Human Movement Science 55 (2017) 8–17

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Full Length Article

Effects of dual task difficulty in motor and cognitive performance: Differences between adults and adolescents

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A R T I C L E I N F O

Keywords:
Adolescence
Cognition
Education
Executive function

A B S T R A C T

In the present study our aim was to compare dual-task performance in thirteen adolescents and fifteen young adults while concurrently performing a cognitive and a motor task. The postural control variables were obtained under three different conditions: i) bipedal stance, ii) tandem stance and iii) unipedal stance. The cognitive task consisted of a backward digit span test in which the participants were asked to memorize a sequence of numbers and then repeat the number in reverse order at three different difficulty levels (i.e. with 3, 4 and 5 digits). The difficulty of the cognitive task was seen to have different effects on adolescents and young adults. Adolescents seem to prioritize postural control during high difficulty postural conditions while a cross-domain competition model appeared in easy postural conditions.

1. Introduction

People often perform simultaneous tasks that require common cognitive mechanisms and resources in the course of their daily activities and learn to perform and integrate simultaneous complex tasks during childhood (Shumway-Cook & Woollacott, 2007). The dual task paradigm (performing a cognitive and motor task) is normally used to study the ability to perform simultaneous tasks in different populations. This paradigm can provide useful information, such as how to prevent falls in older people (Zijlstra, Ufkes, Skelton, Lundin-Olsson, & Zijlstra, 2008) or improve children's learning processes (Reilly, Woollacott, van Donkelaar, & Saavedra, 2008). For this reason, all the aspects related to both the motor and cognitive tasks can help select optimal task parameters for use in an educational environment (Remaud, Boyas, Caron, & Bilodeau, 2012).

To assess this relationship, researchers have used different combinations of cognitive tasks and postural conditions (i.e., motor task). Some of the cognitive tasks used are associated with memory (Mehdizadeh et al., 2015), arithmetic (Vuillerme & Vincent, 2006) and reaction-time (Weaver, Janzen, Adkin, & Tokuno, 2012). Researchers have also increased the postural task difficulty, manipulating upright stance by altering the base of support (Reilly, van Donkelaar, Saavedra, & Woollacott, 2008), varying sensory inputs (Stins, Ledebt, Emck, Van Dokkum, & Beek, 2009) and perturbing stance (Patel & Bhatt, 2015).

Three theories and models have been proposed to explain how the postural and cognitive tasks interfere with each other when performed simultaneously (dual task), as opposed to being carried out separately (single task). First, the cross-domain competition model postulates that postural control and cognitive activity compete for attentional resources (Bonnet & Baudry, 2016; Lacour, Bernard-Demanze, & Dumitrescu, 2008; Wollesen, Voelcker-Rehage, Regenbrecht, & Mattes, 2016). Because of attentional resource sharing, keeping one's balance should be less efficient in dual-task than single task conditions. Secondly, the U-shaped nonlinear

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http://dx.doi.org/10.1016/j.humov.2017.07.004
Received 25 February 2017; Received in revised form 15 May 2017; Accepted 16 July 2017
Available online 24 July 2017
0167-9457/

interaction model suggests a U-shaped relationship between posture control and cognitive demand (Bonnet & Baudry, 2016; Lacour et al., 2008; Wollesen et al., 2016). This means that body balance can be either improved or diminished depending on whether the cognitive demand of the secondary task is low or high. Finally, the task prioritization model takes into account the adaptive responses to age-related degeneration that lead to compensatory behaviors or strategies like task prioritization (Bonnet & Baudry, 2016; Lacour et al., 2008; Wollesen et al., 2016). Its main prediction is that older adults prioritize postural stability and balance at the expense of cognitive performance in dual tasking (Bonnet & Baudry, 2016; Lacour et al., 2008; Wollesen et al., 2016).

Related with the different existing theories, Woollacott and Shumway-Cook (2002) claim that the attention resources required by postural control depend on the nature and complexity of the task, as well as on the individual's age and balance abilities. A great number of papers have been published on dual task interference in postural control in older adults (Shumway-Cook, Woollacott, Kerns, & Baldwin, 1997; Teasdale & Simoneau, 2001). However, the effects of dual tasking in children and adolescents have received less attention from the scientific community. There is also a certain controversy surrounding the effects of a concurrent cognitive task on center of pressure (CoP) displacement. Blanchard et al. (2005) observed a higher postural length path when children (between 8 and 10 years old) performed a concurrent cognitive task (i.e. reading aloud and counting backwards), although they also found a lower sway range and sway variability. On the other hand, Reilly et al. (2008) did not find a reduction of postural sway while performing a visual working memory task in children of a similar age, while Fawcett and Nicolson (1992) found no dual task interference in postural control in children of 11 and 15 years old during bipedal and unipedal postural conditions. Finally, Schaefer, Krampe, Lindenberger, and Baltes (2008), found reduced body sway in children when they simultaneously performed a cognitive task. Moreover, it has been determined that dual task interference is lower in older than younger children (Huang & Mercer, 2001). This reduced interference could be due to the increased automation of motor performance or improved time-sharing skills with maturation, practice and experience (Huang & Mercer, 2001).

Regarding task difficulty, few studies have simultaneously analyzed the complexity of postural and cognitive tasks in children. In Olivier, Cuisinier, Vaugoyeau, Nougier, and Assaiante (2010) the difficulty of the postural task did not affect cognitive performance, but its effect on postural stability depended on age (greater effect on young children). On the other hand, increasing the complexity of the cognitive task reduces cognitive performance, regardless of age and postural task difficulty. Nevertheless, the difficulty of the cognitive task only reduced postural stability in young children performing highly difficult postural tasks.

Although the amount of research on postural control and dual tasks has increased in recent years, there are still not many studies that clarify the effect of the difficulty of the cognitive and postural tasks on childrens' and adolescents' performance. For this reason, the main objective of this study is to determine the effects of task difficulty (both cognitive and postural) on adolescents and young adults by identifying the differences between both groups regarding the effect of postural and cognitive tasks difficulty on postural control and stability as well as on cognitive function. We hypothesized that as dual task difficulty increase, postural control and cognitive performance decrease more in adolescents than in young adults.

2. Method

2.1. Participants

Thirteen adolescents and fifteen young adults participated in this study. All the participants indicated that they had no known neurological or balance disorders and all had normal or corrected-to-normal vision. The subjects' characteristics are shown in Table 1. The participants were informed of the nature and aim of the study and either they or their legal guardians signed an informed consent form. The study was approved by the Institutional Ethical Committee of the University of Valencia.

2.2. Experimental procedures

The experimental session was performed in a room prepared for data collection. First, a measurement anthropometry and body composition was performed. For this, the subjects were measured barefoot using a SECA Model 217 stadiometer (Seca, Hamburg, Germany) and weighed on a bioelectrical impedance scale (Tanita BC-601). The participants completed a familiarization session of the forthcoming experimental tasks, during which they performed a short trial (about 10 s) of each of the postural control and

Table 1
Subjects' characteristics.

	Adolescents Group (n = 13)	Adults Group (n = 15)
Sex		
Male	7	7
Female	6	8
Age (years)	12.23 (0.12)	21.22 (0.8)
Height (m)	1.59 (0.014)	1.68 (0.22)
Weight (kg)	52.01 (2.7)	64.38 (3.02)
BMI (kg/m^2)	20.55 (0.98)	22.48 (0.71)

Sex variables are expressed as number of cases. The other variables are expressed as a mean (standard error of the mean). BMI = body mass index.