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Proprioceptive and visual motion detection acuity contribute to children's dynamic postural control

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Acquiring efficient postural control strategies is key to children's proper motor development. For that, the brain needs to continuously integrate sensory information and convert it into corrective motor commands. Although this entire process naturally hinges on the reliability of senses, very few studies have investigated sensory acuity and its role in postural stability during development. Clarifying this could lead to a better understanding of conditions, such as developmental coordination disorder, where the impairment of balance control is substantial. Therefore, we aim to determine the extent to which postural stability depends on sensory acuity, specifically proprioception and visual motion detection acuity, in typically developing children. Twenty-five typically developing school-aged children took part in the study. A visual motion detection test (VMDT) assessed their visual motion acuity. An ankle joint position sense test (aJPST) assessed their proprioceptive acuity. Force-plate-based posturography quantified their static standing balance stability with the standard deviation of the center of pressure in the antero-posterior ($sdCoP_{AP}$) direction. Finally, the Movement Assessment Battery for Children - Second edition (MABC-2) assessed their dynamic balance along with other motor skills. Correlation analyses and linear mixed models assessed the linear relationship between postural stability and sensory acuity. There was a significant correlation between the balance score of the MABC-2 and both VMDT score ($r = 0.60$, $p = 0.003$) and aJPST score (r = -0.47, $p = 0.02$). However, no such relationship was found between $sdCoP_{AP}$ during upright standing and the two sensory acuity scores. Importantly, the MABC-2 balance scores were associated with $sdCoP_{AP}$, but only to a limited extent. Given that the MABC-2 balance component factors in static and dynamic balance while posturography focuses only on static balance, our results point at a key role of sensory acuity for dynamic balance. Together, these findings bring attention to possible clinical tools for motor impairment detection and subsequent rehabilitation strategies during development.

Postural control refers to the ability to maintain a specific position of the body and achieve balance through coordinated actions. It depends on the continuous integration of information from the visual, proprioceptive, and vestibular systems[1–4]. However, rather than relying on a fixed "sensory dominance" hierarchy, the central nervous system appears to continuously evaluate the relative reliability of each sensory input and flexibly adjust their weighting to maintain balance[1,5–7]. Through this sensory reweighting process, the body can adapt to varying conditions such as environmental changes (e.g., standing in darkness decreases visual weight), task constraints (e.g., standing on one foot), or attentional demands (e.g., focusing on the task)[1], thereby enabling the maintenance of the center of gravity within the base of support and ensuring postural stability.

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As in adults, postural stability in children hinges on the complex process of integration of sensory information from the visual, proprioceptive, and vestibular systems[8]. However, children do not have the same postural responses as adults until middle childhood (6–11 years) or later[9]. Sensory systems mature at different rates, and each child preferentially uses information from one or more systems[10]. For instance, children between the ages of 4 and 6 rely predominantly on visual input for maintaining a bipedal stance[11]. It is only between 7 and 10 years of age that vestibular and proprioceptive inputs are integrated in a manner comparable to adults[12]. Still, the relationship between sensory acuity, defined as the quality of the ability to perceive and discriminate sensory stimuli, and postural stability remains underexplored, leaving gaps in understanding how sensory deficits affect balance maintenance in children.

This issue is particularly relevant for populations in which both sensory processing and motor coordination are impaired, such as Developmental Coordination Disorder (DCD). DCD is a neurodevelopmental disorder affecting approximately 5–6% of school-aged children worldwide, characterized by poor motor abilities, difficulty learning new motor skills, and frequent deficits in both static and dynamic balance[13–15]. Evidence suggests that children with DCD present weaker visual reweighting, no advanced multisensory integration, and delayed responses to multisensory stimuli compared with typically developing children[16], highlighting the potential relevance of studying sensory acuity in the context of postural control.

Considering the above, the present study aims to determine to what extent postural stability is contingent on two aspects of sensory acuity that are particularly relevant for balance maintenance, namely, visual motion detection acuity, and ankle proprioception acuity. Visual motion detection is key to determining the motion of the body relative to the environment and achieving stable upright balance[17,18]and it can be assessed with a visual motion detection test (VMDT;[19]. Likewise, ankle proprioception, which can be assessed with an ankle joint position sense test (aJPST;[20], is key to balance maintenance given that it informs on the orientation of the body relative to the support surface[12,21]. Emphasizing the importance of ankle proprioception, simplistic models of static balance maintenance view the body as a single-segment inverted pendulum whose inclination can be controlled by the muscles acting across the ankle joint[17,18]. Importantly, postural stability is a multifaceted ability. Here, we used posturography to characterize static balance[22]. It consists in monitoring the fluctuations of the center of pressure (CoP) of participants standing upright with a force plate; the CoP being the point of application of the resultant of the force distribution exerted on the support surface. Posturography is widely validated and one of the most used tools to assess balance and postural stability[23]. Besides, the Movement Assessment Battery for Children - Second edition (MABC-2;[24] was used to characterize children's motor abilities, including dynamic balance. MABC-2 is the most used standardized instrument to assess motor proficiency in children. We hypothesized that poor visual motion detection acuity and ankle proprioceptive acuity would be associated with poor motor performances, especially in terms of postural stability. In addition, we hypothesized that the magnitude of postural sways obtained by posturography would be predictive of the MABC-2 score for postural stability.

Materials and methods

Participants selection and study approval

Twenty-five typically developing children were recruited to participate in the study. The study was approved by the *ULB-Hôpital Erasme Ethics Committee* (P2023/313, CCB B4062023000180). Participants had no history of movement disorders and were generally healthy as reported by their parents or legal guardian. The following exclusion criteria were employed: balance disorders, psychiatric disorders, and musculoskeletal injuries. Each child's legal representative gave written informed consent before participation in accordance with the Declaration of Helsinki. The measurements were carried out at the ULB Hôpital Erasme, Brussels, Belgium. Participants received a gift card as compensation for their participation.

Experimental protocol

Subjects underwent a VMDT, an aJPST and an evaluation of the bipedal stance through posturography. In addition, the MABC-2 was used to assess motor skills. The tests were performed in a randomised order, and the protocol took up to three hours, with the possibility of splitting into two sessions if deemed necessary by the parents.

For the VMDT, participants sat in front of a 17-inch computer screen, with their eyes ~ 90 cm away from the screen. The VMDT assessed their ability to recognize the vertical movement (either upwards or downwards) of a black–white Gabor patch oriented horizontally (full width at half maximum: 5.06 cm, corresponding to a visual angle of 3.22 degrees, spatial frequency: $1.16\ \text{cm}^{-1}$ corresponding to 1.83 per degree of visual angle) and presented atop a gray background. In implementing the vertical movement, only the sine carrier was moved within a fixed Gaussian patch. The test included a total of 80 trials.

Figure 1A illustrates the *VMDT* task sequence. Each trial started with a gray screen for 0.5 s, followed by the presentation of the moving Gabor patch for 2 s. Then the participant was prompted to record the perceived motion direction via mouse click. The next trial started after the participant's response. Shift period, defined as the time it takes for a stripe to move by a spatial period, was varied following a two-down/one-up staircase procedure. The initial shift period was 1 s, which a successful trial led to multiply by $\sqrt[4]{2}$ and a failed trial to divide by $\sqrt{2}$. As a result, the shift period converged onto a threshold that reflected each participant's visual motion detection acuity.

Figure 1B illustrates the setup for the *aJPST*. The test was conducted on the dominant leg, as determined by the subject's self-report regarding the leg typically employed for kicking a ball. Participants sat on a chair with their legs at a 90° angle to the thighs. Participants were blindfolded using a mask. The tested foot was placed on a custom-made device consisting of a foot-sized plank that could rotate about an axis situated ~ 6 cm underneath the ankle. A gyroscope (Wit motion HWT901B-RS485), featuring a precision of 0.05°, was fixed to a corner of

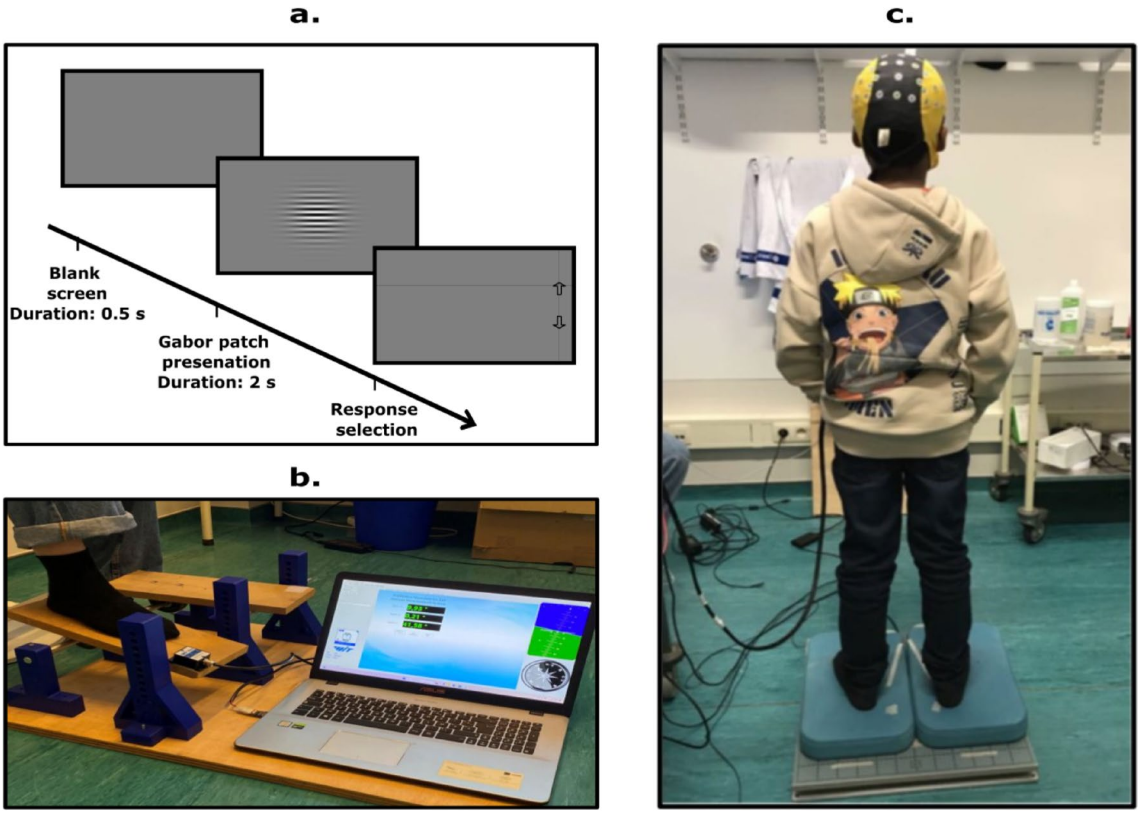

Fig. 1. **A.** Time-course of the VMDT task. Each of the 80 trials started with a gray screen, followed by the visual stimulus, and then by the response selection screen. The Gabor patch moved in either the upwards or downwards direction. The participant moved the cursor to indicate the perceived direction of movement.(adapted from [19]). **B.** aJPST set-up. Participants' dominant foot rested on a movable plank attached to a custom-made structure that allowed rotation of the plank in the plantar/dorsiflexion directions. A gyroscope attached to the movable plank continuously monitored the angle. **C.** Posturography set-up. Participants were equipped with a 64 channel EEG-cap and stood on a force plate across four experimental conditions. EEG data was not analyzed for this study.

the plank and used to record its orientation at 100 Hz during the whole duration of the procedure. Each trial consisted of three stages, and began and ended with the ankle at the 'neutral' position, corresponding to the ankle oriented 90° relative to the shank. First, the ankle was passively mobilized to a predefined angle and held for ~ 3 s. Second, the ankle was passively repositioned to the starting position for ~ 3 s. Finally, the participant was asked to actively move their ankle to the previous position as accurately as possible, and to hold this position for ~ 3 s. Passive mobilizations were performed at constant speed. Nine trials were performed in random order, at three different angles (dorsiflexion: 10°; plantar flexion: 10° and 15°).

Figure 1C illustrates the posturography setup. Participants stood atop a force plate (AccuSway-O, AMTI, Watertown, MA, USA) and underwent four different balance conditions: with the eyes open on a hard surface, with the eyes open on foam pads (Domyos, Decathlon, Villeneuve-d'Ascq, France) with the eyes closed on a hard surface, and with the eyes closed on foam pads. Participants were asked to maintain their balance and stay relaxed. Each participant performed 8 randomized trials (each condition twice) of 5 min each, for a total of 40 min of recording. During each trial, the force plate measured the forces and force moments applied at ground level at a sampling frequency of 1000 Hz.

The *Movement Assessment Battery for Children – Second Edition* (MABC-2;[24]) assesses three major domains: manual dexterity, static and dynamic balance and the capacity of aiming and catching. Participants completed a total of eight subtests, according to their age group. Each participant was given a practice trial to familiarize themselves with the task.

Data processing

Unless specified otherwise, the data analysis was performed using custom scripts in Matlab (version R2024a; Mathworks, Natick, MA, USA).

VMDT

The VMDT score was calculated using the geometric mean of the shift period in the last 30 trials. Participants with higher VMDT score are deemed to possess a better visual motion detection acuity compared to participants with lower scores.

aJPST

The aJPST score was calculated as the mean of the relative angle reproduction error across all trials. The relative angle reproduction error was itself the absolute value of the difference between the imposed and reproduced angles divided by the imposed angle. Increased aJPST scores indicate larger errors and thus correspond to worse proprioceptive acuity.

Posturography

The position of the CoP was calculated using force plate data. CoP time-series were filtered between 0.2 and 10 Hz using a digital filter. To ensure that only data from the bipedal stance were processed, recordings were taken 10 s after ascent and 10 s before descent from the force plate. To quantify postural instability, we assessed the standard deviation of the CoP along the anterior-posterior axis ($sdCoP_{AP}$) for each recording separately. Higher $sdCoP_{AP}$ indicated greater postural instability. A single value per condition was obtained as the mean of $sdCoP_{AP}$ across the two trials of that condition. Of note, CoP fluctuations along the medio-lateral axis were not analysed given that they are more subject to weight shifts in regular bipedal standing.

MABC-2

Motor performance data were obtained from the raw scores of the MABC-2 tests. These scores, that represent individual task scores, were converted to standard scores according to the age of the participants, using the conversion tables in the MABC-2 manual. The standard scores were aggregated within the same components assessing motor performance. Each component was converted into standard scores and percentiles using another conversion table, providing data on static and dynamic balance, aiming and catching ability, and manual dexterity. Finally, the sum of the standard scores was converted to percentiles using a final conversion table, providing an overall measure of each participant's motor performance. These standard scores indicate an individual's relative position within a reference distribution.

Statistical analyses

Statistical analyses were performed using RStudio (version 2024.04.2 + 764). Prior to statistical modeling, VMDT, aJPST and $sdCoP_{AP}$ scores were log-transformed to better approximate a normal distribution, and to comply with the homoscedasticity assumption[19]. Scores were then corrected for outliers by setting values greater than 2.5 SD above or below the mean to this threshold.

Pearson's correlations were used to assess the linear relationship of VMD acuity and proprioceptive error with the results of each component of the MABC-2.

We performed a linear mixed model analysis with lme4 to evaluate how $sdCoP_{AP}$ depends on five fixed effects: condition, age, VMDT score, aJPST score and MABC-2 balance score. We started with a null model that included only a different random intercept for each subject. The model was iteratively incremented with fixed effects and compared to the non-incremented model using a maximum likelihood radio test (χ^2 statistic)[25]. Effects were tested in a planned order: (1) condition, (2) age and, (3) its interaction with condition, (4) VMDT score and, (5) its interaction with condition, (6) aJPST score and, (7) its interaction with condition, (8) MABC-2 balance score, and (9) its interaction with condition. At every step, the added fixed effect was retained in the model if deemed significant ($p < 0.05$). Post-hoc comparisons for significant effects were conducted with t-tests for categorical fixed effects (condition) and Pearson's correlations for continuous ones.

Results

The final sample included twenty-five typically developing children (mean ± SD age, 8.3 ± 2.3 years, range 5–12 years, 12 females). Each child completed the entirety of the protocol.

Relationship between motor abilities and sensory acuity

Figure 2 presents the distribution of motor performance data from the MABC-2 expressed as a percentile of the scores in a reference population. Scores in percentile were 41 ± 28% (manual dexterity; mean ± SD), 47 ± 27% (aiming and catching), 61 ± 22% (balance) and 48 ± 25% (total score). The substantial standard deviation observed in the results could indicate that, even in the context of testing typically developing children, some may potentially be at risk of motor impairments, as indicated by the standardized scoring system of the MABC-2. Two participants in the present study had a total score in the percentile 16, which is considered to be the upper limit of the "orange zone"[19]. This zone is characterized as the area in which children are at risk of motor impairments. Furthermore, both participants received a low score in one of the three components (manual dexterity for one participant and aiming and catching for the other). With the exception of the aforementioned subjects, the remaining participants demonstrated a percentile score that did not indicate any risk of motor impairment.

Sensory acuity varied considerably between children, with VMDT scores characterized by a coefficient of variation of 76.8% (mean ± SD shift period, 32.5 ± 24.9 s) and aJPST score by a coefficient of variation of 64.5% (mean ± SD relative error, 52.2 ± 33.7%). The coefficient of variation was calculated as the ratio between the group's standard deviation and the group's mean for each task.

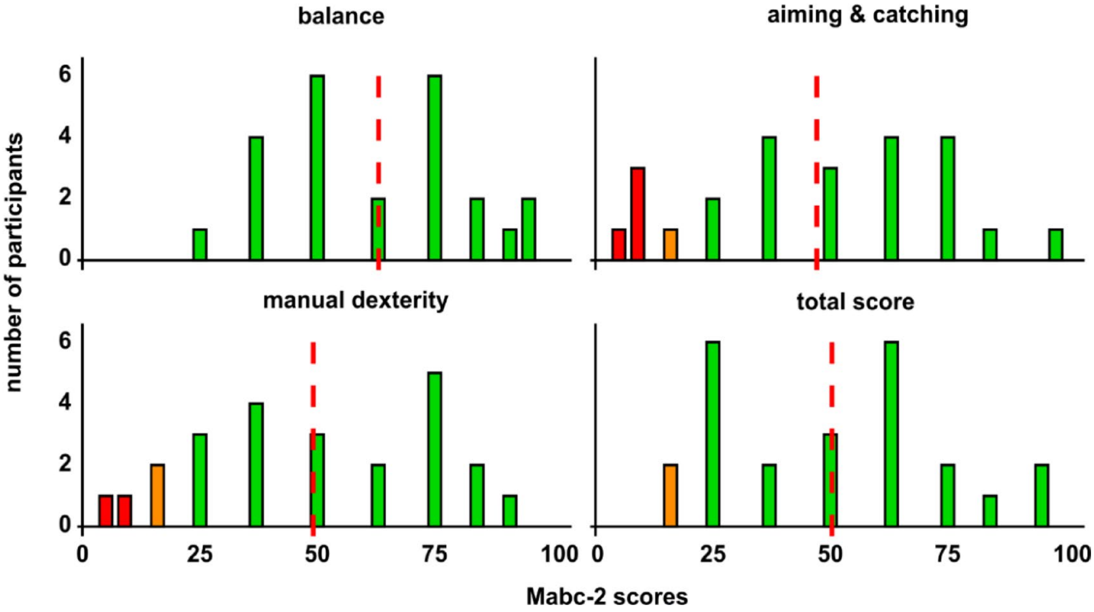

Fig. 2. Distribution of participants MABC-2 scores, expressed in percentile. The red line in each graph represents the mean for each section. Bar color indicates the level of DCD risk as per the MABC-2 manual[24], with red bars indicating a likely presence of DCD (score below the percentile 5), orange bars indicating a risk of DCD (score between percentile 6 and 15) and green bars indicating the absence of risk of DCD (score above percentile 16).

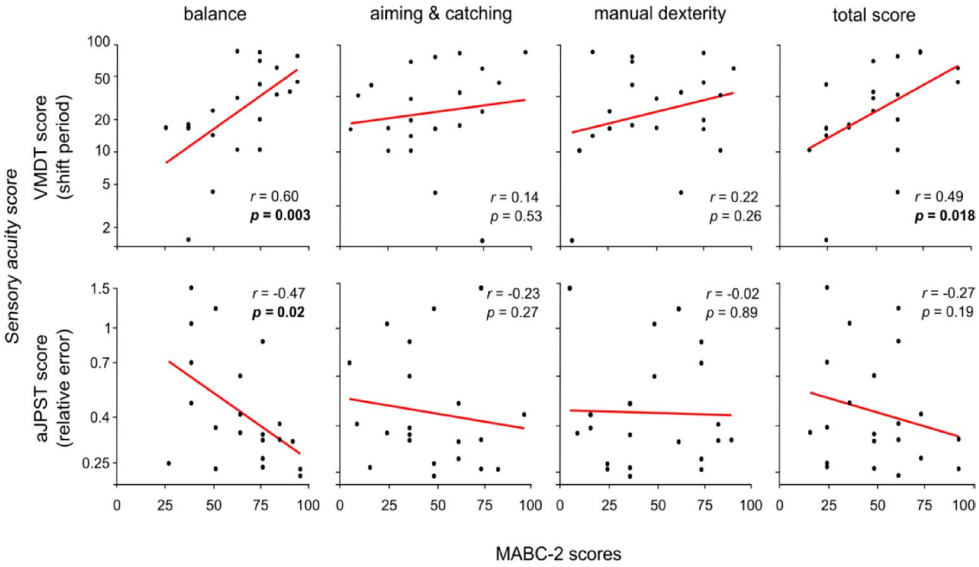

Fig. 3. Relationship between sensory acuity (VMDT shift period and aJPST relative error scores) and MABC-2 scores. Black dots indicate individual participant's values and the regression line across all participants is in red. Correlation value and the corresponding significance level for each association is indicated in the upper or bottom right corner.

Figure 3 presents the results of the correlations between, on the one hand, VMDT and aJPST scores, and, on the other hand, the results of each component of the MABC-2. VMDT score correlated significantly with the balance score ($r = 0.60$, $p = 0.003$) and the total score ($r = 0.49$, $p = 0.018$). aJPST score correlated significantly with the balance score ($r = -0.47$, $p = 0.02$).

Instability assessed with posturography

Figure 4 presents the distribution of sdCoP_{AP} across participants in the four balance conditions. The linear mixed model revealed a significant effect of condition on sdCoP_{AP} ($\chi(3)^2 = 87.1$, $p < 0.0001$). The result of post-hoc

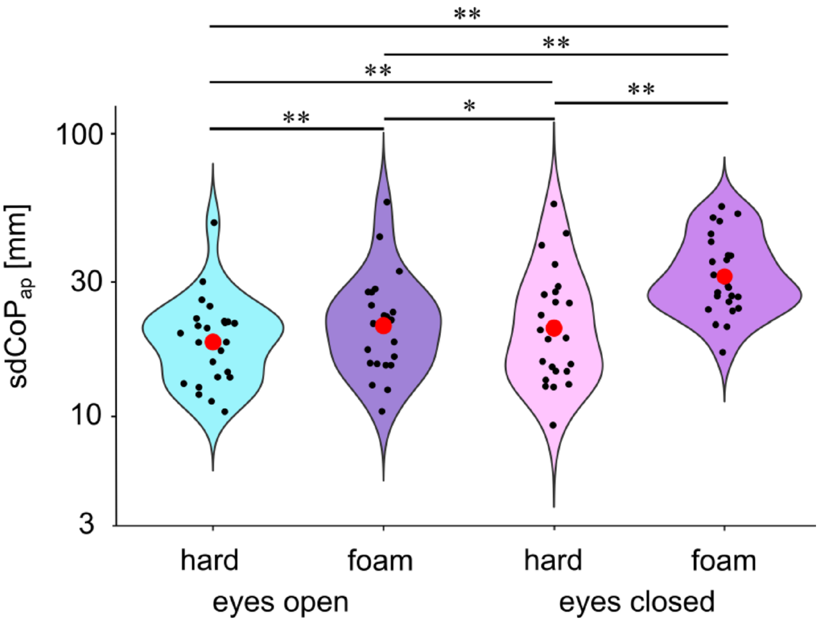

Fig. 4. Distribution of sdCoP$_{AP}$ in the four different conditions on a logarithmic scale. Children showed higher instability in the hardest condition (eyes-closed foam). Black dots indicate individual participants' values and red dots the mean within conditions. Asterisks represent significance levels with: *, $p < 0.05$ and **, $p < 0.01$.

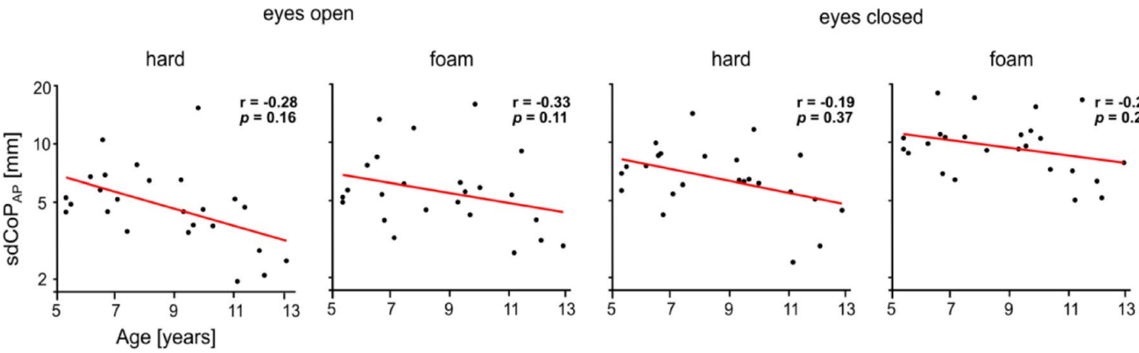

Fig. 5. Relationship between sdCoP$_{AP}$ and age in the four different conditions. Black dots indicate individual participants' values and the regression line across all participants is in red. Correlation value and the corresponding significance level for each association is indicated in the upper right corner.

comparisons between conditions is presented in Fig. 4. As expected, these comparisons revealed that sdCoP$_{AP}$ increased with condition complexity.

The linear mixed model revealed a significant effect of age on sdCoP$_{AP}$ ($\chi(1)^2 = 4.96$, $p = 0.02$), which was not modulated by the standing condition ($\chi(3)^2 = 5.15$, $p = 0.16$). With increasing age, sdCoP$_{AP}$ decreased in all conditions, indicating improved stability (see Fig. 5).

Relationship between instability and sensory acuity

The linear mixed model analysis assessing sdCoP$_{AP}$ did not identify a significant effect of sensory acuity (VMDT score, $\chi(1)^2 = 2.09$, $p = 0.14$; aJPST score, $\chi(1)^2 = 1.03$, $p = 0.30$), nor a significant interaction thereof with the condition (VMDT score, $\chi(4)^2 = 7.88$, $p = 0.09$; aJPST score, $\chi(4)^2 = 5.89$, $p = 0.20$).

Relationship between instability and MABC-2

The linear mixed model analysis assessing sdCoP$_{AP}$ identified a significant effect of the MABC-2 balance score ($\chi(1)^2 = 3.67$, $p = 0.05$), and no significant interaction thereof with the condition ($\chi(4)^2 = 7.85$, $p = 0.09$).

Figure 6 presents the correlation between the MABC-2 balance score and sdCoP$_{AP}$. The correlation was negative in all conditions, albeit significant only in the eyes-closed hard condition ($r = -0.42$; $p = 0.04$).

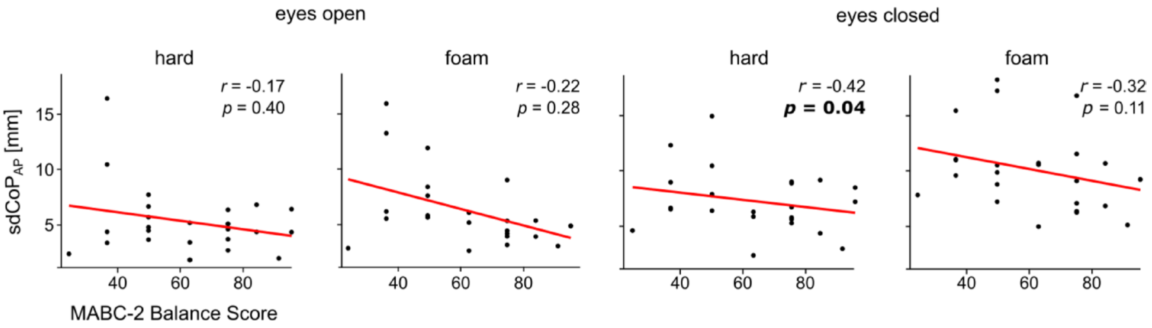

Fig. 6. Relationship between sdCoP$_{AP}$ and the balance score of the MABC-2 in the four different conditions. Graph layout as in Fig. 5. Correlation value and corresponding significance level for each association is indicated in the upper right corner.

Discussion

In this study, we examined the relationship between sensory acuity and balance control. First off, although the present study was conducted in a cohort of typically developing children, notable variability in motor performance was observed, suggesting that even within a non-clinical population, subtle motor difficulties may be present. We found that visual motion detection acuity and ankle proprioceptive acuity were significantly associated with the balance score of the MABC-2 (VMDT $p = 0.003$; aJPST $p = 0.02$), but not with force plate-assessed sway magnitude (VMDT $p = 0.14$, aJPST $p = 0.30$). No significant association emerged between sensory acuity and the other two components of the MABC-2. Furthermore, the two measures of balance showed only a mild degree of association. These results suggest that sensory acuity is more determinant for the aspects of postural control that are captured by the MABC-2 balance component and not by posturography, namely, dynamic balance. Finally, consistent with prior literature, postural stability assessed with posturography decreased with condition complexity, but improved with age within the 5–12 year age range.

A critical finding is the role of sensory acuity, both visual motion detection and proprioception, in maintaining balance. That is, children with a higher score on the MABC-2 balance component displayed higher visual motion detection acuity and higher ankle proprioceptive acuity (i.e., lower errors on the aJPST). The association with visual motion detection acuity is in line with literature on DCD, where impairments in visual processing, including poor fixation, abnormal eye movements, and binocular dysfunction, are often present[26]. In the same vein, *Cheng* and colleague[27] reported that in children with DCD, poor visual performance has a negative impact on MABC-2 motor performance and daily life activities. Similarly, deficits in proprioception, particularly at the ankle joint, are frequently observed in individuals with DCD[26,27]. The association of the MABC-2 balance score with ankle proprioceptive acuity that we observed is in line with the fundamental role of proprioception in motor control. Ankle proprioception was demonstrated to contribute to balance, with extensive benefits of higher acuity, as has been reported in the context of sport performance and limitation of risks of injury[28] as well as for the limitation of balance impairment following stroke[29].

Critically, our data show that even in typically developing children, proprioception acuity at the ankle joint contributes to postural stability. Altogether, our findings support the notion that effective balance control may depend on the reliability of both the visual and proprioceptive systems. Therefore, future studies should determine the added value of VMDT and aJPST scores in clinical evaluations as predictive indicators for the early identification of motor deficits.

Notably, no significant correlations emerged between our measures of sensory acuity and the two MABC-2 components other than balance. Given that our sensory tests assessed aspects of perception that are most relevant for balance maintenance, and less so for manual dexterity and catching abilities, our results are not surprising. However, proprioceptive acuity of upper limb joints and aspects of visual acuity subtending visuomotor coordination could be relevant for manual dexterity and catching ability. Accordingly, wrist proprioceptive acuity was found to be altered both in adults and children with DCD[30,31]. This alteration correlated with the manual dexterity component of the MABC-2 in children with DCD[30], and with levels of body coordination in adults, as assessed with the Bruininks-Oseretsky Test of Motor Proficiency[31]. Likewise, fine motor skills in healthy adults were reported to be associated with a combined measure of near visual acuity, near contrast sensitivity, and disability glare[32].

Although there was a negative trend of linear association between sway magnitude and MABC-2 scores, the correlation between these two aspects was only significant in the eyes closed condition, with a modest magnitude. The weakness of this association is unlikely to root in limited reproducibility of the measures since both the MABC-2 scores[33,34] and force plate-based posturography are highly reproducible[35,36], with intraclass correlation coefficients above 0.80. Instead, the explanation could be the difference in the balance tasks for the two tests, where posturography focuses solely on static balance while the MABC-2 integrates more dynamic tasks. In line with this idea, Liu et al.[37] found weak correlations between static and dynamic balance skills in a cohort of 4 to 5 years old children. The same conclusion was reached by a meta-analysis conducted over the lifespan[38]. Worthy of note, *Horak*'s systems framework conceptualizes postural control as a multi-domain construct that extends beyond a simple static versus dynamic dichotomy[5]. This multidimensional view is also reinforced by systematic reviews highlighting how different balance dimensions impose distinct sensorimotor demands, further supporting a systems-based understanding rather than a unidimensional static/dynamic contrast[38,39]. Following this framework, posturography emphasizes static control only, whereas the MABC-2 assesses functional, task-oriented performance in various contexts, encompassing a broader range of sensorimotor demands.

In our data, sensory acuity was predictive of stability assessed with the MABC-2 but not with posturography. In light of the considerations developed above, this suggests that such acuity is more important for dynamic than static tasks, supporting the idea that dynamic balance relies more on sensory feedback than static balance does[40]. In dynamic tasks, the nervous system uses continuous sensory input to update internal models and generate timely motor corrections. As a result, accurate sensory information is essential for effective dynamic balance control. In contrast, static balance typically relies more on feedforward control mechanisms and may function with less continuous sensory input[41]. This difference may explain why sensory acuity was predictive of MABC-2 performance but not of sway magnitude. Moreover, in children with DCD, while static balance may appear relatively preserved under normal conditions[42], dynamic postural control was shown to be a great challenge compared with typically developed children[43]. Only under difficult, unattended, or novel situations do such children seem to suffer from increased postural sway[44]. Although we did not include children with DCD, our findings may provide some important elements of information for existing theories of this disorder. One influential hypothesis attributes DCD to deficits in internal models[45]. However, given the link between sensory acuity and dynamic balance, our data suggests that impaired sensory acuity may be a more fundamental issue. Such a deficit could compromise the development of accurate internal models, thereby contributing to the motor difficulties observed in DCD.

Finally, another potential explanation for the lack of significant relationship between sensory acuity and static balance stability may lie in the postural control strategy of the central nervous system. Although it would appear natural that sway magnitude be minimized, some models of feedback control suggest that, instead, humans attempt to minimize muscle activity[40,46] with feedback control operating in an intermittent manner[47,48]. Accordingly, sway magnitude may reflect an accepted level of instability rather than the minimal instability theoretically achievable through precise sensory feedback generated corrections.

Force plate posturography results showed that instability increases under more complex conditions, such as on unstable surfaces or when visual information is absent, and decreases as children age. The effect of condition complexity is a classic finding in the field and has been reported extensively in adults[19,22,49] and children[15,50]. The maturation with age is also well documented[51,52], especially between age 6 and 10[53], with adult-like behavior appearing around age 7–8[54,55].

Limitations and perspectives

The main limitation of our study lies in that we did not control for the role of attention in our sensory and balance assessments. Some children found it challenging to sustain concentration and complete each task block, which required ~ 5 min of continuous attention. Future studies should consider shortening individual tasks and adapting them into more child-friendly implementations using colours/cartoons.

Another important limitation is that we did not assess vestibular function. Given that children with neurodevelopmental disorders frequently exhibit vestibular dysfunction[56], the inclusion of this aspect may yield further insights. In addition, our study primarily addressed postural stability, while neglecting other relevant dimensions of postural control. Moreover, the assessment of visual and proprioceptive acuity was limited. For instance, the hip plays a pivotal role in maintaining balance[17], and incorporating measures of proprioceptive function at the hip level might have provided different or more comprehensive results.

Notwithstanding the methodological limitations, our results could lay the ground for future studies on DCD, or any other condition characterised by sensory-perceptual impairments. Indeed, deficits in sensory acuity are well-documented in neurodevelopmental conditions other than DCD. For example, somatosensory (tactile and proprioceptive) impairments are highly prevalent in children with cerebral palsy and have been shown to correlate with poor balance and motor function[57]. In particular, ankle proprioceptive dysfunction has been demonstrated to impair postural responses and increase sway during static standing tasks in this population[58]. Similarly, sensory integration deficits affecting balance have been observed in children with autism spectrum disorder[59]. Future research could, for example, determine whether sensory acuity assessments could help refine diagnostic or therapeutic approaches in these populations.

Conclusions

In conclusion, our study suggests that both visual motion detection and proprioceptive acuity are associated with balance control, with age playing a significant role in this relationship. The results further highlight the key distinction between static and dynamic postural control, where only the latter seems to benefit from better sensory acuity. Collectively, our results indicate that future studies should determine the added value of sensory acuity assessments as clinical tools to benefit diagnosis and treatment of children with motor disorders, such as DCD.

Data availability

Data and analysis scripts used in this study will be made available upon reasonable request to the corresponding author.

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A.I., M.B., M.V.G, N.D, D.V.D., J.F. and G.N. conceived and supervised the project. A.I. performed all the experiments and conducted data analysis with contribution from S.J.M., C.G., E.Y.C., P.C. and M.B. A.I. wrote the initial manuscript. All authors reviewed the manuscript.

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Declarations

Competing interests

The authors declare no competing interests.

Additional information

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