Effects of backpacks on students: Measurement of cervical and shoulder posture

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The aims of this pilot study were to determine whether the weight of a backpack, its position on the spine or time carried affected adolescents' cervical and shoulder posture. Standing posture measured from the sagittal and frontal planes of 13 students was recorded photographically under several load carrying conditions. Cervical and shoulder position angles were calculated and compared. Results revealed that both backpack weight and time carried influenced cervical and shoulder posture. Forward head posture increased when carrying a backpack, especially one with a heavy load. Carrying a backpack weighing 15% of body weight appeared to be too heavy to maintain standing posture for adolescents. These findings have implications for future load carrying studies in adolescents. **[Chansirinukor W, Wilson D, Grimmer K and Dansie B (2001): Effects of backpacks on students: Measurement of cervical and shoulder posture. *Australian Journal of Physiotherapy* 47: 110-116]**

Key words: Adolescence; Back; Posture; Students

Introduction

The backpack is one of several forms of manual load carriage that provides versatility and is often used by hikers, backpackers and soldiers, as well as school students (Knapik et al 1996). The backpack is an appropriate way to load the spine closely and symmetrically, whilst maintaining stability (Knapik et al 1996, Voll and Klimt 1977). However, musculoskeletal problems associated with backpack use have become an increasing concern with school children (Troussier et al 1994). The combined effects of heavy loads, position of the load on the body, size and shape of the load, load distribution, time spent carrying, physical characteristics and physical condition of the individual were hypothesised as factors which were associated with these problems (Haisman 1988, Knapik et al 1996). Past research shows numerous attempts to study the effects of these factors on the health and safety of adult carriers. The maximal loads recommended from these early studies varied, from 25% to 40% of body weight (Haisman 1988). The author also suggested that load requirements for adult females should be lower than adult males to account for physiological and biomechanical differences (Haisman 1988). Most of the studies on the effect of load carriage have focused on small numbers of soldiers and hikers with the purpose of improving the techniques of load carriage. Information derived from these studies might not apply to high school students. High school students are adolescents who experience a period of accelerated growth and development of skeletal and soft tissue (Parfitt 1994). Their spinal structures are thus markedly different from those of adults. As growth of the spinal structures extends over a longer period of time than the other skeletal tissues, incongruities in rate of tissue development can pose a threat to postural integrity (Junghanns 1990). Moreover, external forces such as load carrying may also influence the growth, development and maintenance of the alignment of the human body (LeVeau and Bernhardt 1984). Consequently, posture in adolescents can be affected by both internal and external influences, which may make adolescents more susceptible to injury.

Few researchers have focused on the impact of load carriage on high school students. Ruscoe (1989) investigated the effects of modes of carrying the school bag, weight of bag, carriage time and year level of students on spinal asymmetry and shoulder obliquity in students aged 10 to 17 years. The lateral deviation of the spine was assessed by a scoliometer, while the inclination of the shoulders was evaluated by a goniometer. The results showed no effect on spinal asymmetry from carrying methods, school level, weight of bags and carrying time whereas the first two variables influenced shoulder posture. However, this author measured spinal posture whilst unloaded, and thus spinal deviation might have been a result of habitual load carriage or other unmeasured factors. No information was provided on immediate head-on-neck postural response to loading.

The most recent study was by Pascoe et al (1997) who used a video camera and computer digitising system to investigate the effect of different methods of carrying school bags on gait and postural changes in 10 students aged 11 to 13 years. The authors measured shoulder and spinal angles in a static standing, as well as head angle, trunk angle, head range and trunk range in dynamic conditions. Different methods of carrying the backpack included carrying it over one and both shoulders. The results in a static position showed an increased forward head position and shoulder elevation when comparing unloaded posture with carrying a unilateral load. It was found that the trunk also assumed a forward lean posture in order to counterbalance the load. None of these authors studied the position of the head on the neck or the neck on the thorax. Studying response of these positions to load is important because changes in alignment of the neck can produce strain of cervical joints and soft tissue as well as imbalanced muscle performance. This can cause pain in cervical, upper thoracic and shoulder regions (Mannheimer and Rosenthal 1991).

This pilot study assessed the impact on posture of backpack load carrying, including the weight of the backpack and time carried. The aims of the study were:

- To determine whether, in a pilot group of high school students, cervical and shoulder posture changed when carrying a backpack compared with their posture without a backpack (weight in backpack not standardised).
- To determine whether 15% of body weight in a backpack carried over both shoulders produced changes in cervical and shoulder posture, compared with ‘unloaded’ posture.
- To determine whether carrying the backpack unilaterally (over the right shoulder) altered cervical and shoulder posture.
- To determine whether the time the load was carried altered cervical and shoulder posture.

Method

Subjects Six female and seven male high school students, aged between 13 and 16 years voluntarily participated in the pilot study. Informed consent was obtained from each subject and their parents prior to the study. The study was approved by the Ethics Committee of the University of South Australia.

Load carrying variations In order to assess the effect of increased load on posture, 15% of body weight was employed for maximal load. This proportion of body weight was based on the inferences of previous studies. Pascoe et al (1997) have shown that children aged 11-13 years have an increased forward lean posture when carrying 17% of body weight, implying that such a weight may represent an overload for this age group of children. Voll and Klimt (1977) recommended that a student’s bag should not exceed 10% of body weight. It is likely that the amount of weight the students are able to carry and maintain their normal postural alignment is between 10% and 17% of the student’s body weight. Moreover, the amount of weight that does not change the student’s posture might imply a recommended maximum weight of backpack students should carry. However the appropriateness of this recommendation has not been tested.

Static and dynamic conditions In this study, postural changes in both static and dynamic conditions were measured from body landmarks on serial photographs. To test the effect of load carriage on dynamic posture, posture after walking at the subject’s normal speed for five minutes with a load was photographed. A continuous 5min walk was used to be representative of the time students carried backpacks between classes during the school day. Slide photographs were used and were digitised for all aspects of this study using the Easy Digit™ Analytical Computer Graphics Digitizer Software program[a] This technique is reported to provide accurate postural information (D´Angelo et al 1987).

Subject descriptors Prior to data collection, measurements of height (cm), weight (kg), and weight of the school bag were recorded (details in Table 1). Height was measured using a physician’s scale. Student weight and weight of the school bag were measured using a Mettler TE 120[b] digital scale, measuring to 0.01 kilograms.

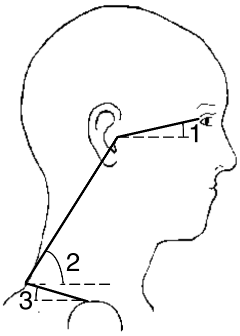

Figure 1. The craniohorizontal (1) and craniovertebral (2) angles, and sagittal shoulder posture (3). (Adapted from Raine and Twomey 1994, p. 26).

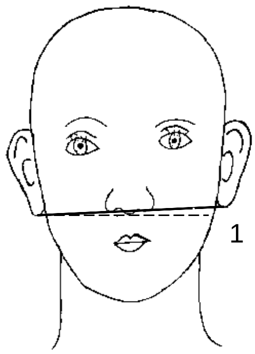

Figure 2. Anterior head alignment (1). (Adapted from Raine and Twomey 1994, p. 26).

Measurement procedures Clothing was rearranged so that shoulders were exposed. With the subject standing, adhesive markers were placed on six anatomical points comprising:

- the external canthus of the right eye;
- right tragus;
- inferior margins of both ears;
- a mid-point between greater tuberosity of humerus and posterior aspect of acromion process of right shoulder; and
- spinous process of C7.

Subjects were asked to stand comfortably with arms by their side in normal standing posture. They were asked to place their weight evenly on both feet. The lateral malleoli were placed between parallel lines, which are perpendicular to the frontal plane, 2cm apart. These two lines were drawn to ensure that the subject's position was kept at the same place while taking the photographs. The subject looked directly ahead. Two cameras were used to photograph posture. One camera was placed 2.8m from the subject's right side while an another one was placed 1.8m in front of the subject. Each camera was positioned perpendicular to the ground by using a spirit level.

Ten photographs of two views of the subjects were then taken – five from the right lateral view and five from the anterior aspect at the same time in non-random order:

- without a backpack;
- carrying student's own backpack over both shoulders;
- carrying student's own backpack over the right shoulder only;
- carrying a backpack weighing 15% of body weight over both shoulders; and
- after a five-minute walk carrying own backpack weight over both shoulders.

In order to evaluate posture of the cervical and shoulder region, four angles of measurement reported by previous researchers (Harrison et al 1996, Raine and Twomey 1994) were used as measures of cervical and shoulder posture in this study. The angles in the lateral views from each slide were obtained as follows:

Craniohorizontal angle The angle formed at the intersection of a horizontal line through the tragus of the ear and a line joining the tragus of the ear and the external canthus of the eye, was measured. It is believed to provide an estimation of head on neck angle or position of the upper cervical spine (Raine and Twomey 1994; Figure 1).

Craniovertebral angle This angle was defined by Wickens and Kiputh (1937). It is the angle formed at the intersection of a horizontal line through the spinous process of C7 and a line to the tragus of the ear. This is believed to provide an estimation of neck on upper trunk positioning. A small angle indicates more forward head posture (Figure 1).

Sagittal shoulder posture The angle formed by the intersection of a horizontal line through C7 and a line between the mid-point of the greater tuberosity of the humerus and the posterior aspect of the acromion, was measured. This angle provides a measurement of the forward shoulder position. A smaller angle indicates that the shoulder is further forward in relation to C7 - in other words, a more rounded shoulder (Raine and Twomey 1994; Figure 1).

The angles in the anterior views from each slide were obtained as follows:

Anterior head alignment This is the angle describing the tilt of the head in the coronal plane. It connects the points at the inferior margins of both ears in relation to the horizontal line. The eyes are level when the angle is zero (Raine and Twomey 1994; Figure 2). In the present study, a positive number of this angle was defined when the left ear lobe was higher than the right ear lobe (right lateral flexion of the neck). A negative number of this angle was defined when the right ear lobe was higher than the left one (left lateral flexion of the neck).

The X, Y co-ordinates of all points were digitised twice by the investigator in a specific sequence using the Easy Digit software, and the relevant angles were calculated using trigonometry. The average of the angles from both measurements was the data used for further investigation.

Assessment of digitisation reliability To assess intra-examiner reliability of the digitisation technique, all four angles in the lateral and anterior views of the first six subjects were digitised twice. An analysis of variance (ANOVA) was conducted for each angle and intraclass correlation coefficients ($ICC_{[1,1]}$) were calculated to measure the correlation between angles derived from the first and second digitisations. The standard error of measurement (SEM) was also calculated for each angle.

Data analysis

Changes in the cervical and shoulder posture Comparisons were made of postural angles with no backpack, and postural angles produced by carrying a backpack over both shoulders, carrying a backpack over the right shoulder, immediately after a 5min walk and carrying a backpack equivalent to 15% of body weight. The significance of changes in the data was estimated using repeated measures analysis of variance on each postural angle within which planned contrasts were made of the unloaded condition with each of four loaded conditions. Statistical tests were considered significant if $p < 0.05$.

Table 1. Characteristics of subjects (N = 13).

Variables	Mean (SD)	Maximum	Minimum
Age (years)	14.8 (1.0)	16.0	13.0
Height (cm)	167.3 (4.9)	175.5	160.2
Mass (kg)	58.9 (9.7)	78.8	44.1
Weight of backpack (kg)	5.2 (1.1)	7.6	4.0
Backpack weight (% body weight)	9.1 (2.1)	13.2	6.4
15 % of student weight (kg)	8.8 (1.5)	11.8	6.6

Results

Table 1 shows the characteristics of subjects, range, mean and standard deviations for weight of the backpack, and the percentage of body weight represented by the backpack weight. Fifteen per cent of student weight is also reported.

Intra-examiner reliability of the digitising technique Digitisation techniques were highly reliable on repeated occasions of measurement on the same slides. The ICC and SEM values between the first and second digitisations ranged from 0.73 to 1.00, and 0.44 degrees to 1.42 degrees, respectively, indicating moderate to high agreement, and low variability of measurements.

Changes in the cervical and shoulder posture Table 2 shows the average and standard deviation values of the craniohorizontal angle, craniovertebral angle, sagittal shoulder posture and anterior head alignment in all conditions. Patterns of postural changes of all angles and conditions are shown in Figure 3. The mean values of the craniovertebral angle in all four experimental conditions reduced in comparison with

Table 2. Mean and SD (degrees) values from postural assessment.

Condition	Craniohorizontal angle Mean (SD)	Craniovertebral angle Mean (SD)	Sagittal shoulder posture Mean (SD)	Anterior head alignment Mean (SD)
Unloaded	16.3 (5.0)	56.7 (3.5)	26.7 (13.1)	0.8 (2.9)
Over both shoulders[#]	15.5 (5.2)	55.5 (3.9)	30.3 (10.1)	1.1 (2.3)
Over right shoulder[#]	14.7 (5.2)	55.3 (4.3)	27.6 (24.0)	1.0 (4.7)
15 % of body weight	16.2 (5.8)	54.2 (4.8)	30.4 (11.2)	2.1 (2.9)
After walk[#]	16.7 (7.1)	54.6 (3.2)	30.0 (11.9)	1.6 (2.8)

[#] Carrying own backpack weight

that produced by the unloaded condition. In contrast, an increase in the average sagittal shoulder posture was found, compared with when unloaded. The *p*-values associated with planned contrasts for all angles, comparing the unloaded position, and carrying the backpack over both shoulders, over the right shoulder, carrying the backpack weighing 15% of body weight and after a 5min walk are displayed in Table 3. Significant differences were found in the craniovertebral angle between the unloaded condition and carrying the backpack weighing 15% of body weight ($p = 0.04$), and after a 5min walk ($p = 0.001$) with the angle increasing in the loaded conditions. This reflects subjects' heads positioned more forward. There was also a significant difference between carrying the backpack equivalent to 15% of body weight and the unloaded condition for the anterior head alignment ($p = 0.03$) and between carrying the backpack over the right shoulder and unloaded for the craniohorizontal angle ($p = 0.04$).

Discussion

Intra-examiner reliability of the digitising technique The high intra-examiner reliability in digitisation of all angles of the same slides suggests that confidence can be placed in the accuracy of the technique when applied to any one set of slides.

The effect of weight of a backpack on changes in cervical and shoulder posture This pilot study found no significant difference from baseline (unloaded) condition when carrying the student's own backpack over both shoulders for all angles (mean percentage of body weight = 9.1, range 6.4 to 13.2% of body weight) (Table 1). The findings indicate that carrying a backpack over both shoulders has the smallest effect on the postural angles measured. This supports the studies of Knapik et al (1996) and Voll and Klimt (1977) who recommend carrying over both shoulders. This may also imply that the subjects' backpack weights were appropriate for them.

However, a decrease of the craniovertebral angle when load carrying was evident (Table 2) indicating a more forward head posture whilst carrying a backpack. Sagittal plane shoulder posture increases under load (Table 2). Based on Raine and Twomey's study (1994), a more rounded shoulder is represented by a smaller sagittal shoulder angle, provided the position of C7 remains fixed. However, the authors argue that a smaller sagittal shoulder angle does not necessarily indicate a more rounded shoulder posture as it is difficult to know if C7 has remained in the same place under different postural conditions. For instance, a larger sagittal shoulder angle may also represent a more rounded shoulder if the forward head posture is increased - for example the marker at C7 is displaced anteriorly. The closer the points at the shoulder and C7 are, the bigger the sagittal shoulder angle is. Therefore, the more anterior head position observed in most subjects in this study when carrying a backpack may contribute to an enlarged sagittal shoulder angle. Further study using a three-dimensional approach is required to identify the relationship between body landmarks.

There was a significant difference between the means of the craniovertebral angle ($p = 0.04$) and anterior head alignment ($p = 0.03$), when carrying a backpack

Table 3. *P*-values of the planned contrasts for craniohorizontal and craniovertebral angles, sagittal shoulder posture and anterior head alignment for each loaded condition compared with the unloaded condition.

Angle	Unloaded and both shoulders #	Unloaded and over right shoulder #	Unloaded and 15 % of body weight	Unloaded and after walk #
Craniohorizontal angle	0.27	*0.04	0.90	0.76
Craniovertebral angle	0.07	0.26	*0.04	*0.001
Sagittal shoulder posture	0.08	0.90	0.05	0.14
Anterior head alignment	0.57	0.82	*0.03	0.14

Carrying own backpack weight *Significant difference ($p < 0.05$)

weighing 15% of body weight over both shoulders, compared with no backpack (Table 3). This supports the finding of Pascoe et al (1997) who reported a forward lean of the head when carrying a backpack weighing 17% of body weight over both shoulders. These postural changes are similar to those reported in this paper for students carrying their own backpack weight over both shoulders, and indicate the effect of increasing load. These findings suggest that postural responses in high school students are sensitive to load carriage equivalent to 15% of body weight, supporting a hypothesis that heavy loads have a significant effect on postural alignment.

The effect of position of carrying a backpack on changes in posture The study found no significant difference when comparing posture without a backpack and whilst carrying over the right shoulder for all angles except the craniohorizontal angle (Table 3). There was variability in response, however, as in five subjects this angle increased and in the rest it decreased. Further investigation is required to test the effect of side of carriage on postural changes. It is not conclusive that carrying a backpack unilaterally on the right shoulder alters cervical posture.

The effect of time of carrying a backpack on changes in posture There was a significant difference ($p = 0.001$) in the craniovertebral angle when carrying a backpack, compared with the unloaded condition, after a 5min walk (Table 3). This angle reduced after carrying the subject's own backpack weight for five minutes, indicating that time carrying a load influences neck on upper trunk position (Table 2). However, the difference in the effect on posture between walking with a load for five minutes, and standing still with a load for five minutes was not tested. Further research is needed to investigate the effect of backpack carriage in static and dynamic conditions on cervical and shoulder posture changes. Moreover, the subjects in this study walked in a controlled environment - that is, walking on the same level, at the same pace, on an even surface. This may not reflect a realistic environment for most students during normal day-time backpack carriage. Extrapolating from the results, however, carrying heavy loads for a longer period of time is likely to affect cervical and shoulder posture.

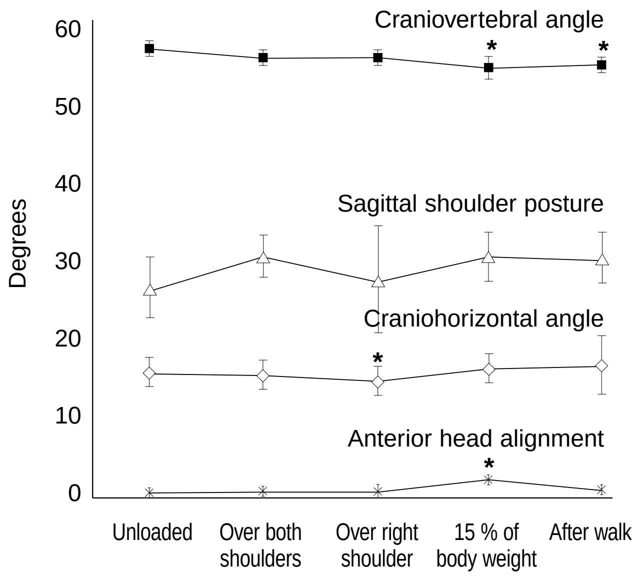

Figure 3. Pattern of postural change under unloaded and all loaded conditions (means and standard errors of the means). Asterisks indicate significant results ($p < 0.05$).

Conclusion

In summary, small but significant differences were found when comparing posture whilst carrying a backpack under different conditions, for the craniohorizontal and craniovertebral angles, sagittal shoulder posture and anterior head alignment. A significant reduction in the craniovertebral angle (or increased forward head position) was found whilst carrying a backpack weighing 15% of body weight over both shoulders. This implies that the weight of the backpack has an effect on changes in cervical and shoulder posture, suggesting that carrying a backpack weighing 15% of body weight would be too heavy for high school students aged 13 to 16 years to be able to maintain their normal postural alignment - in other words, carrying a load of less than 15% of body weight could be recommended.

Moreover, the findings in this pilot study suggest that use of photography and digitisation of points on head and neck demonstrate change under different experimental conditions. Therefore it will be an appropriate measurement tool for larger samples to fully test this observed effect. Further testing of these findings, which have implications for health and safety of high school students, is required.

Acknowledgements The authors are grateful to Associate Professor Jack Crosbie and Dr Roger Adams for consultations and discussions.

Footnotes [(a)] Omnitech Inc., 50 Batusrol Way, Short Hills, NJ 07078, USA. [(b)] Mettler Instrumente AG, CH-8608 Greifensee-Zurich, Switzerland

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