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Gait Kinematics of Load Carriage in Healthy College Students

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Abstract— **Daily use of backpacks have raised some concerns and it has been an issue of research on children and teenagers. This paper shows results of the gait kinematics of load carriage in healthy college students. The analysis was done with videography on the sagittal plane. Three loads were tested (4.1 kg, 6.8 kg and 10.5 kg). It was observed that the angles of ankle and knee do not change, whereas the initial hip angle and the maximum flexion angle showed an increase. Thus all of the observed differences were at the hip level.**

Keywords— **load carriage, gait, backpack.**

I. Introduction

The impact of a load on the human gait is a function of the relation between load mass and body mass of each person [1]. College students usually wore a backpack or a similar device to transport all the materials needed for their academic activities, such as notebooks, books, and laptop. In some cases the backpack weight can be substantially heavy and it can cause discomfort to the users [2].

One approach to analyze how the load carriage affects us is through gait analysis. Human motion analysis and particularly gait analysis has become a useful tool in research and clinical settings [3]. Although there has been some research reports on the use of backpacks. Most of them are focused on children [4], teenagers [2,5], industrial or military use [6]. It has been establish that there is an association between the use of backpacks and back pain and muscle fatigue [3,7]. This has raised concerns on health and it has influenced the design of backpacks [8,9].

However, despite the biomechanical-designed backpacks, the use of a backpack or similar in the college environment has not changed. Thus there is a variety of backpacks, their use is inappropriate and the load is not constant trough the term. These factors contribute to complaint such as back pain and muscle fatigue. The aim of this pilot study was to establish a protocol to evaluate the gait under different load carriage in college students and determinate if is a good practice to use every day certain load. This could lead to advice in a better way the students to the appropriate weight of their backpacks through a campaign about awareness of self-care.

II. Materials and methods

A. Participants

Five healthy subjects were included in the study: 2 males with heights 173.8 ± 0.4 cm and weights 83.7 ± 15.6 kg, and 3 females with heights 163.3 ± 3.5 cm and weights 58.1 ± 10.9 kg. Participants (aged between 20-21 years) signed an informed consent prior to start the measurements. Measurement protocol is in line with the Helsinki declaration.

B. Measurements

Subjects were evaluated through kinematic analysis using videography in the sagittal plane due to that illustrates the most important gait angles [8]. Figure 1 and 2 show the setting and the processing blocks for this study. Briefly, subject wore a set of markers on: base rib cage, greater trochanter, lateral epicondyle of thigh, head of fibula, lateral malleolus, heel and 5th metatarsal, as recommended by [10,11]. A commercial video camera (Sony-HDR-CX250, 60 fps) was used for recording (60 fps is enough to track the human gait [12]). The camera was placed on the sagittal plane of the subject at 90cm over the floor and 4.5m from the subject's track.

Participants were asked to perform three trials for each load condition (without load, 4.1 kg, 6.8 kg and 10 kg), using a commercial bilateral backpack. Heavier load represent on average 15.3 % of body mass (table 1). For all trials, subjects were barefoot, wore jeans and the arm was flexed towards the opposite shoulder.

C. Kinematic Analysis

Trajectories for every one of the markers were obtained using the software Tracker. Joint angles were calculated for hip, knee and ankle as show in figure 3. Then, the angles were filtered with an 8-order Butterworth low-pass filter with a cutoff frequency of 10 Hz.

	Men			Women		
Load (kg)	4.1	6.8	10.5	4.1	6.8	10.5
% of body mass	4.9	8.1	12.5	7.1	11.7	18.1

Table 1. Relation between participant's weights and load carriage.

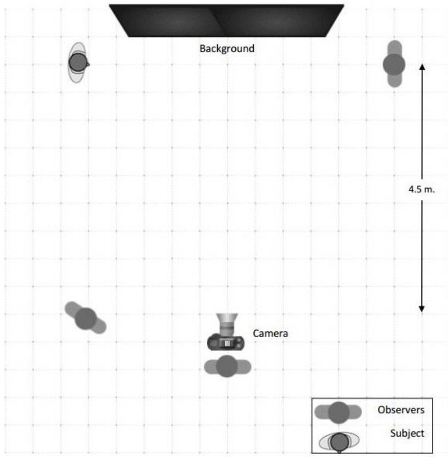

Fig. 2 Setting configuration. The camera was placed on the sagittal plane of the subject at 90cm over the floor and 4.5m from the subject's track.

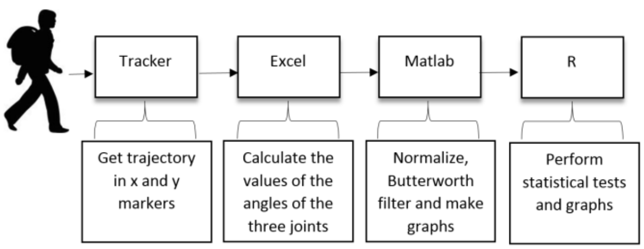

Fig. 3 Kinematic Analysis. The steps involved on the kinematic analyses were as follow; video recording, computation of trajectories and joint angles.

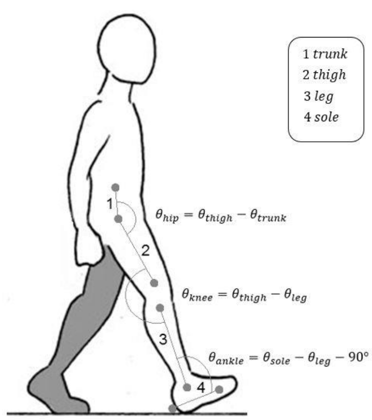

Fig. 3 Joint Angles. Calculation of joint angles considering the markers settings.

D. Statistical Analysis

Data of normalized joint angles were compared using R software and applying a T test for paired samples with α=0.05.

III. Results

Figure 4 shows the joint angles for hip, knee and ankle during the four load-carriage conditions. Figure 5 shows the comparison of the percentages (gait cycle). Figure 6 shows the statistical comparison for the hip angles (initial angle and maximum flexion), which were the only joint angles that showed a statistical significant difference.

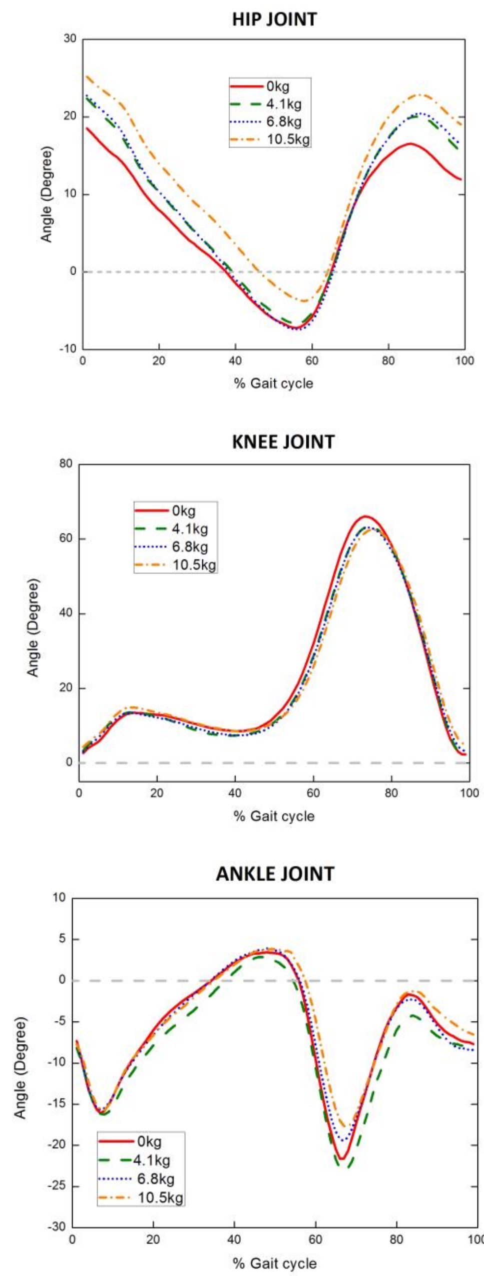

Fig. 4 Joint Angles. Average of hip, knee and ankle angles during the four load-carriage conditions.

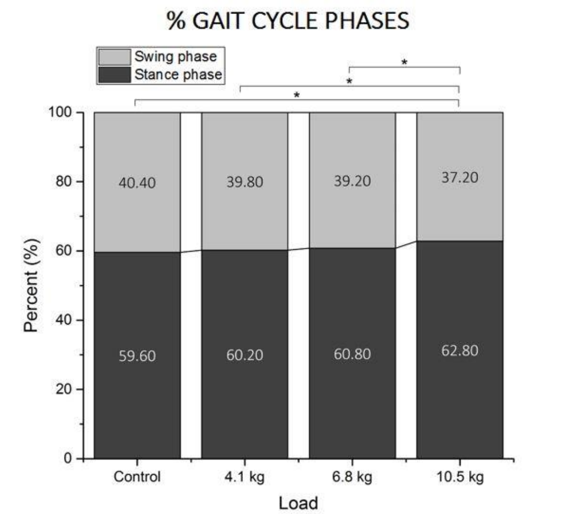

Fig. 5 Percentage of gait cycle during the four load-carriage conditions.

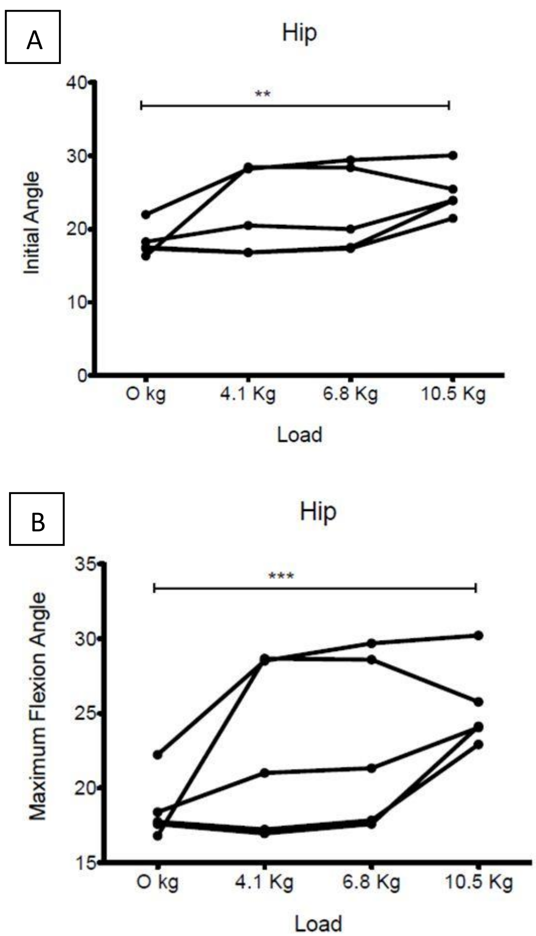

Fig. 6 Statistical comparison for hip angles during the four load-carriage conditions.

IV. Discusion

For this study we decided to take in account these three loads: 4.1 kg, 6.8 kg and 10.5 kg. It is because they represent the most common cases bag's weight that college students carry during the university term. The first load represented a common day with a laptop and a book or notebook inside bag. The second one could be the weight of school bag in a project delivery day with two more books (that we had to give back to library) than the first case. Finally the third load represented a day at final season when school bags have more books, notebooks, folders, final deliveries and laptop, just for giving an example.

In general terms, along the gait cycle, knee flexion angles were decreased meanwhile the extension angles were increased.

In knee joint was observed a decrease in the flexion angle and an offset to the right side of the gait cycle, it means that the percentage of the stance phase was increased, therefore the swing phase was decreased.

For ankle joint, the mean gait cycle began under the neutral position, i.e. in plantar-flexion. Besides the pre-swing phase was increased at gait cycle percentage. For the test with the larger load, in general, an increase was presented at the dorsiflexion angle value.

For hip joint angle, in all cases, the value of the flexion was increased at the initial contact in order to keep the gravity center. In the hip joint angle, it is shown that the flexion angle was increased for all load-carriage conditions.

During the first half of the stance phase, an increase was observed in the knee flexion, it is due to act as protective measure by the body to absorb the impacts and reduce the risk of injury.

A leak in the proper hip extension causes a reduction of the opposite leg step. A limited hip extension modifies the alignments of the pelvis and thigh, producing anterior tilt of the pelvis, trunk and the knee bending to straighten the pelvis and trunk.

Figure 5 shows an increase in the percentage of stance phase with increasing the backpack weight that means than this phase was executed slowly with heavier load.

According to the statistical analysis there exists a significant difference in maximum flexion hip angle ($p < 0.001$), like it happens in initial hip angle ($p < 0.01$), when load carriage is heavier. It is showed in figure 6.

Unfortunately mostly college population is not informed or is not interested in how bad using of load affect their health. Despite every day there exist improvements in design and comfort in backpacks, the selling of backpacks is still more influenced by fashion than by ergonomics.

V. CONCLUSIONS

The observed changes in ankle joint and hip joint kinematics, as well as increase in percentage of stance phase of gait cycle in tests with heavier loads are consistent with results in [13]. In both studies, participants had similar age and they walked with loads which represents 15% of their body mass.

The hip joint angle it is mostly affected from the effects of the 10.5 kg load. The angle is gradually changing to keep stable the gravity center and reduce the energy consumption. When the heel touches the floor, the increase of the flexion angle enlarges the damping between the heel and the sole. In general, we can see that in cases with very heavy loads, the hip dispenses of the extension. It sounds logical to think that becomes natural to walk curved performing a greater effort in the abdominal muscles especially the abdominal rectus to keep the gravity center.

This pilot study gives good results which are consistent with previous researches, but now studying a lost population: college students. This study could be improve using others devices as a force platform; obtaining physiological parameters like energy cost; or measuring time-space variables as cadence.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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