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Short Communication

The effect of school trolley load on spatiotemporal gait parameters of children

E. Orantes-Gonzalez *, J. Heredia-Jimenez, V.M. Soto-Hermoso

Department of Physical Education and Sports, University of Granada, Crta de Alfacar s/n, 18071 Granada, Spain

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ABSTRACT

Objective: The present study evaluated spatiotemporal gait parameters in children when they were carrying school trolleys of different weights.

Methods: We assessed four conditions: without trolley, 10%, 15% and 20% of the subject's body weight. Fourteen students from a primary school (aged 11.43 ± 0.51 years) participated in this study. Velocity, cadence, stride length, stance phase, swing phase, single support phase and double support phase were analysed using an electronic walkway.

Results: Compared with normal walking, the three load conditions produced significant decreases in swing phase ($p < 0.001$) and single support phase ($p < 0.001$) and significant increases in cadence ($p = 0.019$), stance phase ($p < 0.001$) and double support phase ($p < 0.001$). No statistically-significant differences were found between the three load conditions.

Conclusion: Compared with normal walking, walking while carrying a trolley produced significant changes in most of the spatiotemporal gait parameters measured, perhaps due to the load-mediated changes in stability and balance. The spatiotemporal gait parameters were similar between the load conditions, indicating that the amount of load did not affect gait.

1. Introduction

Every day, children have to carry a backpack full of books to school. The effects of transporting a backpack over one or two shoulders have been widely studied. Changes in gait, energy expenditure and posture have been analysed using backpacks of differing loads [1,2]. Recently a new form of carrying backpacks appeared on the market: wheeled backpacks or school trolleys [3].

Many studies that analysed the prevalence of school trolley use by primary school students showed that trolley backpack options were selected among 14–31% of children [4–8], compared to 3.5% found by other authors [3]. Most students that used school trolleys pulled the trolley (98%) [6] and transported an excess load of school materials [9,10]. The average load of a school trolley was 30%, or 2.4 kg greater than the load of a traditional backpack [3,8].

Some studies described possible negative effects inherent in the use of school trolleys. Pau et al. [10] found that when children pulled the trolley up or down staircases, the exerted force could be twice the mass of the carried load. Another study that performed interviews with traumatologists affirmed that use of school trolleys involved asymmetric column efforts and forced postures of the shoulder and spine [11]. Schmidt and Docherty [12] recommended the use of backpacks instead of school trolleys even when the weight to transport was within the recommended range.

With respect to gait analysis, studies that evaluated the effects of asymmetrical load transportation on gait either used only one load condition [13,14] or analysed only adults [15–17]. In previous studies on asymmetrical load transportation in children [13,14], a backpack was transported in the hand loaded with 5% or 17% of the subject's body weight (%BW). The results showed a significant decrease in stride length and a trend towards decreased velocity compared with walking without a backpack. In addition, Kellis and Arampatzi [14] observed an increase in the double support phase and a decrease in the single support phase when children transported a backpack in their hand compared with walking without a backpack.

The increased use of school trolleys has deepened our need for knowledge about the consequences of this mode of school transport. This knowledge is important because children experience significant growth and motor development [18]. Therefore, the purpose of this study was to determine the effects of pulling a school trolley with different loads on the spatiotemporal gait parameters of children.

* Corresponding author. Tel.: +34 958246637.
E-mail address: maevor@ugr.es (E. Orantes-Gonzalez).

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2. Methods

2.1. Participants

Fourteen students (4 boys and 10 girls) from a primary school, aged 11.43 ± 0.51 years, participated in this study. The average body weight was 35.1 ± 10.1 kg and the average height was 1.4 ± 0.1 m. All of the students were volunteers and their parents completed informed consent forms. The Ethics Committee of the university approved this study. Participants were healthy and did not report any history of orthopaedic trauma or neurological problems.

2.2. Protocol and Instruments

Each child was measured with a scale and measuring rod (SECA769, Hamburg, Germany). To analyse the effects of increased loading of school trolleys on gait, we used four conditions: without a trolley (WT) and with a trolley loaded with 10, 15, or 20%BW. The different loads were achieved by filling the trolley with books of different weights. The children pulled the trolley using only the dominant hand.

Each child walked at his comfortable speed along a 15 m walkway. The GaitRite system (GAITRite system; CIRSystems Inc., Clifton, USA) was located in the middle of the walkway so as not to measure the non-stabilized walking periods at the beginning and end of the test. Firstly, the children walked without a load for five times to familiarize themselves with the protocol. Then the children walked WT, and afterwards they completed the three load conditions (10, 15 and 20%BW). The load conditions were executed in a randomized order. Five trials were recorded for each walking condition to be analysed, and researchers discarded the first two trials of each condition to ensure that the children were adapted to the condition.

2.3. Variables analysed

Spatiotemporal parameters were analysed: velocity (m/s), cadence (steps/seg) and stride length (m). These parameters were normalized using the subject's height by following the equations proposed by Hof [19]:

$$\text{Normalized velocity} = \frac{\text{velocity}}{\sqrt{(g \times l_0)}} \quad (1)$$

$$\text{Normalized cadence} = \frac{\text{cadence}}{\sqrt{(g/l_0)}} \quad (2)$$

$$\text{Normalized stride length} = \frac{\text{stride length}}{l_0} \quad (3)$$

where g is the acceleration due to gravity (9.81 m/s^2) and l_0 is the stature of the subject (m).

In addition, swing phase, stance phase, single support phase and double support phase were measured and expressed as a percentage of the gait cycle (%GC).

2.4. Statistical analysis

Data were analysed with SPSS software v.20 (SPSS Inc., Chicago IL). The Shapiro Wilk's test was used to test normal samples. Gait parameters were analysed using one-way ANOVA with Bonferroni confidence interval adjustment, since there was only one independent variable (load). The level of statistical significance was set at $p < 0.05$.

3. Results

There were non-significant differences in the normalized velocity and the normalized stride length when children walked WT compared with pulling the trolley. The normalized cadence was lower when children walked WT than when pulling the trolley. This difference was significant between WT and either 15 or 20%BW (Fig. 1).

The swing and the single support phases were significantly decreased in the 10, 15 and 20%BW conditions compared with the WT condition (Fig. 2). Conversely, the stance and double support phases were significantly increased in the load conditions compared with the WT condition (Fig. 2).

None of the gait parameters studied showed significant differences between the load conditions (comparing 10 and 15%BW, 10 and 20%BW, or 15 and 20%BW).

4. Discussion

The present study shows that the increase in trolley load motivated the subjects to use a cadence adjustment mechanism to maintain their natural velocity because stride lengths were not significantly changed. This result is consistent with that of Hillman and Stansfield [20] who found that children adjust their cadence to change speed, whereas stride length is dictated by other factors peculiar to the individual. In addition, previous studies suggested that an increased walking cadence created a higher hip power, accentuating the importance of the hip in propulsion and stability [21].

In a previous study of children transporting asymmetrical loads, velocity did not change significantly when the children carried a backpack in one hand (17%BW), but the stride length decreased [14]. In contrast, a different study on asymetrical load transportation found significant decreases in velocity and cadence with the load (15%BW), but stride length did not change [22]. Kellis and Arampatzi [14] suggested that the differences in the results between these two studies were due to differences in methodology and sample characteristics.

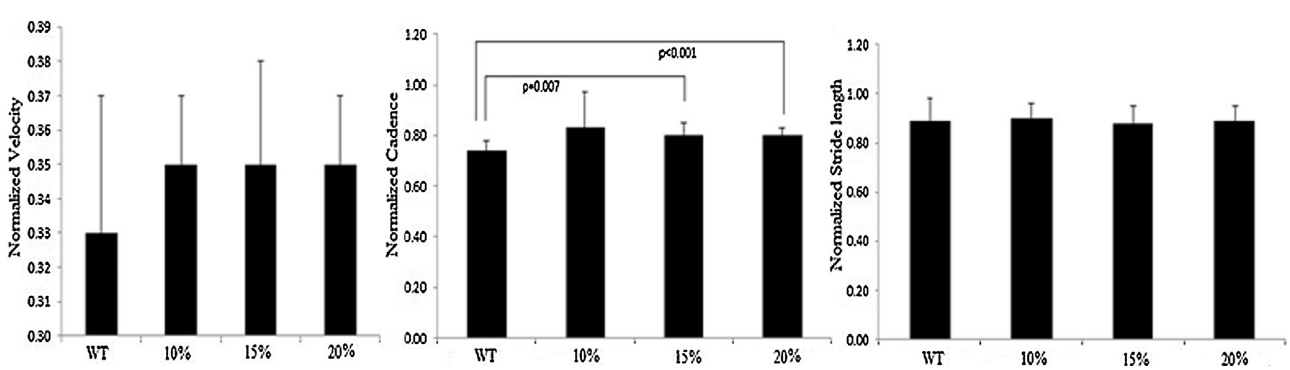

Fig. 1. Spatiotemporal gait parameters in the different conditions analysed. WT: without trolley.