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The effect of different backpack loading systems on trunk forward lean angle during walking among college students

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ABSTRACT

The purpose of this study was to evaluate the effect of different backpack loading systems on trunk forward lean angle during walking among college students. Twenty six students (age 22.41 years) participated in three test sections in three different days. Trunk Forward Lean angle was examined in seven phases of walking with three different conditions (unloaded walking, walking with normal backpack and walking with counterbalance backpack). Participants after 10 min warm-up walked 10 min on the treadmill in different days and different conditions. To analyze the data for trunk forward lean angle in seven phases of walking with three different conditions using a Multivariate Analysis of Variance (MANOVA). A significance level was p<.05 for this analysis. The post hoc test adjustment was then carried out to confirm the significant differences. The results indicated that unloaded walking condition with counterbalance backpack condition and the normal backpack condition differed significantly (p<.05), but there is no significant difference in phase MSW between without backpack and counterbalance backpack conditions. Finding of this study clearly showed the advantage of counterbalance backpack. According to finding of this study the counterbalance backpack allows person to upright position, by shifting the center of gravity of the load forward.

Keyword: Injuries, Counterbalance, Trunk Forward Lean, Walking.

INTRODUCTION

Backpacks are used every day by so many of people for carrying different loads. Carrying heavy loads for long distances is usual with students, military personal, recreational hikers and various types of workers. Knapik, Harman, and Reynolds (1996) have shown that fifty percent of soldiers tasked with a challenging 20-km march not able to completing it due to back and other problems. Condition of backpack is important [1]. Kinoshita (1985) indicated that the positioning of the backpack can destabilize the trunk and force it backwards and hikers normally compensate with forward trunk incline of 6 to 11° [2]. Such a load condition is a constraint and makes it difficult or impossible to retrieve the contents of their backpack during walking. In general, few backpack designs allow for easy movement of their contents to the front.

The various types of backpacks were designed for different load and various specific purposes but most of them can be worn without discomfort. Some studies by various researchers have revealed that the size of the external load determines the extent of the forces experienced by the wearer's joints. This is particularly evident in walking in unpredictable ground [3, 4]. Fergenbaum (2007) indicated that design features of backpacks and shoulder straps play a part in contributing to upper body injury [5]. On the other hand, other investigations have indicated that such upper body injuries are due to carrying heavy backpack loads on long journeys over unfamiliar terrain [6, 7].

The walking phases includes all of the events that occur between two like actions in the cycle, and many researchers choose to analyze the events between when the left heel makes initial contact with the ground and when the left heel next makes contact with the ground. The walking phases have two major phases: the stance phase and the swing phase; and the phases is further broken into seven distinct events [8].

The position of backpack also influences certain aspects of walking, for example, locating the load mass closer to the body center of gravity leads to lower energy expenditure during wearing a backpack. When a double pack is used, the load distributed equally to the front and back of the body results in reduced energy expenditure compared to using a backpack [7]. However, there has been little done on the comparison of different kind of backpack while walking on the treadmill. So this study intended that evaluate the effect of different backpack loading systems on trunk forward lean angle during walking among college students.

MATERIALS AND METHODS

Participants

Twenty six healthy (without any orthopedic disorder, lower limb injuries or cardiovascular problems) subjects participated in current study. The mean age of subjects was 22.41±1.75 years, height was 178 ±4.83 cm, and weight was 75±6.56 kilogram. Subjects were selected from population of college students. Participants were asked to come to the biomechanical laboratory on three different days. In each experimental day, each subject performed one trail to walk with one of the three different conditions. The order of the test was randomized for each participant.

Experimental procedure and data collection

Subjects were asked to come to the biomechanical laboratory and they were completed the consent form. After that the anthropometry data was recorded. This study was in three phases. On each experimental day, each subject after 10 min warm-up performed one of the three trails. Subjects were asked 10 min walked on the treadmill without any backpack. On the second day, subjects walked on the treadmill with normal backpack. On the third day students walked 10 min with new backpack which was counterbalance backpack (half the load on the front of the body and half the load on the back). The weight of the load was 20% of their body weight). Trunk Forward Lean (TFL) angle was measured during seven phases of walking: Loading Response (LR), Mid Stance (MS), Terminal Stance (TS), Pre swing (PS), Initial Swing (IS), Mid Swing (MSW) and Terminal Swing (TSW). Kinematic data were measured by motion analysis system. A 2-Dimention video system was used to record the locomotion of subjects as they crossed the filming zone. Light emitting diodes were positioned on the right side of the students on five anatomical landmarks. These anatomical landmarks including: 5th metatarsal, lateral maleolus, lateral part of the knee, greater trochanter, and lateral and middle part of trunk. A video camera (JVC, Japan) with 50 HZ filming rate and 1.125 s shuttle speeds was placed to the sagital plane of the student. The filming field of 10 second provided at least one phase of walking.

Data analysis

A multivariate analysis of variance (MANOVA) in SPSS was performed to test the effects of three conditions on Trunk Forward Lean (TFL) angle in seven phases of walking. Mean and standard deviation of the seven phases of walking were collected for all conditions (unloaded walking, walking with normal backpack, and walking with counterbalance backpack). To identify the significant effect, we used a Post-Hoc test and results were considered significant at $p < .05$.

RESULTS

The results of current study were shown that the subjects made the degree of TFL angle in phase 1 to phase 7 are (Mean =1.017, .558, .62, .7, 1.51, 3.414, 3.133) respectively. The results indicate that the decrease in the degree of TFL angle made between phase1 (LR) and phase 2 (MS), phase 2 (MS) and phase 3 (TS), phase 3 (TS) and phase 4 (PS), phase 4 (PS) and phase 5 (IS), phase 5 (IS) and phase 6 (MSW), phase 6 (MSW) and phase 7 (TSW) are different across the three conditions; the decrease is greatest for walking with the normal backpack condition, lowest for the walking without backpack condition and walking with counterbalance backpack condition for all phases of walking.

Table 1 The post hoc multiple comparisons for stance phase

Dependent Variable	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
LR (degree)	Normal Backpack	without Backpack	1.2808*	.00809	.000	1.2610	1.3007
		Counterbalance Backpack	1.0732*	.00809	.000	1.0533	1.0930
	Counterbalance Backpack	without Backpack	.2077*	.00809	.000	.1879	.2275
		Normal Backpack	-1.0732*	.00809	.000	-1.0930	-1.0533
MS (degree)	Normal Backpack	without Backpack	.9308*	.00507	.000	.9183	.9432
		Counterbalance Backpack	.7227*	.00507	.000	.7103	.7351
	Counterbalance Backpack	without Backpack	.2081*	.00507	.000	.1957	.2205
		Normal Backpack	-.7227*	.00507	.000	-.7351	-.7103
TS (degree)	Normal Backpack	without Backpack	1.0065*	.00431	.000	.9960	1.0171
		Counterbalance Backpack	.7004*	.00431	.000	.6898	.7109
	Counterbalance Backpack	without Backpack	.3062*	.00431	.000	.2956	.3167
		Normal Backpack	-.7004*	.00431	.000	-.7109	-.6898

**. The mean difference is significant at the .05 level.*

Table 2 The post hoc multiple comparisons for swing phase

Dependent Variable	(I) Condition	(J) Condition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
PS (degree)	Normal Backpack	without Backpack	1.4296*	.01398	.000	1.3954	1.4638
		Counterbalance Backpack	1.3204*	.01398	.000	1.2862	1.3546
	Counterbalance Backpack	without Backpack	.1092*	.01398	.000	.075	.1435
		Normal Backpack	-1.3204*	.01398	.000	-1.354	-1.2862
IS (degree)	Normal Backpack	without Backpack	1.9923*	.00375	.000	1.9831	2.0015
		Counterbalance Backpack	1.8800*	.00375	.000	1.8708	1.8892
	Counterbalance Backpack	without Backpack	.1123*	.00375	.000	.1031	.1215
		Normal Backpack	-1.8800*	.00375	.000	-1.8892	-1.8708
MSW (degree)	Normal Backpack	without Backpack	3.2920*	.00843	.000	3.2714	3.3126
		Counterbalance Backpack	3.2795*	.00843	.000	3.2588	3.3001
	Counterbalance Backpack	without Backpack	.0125	.00843	.423	-.0081	.0332
		Normal Backpack	-3.2795*	.00843	.000	-3.3001	-3.2588
TSW (degree)	Normal Backpack	without Backpack	2.6581*	.00514	.000	2.6455	2.6707
		Counterbalance Backpack	2.4438*	.00514	.000	2.4313	2.4564
	Counterbalance Backpack	without Backpack	.2142*	.00514	.000	.2016	.2268
		Normal Backpack	-2.4438*	.00514	.000	-2.4564	-2.4313

**. The mean difference is significant at the .05 level.*

The post hoc multiple comparisons test indicated that the without backpack condition with counterbalance backpack condition and the normal backpack condition differed significantly ($p<.05$), averaged across the six phases of walking (LR, MS, TS, PS, IS, and TSW), but in phase MSW, normal backpack condition with unloaded walking and counterbalance conditions differed significantly, but post hoc test indicated that there is no significant difference in MSW phase between unloaded walking and counterbalance condition (Table 1 and 2).

Figure 1 shows that there is a general decrease in the degree of TFL made across phase MSW to phase TSW for without backpack and normal backpack, but there is no change for counterbalance backpack. The rate of increase is greater for normal backpack condition from phase MSW to phase TSW than for the other phases.

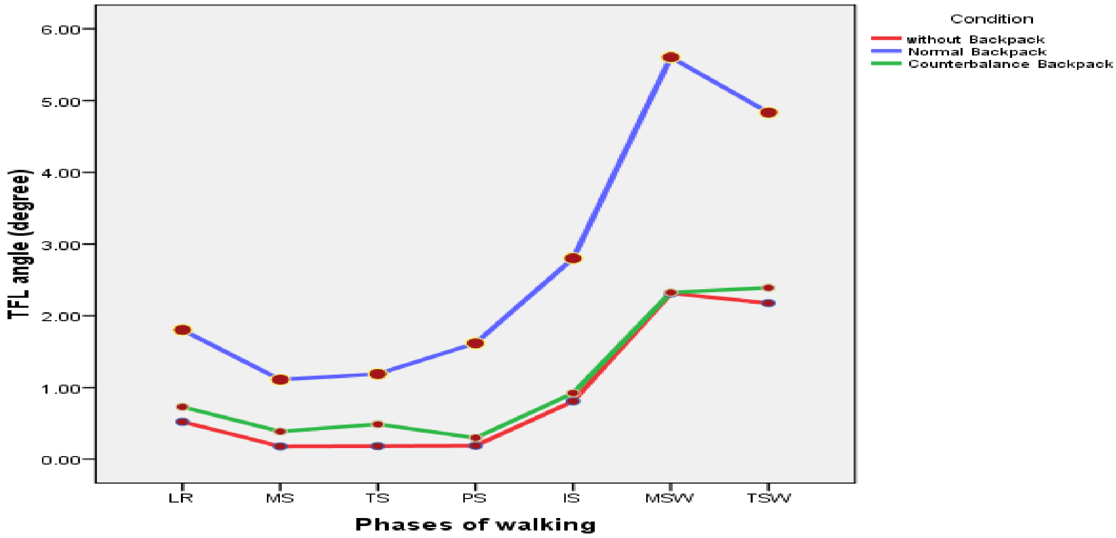

Figure 1 Means of TFL angle in three conditions and seven phases

DISCUSSION

Finding of current study indicated that, there is significant difference among TFL angle in seven phases (LR, MS, TS, PS, IS, TSW, MSW) of walking between unloaded walking and walking with normal backpack conditions. There is also significant difference among TFL angle in six phases (LR, MS, TS, PS, IS, TSW) of walking between walking without backpack and walking with counterbalance backpack, but there is no significant difference in Mid Swing (MSW) phase of walking between walking without backpack and walking with counterbalance backpack conditions. There is also no significant difference in Mid Swing (MSW) phase of walking between walking with normal backpack and walking with counterbalance backpack conditions. The greatest angle was in mid swing phases of walking for all three conditions. The lowest angle was for mid stance phases of walking for all conditions.
The results also showed significant increase (142.39%) for normal backpack condition as a compare with unloaded walking in MSW phase of walking. Comparison between counterbalance backpack condition and without backpack condition showed .56 percent increase. Finding of this study were agreement with finding by Bloom and Ann, (1987); Charteris, (1998); and Kinoshita, (1985) [2, 9, 10]. Carrying the load with normal backpack may be shifted the center of gravity. The trunk gets to increase the forward lean to keep the person in an upright, vertical position. Carrying the load with counterbalance backpack had an intermediate effect in increasing forward lean but was not significantly different from walking without backpack.

Some previous studies showed increases in forward lean when the person carried a backpack bilaterally. Kinoshita et al. (1985) found significant forward lean in participants who carried a backpack bilaterally weighing between 20% and 40% of body weight, and this is in agreement with the findings from current study [2]. Similar finding was reported by Bloom et al. (1987), AL-Khabbaz et al. (2008) [9, 11].

The results of current study indicated that the 20% body weight load which carried with normal backpack induced significant forward lean of trunk. The TFL angle would increase as the walking distance increased. The findings showed that the subjects counterbalanced the load on their back by shifting their trunk forward during usage normal backpack, and this is in agreement with the findings from investigations on children [12-14], and adults [2, 15-18].

CONCLUSION

Carrying a load with a backpack, students want to shift the center of gravity of the body and backpack system back to that of carrying a load without backpack condition. They will try to achieve this position by increase the forward lean angle. According to finding of this study the counterbalance backpack allows person to upright position, by shifting the center of gravity of the load forward. Finding of this study indicated the advantage of new backpack that was counterbalance backpack. When considering the kinematic and ergonomic of load carriage the counterbalance backpack has significant benefits. There are many areas of this study that can be further developed. The fatigue effects of prolonged walking with kind of backpacks should be examined. In this investigation, initial changes in walking patterns caused by load carriage in different conditions were measured. Students, mountain backpacker and soldiers carry backpacks for much longer durations, so fatigue effects on load carriage should be examined, especially the relationship between fatigue and biomechanical aspects and injuries.

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