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Short communication

The effects of a visuo-motor and cognitive dual task on walking adaptability in children with and without Developmental Coordination Disorder

Rosanne Kuijpers [a,b,*], Ellen Smulders [b,c], Brenda E. Groen [a,b], Bouwien C.M. Smits-Engelsman [d], Maria W.G. Nijhuis-van der Sanden [b,e], Vivian Weerdesteyn [a,b]

[a] Sint Maartenskliniek Research, Nijmegen, The Netherlands
[b] Department of Rehabilitation, Donders Institute for Brain, Cognition and Behaviour, Radboud university medical center, Nijmegen, The Netherlands
[c] Master Specialized Physical Therapy, Avans+, Breda, The Netherlands
[d] Department of Health & Rehabilitation Sciences, Faculty of Health Sciences, University of Cape Town, Cape Town, South Africa
[e] IQ Healthcare, Research Institute for Health Sciences, Radboud university medical center, Nijmegen, The Netherlands

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ABSTRACT

Background: Children with Developmental Coordination Disorder (DCD-C) have motor coordination deficits which lead to difficulties in sports and play activities that require adaptations of the walking pattern. Sports and play often involve performing dual tasks, which affects performance in DCD-C more than in typically developing children (TD-C). So far, testing the impact of dual tasking on walking adaptability in DCD-C has received little scientific attention.
Research question: We tested the hypothesis that 6–12 year old DCD-C will show lower levels of walking adaptability than TD-C, and that due to problems with automatization this difference will increase when they are forced to divide their attention between tasks when a concurrent visuo-motor or cognitive task is added.
Methods: Twenty-six DCD-C and sixty-nine TD-C were included in this cross-sectional study. They performed a challenging walking adaptability (WA) task on a treadmill as a single, a visuo-motor dual and a cognitive dual task at a pace of 3.5 km/h. Repeated measures ANCOVAs were performed with condition (single/dual task) as within-subjects factor, group (TD/DCD) as between-subjects factor, and age as covariate.
Results: DCD-C performed poorer on the WA task than TD-C. The group differences increased when a concurrent visuo-motor task was added, but not when adding a concurrent cognitive task. A significant effect of age was found with younger children performing worse on all tasks.
Significance: The results highlight the problems DCD-C have with walking adaptability and dual tasks, which capacities are essential for full participation in sports and play activities. Future research should investigate whether DCD-C may benefit from task-specific walking adaptability training.

1. Background

Five to six percent of school-aged children have Developmental Coordination Disorder (DCD) [1]. Children with DCD (DCD-C) have motor coordination deficits leading to a higher risk to trip and fall [2]; and to difficulties in daily activities that require adaptations of the walking pattern[3,4] which often involve performing dual tasks. Previous studies have demonstrated that DCD-C have more problems with dual tasking than typically developing children (TD-C), which is likely due to their automatization deficit [5,6]. Hence, DCD-C need to allocate more attention to perform a single task than TD-C, and as a result they have less resources left for the concurrent task [7,8]. These deficits may particularly compound walking adaptability, as making gait adaptations with a concurrent motor or cognitive task requires repeated switching of the attentional focus in a time-critical manner. Yet, the impact of dual tasking on walking adaptability in DCD-C has received little scientific interest [9]. Here, we tested the hypothesis that 6–12 year old DCD-C show lower levels of walking adaptability than TD-C; and that the aforementioned automatization deficit will further impact their performance when the addition of a concurrent visuo-motor or cognitive task forces them to divide their attention. Larger dual-task costs were expected for the visuo-motor than the cognitive task, and most

* Correspondence to: Sint Maartenskliniek Research, P.O. Box 9011, 6500 GM Nijmegen, The Netherlands.
E-mail address: r.kuijpers@maartenskliniek.nl (R. Kuijpers).

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prominently in DCD-C, because attention had to be divided over shared visuo-motor resources [8,10].

2. Methods

2.1. Participants

Twenty-six DCD-C (as defined by the DSM-V criteria [1]) and sixty-nine TD-C were included, all 6–12 years without neurological, orthopedic or cardiovascular disorders, or visual problems. All participants' parents gave written informed consent. The study was approved by the regional Medical Ethics Committee (NL59150.091.16).

2.2. Procedure

Walking adaptability (WA) tasks were performed on the C-mill, a treadmill with embedded force plates on which stepping stones or obstacles were projected to evoke gait adjustments [11]. Children first practiced undisturbed treadmill walking. They then performed the WA tasks at a pace of 3.5 km/h in the following order: first as a single task (WA^{single}), second while concurrently performing a secondary visuo-motor task (WA^{motor}), and third with a secondary cognitive task ($WA^{cognitive}$). All tasks were developed for the purpose of this study. In the dual-task conditions, children were instructed to perform both tasks as well as they could.

The WA^{single} involved continuously stepping -as accurately as possible- on white stepping stones projected on the treadmill belt according to the individual walking pattern (as registered by the C-mill during walking without projected context). Ten percent of these stepping stones randomly changed into obstacles (red stripes projected across the stepping stone) two steps before expected foot landing. After one minute of practice, the task was recorded for four minutes.

The secondary visuo-motor task involved stabilizing a tennis ball on a racket. The ball was attached to the racket with a string to prevent it from falling on the treadmill. When the ball fell off the racket, the researcher placed it back. The number of falling balls was registered.

The secondary cognitive task comprised listening to a music piece interspersed with sounds (n = 34) such as a doorbell, a phone, and a rooster. The children had to say 'yes' when they heard the rooster (n = 13). The number of omitted/wrong answers was registered.

The secondary tasks were also performed as a single task while standing still for two minutes, directly before the WA dual task.

The primary outcome was WA success rate during 4 min. A step was considered successful when the measured center of pressure at midstance lay within the stepping stone or outside the obstacle.

3. Statistical analysis

Data were analysed with SPSS V25.0 (SPSS Inc, Armonk, NY). We performed two separate repeated measures ANCOVAs (WA^{single} versus WA^{motor}; WA^{single} versus $WA^{cognitive}$) with condition (single/dual task) as within-subjects factor, group (TD/DCD) as between-subjects factor, and age (in months) as covariate (alpha=0.025 to correct for repeated testing).

For the secondary visuo-motor and cognitive tasks, differences in performance (error rate per 2 min) between the single and dual task were tested with a Wilcoxon signed-rank test. To evaluate the interaction between task (single/dual) and group, we compared differences in error rate of the single and dual task between the groups (TD/DCD) with a Mann Whitney U-test. Alpha was set at.05.

4. Results

The results are displayed in Table 1 and Fig. 1; individual scores are shown in the appendix. Seven TD-C (10%) and four DCD-C (15%), 6–9 years old, did not perform the WA^{motor} because they felt insecure. For

Table 1
Descriptive statistics and comparison between groups (Independent samples T-test, Chi-Square test for gender, Mann Whitney U test for error rates).

	TD (n = 69)	DCD (n = 26)	*p*-value
Group characteristics, mean (SD)			
Age	8.9 (1.9)	9.1 (1.7)	.937
Gender	25 boys (36%) 44 girls (64%)	18 boys (69%) 8 girls (31%)	.004
Length (m)	1.39 (0.12)	1.42 (0.13)	.409
Weight (kg)	32.4 (8.2)	36.6 (11.8)	.051
BMI (kg/m2)	16.5 (2.0)	17.9 (3.1)	.009
MABC-2 total standard score	10.0 (2.7)	4.5 (2.2)	< 0.001
Walking adaptability success rate, mean (SD)			
WA^{single}	87.5 (13.1)	73.2 (17.9)	.001
WA^{motor}	82.5 (16.3)	60.6 (23.0)	< 0.001
$WA^{cognitive}$	86.2 (14.4)	73.0 (16.9)	< 0.001
Secondary task performance, median (IQR)			
Visuo-motor task error rate (errors/2 min)			
Single task	0.0 (0.0)	0.0 (1.0)	.005
Dual task	1.5 (4.0)	7.5 (6.8)	< 0.001
Difference between single and dual task	-1.5 (4.0)	-7.0 (5.0)	< 0.001
Cognitive task error rate (errors/2 min)			
Single task	0.0 (0.0)	0.0 (0.0)	.093
Dual task	0.0 (1.0)	1.0 (1.3)	.022
Difference between single and dual	0.0 (1.0)	-1.0 (1.3)	.008

TD = typically developing; DCD = Developmental Coordination Disorder; SD = standard deviation;IQR = interquartile range.

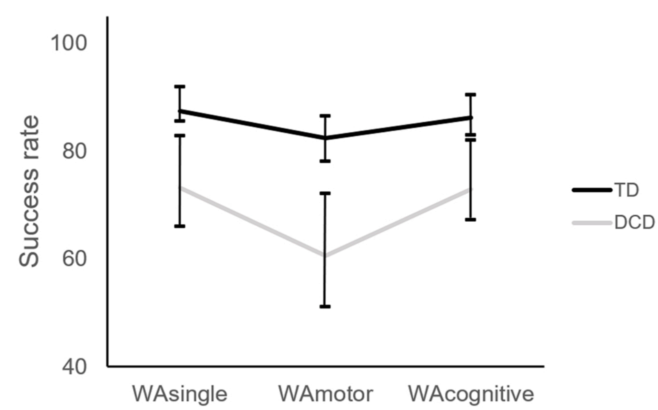

Fig. 1. Mean scores with 95% CI per group per task.

the $WA^{cognitive}$, data of one child with DCD was missing because he developed motion sickness. All children were well able to perform the measurements without concentration problems or getting tired.

WA^{motor} success rates were lower than WA^{single} (*task*, $F(1,81)= 35.12$, $p < .001$, $\eta_p^2 = .30$) and DCD-C performed poorer than TD-C (*group*, $F(1,81)= 38.39$, $p < .001$, $\eta_p^2 = .32$). The difference between the groups was magnified when adding a secondary visuo-motor task (*group*task*, $F(1,81)= 8.84$, $p = .004$, $\eta_p^2 = .10$). Success rates improved with age (*age*, $F(1,81)= 45.47$, $p < .001$, $\eta_p^2 = .36$).

WA^{single} and $WA^{cognitive}$ success rates did not differ (*task*, $F(1,91)= 0.37$, $p = .544$, $\eta_p^2 = .004$), but DCD-C performed poorer than TD-C (*group*, $F(1,91)= 26.18$, $p < .001$, $\eta_p^2 = .22$). No group by task interaction was found (*group*task*, $F(1,91)= 0.33$, $p = .567$, $\eta_p^2 = .004$). Success rates again improved with age (*age*, $F(1,91)= 39.37$, $p < .001$, $\eta_p^2 = .30$).

Under dual-task conditions, we observed higher error rates on the secondary visuo-motor (TD: $z = -5.8$, $p < .001$; DCD: $z = -4.1$, $p < .001$) and cognitive tasks (TD: $z = -4.7$, $p < .001$; DCD: $z = -3.9$,

$p < .001$) compared to single task conditions. DCD-C showed larger decrements in secondary task performance than TD-C (visuo-motor: $U=188.0$, $z = -5.0$, $p < .001$; cognitive: $U=562.0$, $z = -2.7$, $p = .008$).

5. Discussion

This study confirmed our hypothesis that walking adaptability is affected in 6–12-year-old DCD-C, with a disproportionate decrement in both WA and secondary task performance when a concurrent visuo-motor task was added. The concurrent cognitive task did not have a greater impact on walking adaptability in DCD-C compared to TD-C, yet both secondary tasks in DCD-C showed larger decrements under dual-task conditions. The observation that dual-task costs were more pronounced for WA^{motor} may be due to this task recruiting resources from the same (visuo-motor) domain, while the $WA^{cognitive}$ recruits resources from different domains (visuo-motor and auditive) [8,10].

Our findings are consistent with previous dual task studies that included walking tasks [9,12,13], yet our novel standardized assessment on the C-mill imposed time-critical step adjustments to targets and obstacles to further challenge the children's dual-task walking capacity. The fixed walking speed forced the children to divide their attention over the WA and secondary task to keep up performance; this allowed us to test automatization of walking adaptability at the children's maximum capacity. Particularly in the WA^{motor} we found no ceiling effects in success rates even in older TD-C. The substantially lower success rates in DCD-C highlight the difficulties they may experience while dual-tasking in daily activities that require adaptations of the walking pattern to the dynamic environment.

A limitation is that some younger children, mostly DCD-C, did not perform the WA^{motor} because they felt too insecure, which may also be due to this task recruiting resources from the same (visuo-motor) domain which makes it more challenging. Therefore, the reported difference in dual-task effects between the groups may be an underestimation.

Future research may focus on training of walking adaptability in children with motor problems, as mastering this skill is important for participation in daily activities [5,14]. Better automatization of walking adaptability may increase the capacity for dual tasking important in daily-life activities [5].

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Conflict of interest statement

The authors have no competing interests to declare.

Appendix 1

Data of TD children and children with DCD on the three tasks.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.gaitpost.2022.04.019.

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