Effect of Backpack Weight on Postural Angles in Preadolescent Children

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Background: Carrying heavy backpacks could cause a wide spectrum of pain related musculoskeletal disorders and postural dysfunctions.

Objective: To determine the changes in various postural angles with different backpack weights in preadolescent children.

Design: Cross-sectional.

Participants: Healthy male school-children (*n*=200), mean (SD) age: 12.5 (0.5) years, from high schools in Mangalore, India.

Measurements: Bodyweight and height were measured using a forceplate and stadiometer, respectively. From the weight recorded, 5%, 10%, 15%, 20%, and 25% of the bodyweight were calculated and implemented as their respective backpack loads. The Image Tool version 3.0, digitizing software was used for analyzing photographs to determine craniovertebral (CV), head on neck (HON), head and neck on trunk (HNOT), trunk and lower limb angles. Postural angles were compared with no backpack and with backpacks weighing 5% to 25% of the subject's bodyweight.

Results: The CV angle changed significantly after 15% of backpack load ($P<0.05$). The HON and HNOT angles changed significantly after 10% of backpack load ($P<0.05$). The trunk and lower limb angle also changed significantly after 5% of backpack load ($P<0.05$).

Conclusions: Carrying a backpack weighing 15% of body weight change all the postural angles in preadolescent children.

Key words: *Backpack, Postural angles, Preadolescent children, School bag*.

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Backpack use is an appropriate way for carrying loads on the spine, closely and symmetrically, while maintaining stability(1). Students carry their educational loads mostly in backpacks, without the workplace standards that have been developed for adults(2). The daily physical stresses associated with carrying backpacks cause significant forward lean of the head and trunk(3). It is assumed that daily intermittent abnormal postural daptations could result in pain and disability in school going children(1).

The peak rate of growth occurs during puberty and the growth of the appendicular skeletal system ceases around 16 years of age for females and 18 years for males(4,5). However secondary ossification of vertebrae is not complete until the mid twenties(4,5). Therefore, the spine may be susceptible to injury for a greater length of time and therefore, proper backpack use should be emphasized during these years. When the backpack load is positioned posterior to the body, the center of gravity shifts posteriorly, over the base of the support; the area covered by the feet(4). This shift is accomplished by either leaning forward at the ankle or hip or inclining the head and the rigidity of postural muscles controlling these adjustments

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increases to support the load. Children have relatively larger heads and also have higher center of mass at about T12, compared to L5-S1 in adults(5).

Carrying posterior loads by young people has been linked with spinal pain, and the amount of postural change produced by load carriage has been used as a measure of the potential to cause tissue damage(4-6). Back pain in children appears to be more common than was previously thought. Studies have indicated that 10%-30% of healthy children experience back pain, especially low back pain, by their teenage years(2,3). Hence, investigating postural responses to load carrying will help us to understand the impact of school backpacks on children.

We conducted this study to examine the changes in postural angles with various backpack weight in preadolescent children.

METHODS

Sample Recruitment and Selection

We recruited healthy male children between 12–13 years from six schools of Mangalore city. Based on previous literature(2), power analysis with significance of 0.05, power of 0.80, a standard deviation of four degrees, and expected change in any postural angle (reference kept as cranio-vertebral angle) of five degrees were identified to calculate sample size for this study. A minimum sample of 199 is required to detect significant change between baseline and experimental conditions. 410 eligible male participants consented. A smaller portion of female participants also consented for the study but were not included for data analysis due to difficulty in achieving proportional gender representation in sample size. Age cohorts of 12 years and 13 years were made from male participants who volunteered for the study. Stratified random sampling was used to recruit 100 participants for each age cohort and pooled as total test population ($n = 209$).

The Ethical review committee of Srinivas College of Physiotherapy, Physiotherapy Research Center approved the study procedures. Design, method and measurement procedures were evaluated and approved by the Research and Development Wing of Rajiv Gandhi University of Health Sciences, Bangalore. The study procedure was explained to the recruited participants and informed consent was obtained from the parents or guardian. Permission was also obtained from the school principal and class teacher. Children with congenital and structural abnormalities, musculo-skeletal problems, neurological problems, and acute or post-acute illness were excluded. Nine subjects were excluded due to ill health, larger measurement variability and subject's absence on the day of measurement. Sample recruitment, selection and measurements were carried out between December, 2007 to February, 2008.

Study procedure

The subjects were instructed to remove their shoes and to stand on the force plate (Bertec Corporation, USA) and the weight was recorded before taking measurements. The subjects were then instructed to stand on the stadiometer and the height in centimeters was noted. From the weight recorded, 5%, 10%, 15%, 20% and 25% of their bodyweight was calculated, which was implemented as their respective backpack loads. The subject was asked to stand erect near a wall with the right lateral side towards the wall to measure the arm length.

Functional reach test: To measure the functional reach of the participants, a point was marked on the wall at the level of the subject's right acromian process. A leveled yardstick was then fixed to the wall at that point with the help of the marking. Subjects were then asked to stand in a relaxed stance with the shoulders perpendicular to the yardstick. They were asked to extend the elbow with the shoulder at 90 degrees of flexion, make a fist and hold the position for 3 seconds, and that position was then noted. The subjects were then asked to reach, as they could without stepping the outlined foot templates, and to hold for 3 seconds and that position was also noted. Functional reach was recorded as the difference between the two positions.

Postural angles measurements: With the subjects in standing position, adhesive photo reflective markers were placed on the right-sided lateral landmarks, which included the lateral canthus of the eye, the tragus, the greater trochanter and the lateral malleolus. A small photo reflective marker was also placed on the C7 spinous process and ensured that the landmark was detected on the photographs(7).

The subjects were instructed to stand comfortably in a normal standing position and to look straight ahead at a predetermined point on the foot template. To allow for visualization of the greater trochanter marker, the subjects were instructed to move the elbows forward but still touching the body and with minimal shoulder movement. The position was then checked prior to taking the photograph. The photograph was taken within 5 seconds after attaining the position. Sony 8 mega pixels digital camera was attached to an adjustable tripod stand, which was placed at a distance of 3 m from the subject's right side and was positioned perpendicular to the ground(6-8). Photographs of the subject were taken from the right lateral view(1,6,8-12), without the backpack and serially with backpack weighing 5%, 10%, 15%, 20% and 25% of bodyweight over both shoulders . The Image tool UTHCSA version 3.0 (University of Texas Health Service Center, San Antonio, TX) digitizing software was used for analysis of photographs and to calculate the angles(7). The measured postural angles and their description is detailed in the ***Table* I**.

Statistical analysis

SPSS 12 version was used to perform repeated measures ANOVA analysis and post hoc test (Bonferroni analysis) for statistical significance. The alpha level was set at P<0.05. SD was calculated to find the variability of the actual data in each postural angle. For Bonferroni analysis, the P value is corrected by a factor of 15. Keeping six groups for comparison, the value was set at P <0.003. Further, Standard error measurement (SEM) of each postural angle was calculated to determine the precision of an estimated mean of a test population.

RESULTS

Eligible participants and their anthropometric characteristics are reported in ***Table* II**. Mean functional reach with smaller SD values (30.13 ± 5.11cm), indicates homogeneous postural stability in all the participating preadolescents.

Table I POSTURAL ANGLES MEASURED IN THE STUDY

Postural angles	Description
Craniovertebral angle (CVA)	Formed at the intersection of the horizontal line through the spinous process of C7 and a line through the tragus of the ear.
Head on neck angle (HNA)	Formed by the line drawn through the anatomical markers at C7 and the tragus of the ear, and the line through the canthus of the eye and the tragus of the ear.
Head and neck on trunk angle (HNTA)	Formed by a line drawn through the anatomical markers at C7 and the tragus of the ear, and the line drawn through the anatomical markers at C7 and the greater trochanter.
Trunk angle (HT)	Formed between the line drawn through the markers at C7 and the greater trochanter, and a vertical line through the greater trochanter.
Lower limb angle (LLT)	Formed by the line drawn through the anatomical markers placed at the greater trochanter and the ankle, and the vertical line drawn through the greater trochanter.

Analysis of variance (ANOVA) for postural angle for 0% backpack load weight to 25% back pack load weight in preadolescent children population revealed significant change in all measured postural angles pertaining to backpack weight increments (***Table* III**). The narrow range of SD values indicates the lesser variation among measurements taken from the sample.

Bonferroni post hoc analysis was used to determine the minimal load which produces significant changes in all postural angles, compared to 0% of backpack weight. The results of this study showed that CV angle changed significantly after 15% of backpack load (P <0.002). HON and HNOT angle had changed significantly after 10% of

Table II SUBJECT CHARACTERISTICS (N = 200)

Characteristics	Mean ± SD
Age (y)	12.5 ± 0.5
Weight (Kg)	30.9 ± 4.3
Height (cm)	142.5 ± 7.4
Arm length (cm)	54.8 ± 4.6
Functional reach (upper limb, cm)	30.1 ± 5.1

TABLE III POSTURAL ANGLES FOR 0-25% BACKPACK LOAD IN PREADOLESCENT CHILDREN (*N*= 200)

Postural angles	Mean (degrees) 0% wt to 25% wt	SD (degrees) 0% wt to 25% wt	*P* value*
Craniovertebral angle	55.11 to 51.49	9.02 to 5.6	< 0.001
Head on neck angle	146.52 to 152.07	8.26 to 8.13	< 0.001
Head and neck on trunk angle	136.90 to 141.23	6.18 to 6.09	< 0.001
Trunk angle	9.66 to 3.06	7.87 to 2.06	< 0.001
Lower limb angle	3.50 to 6.11	2.02 to 2.44	< 0.001

*Wt: weight; *analysis of variance.*

TABLE IV MEAN DIFFERENCE BETWEEN VARIOUS BACKPACK LOADS OF POSTURAL ANGLES IN PREADOLESCENT CHILDREN*

Postural angles	Minimal* backpack load	Mean difference (degrees)	Standard deviation (degrees)	Standard error (degrees)	*P* value†
Craniovertebral angle	0% to 15%	2.31	9.02 to 5.81	0.59	*P*< 0.002
Head on neck angle	0% to 10%	3.18	8.26 to 8.13	0.428	*P*< 0.001
Head and neck on trunk angle	0% to 10%	3.41	6.18 to 6.33	0.322	*P*< 0.001
Trunk angle	0% to 5%	3.21	7.87 to 2.93	0.540	*P*< 0.001
Lower limb angle	0% to 5%	0.64	2.02 to 2.06	0.099	*P*< 0.001

**Only the minimum backpack load which changed the postural angles significantly from 0% backpack load is reported, †Bonferroni multiple comparisons*.

backpack load (*P* <0.001). Trunk and lower limb angle has changed significantly after 5% of backpack load (*P* <0.001). The smaller standard error measurement values (SEM = 0.099° to 0.591°) indicate the good precision of measured postural angle values **(*Table* IV)**.

DISCUSSION

A lesser CV angle and higher HON and HNOT angle with increasing backpack loads found in our study is supported by many previous studies (2,3,7,9,13). The smaller CV angle, higher HON angle and HNOT angles indicate the forward head position (FHP) in response to posterior backpack load. Persistent forward head posture was found to be the major cause for many musculoskeletal disorders around neck and shoulder region in adults(13). Lesser CV or FHP has been associated with greater neck disability(13), tension type headaches(14), syndromes of the neck(15), temporomandibular disorders(16), increased incidence of cervical and interscapular pain and headache(17) etc. The striking finding in our study was that decrease in trunk angle and an increase in lower limb angle in response to 5% of backpack load. This sagittal trunk shift may aggravate the dorsal and low back pain(18). These significant alterations in postural angles may cause or precipitate pain related musculoskeletal dysfunction(18-21), significant changes in respiratory parameters(19) and metabolic cost measures(20).

Grimmer, *et al*.(2) reported similar changes in sagittal position of body segments to adjust the body's center of gravity to accommodate a posterior load. They, however, could not find evidence to support the 'rule-of-thumb' that loads should be limited to 10% of body weight(2). Further, Haselgrove and Straker(21) reported carrying backpack less than 30 minutes actively to school may decrease the odds of back and neck pain.

Absence of female participants was the limitation of this study and this aspect warrants further exploration in terms of higher reports of neck or back pain in female students carrying backpacks(21). Awareness should be created among health care

WHAT IS ALREADY KNOWN?

- Carrying a backpack more than 10% of body weight is associated with increased incidence of pain in the neck and back

WHAT THIS STUDY ADDS?

- Backpack load of even 5% of body weight can significantly change trunk and lower limb angles and 15% of backpack load changes all the angles pertaining to head, neck, trunk, and lower limb and affects overall posture.

professionals, teachers, parents to restrict backpack load less than 5% of bodyweight by using school locker shelves, compact discs, USB flash drives and need to regularly monitor the musculoskeletal problems associated with carrying heavy backpack load in preadolescent children. So musculoskeletal dysfunction and its relation to preadolescent postural responses to backpack load need to be further explored through longitudinal and prospective studies, respectively to determine whether carrying backpack increases the incidence of regional pain and to correlate these clinical implications on school children.

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