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# One-shoulder carrying school backpack strongly affects gait swing phase and pelvic tilt: a case study

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**Abstract:** The use of backpacks is common to both adults and children and often leads to the onset of musculoskeletal discomforts. Although a large number of studies have focused on the optimal load for children schoolbags, there is no general consensus. Here we report a 13-yr old girl case study, showing the impact of weight and wearing the school backpack on gait parameters. The variation of gait parameters and pelvis angles in different conditions were studied: without backpack (CTRL), or with backpack at 10% Body Weight (10BW), 15% BW (15BW) and 20% BW (20BW), carried "on both shoulders" (2S), "on one shoulder" (1S), or "with one hand" (1H). Swing phase was comparably modified by 2S/20BW and 1S/10BW conditions, suggesting that a lower backpack weight was sufficient to induce gait alterations when carried in asymmetrical conditions. Pelvic tilt, which was preserved by a two-shoulders distributed 10% BW load (2S/10BW), was strongly reduced in asymmetrical condition (1S/10BW), suggesting that a low weight carried on a single shoulder generates postural modifications including reduction of pelvic tilting, which is known to be associated to low back pain.

**Key words:** backpack load, schoolbag carrying, pelvic angles, back pain

## Introduction

The use of backpacks is common to both adults and children and often leads to the onset of musculoskeletal discomforts; therefore, recently a large number of studies have focused on the optimal load for children schoolbags, suggesting a safer schoolbag load of about the 10-15 percentage of body weight (PBW) (1,2). In the landscape of evidences, scientific literature mostly shows cross-sectional study designs in primary school children (1-3). In parallel with the safer weight of backpacks, also the time spent in carrying has been investigated (4), in order to draft guidelines for teachers, parents and children too. However, results are still confusing (5), suggesting that the back pain in children carrying schoolbags might be a multifactorial problem (1,6), associated to gender (3), body mass index (BMI) and/or different biomechanical and physiological response to load (7).

We also hypothesize that backpack wearing habits may as well impact on musculoskeletal system and, in particular, on gait parameters (8). Therefore, here we report a 13-years-old girl case study, showing the impact of weight and wearing the school backpack on gait parameters.

## Materials and Methods

Stabilometric and gait analyses were performed on a 13-yr old girl, after parents' consent. Anthropometric data (height, weight, body mass index and percentage of fat mass) were collected. Fat mass (%FM) was tested using bioelectrical impedance analyser

(BIA) (InBody 230; Biospace, Seoul, South Korea). Stabilometric analysis was done through PoData system (Chinesport, Udine, Italy) to achieve plantar pressure body weight distribution, during orthostatic position. Gait analysis was performed using a wearable inertial sensor (G-sensor, BTS Engineer), placed at the level of S1, on a 10-mt walking distance. We studied the variation of gait parameters (speed, percentage of stride length and swing phase) and pelvis angles (tilt, pelvic obliquity and rotation).

The test was performed without backpack, as control (CTRL), or with backpack at 10% BW (10BW), 15% BW (15BW) and 20% BW (20W), carried "*on both shoulders*" (2S), "*on one shoulder*" (1S), or "*with one hand*" (1H). We waited ten minutes between tests.

## Results

Anthropometric data were: 52.8 kg weight, 155 cm height, BMI 22 (normal range 17.3-23.3) and 22 %FM (normal range 17-27).

Stabilometric analysis showed asymmetrical body weight distribution on plantar pressure (46% left vs 54% right) at CTRL condition.

Gait analysis showed no differences in gait speed comparing all the different conditions of backpack weight on two-shoulders carrying (2S). However, both gait speed and percentage of stride length (%SL) were reduced in the asymmetrical schoolbag wearing (1S and 1H), independently from PBW backpack weights (10-20BW). Of note, swing phase, which increased accordingly with backpack weight (from 10BW to 20BW conditions), was comparable between the 2S/20BW and 1S/10BW conditions (39.00 ± 4.43 % cycle), suggesting that a lower backpack weight (10BW) was sufficient to induce gait alterations when carried in asymmetrical conditions (1S and 1H). Pelvic angles were modified (CTRL: tilt range 6.7-7.4; obliquity range 10.3-10.6; rotation range 14.3-14.3) according with backpack weights and wearing, showing a progressive reduction of all the parameters (Table 1). Of note, in 2S condition, obliquity and rotation progressively reduced starting from 10BW to 20BW, whereas tilt started to decrease from 15BW. On the contrary, in 1S condition, both tilt and rotation progressively reduced starting from 10BW, whereas obliquity dramatically reduced in 20BW. In 1H, all parameters strongly decreased starting from 10BW and their ranges appeared about 3 degrees in 20BW.

The comparison between CTRL and 2S/10BW conditions – commonly considered the best condition to carry a backpack[2] – showed that a 10% BW backpack load induced the reduction of both pelvic rotation and obliquity, however preserving pelvic tilting angle (Figure 1A).

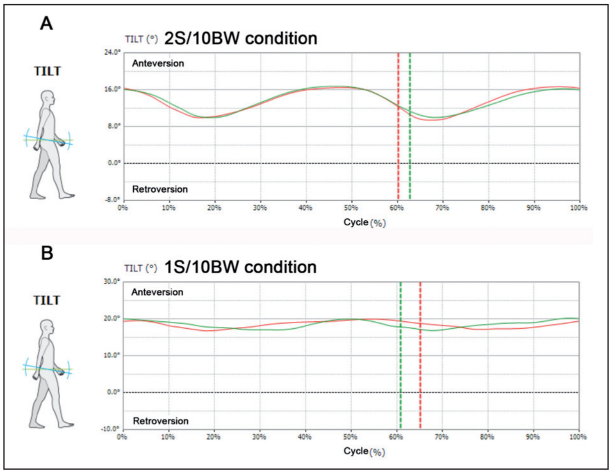


**Figure 1.** Pelvis tilting range in 2S/10BW (A) and 1S/10BW (B) conditions during left (red lines) and right (green lines) limbs gait cycle.

**Table 1.** Pelvic angle ranges according with backpack weights and wearing

| | 2S | | | 1S | | | 1H | | |
|---|---|---|---|---|---|---|---|---|---|
| | Tilt (°) | Obliquity (°) | Rotation (°) | Tilt (°) | Obliquity (°) | Rotation (°) | Tilt (°) | Obliquity (°) | Rotation (°) |
| **10BW** | 7.2-6.8 | 5.1-4.7 | 6.0-5.8 | 3.1-3.3 | 9.5-9.9 | 10.6-10.7 | 5.6-4.2 | 8.4-7.8 | 6.6-6.3 |
| **15BW** | 3.8-4.5 | 5.0-5.7 | 7.3-8.0 | 3.6-3.3 | 8.7-8.7 | 6.7-6.8 | 6.9-4.9 | 5.0-4.4 | 6.6-6.5 |
| **20BW** | 3.2-3.2 | 2.4-2.2 | 5.5-5.7 | 5.5-5.5 | 2.9-2.9 | 7.2-7.1 | 2.9-3.8 | 2.8-2.3 | 3.9-2.5 |

Legend. 10BW: backpack at 10% BW; 15BW: backpack at 15% BW; 20BW: backpack at 20% BW;
2S: backpack carried on both shoulders; 1S: backpack carried on one shoulder; 1H: backpack carried on one hand

## Conclusions

Our data show that swing phase was comparably modified by 2S/20BW and 1S/10BW conditions, suggesting that a lower backpack weight is sufficient to induce gait alterations when carried in asymmetrical conditions. In this case, moving the load on a single shoulder (1S/10BW), the control of both pelvic rotation and obliquity became less efficient, increasing both these angle ranges. Consequently, pelvis stabilization is obtained minimizing pelvic tilting (Figure 1B), which is known to be associated to low back pain (9). Therefore, prolonged periods of asymmetrical carriage of even light weights (10%BW) generate postural alterations that might predispose to low back pain.

Further research is needed to evaluate the impact of school backpack load and its incorrect carrying on children's health bodies in order to develop evidence-based guidelines and targeted prevention measures.

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