, comorbid ID/DCD contributes to lower skill levels, but has distinct challenges, underscoring the need for carefully subgrouping children with autism or ADHD.

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Tables

Table 1. Description of the MABC-2 items				
MABC-2 Items		**Age Band 1 (3–6 years)**	**Age Band 2 (7–10 years)**	**Age Band 3 (11-16 years)**
Manual dexterity	**Item 1**	Posting coins	Placing pegs	Turning Pegs
	Item 2	Threading beads	Threading lace	Triangle with nuts and bolts
	Item 3	Drawing trail 1	Drawing trail 2	Drawing trail 3
Aiming & catching	**Item 4**	Catching bean bag	Catching ball	Throwing and catching ball with 1 hand
	Item 5	Throwing bean bag onto mat	Throwing bean bag onto mat	Throwing at wall-mounted target
Balance	**Item 6**	One-leg balance	One-board balance	Two-board balance
	Item 7	Walking heels raised	Walking heel-to-toe forwards	Walking heel-to-toe backwards
	Item 8	Jumping on mats	Hopping on mats	Hopping sideways on mats

Table 2: MABC-2 total score classified into traffic light zones for interpretation				
	MABC-2 Traffic light classification			
Subgroups	Green zone	Amber zone	Red zone	**Total**
Autism-only	8	3	6	17
Autism+DCD	0	12	28	40
Autism+ID	0	1	16	17
ADHD-only	9	1	4	14
ADHD+DCD	0	7	5	12
DCD	1	6	18	25
Total	18	30	77	125

Figures

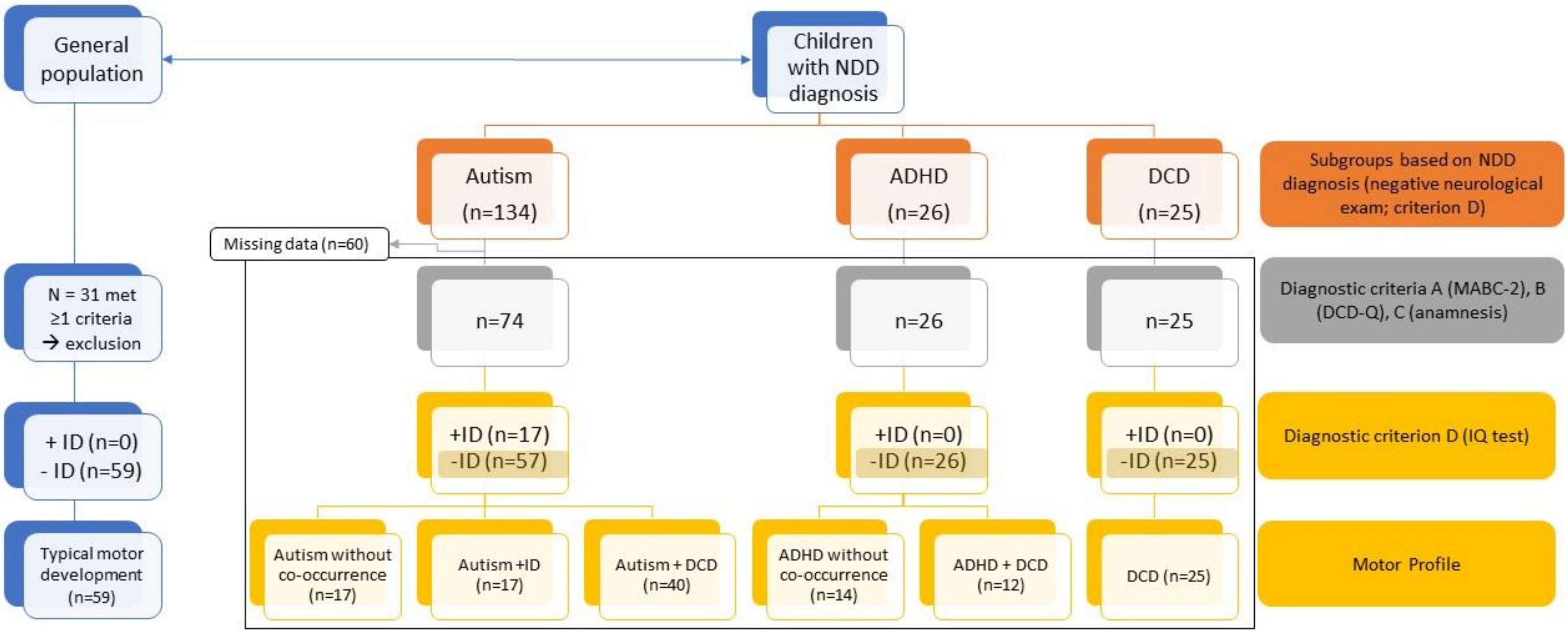

Figure 1*: The selection process of the control group with typical motor development from the general population and the identification of developmental coordination disorder within the group of children with neurodevelopmental disorders*

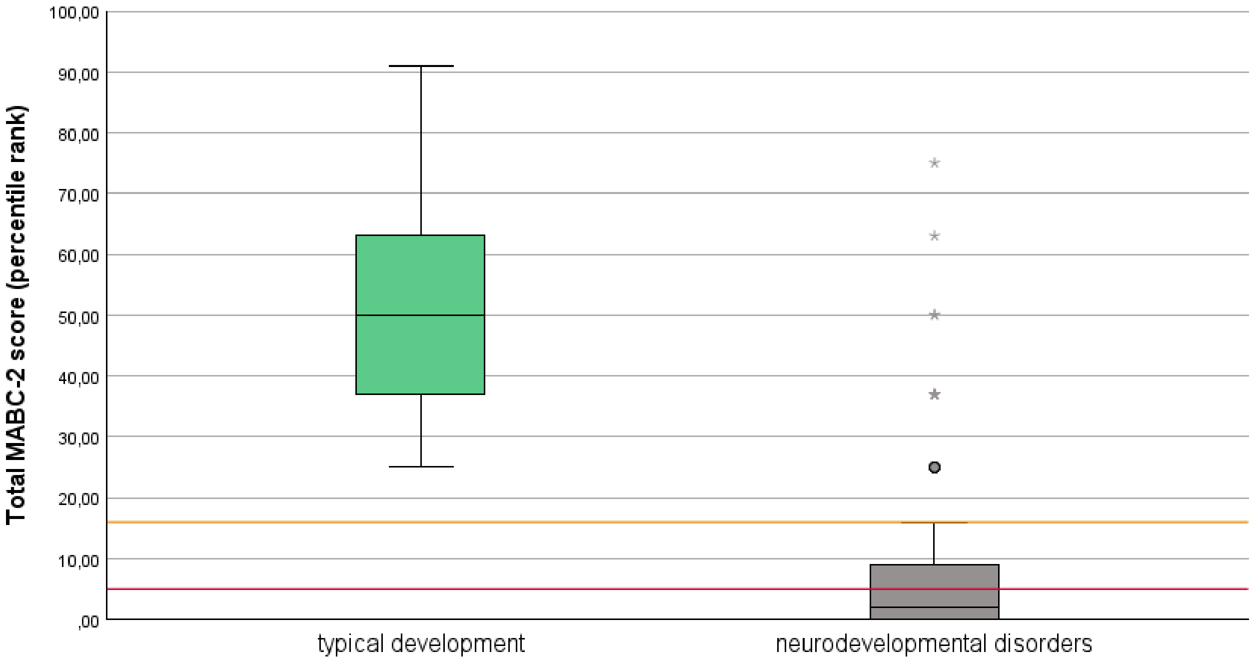

Figure 2*: MABC-2 total score percentile rank for the TD and NDD groups. Orange line represents P16; Red line represent P5*

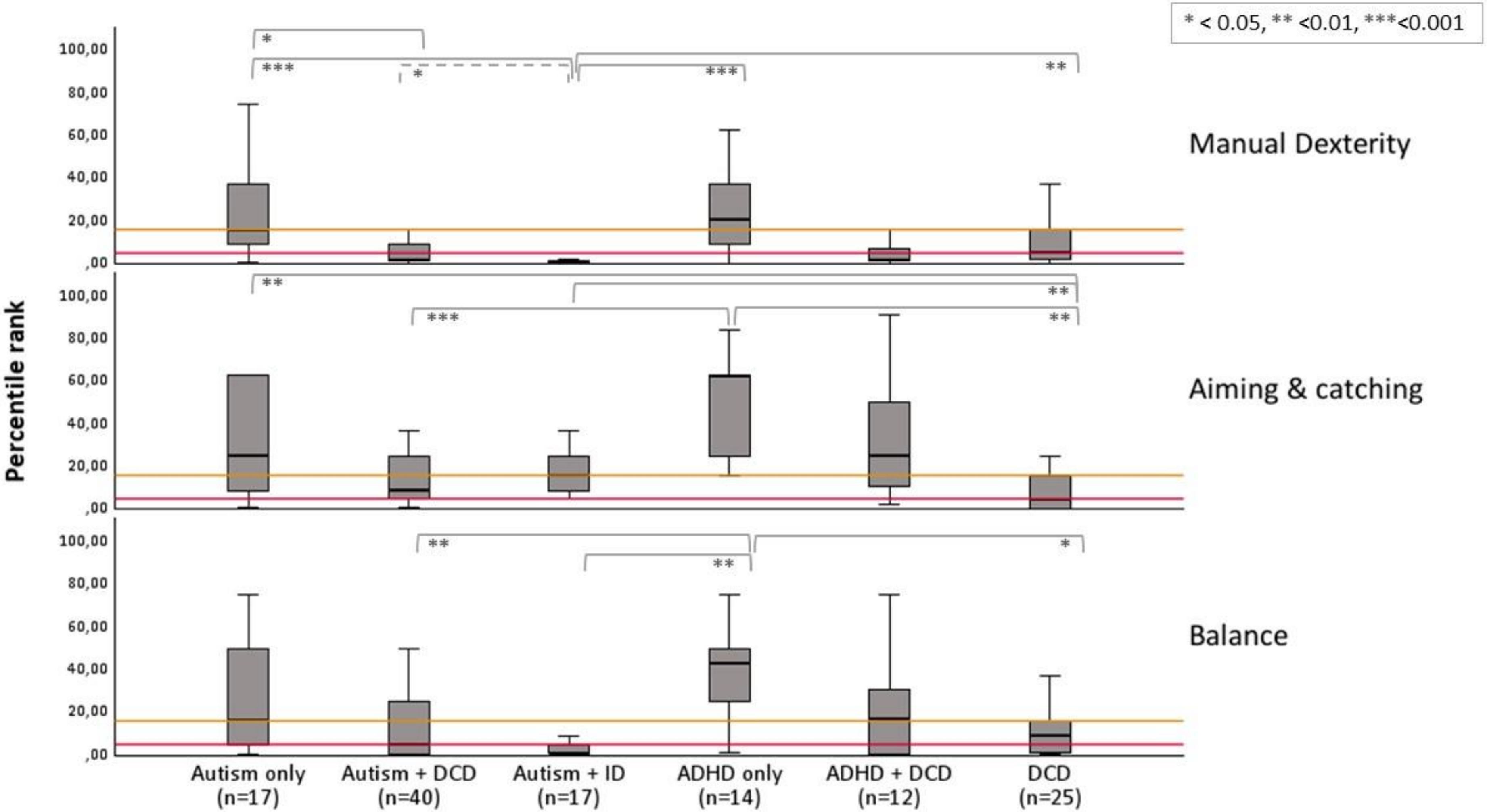

Figure 3*: Comparison of domain performances among children with different neurodevelopmental disorders. Orange line represents P16; Red line represent P5.*

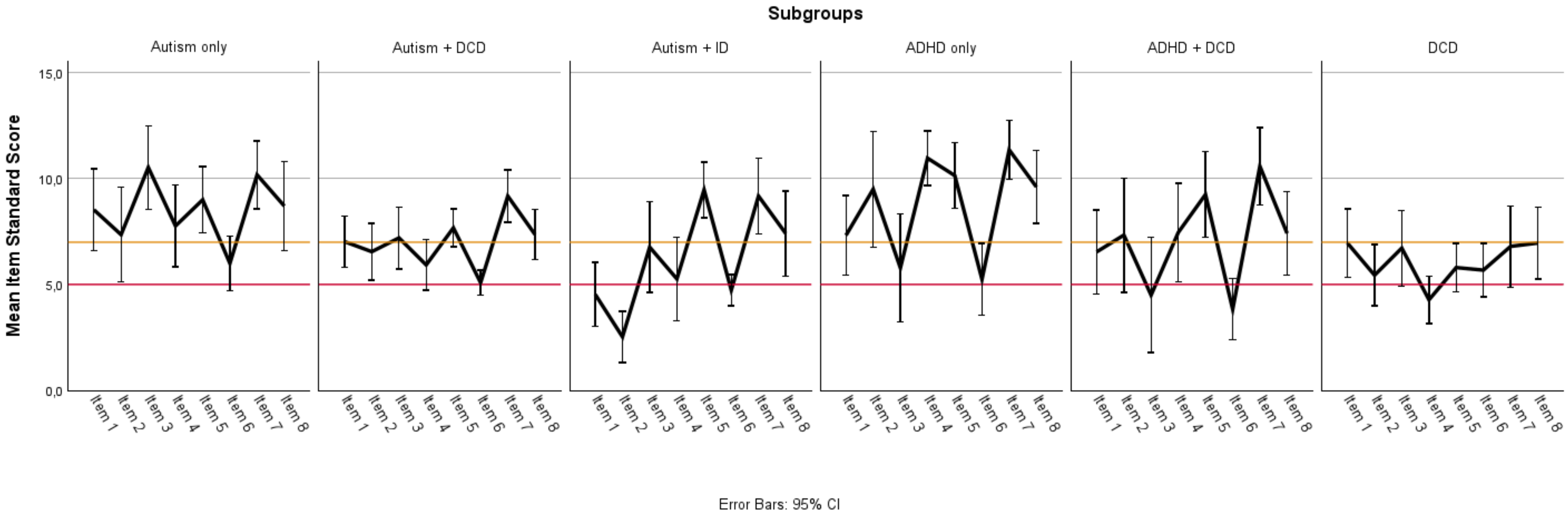

Figure 4*: Comparison of item performances across subgroups of children with neurodevelopmental disorders. Orange line represents P16; Red line represents P5.*