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Pulling a school trolley: A good kinematic option for children☆

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ABSTRACT

This study analyzed the kinematic gait parameters associated with pulling a school trolley with different loads and the effects of the type of packing device user (backpack vs. trolley) and body side (loadedunloaded). Methods Fifty-three elementary subjects walked at a selfselected speed under four experimental conditions: without a trolley and pulling a trolley with 10%, 15% and 20% of the subject's body weight (BW). Averages and standard deviations of spatiotemporal gait parameters and 3D kinematics of the lower limbs and thorax were obtained for the loaded and unloaded sides of the body. Results Spatiotemporal gait parameters were affected by pulling a trolley with a load of 20% BW, although the changes were not important (decrease of 0.02 units in velocity and stride length, decrease of 0.32% in single support and increase of 0.31% in double support). In the 3D kinematics analysis, the main effects of trolley load were observed in the thorax, with increased flexion as the load increased, and in the pelvis between baseline and 10%–15% BW. No interaction was found between kinematic parameters and the type of packing device user (trolley or backpack). Considering the loaded and unloaded sides of the body, the transverse plane of the thorax was the main site affected by the asymmetrical task. Conclusion Although some of the analyzed kinematic parameters were influenced by the use of a school trolley, the adaptations were minimal, and trolleys could be considered a good option for use in the transportation of school supplies

1. Introduction

Children often use school trolleys daily as an alternative option to the traditional backpack. Although the average weight of a school trolley is greater than that of a backpack (approximately 30% or 2.4 kg more) [1,2], the use of school trolleys allows children to avoid supporting the load on their backs and also provides an easier mode of transportation. Previous reports suggest that between 14.5 and 48.9% of children use trolleys [3–5], with the frequency of use varying by country.

On the other hand, previous studies considered the use of school trolleys to be an asymmetrical effort, and trolley use among children was related to a higher risk for scoliosis [6] and forced postures of the shoulder and spine [3]. A previous study analyzed the negative effects of pulling a trolley with a 20% of body weight (BW) load when encountering staircases and affirmed that subjects must support a peak force of nearly twice the mass of the carried load. However, the authors did not specify the possible negative effects of these forces on the musculoskeletal system of the child [7].

A single previous study analyzed the spatiotemporal gait parameters of pulling a trolley with loads of different weights and concluded that the use of a trolley produced gait changes independently of the amount of load transported (range 10–20% BW) [8]. Schmidt and Docherty [9] compared the kinematics of the trunk between two groups: one group carried a backpack, and the other group pulled a trolley. In both groups, the load to transport was approximately 11% BW. The conclusion of this study was that it is more important to adhere to an appropriate weight when carrying a backpack than to use trolleys. However, the instrument used in this study was not validated in children, and the authors did not specify the proportion of students that used the school trolley in their daily lives.

There is a need to investigate the impact of trolley use and trolley mass on walking kinematics, given the high frequency of trolley use among school-aged children and also considering that no previous studies provided an analysis of gait and posture while pulling a school trolley. Therefore, the aim of this study was to

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analyze the kinematics of gait while pulling a school trolley with different loads in elementary school participants.

2. Methods

2.1. Participants

Fifty-three participants (25 boys and 28 girls) from an elementary school (aged 10.01 ± 1.69 years) participated in this study. The average body mass was 40.05 ± 11.09 kg, and the average height was 1.46 ± 0.09 m. All of the participants were volunteers, and their parents completed an informed consent form. The Ethics Committee of the University approved this study. The participants were healthy and did not report any history of orthopedic trauma or neurological problems. Fifty percent of the evaluated participants used the school trolley as their daily preferred option to transport their school supplies to and from school, while the other half used backpacks.

2.2. Protocol and instruments

Each child was measured with a scale and measuring rod (SECA769, Hamburg, Germany). To analyze the effects of an increased load in a school trolley on gait kinematic variables, the children walked under four experimental conditions: without a trolley (WT) and while pulling a school trolley with a 10, 15, and 20% BW load.

A 3D motion capture system (Qualisys AB, Göteborg, Sweden) was used to analyze the kinematics of gait. Twenty-six reflective markers were placed with adhesive tape on the children's skin on both sides of the lower body and the trunk. Nine infrared high-speed cameras with a capture rate of 250 Hz were used to collect the positions of the reflective markers.

The markers were situated on the first and fifth metatarsal head, the second metatarsophalangeal, medial and lateral malleolus, the large posterior surface of the calcaneus, the lateral and medial femoral epicondyle, the anterior and posterior superior iliac spine, the acromioclavicular joints, the jugular notch, the xiphisternal joint and the costal cartilage of the seventh rib. In addition, a cluster with four markers was placed on the lateral portion of the shank and thigh of both legs. Because carrying a backpack could obfuscate the markers on the hip, two additional clusters with three markers were placed on the lateral hips (Fig. 1). The external and medial markers on the malleolus and on the epicondyle, the posterior superior iliac spine markers and the acromioclavicular joint markers were used only for calibration and were removed prior to dynamic trials.

The Visual 3D software (C-Motion Inc., Germantown, USA) was used to compute the gait kinematics. A lower limb model with 8 segments and a thorax were built, allowing 6° of freedom per segment. Each child walked for one minute per condition at his or her chosen speed along a 15 m walkway. Three minutes of rest were provided between conditions. Infrared cameras were orientated to the three center meters of the walkway to discard the acceleration and deceleration phases of the gait. First, the children completed a familiarization phase while walking without a trolley (WT). Then, the children completed the four experimental conditions in a randomized order. The different loads were achieved by filling the trolley with books of different weights. The school trolley was pulled using the dominant hand, and for kinematic analysis, that side was considered to be the loaded side.

2.3. Outcome variables

The coordinate-based algorithm [10] computed by Visual 3D was used to find the foot strikes and toe-offs to calculate the spatiotemporal gait parameters. Velocity (m/s), cadence (steps/s) and stride length (m) were normalized using the participant's height according to the equations proposed by Hof [11]. In addition, the stance phase, single support phase and double support phase were measured and expressed as a percentage of the

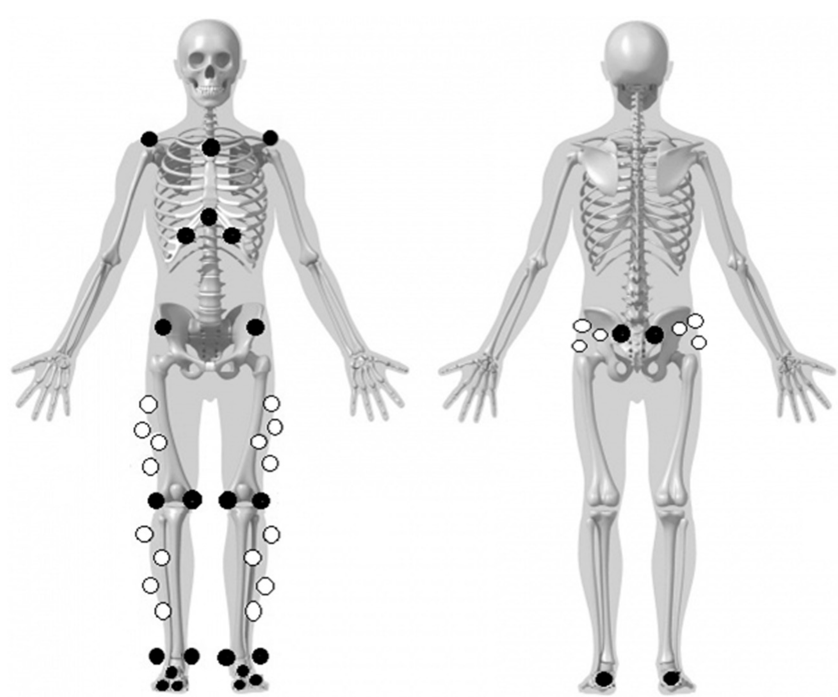

Fig. 1. Anterior and posterior views of marker placement. Adapted from "Marker Set Guidelines," C-Motion's Visual3D biomechanics research software. The white markers represent clusters.