Dual-task effect on gait in healthy adolescents: Association between health-related indicators and dual-task performance

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Abstract

The purpose of this study was to determine how dual-task (DT) effect on gait differs among adolescents with different fitness and health profiles. The gait performances of 365 adolescents aged 13-14 years were assessed at single and DT walking. The proportional changes in gait parameters from single to dual were regressed against gender, body mass index (BMIz), three components of MABC-2 (balance, aiming &catching and manual dexterity), group (high vs low motor competence), body strength, physical fitness level using multiple regression analyses; and gender and four items of balance subtest of MABC-2 in the secondary analysis. The analyses showed that being female was associated with greater reduction in gait speed and stride length and an increase in double support time and step time; and having lower score in balance was related to greater reduction in gait speed, and cadence, and an increase in step time. Only zig-zag hopping item of the balance subtest was associated with DT effect on gait speed and stride length. No significant relationships were found between DT effect on gait and the rest of the predictors. Females and adolescents with lower level of balance function may be at higher risk of having DT deficit during walking.

Keywords: gait, dual-task, gender, adolescents, fitness

Introduction

In order to walk safely and efficiently, human gait should be adapted to environmental constraints and mental demands. This adaptation may require the ability to perform two tasks simultaneously, referred to as dual-task (DT) ability. In adolescents, DT ability is an essential skill for activities of daily living (e.g., walking and talking on the phone) (Chen, Lo, Kay, & Chou, 2018), participation in school-related activities (e.g., taking note while listening to teachers), and engagement in physical activities including unstructured activities (e.g., listening to peers while playing game), and sports (e.g., balancing on ice while dribbling in hockey). Thus, experiencing DT deficit may adversely affect the performance of adolescents in daily life, increase the risk of accidental injury, and reduce participation in social and physical activities.

DT often deteriorates task performances owing to DT interference between tasks (Pashler, 1994). This interference is considered to be the result of allocating attention or capacities between tasks (capacity sharing theory) or shifting attention from one task to another (bottleneck theory) (Pashler, 1993; C. D. Wickens, 2008). During gait, DT interference reduces walking speed, increases double support time, and impairs fluidity of walking (Cherng, Liang, Chen, & Chen, 2009; Hagmann-von Arx, Manicolo, Lemola, & Grob, 2016). These changes observed in gait are considered to be different in adolescents than adults due to ongoing development of the prefrontal cortex (PFC) during adolescence (Rossi, Pessoa, Desimone, & Ungerleider, 2009). The PFC is thought to play a key role in the control of the cognitive process, executive function, and attention (Chaparro, Stine-Morrow, & Hernandez, 2019). Thus, the immaturity of PFC until the early 20s may make adolescents vulnerable in some DT conditions requiring complex cognitive processing [46]. These influences may be experienced differently in individuals with diverse demographics (e.g., gender) and health profile (e.g., body mass index) (Howell, Stracciolini, Geminiani, & Meehan, 2017a; Hung, Gill, & Meredith, 2013). Males and females, for example, may differ in attentional span or priority strategy, which could affect their approaches to allocate attention or resources between gait and concurrent task when they are performed together (Günther, Knospe, Herpertz-Dahlmann, & Konrad, 2015; Yogev-Seligmann et al., 2010). In the pediatric population, Howell et al. highlighted the potential influence of gender on DT walking in adolescents in their studies (Howell, Stracciolini, Geminiani, & Meehan, 2017b); yet, the evidence in this respect is still weak. In the adult population, on the other hand, there is a popular belief that women are better at multitasking than men; though, empirical studies in this area failed to support this stereotype and reported mixed results (Szameitat, Hamaida, Tulley, Saylik, & Otermans, 2015).

Besides, children with low-level of motor skill may behave differently in a DT condition than those with a high-level of motor competency due to limited capacities to invest in two tasks at the same time (Whitall et al., 2006). The low residual capacities or inadequate abilities may require increased attentional or processing resources for single-task performance, surging task interference during DT performance (Hung & Meredith, 2014). Despite the availability of studies that compare groups with various motor competencies, such as in adolescents with developmental coordination disorders (DCD) (Cherng et al., 2009; Schott, El-Rajab, & Klotzbier, 2016), the elements of motor dysfunction contributing to DT effect is still unclear. DCD is a complex health condition that demonstrate a larger variability in motor performance, implying that a motor task is less automatic or less developed (Woodruff, Bothwell-Myers, Tingley, & Albert, 2002). It can be diagnosed as a result of a deficit in fine and/or gross motor patterns (Farmer, Echenne, Drouin, & Bentourkia, 2017; Schott et al., 2016). However, the impact of a fine motor deficit on DT walking may not be the same as that of a gross motor dysfunction since resources used for gait are mostly associated with gross motor skill (Malt, Aarli, Bogen, & Fevang, 2016),which yet to be determined.

DT performance may also be affected by physical and muscle fitness. The greater aerobic capacity was associated with greater oxygenation of PFC and better cognition (Mekari et al., 2019). Studies in adults and children showed a positive relationship between physical fitness and cognitive function including attention, memory, and executive function (Ishihara, Sugasawa, Matsuda, & Mizuno, 2018). In adults, the greater aerobic fitness was related to the better DT performance (Chaparro et al., 2019), yet there is no such evidence in children and adolescents. Muscle fitness is also an important indicator of walking ability (Rantanen et al., 1999; Savino et al., 2013). Adults with high muscle fitness showed greater walking competency than those with low(Rantanen et al., 1999; Savino et al., 2013), yet, it is still not clear the better walking performance due to high muscle fitness reduces DT effect on gait, particularly in adolescents.

Therefore, a comprehensive analysis of individual elements and their association with DT performance is needed to provide insight into determinants of DT deficit and the related management strategies in youth. This in turn may allow one to identify risk factors for inability to coordinate more than one task at a time, potential fall, accidental injuries, issues related to participation and engagement in daily activities which may consequently help manage DT deficit in these conditions. We hypothesized that DT performance during walking varies among healthy adolescents differing in gender, different components of motor competency, BMI, muscle and physical fitness level.

Therefore, in this study, we aimed to understand the extent to which DT effect on gait was associated with the following factors: gender, motor competency, BMI, muscle fitness, and physical fitness level in healthy adolescents.

Method

Participants

Data for this study were obtained from a controlled feasibility, non-randomised trial registered under ClinicalTrials.gov on April 4, 2017 (revised May 2018, NCT03150784) and approved by the University Ethics Committee (UREC Registration No: 161033). The cross-sectional data presented here, include a sub-section of the screening data obtained as part of the recruitment strategy for the main trial. Written informed consent was obtained from all participants. Following the Helsinki Declaration recommendations for research on human participants adopted by the 18th World Medical Association and later revisions [30], parents and participants were informed that withdrawal from the study at any point would have no detrimental impact on their performance at school.

365 participants consented and were included in this study based on the following criteria: 1) normal intelligence reported by corresponding teachers, 2) no contraindications to perform maximal exercise of physical training as identified by the Physical Activity Health Questionnaire (PARQ). Children with muscular or neurological degenerative conditions, with uncontrolled epilepsy, seizures (must be stable epilepsy or on medication for greater than 12 weeks) and surgery in the previous 6 months were excluded from the study. If there

were any concerns regarding a child being able to participate safely, parents/guardians were asked to report any concern to the GP/pediatricians/physiotherapist.

Predictor and measures

The descriptive measures were recorded at the baseline assessment which included gender, height, weight, and leg length.

Predictors related to motor skill and acquisition: The movement Assessment Battery for Children, 2nd edition **(**MABC- 2) is a valid and reliable test to measure motor skill and acquisition of children and adolescents aged 3- 16 years. It includes three sub-tests: manual dexterity, aiming and catching, and balance (ACSM, 2003). For this study, we used the test set for age band 3 (11-16 years).

- Manual dexterity (MD): MD component consists of three tasks: turning pegs, triangle with nuts and bolts, and drawing trail age band 3. The scores obtained in the tasks are summed as row score for the analysis.
- Aiming and catching (AC): AC includes two tasks: catching with one hand and throwing with wall target. The scores obtained in the tasks are summed as row score for the analysis.
- Balance (BAL): BAL includes tandem stance on balance boards (two-board balance), walking toe-heal backward and zigzag hopping right (R) and left (L). The scores obtained in the tasks are summed as row score for the analysis.
- Low versus high motor competency: The raw score of each subtest were summed as overall raw score which was then converted to standard score to calculate the

percentile ranks of total scores (Henderson, Sugden, & Barnett, 2007). The percentile ranks were then used to divide participants into two groups. The adolescents below 15 percentiles are categorized as low motor competence (LMC) (n=240) and those with 15 percentile and above as high motor competence (HMC) (n=125).

Muscle fitness: In this study, grip strength was used proxy of muscular fitness (Willems et al., 2017).Grip strength was measured using a hand dynamometer (Fernandez-Santos, Ruiz, Cohen, Gonzalez-Montesinos, & Castro-Pinero, 2015).

Power and aerobic capacity: The lower limb power was measured via a broad jump test (Krishnan, Sharma, Bhatt, Dixit, & Pradeep, 2017). 20m shuttle run test was also performed to measure aerobic capacity by predicting VO_2 max (Silva et al., 2012).

BMI z-score (BMIz):BMIz are measures of relative weight adjusted for participants` age and sex (Cole, Faith, Pietrobelli, & Heo, 2005). BMIz shows the standard deviation (SD) above or below the mean BMI of reference population (adolescents at same age and sex). The percentile ranks of BMIz were calculated to illustrate the characteristics of participants.

Procedure and outcome

The adolescents (13-14y) who consented to the study were evaluated at three mainstream secondary schools (Oxford, UK). Participants were separated into groups of 3-4. Each group started at a different station which was manned by experienced trained researchers. Each group rotated around all stations in a circuit-style format until all stations were completed by all participants. Participants completed the circuit during one of their scheduled physical education lessons.

Gait was assessed during DT and single task (ST) conditions, over a 10-metre distance (obstacle-free walking path), allowing participants to take 10-15 steps. The participants performed one trial for each condition. Each participant performed single walking prior to DT walking. During the single walk condition, participants were instructed to walk at self-selected walking speed. During the DT condition, participants walked on the same path while performing a concurrent working memory task requiring participants to recite alternate letters of the alphabet as accurately and as quickly as possible. All participants started the dual task condition with the letter “A” . Participants were instructed to prioritize each task equally.

An inertial measurement unit (IMU, LPMS-B2, Life Performance Research, Japan) was used to record tri-axial accelerometry and gyroscopic data during the single and DT walking. The IMU was fixed with adhesive tape over the participant’s fourth lumbar vertebra to emulate the motion of the participant’s projected centre of mass. The device, using a well established methodology programmed within LabVIEW2019 and known commercially as DataGait (Oxford, UK), collected data at a sampling frequency of 100Hz after which vertical position was derived by means of quaternion rotation matrix multiplication and double integration achieving millimeter accuracy(Patrick Esser, Dawes, Collett, & Howells, 2009). Vertical position was used to drive established inverted pendulum mechanics (Zijlstra & Hof, 2003) and was corrected for double stance using foot size (Gonzalez, Alvarez, Lopez, & Alvarez, 2007), resulting in spatiotemporal outcome measurements (P. Esser, Dawes, Collett, Feltham, & Howells, 2011). In this study, we utilized walking speed [m/s], normalized walking speed [m/s] corrected for leg length & gravity as an arbitrary number (Stansfield et al., 2003), step time [ms], step length [m], cadence [steps/minutes], and percentage of time spent in double support (DS time) normalised per gait cycle [%].

Analysis

Descriptive statistics were used to summarize the demographic information of the participants, and all performance scores. The normality of data was visually evaluated by histograms, and Quantile–Quantile plots; and tested using the Shapiro–Wilk test. The observed outliers were removed from the data to improve the normality of the data. In the condition where data was not normally distributed after outlier removal, the log transformation was done.

Before the main analysis, the collinearity among independent variables were checked through Variance Inflation Factor (VIF) and regression correlation matrix for Klein Goldberger model. Collinearity was determined to be present when the variance inflation factor was over 5 or correlation coefficient is higher than 0.5 (Vatcheva, Lee, McCormick, & Rahbar, 2016). High correlations were evident only between BMI and VO_2 max score (r = 0.58), broad jump and VO_2 max score (r = 0.52) and gender and VO_2 max score (r = 0.51). Thus, VO_2 max was removed from multiple regression analysis.

The proportional change in outcome of interest (gait speed, normalized gait speed, stride length, cadence, step time, stride length and DS time) were calculated using the following formula: *(DT performance - Single performance) / (Single performance+ Dual performance)/2*(Estrada, Ferrer, & Pardo, 2019)). Calculating proportional DT effect allows us to compare the effect of dual tasking in individuals having varying baseline performances.

The outcomes of interest were regressed against seven independent variables: MD, AC, BAL, power (broad jump test), BMI, gender, and group (HMC vs LMC) using multiple regression analysis. The categorical variable (group and gender) were included into the regression analysis after transforming the data into dummy variables with HMC and female as the reference values. A secondary multiple regression analysis was also done including only variables that had a significant association with proportional changes in gait parameters in the primary analysis that are the four components of balance subtest and gender.

The model was inspected visually for linearity, heteroscedasticity, and normality of the residuals. The alpha level was .05. All analyses were done through R statistical software using the packages of 'olsrr'and 'lubridate' (Version 3.6.0, St .Louis, Missouri, USA) (Team & 2013).

Results

Table 1 summarizes the demographic and characteristics of participants including age, gender, power, strength and motor competency; Table 2 presents the mean and standard deviation (sd) of single walking, DT walking and proportional change in gait parameters between single and DT conditions.

[Table 1: see appendix]

[Table 2: see appendix]

Multiple regression analysis

The result of multiple regression analyses is presented in Table 3. The predictors included in the analysis explained 2.5 -7.8 % of the variation in proportional change in different gait parameters (Table 3). The analyses showed that only two of the predictors-gender and balance scale score- had significant relationships with DT effects on gait (Table 3). Being female was associated with having greater reduction in gait speed, cadence and stride length; and increase in step time and DS time relative to male (Fig. 1). Similarly, having low score in balance subtest of MABC-2 was associated with higher decrement in gait speed, normalized gait speed, and cadence; and increase in step time (Table 3) (Fig. 2). The secondary analysis revealed that among four components of balance subtest, only zig zag hopping (R) task was significantly associated with DT effect on gait where adolescents with better performance in zig-zag hopping had (R) less decrement in gait speed, normalized gait speed, and stride length (Table 4).

[Tables 3 and 4: see appendix]

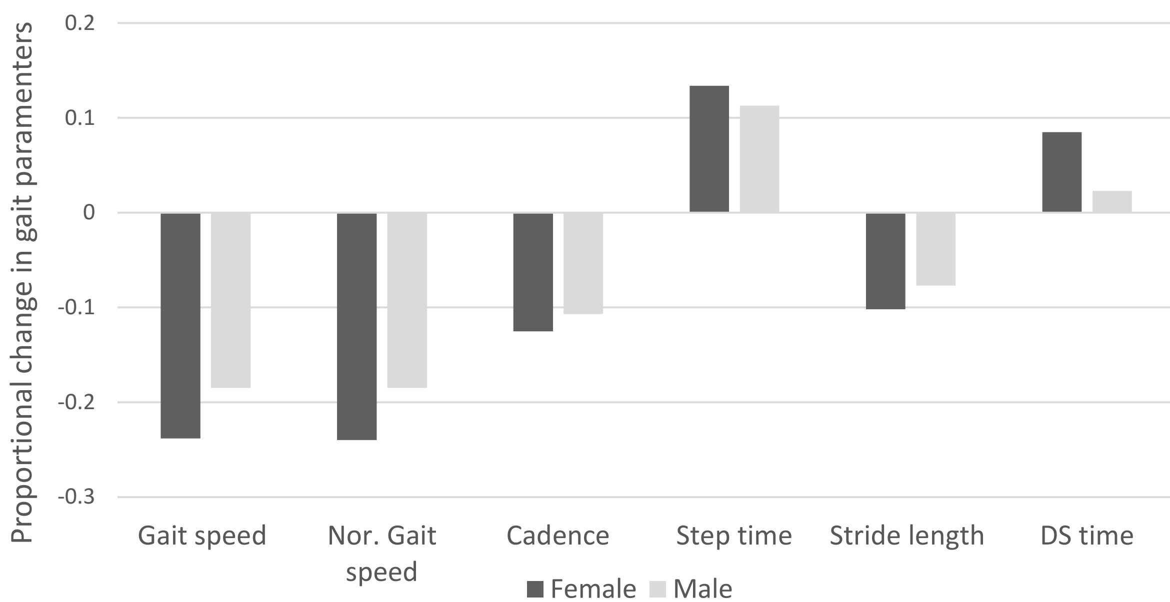

Fig.1 shows the proportional change in gait parameters between single and DT walking by gender. Vertical line shows the proportional change in gait parameters and the horizontal line illustrates five gait parameters. The bars in black (left) represents males, and the bars in light gray represent females.

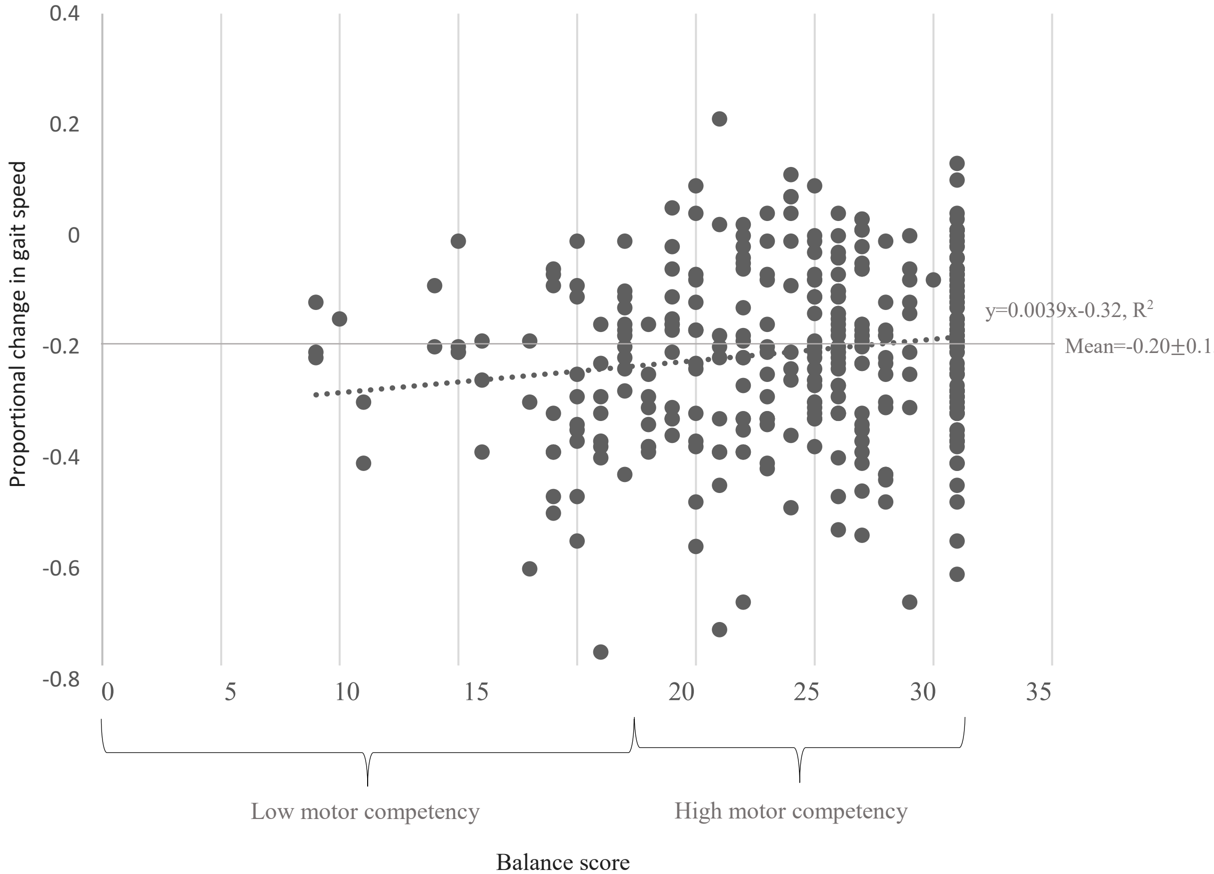

Fig. 2 shows the relationship between proportional change in gait speed and balance scale score of MABC in study participants. The vertical line shows the proportional change in gait speed and the horizontal line shows the balance scale score.

Discussion

This study showed that DT effect on gait varies across gender and adolescents with different levels of balance ability but was comparable among individuals differing in BMI, body strength, ability in manual dexterity and aim and catching, physical fitness and overall motor competence (high vs low).

The multiple regression analysis revealed that gender had a significant role in DT walking of adolescents which was observed in several gait parameters. Females walked with a shorter stride length, spent more time in double support, and walked slower than males during DT conditions. To the best of our knowledge, there is only one study reporting gender effect on DT walking where healthy male and female performed comparably (Howell et al., 2017a). The study, however, reported female adolescents sustaining a concussion had more deterioration in gait; that is, a higher reduction in cadence than males while performing a concurrent task (Howell et al., 2017b). This may be related to differences in cognitive attributes in males and females. It is known that males have superior working memory and mental imagination than females, yet females outperform males in perceptual skill and verbal cognition (Upadhayay & GUraGaiN, 2014). The concurrent tasks used in this study requires mental imagination and working memory in tandem with a vocal response. Therefore, the concurrent task might be less automatic and more attentionally demanding for females than males. This, consequently, requires higher prefrontal cortex involvement in DT condition in females, which was revealed by a recent imaging study (Tschernegg et al., 2017), that may lead to a greater conflict between gait and the concurrent task to use same brain region or neural pathway. This assumption, however, is still ambiguous as these studies including the current study failed to provide performance scores on the concurrent tasks. Gender differences in DT performance may also be explained by differences in fitness levels in males and females. Being male in this study were associated with a higher level of physical fitness that was revealed in collinearity analysis. Recent studies reported that higher fit individuals with better cardiorespiratory function have greater cerebral oxygenation in the frontal and prefrontal cortex (PFC), leading to a better performance in executive function including cognitive inhibition and task switching (Olivier Dupuy et al., 2015). Executive function is essential to allocate attention between tasks in a DT condition (Strobach, Wendt, & Janczyk, 2018) so that individuals with high levels of executive function owing to better physical fitness may experience less task interference in a DT condition than those with low fitness level. This association can be seen in this study as well as studies done in adult athletes where master athletes presented better DT performance than those who are lower fit (O. Dupuy, Bosquet, Fraser, Labelle, & Bherer, 2018).

Another significant predictor for DT effect was the balance ability of participants. Adolescents with a low level of balance skill reduced their walking speed at DT conditions to a greater extent than those with a high level. An individual with an advanced level of balance function may have an automatic postural control strategy owing to enhanced functional brain plasticity that require less cortical engagement for motor planning and strategy (Yarrow, Brown, & Krakauer, 2009). Therefore, in a DT condition, there may be less conflict between gait and concurrent task for overlapping resources in high skill adolescents who demand less cortical engagement overall, thereby resulting in the lower interference effect on gait. Support for this interpretation comes from studies showing a reduced PFC activity during walking after mastering balance skill with exercise program (Eggenberger, Wolf, Schumann, & de Bruin, 2016) or gait balance via treadmill training (Maidan et al., 2018). The secondary analysis also revealed that particularly adolescents performing better in zig-zag hopping task presented with less reduction in step length and gait velocity under DT condition. Zig-zag hopping is a goal-directed task that requires visual-motor and cognitive-motor interactions for decision making and action planning, and muscle coordination and lower extremity muscle strength for task execution. Adolescents showing higher ability in zig-zag task might have greater capacity in related resources that leads to experience lower DT effect on gait than those with lower ability. A potential link between leg muscle capacity and DT walking has been already reported in a recent study where children with greater leg muscle quality showed better performance in DT walking (Beurskens, Muehlbauer, & Granacher, 2015). The high correlation between leg muscle strength and stride length (Muehlbauer, Granacher, Borde, & Hortobágyi, 2018) may also explain the significant relationship between zig-zag performance and DT effect on stride length and gait speed, rather than other gait parameters.

Having a high or low competency in ball skill or manual dexterity, on the other hand, was not associated with DT effect on gait in this study. Mastering fine motor skill appears to not grant for gait, consequently for DT effect on gait. This may also explain the comparable walking performance of children with and without DCD under DT conditions in a previous study where DCD was diagnosed based on the scores obtained on MABC -2 (total score<15th percentile) (Cherng et al., 2009). DCD is characterized with deficit or delay in execution of motor skills including fine or/and gross motor performance at an age-appropriate level (Farmer et al., 2017). Generally, deficit in one component of motor skill seems to predominate while others are practically at normal level. Children with fine motor dysfunction, for example, may present with normal balance and gait function; consequently, may have comparable DT walking performances with TDC as it was shown in the current study. This argument, however, may not align with automatization deficit and internal modeling deficit hypotheses (Zwicker, Missiuna, Harris, & Boyd, 2012). According to these hypotheses, children with DCD are assumed to have cerebral engagement more so than TDC regardless of area of deficit - e.g., manual dexterity or balance function-; therefore, might show greater DT interference. However, the majority of the studies in this respect failed to support this assumption (Cherng et al., 2009; Getchell, Liang, Golden, & Logan, 2014; Schott et al., 2016).

DT effect on gait also did not vary across adolescents with different BMI. However, children (4-12 years) who are obese, or overweight have been reported to walk slower and had higher postural instability under a DT condition (carrying a box) as opposed to those with normal weight (Hung et al., 2013). The inconsistencies between studies may result from the task choice. Obese children are considered to have less ability in upper extremity (UE) bilateral coordination and fine motor precision then children with healthy weight (Gentier et al., 2013). This inability necessitates to allocate the greater amount of resources to UE functional task for a precise motor response relative to children with healthy weight during a DT condition (Christopher D Wickens, 1991). In turn, this may lead to a greater DT effect on gait in obese children relative to children with healthy weight while carrying a box when compared to the cognitive task leading comparable DT effects among individuals with varying BMI in the current study.

To conclude, female adolescents and adolescents with lower level of balance function presented with higher DT deficit during walking. They, consequently, may be less likely to participate in balance challenging activities or daily activities requiring dual tasking.

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Table 1. Baseline characteristics and predictors

Variables (n)	Mean (sd)	N (%)
Gender		
Female	-	161(44.1)
Male	-	204(55.9)
Age		
13 years	-	293(80.3)
14 years	-	72 (19.7)
Group		
HMC (>15th percentile)	-	240 (65.8)
LMC (<15th percentile)	-	125(34.25)
BMI WHO classification		
BMI percentile <5:Underweight		20(5.47)
BMI percentile ≥5 and <85:Healthy Weight		258(71.6)
BMI percentile ≥85 and <95:Overweight		55(15.1)
BMI percentile ≥95:Obese		32(8.76)
BMIz score	0.23(1.39)	365 (100)
MABC-2		
Manual dexterity	20.57 (6.82)	365 (100)
Aiming-Catching	17.38 (5.10)	365(100)
Balance	29.26 (6.17)	365 (100)
Power and fitness		
Broad jump (cm)	159.71(26.5)	360(98.6)
VO2 max (mL*kg^{-1} *min^{-1})	51.44(8.84)	359(98.6)

Table 2. Mean and sd of gait parameters at single and dual conditions, and proportional changes from single to dual conditions for all participants.

Gait parameters	Single walking Mean [sd]
Gait speed [m/s]	1.33 [0.15]
Nor. gait speed [au]	0.45 [0.05]
Step time [ms]	538.27 [42.21]
Cadence [steps/min]	112.73 [7.79]
Stride length [m]	1.42 [0.13]
DS [%]	29.98 [7.11]

Nor.: normalized, DS: double support

Table 3. Multiple regression analysis: The relationship between each predictor with DT effect on each gait parameters

	Proportional change in gait parameters											
	Gait speed*		**Nor. gait speed***		**Step time***		**Stride length**		**Cadence**		**DS time***	
PREDICTORS	*β*	***p***	*β*	***p***	*β*	***p***	*β*	***p***	*β*	***p***	*β*	***p***
Balance (9-36)	0.008	**0.001**	0.008	**<0.001**	-0.003	**0.008**	0.002	0.123	0.004	**0.002**	-0.0002	0.937
Aim & catching (5-30)	0.001	0.651	0.001	0.829	0.001	0.359	0.0002	0.805	-0.001	0.559	0.004	0.145
Manual dexterity (3-36)	0.001	0.594	0.001	0.300	-0.001	0.769	0.0005	0.536	0.0003	0.790	0.002	0.350
BMIz (-7.81-4.61)	-0.001	0.326	-0.002	0.516	0.001	0.861	-0.0009	0.797	-0.004	0.371	0.001	0.871
Broad jump (100-240)	-0.001	0.183	-0.001	0.127	0.0003	0.219	-0.0002	0.387	-0.0004	0.142	-0.0002	0.720
Grip strength (1-63)	0.001	0.481	0.001	0.382	-0.001	0.412	-0.0001	0.858	0.001	0.253	0.001	0.647
Gender (female)	-0.090	**0.002**	-0.09	**<0.001**	0.029	**0.019**	-0.031	**0.006**	-0.031	**0.039**	0.083	**0.010**
Group (LMC)	-0.058	0.147	-0.05	0.191	0.012	0.499	-0.007	0.2	-0.030	0.185	0.007	0.872
$\mathbf{R^2}$	**0.071**		**0.075**		**0.035**		**0.034**		**0.045**		**0.032**	

Nor.: normalized, DS: double stance, BMIz: Body mass index

Table 4. Multiple regression analysis:The association of gender and four categories of balance component with proportional changes in gait parameters

	Proportional change in gait parameters											
	Gait speed*		**Nor. gait speed***		**Step time***		**Stride length**		**Cadence**		**DS time***	
PREDICTORS	*β*	***p***	*β*	***p***	*β*	***p***	*β*	***p***	*β*	***p***	*β*	***p***
Two board balance	0.001	0.377	0.001	0.323	-0.001	0.377	0.0001	0.772	0.0004	0.528	0.001	0.362
Walking backwards	0.002	0.543	0.002	0.607	0.0002	0.842	0.0004	0.715	0.001	0.494	-0.002	0.607
Zig-zag hopping (L)	0.008	0.406	0.0006	0.557	-0.005	0.313	-0.003	0.470	0.007	0.257	0.009	0.459
Zig-zag hopping (R)	0.027	**0.023**	0.030	**0.006**	-0.008	0.145	0.0113	**0.020**	0.006	0.327	-0.011	0.401
Gender (Female)	-0.07	**0.001**	-0.07	**0.001**	0.017	0.114	-0.024	**0.008**	-0.017	0.176	0.066	**0.014**
$\mathbf{R^2}$	0.074		0.073		0.028		0.04		0.023		0.023	

Nor.: normalized, DS: double stance, BMIz: Body mass index