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Effects of a dual-task activity on gait parameters of people with and without intellectual disabilities

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Abstract

Background The main objective of this study was to evaluate gait parameters in people with intellectual disability (ID) and without intellectual disability (WID) in two different walking conditions [single task vs. dual task (DT)]. A secondary aim was to evaluate the dual-task cost (DTC) that the DT causes in each group.
Methods A total of 119 participants joined in this study: 56 ID (30 men) and 63 WID (30 men). The OptoGait system was used to assess gait. In addition, Witty photocells were added to assess gait under the DT condition.
Results Single support time was lower for participants with ID ($P < 0.01$), while double support time was higher ($P < 0.05$). All coefficients of variation for gait parameters were higher in participants with ID. Additionally, changes in gait were observed in both groups during the DT condition compared with the single-task condition. These changes were larger for participants with ID in step length, double support time and gait speed ($P < 0.001$), resulting in a higher DTC in these variables in the ID group ($P < 0.01$).
Conclusions Both groups reduced gait performance in the DT condition. However, greater gait variability occurred in the ID group. In addition, DTC was higher for the ID group in all variables analysed. Therefore, people with ID show worse gait performance during a DT than people WID.

Keywords adults, dual task, mild and moderate disability, motor control, spatiotemporal gait parameter

Introduction

Human gait is an efficient and complex process that requires a combination of the visual, vestibular and proprioceptive systems, as well as an adequate combination of muscle strength, neuromuscular synchronisation and joint mobility (Smith *et al.* 2017). Thus, gait cannot be considered an automated motor activity as it requires high cognitive processing (Yogev-Seligmann *et al.* 2008). Besides, gait is not performed in isolation because, to effectively complete daily tasks, people must have the ability to multitask by simultaneously engaging in demanding physical and cognitive activities while walking around their surroundings. Hence, it is necessary to process

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external stimuli to be able to solve different situations while walking (e.g. phone calls, animals, overcome and avoid obstacles) (Leone *et al.* 2017; Latorre Román *et al.* 2020). Thus, there are many situations in which people are required to perform two tasks simultaneously (motor–motor, cognitive–motor or vice versa), known as a dual task (DT) (Kachouri *et al.* 2020).

The DT paradigm is a methodology that assesses the main task (e.g. gait and balance), while the participant has to complete a secondary task that can be cognitive, such as talking or motoring (e.g. transporting an object) (Holmes *et al.* 2010). Consequently, a DT can have an influence on the performance of one task or even both tasks when compared with a single task (ST). This change in the task's performance can be explained by two theories (Leone *et al.* 2017): (1) the central capacity sharing model, which postulates that if two tasks have to be performed at the same time, attentional resources must be redistributed between both tasks (Goodale & Westwood 2004), and (2) the bottleneck theory, in which both tasks compete for attention and cognitive resources. As a result, the task must be carried out sequentially instead of simultaneously, implying an efficiency and performance reduction in both tasks (Yogev-Seligmann *et al.* 2008). Notice that the performance of each task will depend on the task's complexity because if the cognitive demand is relatively low and individual motor capacity is adequate, attention will be prioritised for the cognitive task rather than the motor one. However, when cognitive demand increases and motor capacity is relatively low, attention would be prioritised towards the motor task to reduce the risks of instability and falls (Al-Yahya *et al.* 2011). Anyway, when a DT is executed using a similar set of cognitive resources, it will cause a reduction in performance, which is known as dual-task cost (DTC) (Leone *et al.* 2017). The DTC is expressed in percentage, and it is calculated by the following formula: ($DTC = [DT - ST]/ST * \pm 100$) (Plummer *et al.* 2016).

Gait has been investigated under the DT paradigm in children and young adults with Dravet syndrome (Verheyen *et al.* 2023), children with Down syndrome (Holfelder *et al.* 2022) and children with general intellectual disability (ID) syndromes (Kachouri *et al.* 2020), concluding that DT can be an appropriate methodology to detect some problems associated with gait control and cognitive impairment (Bianchini *et al.* 2022). However, only a few studies have investigated the effect of DT on adults with general ID. In this regard, Oppewal & Hilgenkamp (2019) observed that dual tasking produces changes in gait parameters in adults with ID. Also, Van Biesen *et al.* (2018) observed that the cognitive deficits that characterise individuals with ID cause greater DTC in balance parameters compared with their peers without intellectual disability (WID).

In that sense, Kachouri *et al.* (2020) conducted research on children with ID using a simple cognitive task (saying animal names) and a complex motor task (walking while holding a glass of water), concluding that there is a greater decrement in gait parameters during the DT condition in children with ID compared with children with typical development. This decrement is greater in motor tasks than in cognitive tasks. Furthermore, Holfelder *et al.* (2022) obtained similar results in their research using a similar task to Kachouri *et al.* (2020) in children with Down syndrome.

In this regard, Asai *et al.* (2019) conducted research comparing gait parameters between adults and older adults in the DT condition (walking while serially counting aloud backwards by one from a number chosen at random from 70 to 100). They concluded that the DT condition affects spatiotemporal gait parameters in older adults, as a higher body swing during gait was observed. Notice that people with ID usually have some problems associated with their condition that can affect gait patterns due to the difficulty of maintaining balance (Enkelaar *et al.* 2012; Leyssens *et al.* 2022), as well as factors associated with lifestyle (e.g. sedentarism and obesity) (Walsh *et al.* 2018; Spaniol & Danielsson 2022). Nevertheless, no previous studies have compared gait parameters under the DT condition between people with and WID.

Therefore, the main objective of this study was to evaluate gait parameters in people with ID and WID in two different walking conditions (ST vs. DT). A secondary aim was to evaluate the DTC that the DT causes in each participant group. Our initial hypotheses were as follows: (1) gait patterns under the DT condition will reduce cadence and speed and increase gait variability compared with ST in people with ID and WID; (2) the DTC will be higher for all gait variables analysed in the ID group than in the WID group.

Methods

Participants

A total of 119 participants joined in this study: 56 with ID (30 men; age: 37.3 ± 8.6 years; height = 1.61 ± 11.83 m; body mass = 73.5 ± 14.5 kg; body mass index = 28.0 ± 5.1 kg/m^2) and 63 WID (30 men; age: 37.9 ± 10.5 years; height = 1.69 ± 7.31 m; body mass = 77.0 ± 11.3 kg; body mass index = 25.0 ± 2.5 kg/m^2). The participants were selected among 370 people with ID who attend five different day centres for people with ID and six special centres that help people with ID find a job. To join in this study, informed consent was signed by the participants or their parents/legal tutor. Of this large pool of potential participants, only 141 individuals met all the inclusion criteria (see details below). Finally, we randomly selected 65 individuals for the ID group. All participants had a mild or moderate disability level. In the current study, ID is interpreted according to the World Health Organization's 1st Edition of the International Classification of Diseases and the Spanish National Government (Royal Order 1971/1999, 23 December), and the disability score of participants exceeded 30%. These ID scores are represented by combining the intelligence quotient and the adaptative behaviour (physical, intellectual and/or sensory) score and are expressed through five ascendent degrees: non-existent (0%), limited (15–29%), mild (30–59%), moderate (60–75%) and severe or very severe (≥76%). For the WID group, the participants were selected among 205 volunteers who work in the same centre as the ID group. Considering only the participants that met the inclusion criteria, we randomly selected 65 individuals for the WID group.

The inclusion criteria were as follows: (1) to have an ID between 30% and 75% (only for participants with ID); (2) age over 18 and under 65 years old; (3) not to have any physical or motor impairments to perform autonomous walking (walk without any help such as a caregiver or crutch) for more than 20 consecutive minutes; (4) to have vision and hearing sufficient to allow understanding and completing the study protocol; and (5) no lower back pain or any pathology of the lower limbs that may affect gait.

Before the start of the study, all participants read and signed an informed consent form. If the participant could not read or understand the document properly, it was signed by their parents or a legal tutor. The study was approved by the Ethics Committee of the University of Granada (Spain) (reference code: 2354/CEIH/2021).

Materials

Figure 1 shows both protocols used to assess gait during the ST and DT conditions.

Gait without external stimuli (single-task condition)

To obtain gait parameters (step length, single and double support and gait velocity), the OptoGait photocell system (Microgate Srl, Bolzano, Italy) was used (Fig. 1a). OptoGait is an optical data acquisition system composed of a transmitter and a receiver bar. Each 1-m bar (5 m of it was used in our study) contains 96 infrared LEDs (1041-cm resolution) and is located on the transmitter bar, continuously communicating with the LEDs located on the receiver bar. The bars measure flight and contact times during execution with an accuracy of 1/1000 of a second. OptoGait has strong concurrent validity in relation to the assessment of spatiotemporal gait parameters in young adults (Lee *et al*. 2014), and it has been used to assess spatiotemporal gait parameters in adults with ID (Oppewal & Hilgenkamp 2019).

Gait with external stimuli (dual-task condition)

The OptoGait system was used. Furthermore, four photocells (Witty, Microgate Srl, Bolzano, Italy) were placed 1 m before the cone, which indicated the start point (two of them), as well as 1 m behind the cone situated at the end of the 5-m corridor (two of them). Each photocell could show three different colour combinations (red/blue/green) randomly. In addition, two tripods (one for each photocell) were placed at the ends of the gait corridor (1 m behind the cones where participants had to turn around). The tripods allowed the photocells to be positioned 1 m vertically from the ground. Hence, participants could receive the visual stimulus while maintaining a steady gait, as it appeared in the same gait direction. Furthermore, another photocell (Witty, Microgate Srl; 0.001-s accuracy) allowed us to control the ignition of the

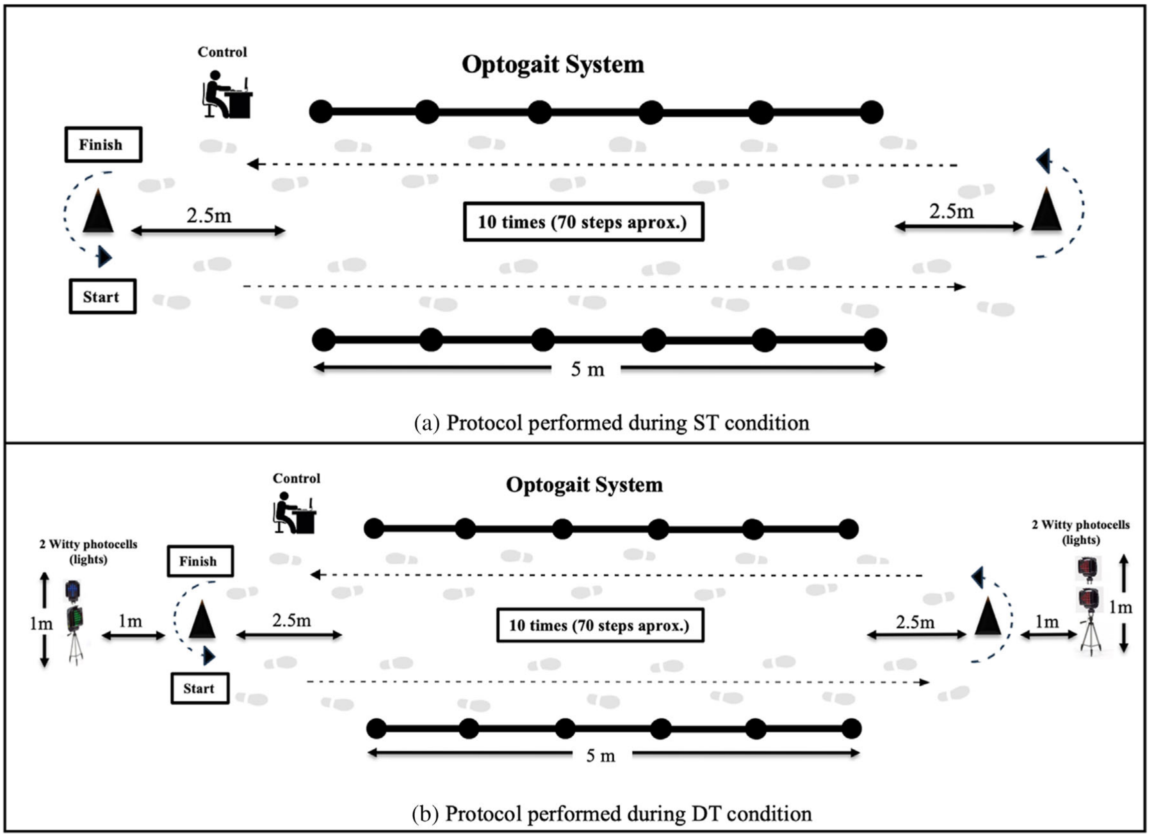

Figure 1. Protocols used to assess gait during (a) single-task (ST) and (b) dual-task (DT) conditions.

photocells. This photocell was controlled by one of the researchers without being perceived by the participants; thus, they never knew when a new stimulus would appear again (Fig. 1b).

Dual-task cost

Dual-task cost was obtained using the following formula: DTC = ([ST − DT]/ST)·100. For the temporal data, the DTC was multiplied by −1 to reflect the inverse relationship between times and gait performance (i.e. lower DTC implies greater performance in the gait task).

Procedure

The study was carried out on two different days. The first day, the ID group was assessed, whereas the second day, the WID group was evaluated. The same protocol was applied for both groups, and the same room conditions in relation to temperature (26°), luminosity and evaluation schedule were maintained. The task (ST vs. DT) was randomised for all participants. The ST condition consisted of walking through a 5-m corridor that was made up of 10 parallel bars (the OptoGait system). The participants started the test behind a cone that was situated 2.5 m before the first OptoGait bar. Once the participants walked through the 5-m corridor, the gait parameters were registered. Then, participants crossed the corridor a total of 10 times continuously, each time turning at the cone 2.5 m past the end of the 5-m walkway, corresponding to approximately 70 steps. This distance (2.5 m) was selected to avoid acceleration and deceleration during the test and to have a steady gait at the moment of crossing the corridor, as the gait parameters were recorded while the participants crossed through (Fig. 1a). They wore their own shoes, and the gait speed was self-selected. The instruction 'You should walk as you usually walk' was given by the evaluator before the start of the test.

The DT condition was performed through the same walking corridor. Also, the distance covered by the participants was the same as in the ST condition (i.e. cross the corridor 10 times, approximately 70 steps). To complete it, the participants had to attend to different colour stimuli that appeared on each photocell with three possible colour combinations (green, blue and red) while they were walking through the corridor. At this time, the instruction was as follows: 'You should walk as you usually walk, but you have to attend to the lights that will appear in the photocells. If two red lights appear, then you have to stop until the light disappears. After that, you should start to walk again. Moreover, if another colour combination appears (red–blue, green–red, blue–blue, green–green, and so on), you have to skip the stimulus and continue walking.' The combination of light stimuli was randomised by the Witty software. The time to send the stimulus signal was controlled by the evaluator, so all participants received a similar number of stimuli (Fig. 1b). If the participants stopped inside the corridor due to the stimuli, the data registered corresponded to the two steps before the stop, and the four steps after it were deleted to eliminate the effect of gait acceleration and deceleration. The participants practised the test before starting the valid trials until they became familiar with the procedure, and the evaluator himself carried out the evaluation of the trials. The test was repeated by the participants when the trial was considered invalid. Participants were allowed to rest between conditions (i.e. ST and DT) for as long as they considered necessary, leaving at least a 1-min rest between conditions to be sure that they could complete the next task properly.

Notice that to register participants' gait properly, the OptoGait system analytically recorded each participant's steps as the participants were crossing the corridor (ST and DT conditions). These steps were those used to carry out the statistical analysis and those that allowed us to analyse each gait variable [step length, single and double support, coefficient of variation (Cv) and gait speed] and to calculate DTC.

Statistical analysis

The results are expressed as means and standard deviations. An a priori calculation for a repeated-measures analysis of variance using the G*Power (version 3.I.9.6) software was performed to calculate the minimum sample size required. The analysis, based on an assumed effect size of 0.2, 2 repeated measurements, a power of 0.9 and $\alpha = 0.05$, projected a necessary total sample size of 68 participants (34 per group). The normal distribution of the dependent variables was verified through the Kolmogorov–Smirnov test ($P = 0.066$ and 0.200). The homogeneity of the variances was tested by the Levene test, and the Greenhouse–Geisser correction was applied if the assumption of sphericity was violated. A mixed analysis of variance with task as a within-subject factor (ST vs. DT) and group as a between-subject factor (ID vs. WID group) with Bonferroni's *post hoc* corrections was applied to each dependent variable. The differences between ST and DT in each group were analysed by a paired-samples *t*-test. An independent *t*-test was used to determine differences between groups in the DTC. A 95% confidence interval was considered, and a significance level of $P \leq 0.05$ was established. Statistical analyses were conducted using the statistical software IBM SPSS® Statistics 25.0 for Windows (SPSS Inc., Chicago, IL, USA).

Results

The descriptive values and analysis of variance results for the four dependent variables and their respective Cvs are presented in Table 1. The main effect of walking modalities (task) was significant for all variables (P values ranged from <0.001 to 0.020) except for Cv single support ($P = 0.108$). Step length and gait speed were greater for the ST condition, while single and double support were greater for the DT condition. Cv was greater for the DT condition. The main effect for groups was significant for support times and Cv for all variables (P values ranged from <0.001 to 0.017). Single support time was longer for the WID group, while double support time was longer for the ID group. The Cv of all variables was higher for the ID group, except for Cv single support, which was higher for the WID group. The Task × Group interaction obtained statistical significance for step length, double support and gait velocity. Significant differences were found in Cv step length and Cv gait velocity because the P value ranged between <0.001 and 0.008. The significance achieved for all variables occurred because the differences between the ST and

Table 1 Results of the analysis of variance (ANOVA) for the single-task and dual-task collections concerning the different variables gathered during the gait tests

	ANOVA						With intellectual disability		Without intellectual disability	
	Task		Group		T * G					
Variables	P	η_p^2	P	η_p^2	P	η_p^2	Single task	Dual task	Single task	Dual task
Step length (% height)	<0.001	0.446	0.155	0.017	0.001	0.086	0.42 ± 0.04	0.40 ± 0.04***	0.42 ± 0.03	0.41 ± 0.03***
Single support (s)	0.020	0.045	0.003	0.071	0.561	0.003	0.367 ± 0.037	0.371 ± 0.040	0.384 ± 0.022	0.386 ± 0.023
Double support (s)	<0.001	0.161	0.017	0.047	<0.001	0.100	0.148 ± 0.045	0.172 ± 0.048***	0.140 ± 0.038	0.143 ± 0.043
Gait velocity (ms^{-1})	<0.001	0.294	0.062	0.029	<0.001	0.106	1.39 ± 0.20	1.28 ± 0.20***	1.41 ± 0.15	1.38 ± 0.16**
Cv step length (%)	<0.001	0.122	<0.001	0.256	0.008	0.058	3.40 ± 0.95	3.90 ± 1.55**	2.66 ± 0.26	2.76 ± 0.37*
Cv single support (%)	0.108	0.022	<0.001	0.184	0.816	<0.001	5.55 ± 1.16	5.82 ± 1.37	6.62 ± 1.44	6.83 ± 1.44
Cv double support (%)	<0.001	0.165	<0.001	0.196	0.431	0.005	10.73 ± 2.34	11.82 ± 3.31**	13.12 ± 2.92	14.64 ± 3.44***
Cv gait velocity (%)	<0.001	0.125	0.009	0.058	0.003	0.071	4.24 ± 1.19	5.32 ± 1.93***	4.16 ± 1.02	4.33 ± 1.27

*$P < 0.05$.
**$P < 0.01$.
***$P < 0.001$.
Results are shown as means ± standard deviations. Task, main factor task (single task and dual task); Group, main factor group (with and without intellectual disability); T * G, Task × Group interaction; Cv, coefficient of variation.

DT conditions were greater for the ID group than for the WID group.

The descriptive values and Student's t results for the DTC of the four variables are shown in Fig. 2. The data show significant differences for all variables (the P value ranged between <0.001 and 0.002), except for the DTC variable single support ($P = 0.530$). The DTC of the variables that reached significance was higher in the group with ID than WID.

Discussion

The main objective of this study was to evaluate gait parameters in people with ID and WID in two different walking conditions (ST vs. DT). A secondary aim was to evaluate the DTC that a DT causes in each participant group. The main finding of this study was that both groups achieved a higher gait velocity in ST condition than in DT condition, which occurred due to the reduction in step length and the increase in double support time during DT condition compared with ST. According to these findings, both groups experienced DTC for gait velocity, step length and double support; nevertheless, it was greater for the ID group than for the WID group. These results are consistent with general theories on DTC for gait parameters (Stöckel & Mau-Moeller 2020) and could be explained by the lower performance of people with ID with respect to executive function tasks, balance ability and walking compared with their peers of the same age WID (Enkelaar *et al.* 2012; Almuhtaseb *et al.* 2014; Spaniol & Danielsson 2022). Consequently, it could be assumed that the lower walking performance in people with ID would be related to the negative effects that the cognitive deficits associated with people with ID have on balance and the automatic processes of the walking pattern (Bahiraei *et al.* 2018; Pineda *et al.* 2023).

From a more mechanistic perspective, the greater DTC of step length and double support time in the ID group compared with the WID group shows an adjustment mechanism that allows people with ID to increase stability during walking. Indeed, reducing the step length and increasing the time in double support constitute a compensatory strategy that allows people with ID to respond successfully to the external stimuli presented during DT walking. This has been described as a cautious gait strategy often used by people with neurological deficits to reduce the risk of falling (Gutiérrez-Cruz *et al.* 2016).

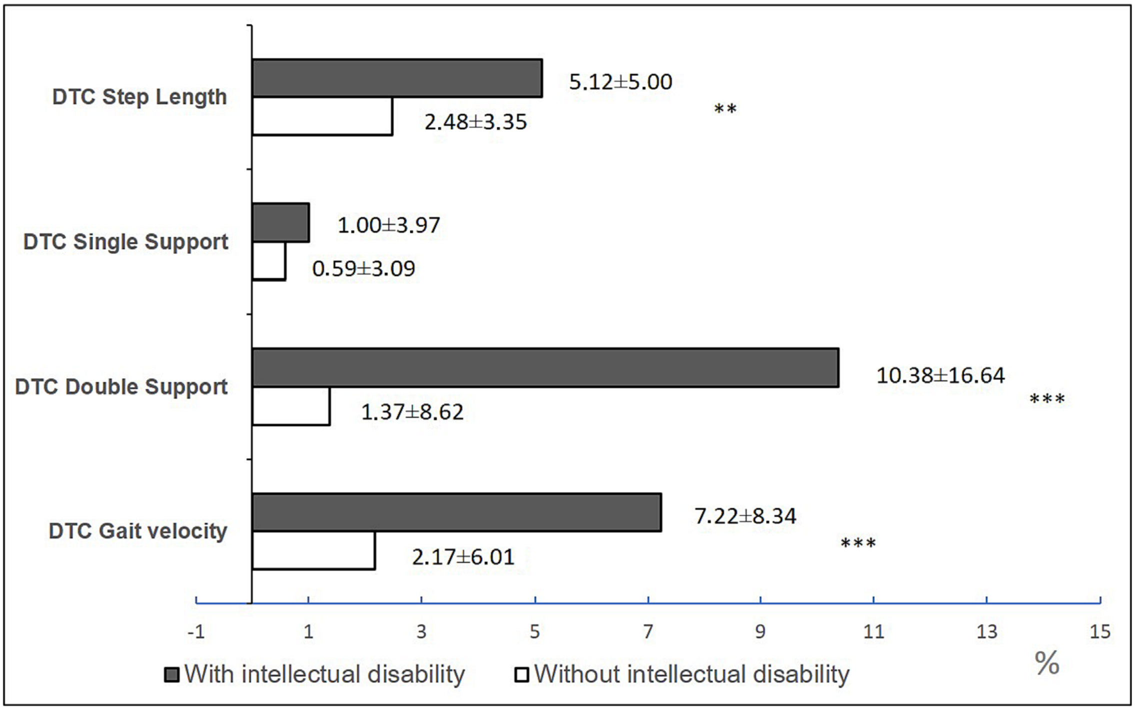

Figure 2. Cost of the dual task (%) = −1·[(single-task performance – dual-task performance)/single-task performance]·100 expressed through dual-task cost (DTC) step length, DTC single support, DTC double support and DTC gait velocity in participants with (full bars) and without intellectual disability (empty bars). Numbers represent the mean ± standard deviation (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$).

Furthermore, the current study has found that Cv increases during the DT gait condition relative to ST gait for both groups and all the variables analysed, which implies greater gait variability during the DT condition. This is consistent with the general DT paradigm and specifically with previous research, which indicated that the variability of gait parameters increases for the DT condition in healthy adults (Smith *et al.* 2017; Stöckel & Mau-Moeller 2020).

The results presented in this research on Cv step length and Cv gait speed have revealed that the gait pattern was more variable in the ID group for the two walking conditions (ST and DT). Furthermore, higher variability was found in the ID group than in the WID group during the DT. These results are in agreement with the study carried out by Párraga-Montilla *et al.* (2021), as the authors analysed gait parameters (Cv step length and step length), concluding that a greater Cv of step length can be an indicator to detect mild cognitive impairment in older adults. Furthermore, these results are in concordance with the contributions of Gutiérrez-Cruz *et al.* (2020), as the authors reported that a higher Cv of step length in people with multiple sclerosis was found compared with their healthy peers. This finding reveals the effect that certain cognitive/motor deficits (typical of people with ID) have on the spatial variability of the gait pattern. However, the temporal data indicate the opposite: the temporal variability is smaller in the ID group for the two walking conditions, which could be related to the cautious walking strategy in an attempt to spend as little time as possible in the period where balance is most compromised (single support time). In fact, the Cv of the single support time was the only variable that did not reach statistical significance when the ST and DT gait conditions were compared in the two groups.

Limitations and strengths

Some limitations must be considered when interpreting the findings of this study: (1) the effect of the DT on the proposed cognitive task was not evaluated, so it is not possible to know the level of difficulty of the task for both groups, which is relevant given the multidimensional nature of the cognitive and motor impairment of people with ID and the comparison with people WID. Therefore, this aspect could also affect the evaluation of DTC gait parameters. (2) The age range of the participants was too wide (between 18 and 65 years), especially considering the premature aging that people with ID usually suffer (McKenzie *et al.* 2016). However, in this study, only a weak correlation ($P < 0.05$) has been found between age and simple support time for individuals with ID ($r = -0.288$ for ST and $r = 0.285$ for DT). In the WID group, age did not correlate with any of the dependent variables. (3) The difficulty of the interference task was not adjusted for the age and cognitive functioning of the participants. (4) Although the participants were instructed not to focus specifically on walking or the cognitive task, the degree to which participants prioritised either walking or the cognitive task cannot be unequivocally identified, which may have influenced the results.

However, a strength of this study is that the procedures performed in this investigation used a natural gait in the usual place of coexistence. In addition, the stimuli used are similar to those that this population has to face on a daily basis. Thus, it was possible to evaluate gait parameters in the ST and DT conditions in an environment that simulates the real-life situations that people with ID and WID face daily.

These findings should be kept in mind because external distractors can have adverse consequences (i.e. falls) in daily life for people with ID. Nevertheless, these results should be interpreted carefully due to the wide range of disabilities among the participants (30–75%). Therefore, more studies are necessary to determine if the performance during a DT can be a predictor of falls or other problems associated with gait stability in people with ID. Future studies should be carried out, considering small groups according to their level of disability, to better understand how DT influences gait parameters.

Practical applications

From a practical point of view, greater performance during a DT could imply better motor and cognitive functioning; therefore, DT training could potentially improve cognitive and motor performance in participants with ID (Fritz *et al.* 2015). In addition, there may also be merit to recommend for some people with ID, especially for those who do not improve DT performance with training, the potential benefits of minimising DT activities during walking (e.g. stopping walking while talking or turning head to check for traffic at a curb), as the risk of falling can be higher in this population group.

Conclusions

Gait parameters showed a reduction in performance during the DT condition in comparison with the ST in the ID and WID groups. Nevertheless, people with ID demonstrated worse gait performance under the DT condition, as this group had reduced gait velocity and step length, whereas an increase in single and double support was observed when the DT condition was performed. In addition, the DTC was higher for the ID group in all gait variables analysed. Therefore, people with ID show worsening gait performance during a DT.

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Conflict of interest

There is no conflict of interest to declare.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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