LOADED BACKPACK POSITIONS AFFECTS TRUNK POSITION DURING WALKING

Donald H Sussman, PhD[1], Martha Walker, MS, PT[2], Michael Tamburello, PhD[2], Bonnie VanLunen, PhD[1], Elizabeth A Dowling, PhD[1], Kelly R. Campbell[3], Joseph D. Flores[3], Rasha A. Ibrahimb[3], Eleanor A. Larson[3]
[1]Exercise Science Program, [2]Program in Physical Therapy, [3]Physical Therapy Student, Old Dominion University

The effects of backpack loading on lower extremity function was examined. Ten subjects were prepared with a 20 3D-reflective marker set, videotaped by a 4-camera setup, on a level treadmill in four conditions: without backpack (WO), one-strap on right shoulder (1SR), two-strap on back (2SB), and two strap on front (2SF). The videotape was digitized. Significant differences ($p \leq 0.05$) were found for: head tilt between WO ($1.65^0 \pm 0.61$) compared to 1SR ($2.69^0 \pm 0.87$); forward trunk lean between WO ($7.12^0 \pm 2.16$) compared to the mean of all backpack positions ($4.26^0+1.81$) and lateral trunk lean between WO ($7.22^0 \pm 2.01$) compared to the mean of all backpack positions ($3.90^0 \pm 1.54$). Backpack loading in most any position may require the stretching and strengthening of muscles affected by kinematic changes caused by wearing a loaded backpack.

KEY WORDS: load-bearing, backpack, kinematics, gait

INTRODUCTION: Most of the research on backpacks has focused on adult use for recreational hiking, industrial applications, or carrying of loads by military soldiers. Previous investigations have examined the effects of carrying a backpack on such variables such as oxygen cost (Bloom & Woodhull-McNeal, 1987, Bobet & Norman, 1984, Chartens, 1998 and Cymerman, Pandolf, Young & Maher, 1981), walking kinematics (Epstein, Rosenblum, Burnstein & Sawka, 1988), EMG activity (Epstein, Stroschein & Pandolf, 1987 and Evans, Zerib, Faria & Monod, 1983), and posture and the gait cycle (Kirk & Schneider, 1992).

College students carry their books and school materials using some type of backpack. One study (Pascoe, Pascoe, Wang, Shim & Kim, 1997) investigated the impact which carrying backpacks has on the gait cycle among youths aged 11-13 years. That study detailed the effects that different backpack positions (without a backpack, one-strap on the back, two-straps on the back, and one-strap across the body) had on the gait cycle and posture. It was concluded that one-strap bags (on the back and across the body) promoted lateral spinal bending and shoulder elevation, while the two-strap on the back, backpack position significantly reduced these carrying stresses. It was also found that carrying a backpack (either one-strap or two-strap) promoted significant forward lean of the head and trunk as compared to without a backpack and one-strap across the body.

No biomechanical investigations, have studied the gait characteristics in adult populations. Information is available concerning the rigors and stresses related to competitive athletics, training, and weight-resistive exercises for adults. However, the use of backpacks may represent an overlooked daily physical stress. Therefore, the purpose of this investigation was to determine the impact of different methods of carrying backpacks on gait characteristics of college students aged 20 - 40 years.

METHODS: Approval of this study was obtained from a University Human Subjects Institutional Review Board. The subjects read and signed the approved informed consent document prior to volunteering to participate in this investigation. This study consisted of a three-phases. Phase 1: The types and weights of bags of fifty randomly selected college students were measured using a digital scale. The bags were weighed as the students went to class in order to reflect a true average weight that was normally carried and not a measure of the extreme. For example, a student going to study at the library will carry more books than normal, thus increasing the weight of their backpack. Twenty-five backpacks were weighed at the University's Physical Sciences Building and the second set of twenty-five were weighed at the Humanities Building to obtain a cross-sectional sample of college students. To keep qualifying characteristics consistent, every tenth student who was carrying a backpack had their type of bag and bag weight recorded. The fifty weights were then averaged to obtain an average weight of 13 pounds, which was used in phase two of the study. Phase 2: This phase of the investigation involved the videotaping of the ten subjects in the University's Physical Therapy Motion Analysis Laboratory. Each subject read and signed the informed consent document and filled out a questionnaire to determine their eligibility for this study. Demographic characteristics such as age, height, and weight were then recorded. Each subject wore a black head-band, a black shirt, black stretch pants, and black socks worn over their normal walking shoes, which were specially fitted with Velcro™ straps to secure the reflective markers. The markers were placed bilaterally in the following locations: 1 cm above the ears at the temporal line, acromion process, humeral lateral epicondyle, between the ulnar and radial styloid processes on the dorsal side, ASIS, greater trochanter, lateral epicondyle (knee), lateral malleolus, heel, and 5th metatarsal head. The reflective markers represented the bony prominences used as landmarks in goniometric measurements to record and calculate specific angles incurred during gait. Subjects participated in four trial conditions on a level treadmill: without backpack (WO) which served as a control, one-strap on right shoulder (1SR), two-strap on back (2SB), and two-strap on front (2SF). The order of these conditions were counterbalanced in order to avoid any type of learning bias that may occur. The subject first warmed up for two minutes on the treadmill at a speed that was comfortable to them in order to accustom the subject to walking on a treadmill. After the two-minute warmup on the treadmill, 50 steps were videotaped for future analysis. The subject was then allowed to rest for one minute before the next test condition commenced. These procedures were repeated until all four conditions were met completed. Phase 3: The videotape was then processed through the PEAK Motus2000 motion measurement software system. Five complete gait cycles were captured from the 4 cameras by the PEAK Motus2000 software and saved as AVI files. These AVI files were then digitized using the PEAK Motus2000 automatic digitizing module. Subsequently, the X-Y coordinates were filtered and splined in order to generate the limb position data required for analysis in this study. Statistical Analysis: The effects of the experimental conditions (WO, 1S, 2SB, and 2SF) on selected kinematic dependent variables were analyzed using a Fixed Effects ANOVA with the significance level set as $p \leq 0.05$. When significance was observed, a Tukey *post hoc* test identified the specific mean trial differences.

RESULTS AND DISCUSSION: The survey portion of the procedure provided descriptive characteristics including how the subjects carried their books and supplies, whether they carried their bag the same way all the time, on which side of their body they carried their bag, any problems associated with carrying their backpack, and how heavy they considered their average load to be. The two-strapped backpack was more popular (75%) than the mailbag (25%). The backpacks were more often carried over one shoulder on the right (75%) than over both shoulders on the back (25%). Most of the subjects stated that they carried their bags on the same side consistently (75%) with 25% varying the way they carried their bag. The majority of the subjects (50%) described their bags as medium weight, 25% as lightweight, and 25% as heavy. The most commonly reported physical symptoms were muscle soreness (50%), followed by back pain (25%), numbness (13%), and occasional discomfort (13% specified in the OTHER category on the survey).

Significant differences were found for head tilt (p=0.035), forward lean (p=0.004), and lateral lean (p=0.002). The post hoc test showed that for head tilt, significant differences were found between WO and 1SR (p=0.015). It should be noted that although 2SB and 2SF showed a large range difference, these findings were not significant because they fall outside the standard deviation, and are therefore not reliable. Significant differences were found for forward trunk lean between WO and 2SB (p=0.012) as well as between 2SF and 2SB (p=0.031) which are comparable to the results found by Pascoe et al. (1997). Lastly, significant differences were noted for lateral trunk lean between WO and 2SF (p=0.020), WO and 2SB (p=0.014), and WO and 1SR (p=0.009) which are also comparable to the results of Pascoe et al. (1997). The range of head tilt angles increased with the backpack on the right shoulder as compared to the control. This is thought to have occurred in order to compensate for the weight of the backpack in order to maintain equilibrium. Forward lean angle ranges decreased with the backpack on the back as compared to the control and chest positions. This is primarily due to the weight and position of the bag on the individual. Lateral lean angle ranges decreased with the backpack on the chest and right shoulder positions and increased with the backpack on the back as compared to the control angle ranges. The decrease in angles is due to the necessary compensation of the backpack weight for equilibrium maintenance. The increase is, once again, primarily due to the weight and position of the backpack. These results promote the primary hypothesis that significant gait characteristics change with a loaded backpack as compared to without a backpack (control).

Table 1 Significant t-test and Means for WO Compared to 1SR, 2SB and 2SF for Head Tilt, Forward Lean and Lateral Tilt

Dependent Variable		Mean (degrees)	SD
Head Tilt	WO	1.65	0.62
	1SR	2.69[a]	0.87
	2SB	2.19	1.22
	2SF	2.01	0.95
Forward Lean	WO	7.12	2.16
	1SR	3.15	3.91
	2SB	4.13[a]	2.58
	2SF	4.76[b]	1.30
Lateral Lean			
	WO	6.39	1.11
	1SR	4.83[a]	1.09
	2SB	6.41[a]	0.97
	2SF	3.48[a]	1.21

[a]Significant difference with WO backpack carrying position ($p < 0.05$)
[b]Significant difference between 2SB and 2SF backpack carrying positions ($p < 0.05$)

CONCLUSIONS: These findings can be applied to physical therapy practice in a number of ways. With many individuals returning to college after having been in another career, the age of a “student” is now unpredictable. It is important to remember this when taking the history of patients that may be complaining of back, shoulder, or neck pain. These patients should be asked if they carry a backpack and in what position. This information may help in guiding a therapist with a clinical diagnosis. Also, knowing which target muscles are being stressed the most, a therapist can instruct the patient in stretching and strengthening these muscles to complement the deviations present in their gait. Gait characteristic changes will also be important to remember when gait training an individual that utilizes a backpack. Most importantly, these findings can be expressed when educating patients on proper backpack positioning and posture training. Future studies may investigate EMG activity in the lower and upper extremity as a function of backpack position.

REFERENCES:

Bloom, D. and Woodhull-McNeal, A.P. (1987) Postural adjustments while standing with two types of loaded backpack. *Ergonomics*, **30**, 1425-1430.
Bobet, J. and Norman, R. (1984) Effects of load placement on back muscle activity in load carriage. *European Journal of Applied Physiology*, **53**, 71-75.
Chartens, J. (1998) Comparison of effects of backpack loading and of walking speed on foot-floor contact patterns. *Ergonomics*, **41**, 1792-1809.

Cymerman, A., Pandolf, K., Young, A. and Maher, J. (1981) Energy expenditure during load carriage at high altitude. *Journal of Applied Physiology*, **51**, 14-18.
Epstein, Y., Rosenblum, J., Burnstein, R., and Sawka, M.N. (1988) External load can alter the energy cost of prolonged exercise. *European Journal of Applied Physiology*, **57**, 243-247.
Epstein, Y. Stroschein, L. and Pandolf, K. (1987) Predicting metabolic cost of running with and withoutbackpack loads. *European Journal of Applied Physiology,* **56**, 495-500.
Evans, O.M., Zerib, Y., Faria, M.H., and Monod, H. (1983) Physiological responses to load holding and load carriage. *Ergonomics*, **26**, 161-173.
Haisman, M.F. (1988) Determinants of load carrying ability. *Ergonomics*, **19**, 111- 121.
Holewijn, M. (1990) Physiological strain due to load carrying. *European Journal of Applied Physiology*, **61**, 237-245.
Kirk, J. and Schneider, D. (1992) Physiological and perceptual responses to load-carrying in female subjects using internal and external frame backpacks. *Ergonomics*, **35** (4), 445-455.
Pascoe, D.D., Pascoe D.E., Wang, Y., Shim, D., and Kim, C. (1997) Influence of carrying book bags on gait cycle and posture of youths. *Ergonomics*, **40**, 631-641.