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The Postural Effect of Different Types of Load Carriage in Walking Gait

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Abstract— **College students carry their bag to attend class every day, mainly using backpack or sling bag. Heavy load carriage may affect body posture, and prolonged load carriage may cause permanent postural change and gait alteration. This study aims to identify the effect of different load carriage styles on the walking gait. Twelve female college students performed normal walking while carrying 5%, 10% and 15% of load in backpack and sling bag. Paired sample t-test with an alpha level of 0.05 were used to compare the normalized data. The result revealed that load carriage will significantly alter the trunk posture. Backpack carriage will significantly increase the truck inclination angle while sling bag carriage significantly increase the trunk lateral bend angle. Load carriage also caused significant changes in pelvis orientation, sling bag load carriage significantly reduce the pelvis tilt and obliquity, while backpack significantly reduce the pelvis obliquity, even with only 5% of body weight load carriage. Hence, prolonged load carriage shall be avoided to prevent postural alteration.**

Keywords—Load carriage, backpack, sling bag, walking gait.

I. Introduction

A load carrying system is necessary for college students to transport their heavy books and stationery to attend classes. A common problem faced was the weight of the bag. This can affect the posture of the bag users [1-4] and cause permanent postural change which leads to back problems [5] in the long run. Gait alteration can also occur when compensatory pelvic motions occur due to the heavy load [3, 6, 7]. Hence, injuries in the orthopaedic, musculoskeletal, and even soft tissue are common in heavy bag users.

Past studies were mostly focus on the effect of wearing a backpack on adults [4, 8, 9], children [2, 3, 10] or military personnels [1]. Studies which incorporated the use of sling bags are limited. Thus, comparison between backpack and sling bag load carriage also has no conclusive answer.

The purpose of this study was to identify the effect of different load carriage methods on the walking gait in combination with different weight of load carriage and types of bags used. In this study, the biomechanical changes in posture and gait with different types of load carriage during walking were being investigated.

In this current study, the backpack and sling bag were used. Backpack and sling bag were chosen as they are the type of bags widely used by college students which have a significant effect on the trunk bend and inclination angle according to that of the past studies. [1-3] The weight of the bags is being set at 0% (baseline), 5%, 10% and 15% of the subject's body to ensure that the loads are specifically tailored to each subject's weight while being able to prove the results from the previous studies.

II. Methodology

A. Subject

The targeted population for this research were healthy local college students, twelve female students been recruited, and their anthropometry data was shown in Table I. This study will only focus on female students as males and females had significant different in pelvis anatomy as well as physiology [11]. The subjects were to be excluded from the study if they suffered from any injury or pain in their back, neck, arm, and leg which can affect the subject's walking posture within the past 12 months. Participation of subjects was on a voluntary basis. Signed consent form was obtained from all the subjects. The study has been ethically approved by the Institute's Scientific and Ethical Review Committee, U/SERC/175/2022.

B. Selection of Bag

Two types of bags were selected for this experiment, based on the common selection of college students. Laptop backpack and sling bag have been selected as shown in Fig. 1. The dimension and weight of the bag were shown in Table II.

(a) (b)

Figure 1. Bag use for study (a) laptop bag, (b) sling bag.

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TABLE I. ANTHROPOMETRY DATA (N=12)

Parameter	Mean ± Standard Deviation
Age (years)	22.17 ± 1.70
Body Weight (kg)	47.50 ± 2.65
Body Height (m)	1.56 ± 0.06
Leg Length (m)	0.94 ± 0.04

TABLE II. MEASUREMENTS FOR BAGS

Type of bag	Length (mm)	Width (mm)	Height (mm)	Weight (kg)
Laptop backpack	430	290	890	0.5
Sling bag	400	120	300	0.4

C. *Experimental study*

Basic anthropometric data such as body weight, height and length of lower limb were measured and recorded. Colour tape markers were attached to the upper body joints and lower extremity joints to calculate the sagittal and frontal plane joint angles. BTS G-WALK ® sensor was attached to the spinal L5 to study the dysfunctional human movement, as shown in Fig. 2 - 3. Video was recorded from right sagittal plane and frontal plane throughout the experiments.

Subjects were required to walk at their preferred speed on force plate embedded treadmill (H/P Cosmos Instrumented Treadmill, TLA10004681). Subjects were given some time to familiarized themselves on the treadmill, helping them to achieve normal walking gait. 30 seconds of gait data will be recorded using treadmill while the BTS G-WALK ® sensor system will record the kinematic data of the whole walking process. Two trials of data are collected for each condition. Each subject is required to walk on the treadmill with backpack and sling bag weighting 0%, 5%, 10% and 15% of their body weight (BW). The sequence of the condition is randomized and adequate rest time is given to prevent fatigue.

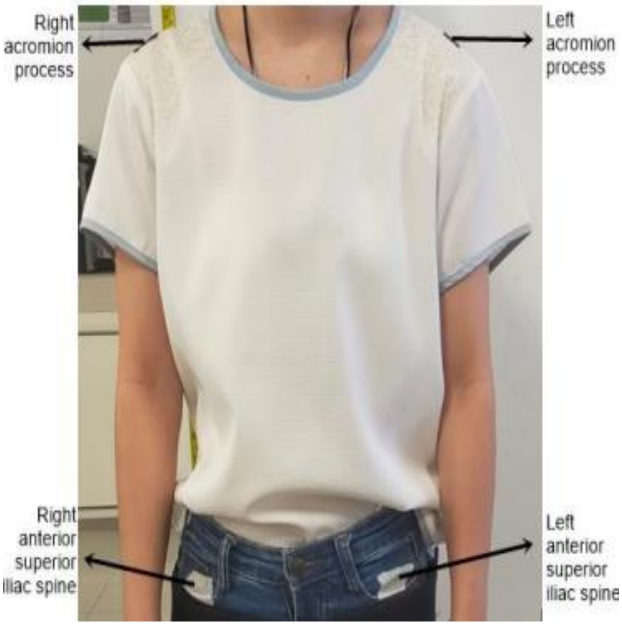

Figure 2. Placement of markers (Frontal view).

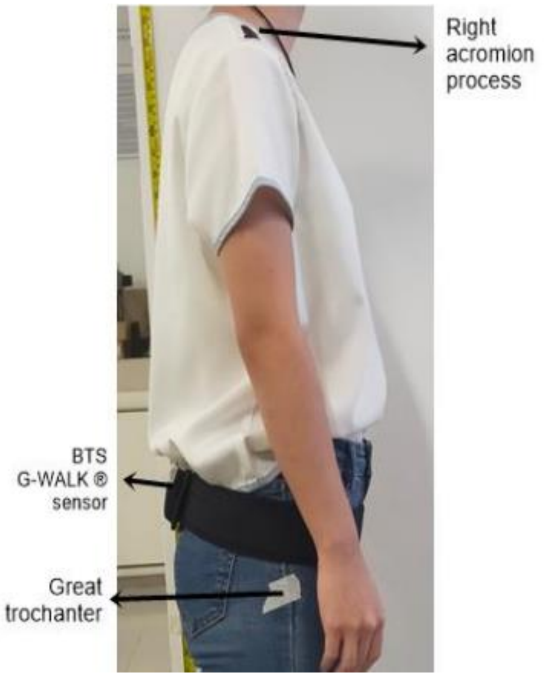

Figure 3. Placement of markers and BTS G-walk ® Sensor. (Sagital view)

D. *Data Analysis*

Data recorded by the treadmill were normalized by the anthropometry data of each subject to reduce bias [12], as shown in Table III. Lateral trunk bend angle and trunk inclination angle are determined using Kinovea, as shown in Figure 3. Statistical analysis was performed with SPSS (IBM Corp. Released 2019. IBM SPSS Statistics for Windows, Version 26.0. Armonk, NY: IBM Corp), paired sample t-test with alpha level of 0.05 is used to compare between the groups.

TABLE III. ANTHROPOMETRY DATA

Parameter	Normalise data
Step Length, l_{step}	$\hat{l}_{step} = \frac{l}{l_o}$
Stride Length, l_{stride}	$\hat{l}_{stride} = \frac{l}{l_o}$
Cadence, c	$\hat{c} = \frac{c}{60\sqrt{g/l_o}}$
VGRF, F	$F = \frac{F}{m_{body} \times g}$

Figure 4. Determination of lateral trunk bend angle (left) and trunk inclination angle (right) using Kinovea, based on the markers placed.

TABLE IV. KINETIC AND KINEMATIC DATA

Load	Bag	Trunk inclination angle	Lateral trunk bend angle	Maximum VGRF	Cadence	Step length	Stride Length	Pelvic tilt angle	Pelvic obliquity angle	Pelvic rotation angle
No load		3.17 ± 1.41	0.65 ± 0.50	1.02 ± 0.19	4.22 ± 0.30	0.69 ± 0.06	1.11 ± 0.08	5.57 ± 0.87	6.61 ± 1.23	7.17 ± 1.61
5% of BW	BP	5.03 ± 0.74[a,b]	0.22 ± 0.15[b]	1.12 ± 0.18	4.17 ± 0.36	0.64 ± 0.06	1.18 ± 0.10[a]	6.37 ± 0.99[b]	5.73 ± 0.89[a]	8.25 ± 2.43
	SB	0.93 ± 1.04	2.43 ± 1.44[a]	1.00 ± 0.14	3.95 ± 0.30	0.66 ± 0.16	1.24 ± 0.19	5.35 ± 1.08	5.78 ± 1.08[a]	7.08 ± 1.49
10% of BW	BP	5.68 ± 0.20[a,b]	0.23 ± 0.20[b]	1.15 ± 0.30	4.03 ± 0.22	0.62 ± 0.05	1.21 ± 0.08	5.81 ± 1.26[b]	5.17 ± 1.04[a]	7.50 ± 2.22
	SB	0.76 ± 0.84	4.18 ± 1.96[a]	1.05 ± 0.22	4.18 ± 0.46	0.64 ± 0.10	1.13 ± 0.17	4.55 ± 0.91[a]	5.92 ± 1.28[a]	7.06 ± 1.26
15% of BW	BP	6.83 ± 0.43[a,b]	0.22 ± 0.23[b]	1.10 ± 0.23	3.99 ± 0.33[a]	0.60 ± 0.04	1.16 ± 0.08[b]	5.64 ± 1.01[b]	4.45 ± 1.50[a,b]	6.47 ± 2.66
	SB	0.85 ± 0.79	6.36 ± 2.55[a]	1.03 ± 0.18	3.96 ± 0.23[a]	0.60 ± 0.07	1.06 ± 0.01	4.00 ± 0.97[a]	5.75 ± 1.11[a]	7.03 ± 1.08

Mean ± SD. BW = body weight, BP = backpack, SB = sling bag, a: Significant with p<.05 compare with baseline, b: significant with p<.05 compare with sling bag

III. RESULTS & DISCUSSIONS

Kinetic and kinematic data of the experiment has been summarized in Table IV.

The trunk angle is affected with load carriage. Trunk inclination angle for backpack was observed to have significantly increase as the weight of the backpack increases, which tallies to the previous study [1-3]. Sling bag load carriages do not alter the trunk inclination angle, but it significantly caused the increment of lateral bend angle, where similar finding also been reported by previous studies [6, 13]. Previous studies proposed that load should not exceed 10% of the carrier BW to avoid excessive spinal tilt [14, 15], however, result of this study shows that even load carriage as low as 5% of BW is significantly increase the trunk bending angle either in frontal plane or sagittal plane, when compare with the habitual posture. Prolonged loading may lead to a change of body orientation, that may cause the alteration of spinal curve, where changes in the spinal curve results in postural deformities like scoliosis or kyphosis. Therefore, prolonged load carriage shall be avoided to prevent injury.

Our previous study had suggested that load carriage do not influence the walking VGRF and spatiotemporal data, include step length, stride length and cadence [16]. Once again, current study also reports little to no difference in the result for both backpack and sling bag on VGRF and spatiotemporal data. This may be due to the load carriage is below 20% of BW, thus the effect of additional load is negligible, similar finding also reported from other studies [9, 17].

Load carriage shows a more significant effect on pelvic orientation than kinetic and kinematic parameters. In the sagittal plane, backpack load carriage shows higher tilt angle than baseline, while sling bag had significant decrease the tilt angle with 10% of BW load carriage ($t = 3.427$, $p = .006$) and 15% of BW load carriage ($t = 4.953$, $p < .001$), as such there shows significant different found between backpack and sling bag in all load carriage condition(5% BW $t = 4.052$, $p = .002$, 10% BW $t = 3.646$, $p = .004$, 15% BW $t = 4.886$, $p < .001$). In frontal plane, both backpack and sling bag load carriage had significantly reduced the obliquity angle (backpack 5% BW $t = 2.669$, $p = .022$, 10% BW $t = 3.200$, $p = .008$, 15% BW $t = 3.650$, $p = .004$; sling bag 5% BW $t = 2.611$, $p = .024$, 10% BW $t = 3.315$, $p = .007$, 15% BW $t = 4.363$, $p = .001$). Even though there is no significant changes have been found in the transverse plane, but generally, backpack increased the rotation angle, but sling bag reduce the rotation angle.

There are several studies had conducted to determine the effect of load carriage on pelvic orientation, and backpack load carriage had reported to increase the tilt angle [18, 19] and reduce the obliquity and rotation angle [19], which is tally with current finding. However, there is no study that had been conducted on sling bag load carriage, but an experiment by Lim et. al. using side load carriage also suggested that side load carriage able to decrease the pelvic sway in transverse plane [20].

Motions of the pelvis during walking gait help to decrease the movement of the center of mass in the vertical and horizontal direction [21]. Alteration of these movements may cause the compensation of other body parts and thus leads to certain medical conditions such as low back pain, weak muscle, poor postural habits etc.

The present study may provide fundamental information to the public on the effect of load carriage on postural, especially trunk and pelvic orientation.

There are few limitations in current study. Small sample size, single gender with same age group unable to represent other populations. The load carriage alters the walking gait and pelvic orientation, but this study does not include the investigation on muscle activities, which may be important to observe the body adaptation for the posture alteration. The study also does not investigate the trunk-pelvis coordination as trunk and pelvic represent the core for human body.

Further investigation should be carried out to increase the sample size and investigate the correlation between trunk-pelvis coordination.

IV. Conclusion

The effect of different load carriage styles on the walking posture in combination with different weight of load carriage and types of bags used has been investigated. Load carriage using backpack or sling bag will significantly affect the trunk posture, even as low as 5% of carrier's body weight load carriage. Hene prolonged load carriage shall be avoided to prevent postural injury.

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