Gait & Posture 52 (2017) 189–193

Contents lists available at ScienceDirect

Gait & Posture

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

Full length article

Children require less gait kinematic adaptations to pull a trolley than to carry a backpack

Eva Orantes-Gonzalez[a,*], Jose Heredia-Jimenez[a], George J. Beneck[b]

[a] Department of Physical Education and Sports, University of Granada, Granada, Spain
[b] Department of Physical Therapy, California State University Long Beach, Long Beach, CA, USA

ARTICLE INFO

Article history:
Received 8 July 2016
Received in revised form 22 October 2016
Accepted 25 November 2016

Keywords:
Load
Students
Gait
Wheeled backpack

ABSTRACT

To transport school materials, trolleys have been proposed for children as an alternative to carrying a backpack. However, there is limited evidence comparing the adaptations associated with carrying school trolley versus backpack. This study compared the effects of carrying a backpack and pulling a trolley on gait kinematics in children. Fifty-three students were evaluated. Children walked at self-selected speeds across a walkway with no bag (control), carrying a backpack with the 15% of child's body weight (%BW) and pulling a trolley with the same load. Spatiotemporal gait parameters and 3D kinematics of lower extremities and thorax were computed. No significant differences were obtained in spatiotemporal parameters between pulling a trolley and control. Carrying a backpack resulted in larger kinematics gait alterations than pulling the trolley compared to control. In conclusion, pulling a school trolley (15%BW) was more similar to not carrying a bag than carrying a backpack of the same load during level walking.

1. Introduction

Children routinely use either a backpack or trolley to carry books and other supplies when traveling to and from school. Recommendations for backpack loads range from 10 to 20% of body weight (BW) [1–3]. However, previous studies affirmed that between 4.7% to 38% of children transport backpacks in excess of 20% BW on a daily basis [4–7]. The school trolley had been proposed as an alternative to the traditional backpack because it eliminates the need to support the load on the back and parents think trolleys seem to solve the problem of the increasingly heavy loads being carried on a young child's back [8]. In contrast to carrying a backpack, pulling a trolley is an asymmetric activity pulling loads which are on average 15.7% BW [9] and around a 30% or 2.4 kg heavier than a backpack [8,10]. Heavier loads may be pulled with a trolley due to the weight of the trolley and the safety perception associated with its use [11].

The findings of previous studies agree that carrying a loaded backpack results in an increase in the double support phase and a reduction of the swing phase [12–16]. However, some gait parameters were not so consistent across studies. For example, velocity, stride length and cadence were unchanged by carrying a loaded backpack in some studies [12,17,18], but were significantly reduced in other studies [14,16,19]. Kellis and Arampatzi [16] explained that these differences may have been due to differences in methodologies and the characteristics of the participants. Carrying a backpack produces a forward inclination of the trunk to compensate for the extra load on the back [17–20]. Flexion of the trunk is associated with musculoskeletal pain in children and adults [21–23]. Below the trunk, the only significant influence of wearing a backpack was an increase in knee flexion peak during the loading response which may have resulted from an increased need for shock absorption due to the backpack load [14–17].

Pulling a school trolley involves asymmetric loading and potential consequences to the upper extremity used, such as the large dynamics forces that trolleys involved in the stair ascent and descent [24]. The use of the school trolleys was reported between 3.5-44% depending on the country evaluated [7–9,25–28]. The study of gait parameters while pulling a school trolley is limited. Only one previous study analyzed the spatiotemporal gait parameters in children pulling a school trolley with different loads [29]. In that study, the changes in the spatiotemporal gait parameters were independent of the amount of load transported (range 10–20% BW). The main adaptations associated with pulling a school trolley (10%, 15% and 20% BW) were an increase of double support phase and stance phase, and a decrease in the swing and single limb support phase compared to no bag walking. In regards

* Corresponding author at: Crta de Alfacar s/n, Faculty of Sport Sciences, University of Granada. 18011 Granada, Spain.
E-mail address: maevor@ugr.es (E. Orantes-Gonzalez).

http://dx.doi.org/10.1016/j.gaitpost.2016.11.041
0966-6362/

to velocity, cadence and stride length, only a significant decrease in cadence was found between walking with and without the trolley.

Understanding the comparative effects of pulling a school trolley versus carrying a backpack on gait and posture should provide insight regarding recommendations for their use. Therefore, the purpose of this study was to compare the effects of carrying a backpack and pulling a school trolley on kinematics of the trunk and lower limbs.

2. Method

2.1. Study design

This study is a within-subjects design where the independent variable was the carrier type with 3 levels: 1) no bag condition (control), 2) carrying a backpack, and 3) pulling a school trolley. The Ethics Committee of the University of Granada approved this study. All of the students were volunteers and their parents completed an informed consent form.

2.2. Participants

Fifty-three subjects (24 boys and 29 girls) from an elementary school, aged 9.94 ± 1.74 years, participated in this study. The average body weight was 39.75 ± 12.14 kg and the average height was 1.45 ± 0.13 m. The daily backpack weight that children transport to the school represented an average of 15.1% BW. Children were excluded if they had recent orthopaedic trauma, neurologic problems, or were unable to carry a backpack or trolley.

2.3. Procedure

Each child was measured with a scale and measuring rod (SECA769, Hamburg, Germany). In addition, the backpack that children transported to school were weighed on the same scale. To analyze the effects of a loaded school trolley and traditional backpack on gait kinematics, children walked under three experimental conditions: no bag condition (control), carrying a backpack and pulling a trolley, both with 15% BW (as gross weight).

A 3D motion capture system (Qualisys AB, Göteborg, Sweden) was used to analyze the kinematics of gait with a full body modified CAST model marker set without head and upper extremities. Twenty six reflective markers were placed with adhesive tape on the children's skin in both sides of the lower body and trunk. The palpation of the reflective markers was done following the recommendations proposed by Sint [30]. Markers setup is in agreement with the suggestion of CODA protocols (Charnwood Dynamics Ltd, Leicestershire, United Kingdom) for model of pelvis segment.

Markers were place on the first and fifth metatarsal head, second metatarsophalangeal, medial and lateral malleolus, large posterior surface of calcaneus, lateral and medial femoral epicondyle, anterior and posterior superior iliac spine, acromioclavicular joints, jugular notch, xiphisternal joint and costal cartilage of the seventh ribs. Besides, were placed a cluster with four markers in the lateral of the shank and tight of both legs. Because of carrying a backpack could cover the markers of the hip, two clusters more with three markers each was placed on the lateral hips. For the dynamic conditions, the malleolus, epicondyles, posterior superior iliac spines and acromioclavicular joints markers were removed from the subject.

The reflective marker locations were collected through nine infrared high-speed cameras at a rate of 250 Hz. The calibration of the space was done with a wand (length of 751.1 mm) before each data collection and the standard deviation of the wand's length measures were below 0.5 mm. Visual3D software (C-Motion Inc., Germantown, USA) was used to compute the gait kinematics.

Each child walked at his comfortable speed along a 15 m walkway. Infrared cameras were orientated to the 3 center meters of the walkway to discard the acceleration or deceleration phases of gait. First, children walked with no bag to familiarize themselves with the protocol. Then, children walked under the next experimental condition: control; and carrying a backpack and pulling a trolley loaded with 15% BW in a randomized order (Fig. 1).

Children walked for one minute in each of the condition. Three minutes of rest was performed between each of the experimental conditions to avoid fatigue. The different loads were achieved by filling the backpack and trolley with books of different weights. Each participant carried the backpack over the two shoulders aligning the bottom of the backpack with the waist. The school trolley was pulled using the dominant hand.

2.4. Outcome variables

The coordinate based algorithm in Visual 3D was used to find the foot strikes and toeoffs to calculate the spatiotemporal gait

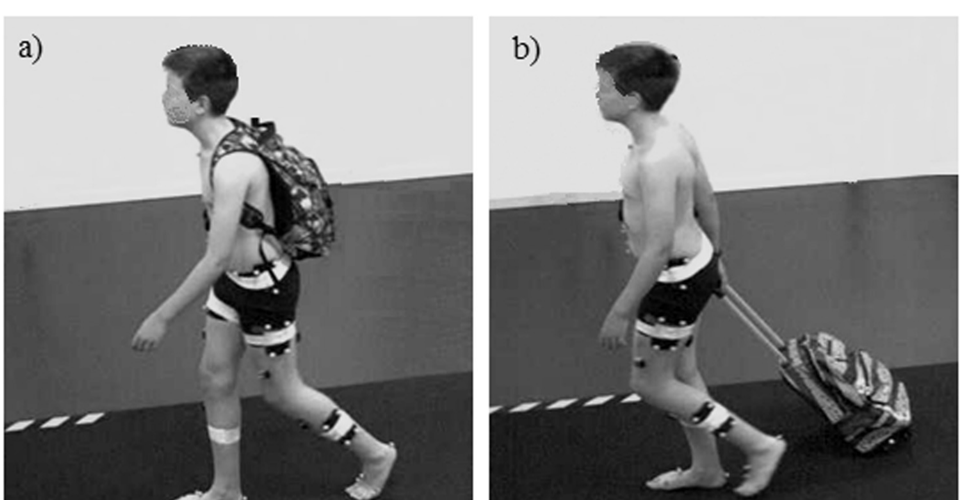

Fig. 1. a) Subject carrying the backpack; b) Subject pulling the trolley over the walkway.