Postural Compensations and Subjective Complaints Due to Backpack Loads and Wear Time in Schoolchildren

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Purpose: This study investigated the effects of carrying weighted backpacks of up to 20% of body weight on the posture and pain complaints of elementary-school children. **Methods:** Craniovertebral, forward trunk lean and pelvic tilt angles were measured from sagittal photographs of 62 children (8-11 years old) before and after walking while carrying backpacks containing 10%, 15%, or 20% of body weight. Pain severity after a 6-minute walk with the loaded backpack was recorded. Subjective complaints of pain were assessed using a visual analog scale after walking. **Results:** Repeated-measures ANOVA revealed statistically significant differences in postural angles and increased complaints of pain after walking with increased backpack loads. **Conclusion:** These results indicate that typical backpack loads create worsening postural changes due to backpack loads and time spent carrying those loads, putting children at increased risk for injury and pain, the latter of which is a strong predictor for back pain in adulthood. **(Pediatr Phys Ther 2013;25:15–24)** *Key words: back pain, biomechanics, child, female, human, lifting, male, pain, posture, risk factors, weight-bearing*

INTRODUCTION

Backpacks are commonly used in the United States in populations that include 40 million students,[1,2] 1.4 million active military personnel,[3] 34 million hikers[4] and 4 million Boy Scout youths and leaders.[5] Backpack use by schoolchildren has increased recently because of several factors, including decreased availability of school lockers,[6,7] increased homework,[6] larger textbooks,[6] and other objects being carried to school,[8] all leading to both an increase in backpack weight and amount of time spent carrying backpacks.[7] Backpacks are associated with complaints of back and neck pain and have been linked to low back problems and pain in youth,[1,9-11] with the identification of both weight and duration of backpack carriage as a risk factor for nonspecific back pain in youth.[11-13] A history of back pain in childhood is the strongest predictor of having back pain and musculoskeletal discomfort in adulthood.[14-19] Studies examining the prevalence of low back pain (LBP) in adults report a 1-year prevalence of LBP at 50%, with a lifetime prevalence of LBP at 70% to 80%.[20-22] The prevalence of LBP experienced by youth ranges from 12% in 12-year-old students to as high as 74% in 17-year-old students.[9,12,23-26] A study of Italian youth found that 46.1% of sixth-grade students reported back pain caused by their backpacks.[13] Approximately 16% to 23% of school-aged children have missed school activities or sought medical attention due to the severity of back pain.[7,25,27,28]

Children demonstrate a forward trunk lean (FTL) and a forward head to maintain an upright and erect posture when carrying a loaded backpack.[29-31] An FTL counters the posterior mass of a loaded backpack during stance and

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gait. This FTL has been reported in studies of 9- to 13-year-old children carrying backpack loads containing 5%,[32] 10%, 15%, 20%,[33,34] and 25%[34] of the child's body weight (BW) during stance and gait. The lumbosacral forces resulting from the FTL while carrying backpack loads of 15% BW and 30% BW are 26.7% and 64% greater, respectively, than the lumbosacral forces of an upright unloaded posture.[35]

The forward head position (FHP) involves cervical spine hyperextension, with shortened cervical extensors and lengthened cervical flexors.[36] This neck posture is associated with increased tension, fatigue, and compressive forces within the posterior cervical region.[37] Neck pain is common in adults and youth, with 1-year prevalence over 37% for adults, and women reporting neck pain more frequently than men in 23 of 30 studies examined by Fejer et al.[38] Neck pain has a cumulative annual incidence of 28.4% among adolescents 12 to 16 years of age,[9] with 50% of 12- to 18-year-old children reporting occasional symptoms of neck and upper limb pain.[36,39] Neck pain related to backpack use has been reported in children 8 to 11 years of age[40] and 13 to 17 years of age.[41] Several researchers have suggested that a relationship exists between backpack use and neck pain in youth.[40-42]

The magnitude of weight carried by children in their backpacks generally exceeds the recommended 10% BW limit.[27,31,43] Geographic differences may exist with average backpack loads of 17% BW[31] 19% BW,[27] and 22% BW[43] and maximum backpack loads of 41% BW, 38% BW,[27] and 46.2% BW[43] reportedly carried by children in the United States,[12] France,[27] and Italy, respectively.

The purpose of this study was to examine (1) the effects of backpacks weight (up to 20% of BW) on children's posture and subjective complaints of pain and (2) the effects of time spent walking with the backpack loads on postural changes and subjective complaints of pain. A final goal of this study was to identify and recommend a weight limit for backpacks carried by elementary-school children.

METHODS

Design

This study used a 2-factor repeated-measures design, with the participants serving as their own controls. A randomization table was used to determine the order of the backpack loads containing 10%, 15%, or 20% of the child's BW to be carried during each testing session over 3 consecutive weeks.

Participants

A convenience sample of 62 primary-school children deemed healthy, 41 girls and 21 boys, aged 8 through 11 years (mean age = 9.77 ± 1.07 years) met criteria to participate in this study (Table 1). Participants were included if they were able-bodied, aged 8 to 11, and were able to attend all data collection sessions. Participants were excluded if they reported or exhibited a clinical presentation suggestive of serious pathology, a systemic illness, neurological/muscular degenerative disorder, a preexisting condition that prevented them from carrying a loaded backpack using both shoulder straps, or a history of LBP complaints limiting backpack use. Assent and informed consent were provided by the participants and their parents. Approval for this study was received from the Institutional Review Board.

TABLE 1
Subject Demographics (N = 62)

Variable	Mean (SD)	Min	Max
Age, y	9.77 (1.07)	8.0	11.0
Height, cm	143.50 (10.10)	127.00	176.53
Weight, kg	39.01 (9.26)	22.97	65.56
BMI	18.73 (3.00)	13.68	26.18
Unloaded baseline CVA[a]	49.09 (5.34)	57.69	63.43
Unloaded baseline FTL[a]	− 2.90 (2.98)	− 10.74	5.53
Unloaded baseline TILT[a]	19.72 (5.87)	6.02	34.37

Abbreviations: BMI, body mass index; CVA, craniovertebral angle; FTL, forward trunk lean; TILT, pelvic tilt.
[a]Mean for all unloaded trials per measure.

Outcome Measures

Postural Angles. Digital photography enables researchers to examine and measure various postural angles in a noninvasive manner. While radiographs are considered the "gold standard" for imaging because of the visualization of skeletal bone rather than measuring through soft tissues, digital photographs limit radiograph exposure and enable measurement of several postural angles. Various investigators have verified the reliability of digital photographs for obtaining clinical measurements of sagittal postural angles.[44-46] For this study, digital photographs were taken of the left-sided profile (sagittal view) of the participant according to a protocol developed by Grimmer et al[47] and adapted for this study.

The postural angles examined in this study are illustrated in Figure 1: craniovertebral angle (CVA), FTL, and pelvic tilt (TILT). To measure these angles through digital photographs, adhesive reflective markers were placed by an experienced physical therapist on the spinous process of C7 and on the left side of the body on the tragus of the ear, over the acromion-clavicular joint, the greater trochanter, the anterior superior iliac spine (ASIS), the posterior superior iliac spine (PSIS), the lateral knee joint line, and the lateral malleolus (markers are visible in Figure 1). Participants looked directly ahead at a target while a photograph was taken with a 5-megapixel digital camera[48] fixed on a tripod at a height of 120 cm. Photographs were taken before donning the backpack (unloaded), immediately after donning the backpack (initial load) and again after walking for 6 minutes while carrying the backpack (postwalk). After all data collection sessions were completed, the digital photographs were analyzed to obtain the angle values (in degrees) by an independent researcher

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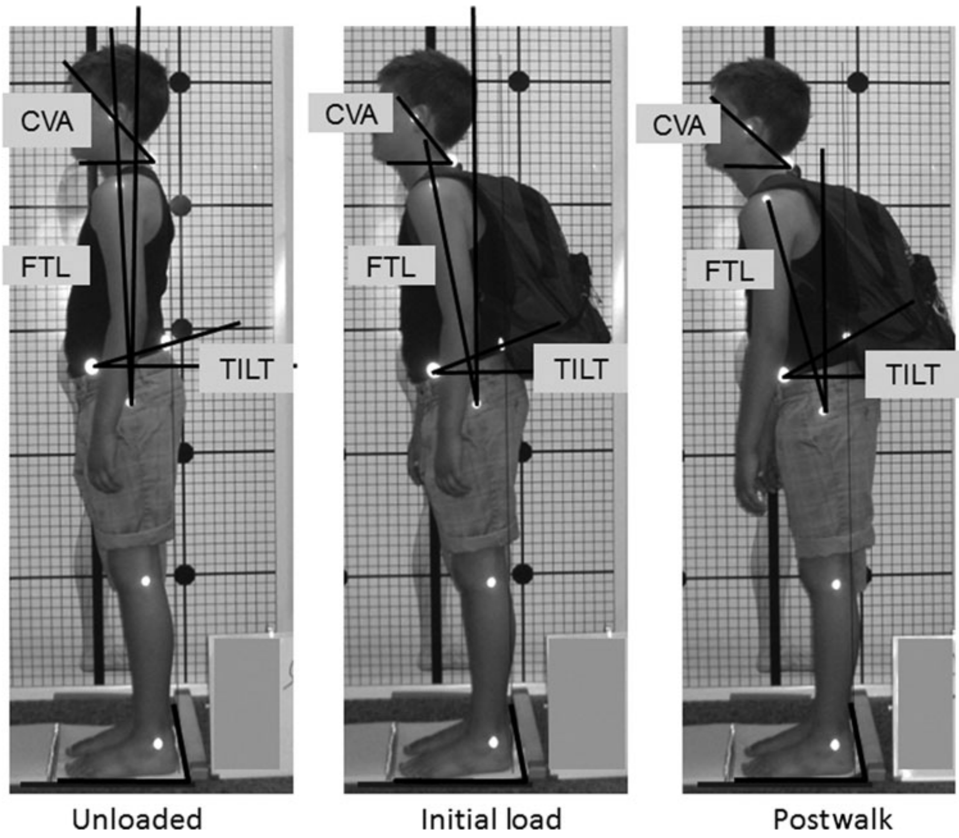

Fig. 1. Craniovertebral angle (CVA), forward trunk lean (FTL), and pelvic tilt (TILT) angles at unloaded, initial load, and postwalk.

using Image Tool V.3 (University of Texas Health Science Center at San Antonio).[49]

Craniovertebral Angle

The forward head posture is represented by the CVA (Figure 1) and defined as the angle between a horizontal line through the C7 spinous process and a second line through the spinous process of C7 and the tragus of the ear.[50] Normal CVA values for 12-year-old children range from 46.9° to 49.4°.[51] A smaller value indicates a more FHP. The CVA has been used in studies examining posture, headaches, temporal-mandibular joint dysfunction, as well as numerous backpack studies.[18,29,45,46,51-53] The CVA has demonstrated high reliability and very high intrarater[18,54-56] and interrater reliability[57] for measurement of forward head posture.

Forward Trunk Lean

Forward trunk lean (Figure 1) is the angle formed by the intersection of the line from the acromion to the greater trochanter and a vertical reference line.[50] This measure has shown significant changes associated with increased load carried.[31-33,58-62] Forward trunk lean has demonstrated good intrarater reliability for measurement of trunk flexion.[45] A neutral, erect posture should measure close to 0°. A positive FTL measurement indicated that the participant was leaning forward or into trunk flexion.

Pelvic Tilt

According to Kendall et al,[36] a neutral pelvis is one in which the ASISs are in the same horizontal plane as the PSISs. An anteriorly tilted pelvis will demonstrate a greater angle between the ASIS/PSIS plane and the true horizontal plane, thus increasing sacral inclination and lumbar lordosis.[36,39] Young children demonstrate an increased TILT but develop adult-like movement patterns by 7 years of age.[63] Significant changes in TILT[64] and increases in lumbar lordosis angles[53] have been recorded in children after carrying a 15% BW backpack load. The TILT angle measurement has shown good interrater[65] and intrarater reliability[65-67] and is formed by the intersection of a line connecting the ASIS and PSIS with a horizontal line (Figure 1). A larger angle indicates an increase in anterior TILT.

Postwalk Pain Survey With Visual Analog Scale

A short postwalk pain survey (Figure 2) was used to assess the subjective complaints of "soreness" or severity of pain in the neck and mid and low back regions after each walking trial. The survey included a visual analog scale (VAS) and a body diagram (modified from Young[68]). The VAS has been shown to produce reliable information in youth.[69] Body diagrams and other visual methods for indicating the region of pain have been used in previous studies and are ideal methods for localizing problems.[69]

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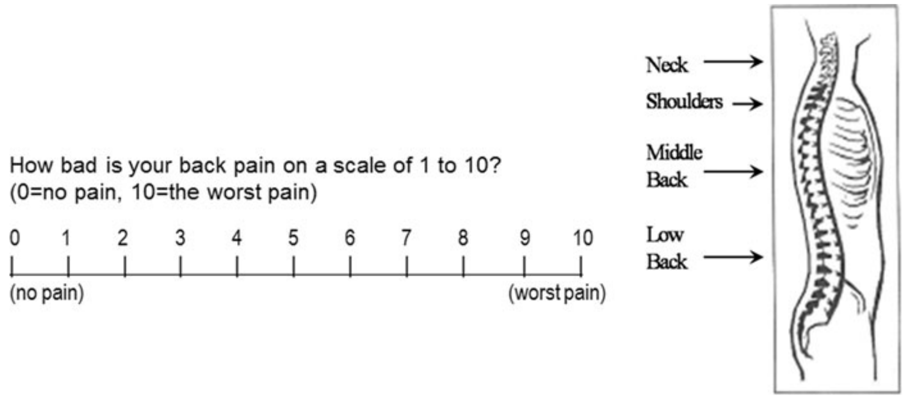

Fig. 2. Excerpt from the Post-walk Pain Survey showing the visual analog scale (VAS) and body diagram. Body diagram has been adapted from Young et al.[68]

The VAS is divided into equal increments from 0 to 10, beginning with "no pain" (0) and ending with "worst pain" (10). The body diagram is a sagittal line drawing of the spine with arrows pointing to the neck and mid and low back regions to enable localization of pain.

Data Collection Procedure

During the initial data collection session, the child's age and basic anthropometric measurements of height and weight were recorded. The participant's weight was obtained at the beginning of each subsequent data collection session to ensure an accurate backpack loading as a percentage of the child's weight that day.

Unloaded. At the beginning of each data collection session, the reflective markers were placed as described above and the "unloaded" photograph was taken of the left side of the participant while he or she stood without a backpack. The participant was asked to stand as "normally" as possible (see Figure 1).

Initial Load. The loaded backpack was placed on the participant's back, with the center of the load positioned approximately at the level of T10, and the "initial load" photograph was taken immediately. The participant then walked for 6 minutes at a comfortable self-paced speed while carrying the loaded backpack around a marked course.

Postwalk. After walking, the participant returned to the photograph location and the "postwalk" picture was obtained. The backpack was removed and the participant completed the postwalk pain survey.

To reduce the effects of fatigue during repeated trials in 1 day, participants returned during the next 2 consecutive weeks and were retested with the remaining randomly assigned backpack weigh conditions.

For this study, the backpack loads were created through the use of school textbooks of various weights, which were placed into a typical student backpack with the largest books closest to the participants back, and secured with a hook-and-loop fastener to maintain a stable, static load. To normalize the weight carried and ensure accuracy of the backpack load as a percentage of the child's BW, the children were weighted at the beginning of each session. Only the research assistant who measured the participant's weight and loaded the backpack each session knew the percentage of BW for the each testing session and that assistant was not involved in any other data collection. The researcher who placed the markers and took the photographs was blinded to the amount of weight being carried by the participants throughout all data collection.

To standardize the measurements throughout all trials, the participants stood next to an "L" marked on the ground 3 m away from the camera. The lateral edge of the participant's left foot was lined up along the longer length of the L, and both heels were placed at the edge of shorter length of the "L" as portrayed in Figure 1. To ensure consistent foot placement during the data collection, the participant's feet were initially traced while he or she stood unloaded with a comfortable standing base on a thin pad of paper that was aligned within the "L." For all subsequent photographs, each participant returned to his or her traced footprints on the paper.

Statistical Analysis

This study was a 2-factor repeated-measures design, with the participants serving as their own controls. Statistical analysis was completed using SAS 9.1.3 (SAS Institute Inc, Cary, NC). A 2-factor, repeated-measures analysis of variance was used, followed by pairwise comparisons to test for the main effect of backpack load, the main effect of testing condition, and a weight × condition interaction in the postural angles of CVA, FTL, and TILT. One-factor, repeated-measures ANOVAs were used to examine differences in VAS pain scores among the weights after walking 6 minutes, followed by pairwise comparisons (paired t test) to examine the effects at each weight. Results were considered significant at an α level of 0.05. No significance differences were found among each of the unloaded CVA, FTL, and TILT angle measures across the 3 test days. See Table 2 for the mean and SD of each unloaded postural angle.

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RESULTS

Effect of Backpack Weight and Condition on CVA

A main effect of weight ($F_{2,122}$ = 9.0, P = .0002) was observed among the backpack weights. In general, the CVA decreased as the load increased at both initial load and postwalk conditions. The interaction between weight and condition was significant ($F_{4,244}$ = 6.61, P < .0001) and indicated differences among the weights in the changes in CVA across the testing conditions (Figure 3).

All weight conditions produced an immediate and significant change in CVA upon initial loading (10% BW: P < .0001; 15% BW: P < .0001; and 20% BW: P < .0001). The change was less for the 10% load than for the other 2 conditions. Significant differences in the CVA were noted between the 10% BW and 20% BW loads (P < .0001) and the 10% and 15% BW loads (P < .0001). At postwalk, there was an additional decrease in the CVA angle for all weight conditions, but the percent decrease differed among the 3 weight conditions. Significant differences were found among the postwalk CVA measures for all backpack weights (P < .0001), with the 20% BW load producing the smallest CVA, indicating a greater increase in the FHP with the heavier load.

A main effect of condition ($F_{2,122}$ = 110.93, P < .0001) was statistically significant. In general, the CVA measures decreased significantly at both initial load and postwalk for all weights. Pairwise comparisons identified significant differences in the postwalk CVA as shown in Table 3. The differences in the CVA from initial load to postwalk were statistically significant for the 10% BW and 20% BW loads (P = .0073 and P < .0001, respectively), but not the 15% BW load. The differences in the CVA from unloaded to postwalk were statistically significant for all loads (10% BW: P < .0001; 15% BW: P < .0001; and 20% BW: P < .0001). The mean CVA changes for each backpack weight (10% BW, 15% BW, and 20% BW) are shown in Figure 3.

TABLE 2

Craniovertebral Angle, Forward Trunk Lean, and Pelvic Tilt Measures for Each Backpack Load and Time Condition Backpack Load (as a Percentage of Bodyweight)

Condition	10% BW, Mean (SD)	15% BW, Mean (SD)	20% BW, Mean (SD)
Unloaded CVA	49.4° (5.26°)	48.8° (5.59°)	49.1° (5.24°)
Initial load CVA	46.8° (5.21°)	44.3° (6.36°)	44.5° (6.34°)
Postwalk CVA	45.4° (5.85°)	43.8° (6.30°)	42.4° (6.10°)
Unloaded FTL	− 2.9° (3.21°)	− 2.6° (3.05°)	− 3.2° (2.67°)
Initial load FTL	0.9° (3.21°)	1.8° (3.40°)	3.1° (3.78°)
Postwalk FTL	0.9° (3.40°)	2.4° (3.19°)	3.9° (4.99°)
Unloaded TILT	20.1° (5.75°)	20.0° (6.12°)	19.1° (5.78°)
Initial load TILT	23.2° (7.51°)	23.2° (7.02°)	22.2° (6.92°)
Postwalk TILT	25.2° (6.85°)	25.4° (7.56°)	24.2° (8.82°)

Abbreviations: BW, body weight; CVA, craniovertebral angle; FTL, forward trunk lean; TILT, pelvic tilt.

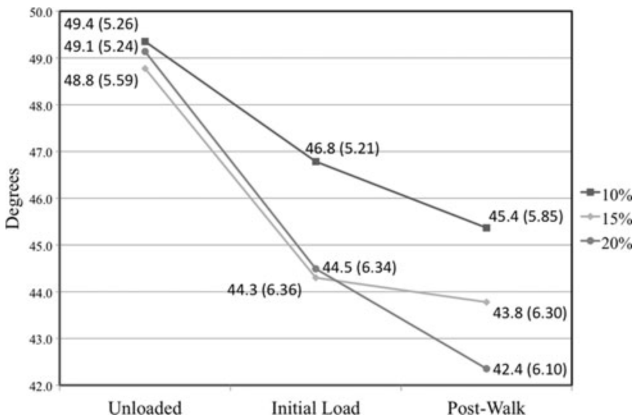

Fig. 3. Craniovertebral angle. Mean angle (and SD) changes while carrying a loaded backpack.

Effect of Backpack Weight and Condition on FTL

A main effect of weight ($F_{2,122}$ = 10.40, P < .0001) was observed among the backpack weights. In general, the FTL angle increased with heavier backpack loads. The interaction between weight and condition was significant ($F_{4,244}$ = 14.37, P < .0001) and indicated differences among the weights in the changes in FTL across the testing conditions (Figure 4).

All weight conditions produced an immediate and significant change in FTL upon initial loading (10% BW: P < .0001; 15% BW: P < .0001; and 20% BW: P < .0001). The change was less for the 10% load than for the other 2 conditions. Significant differences in the FTL were noted between the 10% BW and 20% BW loads (P < .0001), the 10% and 15% BW loads (P = .0454), and the 15% and 20% loads (P = .0318). At postwalk, an additional increase in the FTL angle for all weight conditions was found, but the percent increase differed among the 3 weight conditions as listed in Table 2. Significant differences were found among the postwalk FTL angles for all backpack weights (P < .0001), with the 20% BW load producing the greatest FTL, indicating an increased FTL with the heavier load.

A main effect of condition ($F_{2,122}$ = 226.99, P < .0001) was observed among the testing conditions. The FTL angles increased significantly at both initial loading and postwalk. Pairwise comparisons identified significant changes in the postwalk FTL measures as shown in Table 3. The differences in FTL from initial walk to postwalk were statistically significant for the 15% BW and 20% BW loads (P = .0478 and P = .0322, respectively), but not the 10% BW load. The differences in FTL from unloaded and postwalk were statistically significant for all loads (10% BW: P < .0001; 15% BW: P < .0001; and 20% BW: P < .0001). The mean FTL angle changes for each backpack weight (10% BW, 15% BW, and 20% BW) are shown in Figure 4.

Effect of Backpack Condition on TILT

There was no main effect of weight ($F_{2,122}$ = 0.75, P = .4729) among the backpack weights. In general, the TILT did not increase with heavier backpack loads and

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TABLE 3

Pairwise Comparisons of Craniovertebral Angle, Forward Trunk Lean, and Pelvic Tilt by Load and Condition

	10% BW Backpack	15% BW Backpack	20% BW Backpack
Unloaded vs initial load CVA			
Mean difference (SD)	2.6° (3.88°)	4.5° (4.47°)	4.7° (4.25°)
P	<.0001	<.0001	<.0001
Change from unloaded, %	5.21	9.18	9.46
Initial load vs postwalk CVA			
Mean difference (SD)	1.4° (0.51°)	0.5° (0.58°)	2.1° (0.46°)
P	0.0073	0.3733	<.0001
Change from initial, %	3.01	1.17	4.81
Unloaded vs postwalk CVA			
Mean difference (SD)	4.0° (3.53°)	5.0° (4.49°)	6.8° (4.13°)
P	<.0001	<.0001	<.0001
Change from unloaded, %	8.09	10.25	13.82
Unloaded vs initial load FTL			
Mean difference (SD)	3.8° (2.75°)	4.5° (3.06°)	6.2° (3.03°)
P	<.0001	<.0001	<.0001
Change from unloaded, %	129.79	169.20	196.52
Initial load vs postwalk FTL			
Mean difference (SD)	0.0° (0.32°)	0.5° (0.27°)	0.9° (0.39°)
P	0.8745	0.0478	0.0322
Change from initial, %	5.75	29.67	28.52
Unloaded vs postwalk FTL			
Mean difference (SD)	3.8° (2.98°)	5.0° (2.92°)	7.1° (4.07°)
P	<.0001	<.0001	<.0001
Change from unloaded, %	131.51	189.73	224.05
Unloaded vs initial load TILT			
Mean difference (SD)	3.1° (4.40°)	3.2° (4.33°)	3.1° (4.43°)
P	<.0001	<.0001	<.0001
Change from unloaded, %	15.39	16.06	16.41
Initial load vs postwalk TILT			
Mean difference (SD)	2.0° (0.63°)	2.2° (0.62°)	2.0° (0.78°)
P	0.0019	0.0007	0.0129
Change from initial, %	8.76	9.57	9.01
Unloaded vs postwalk TILT			
Mean difference (SD)	5.1° (3.96°)	5.4° (4.87°)	5.1° (6.29°)
P	<.0001	<.0001	<.0001
Change from unloaded, %	25.50	27.21	26.90

Abbreviations: BW, body weight; CVA, craniovertebral angle; FTL, forward trunk lean; TILT, pelvic tilt.

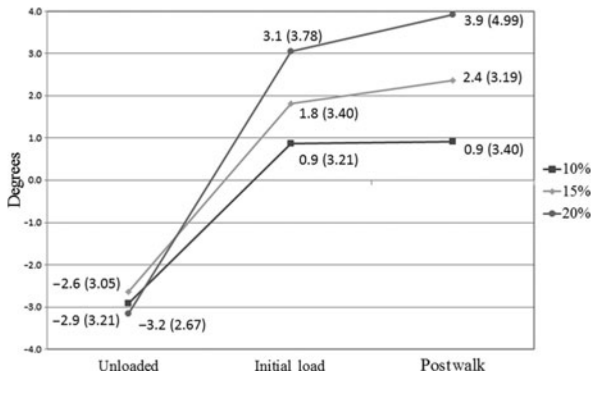

Fig. 4. Forward trunk lean. Mean angle (and SD) changes while carrying a loaded backpack.

no significant differences were found in the TILT among the backpack weights at unloaded, initial load, or postwalk. The interaction between weight and condition was not significant ($F_{4,244} = 0.08$, $P = .9886$) and did not indicate differences among the weights in the changes in TILT across the testing conditions. However, a main effect of condition ($F_{2,122} = 70.74$, $P < .0001$) was observed among the testing conditions. In general, TILT increased over time, after walking, moving into a greater anterior TILT. The TILT angles increased significantly at postwalk. Pairwise comparisons identified significant changes in the postwalk TILT measures as shown in Table 3. The differences in TILT from unloaded to initial walk were statistically significant for all loads (10% BW: $P < .0001$; 15% BW: $P < .0001$; and 20% BW: $P < .0001$). The differences in TILT from initial loading to postwalk were statistically significant for all loads (10% BW: $P = .0019$; 15% BW: $P = .00097$; and 20% BW: $P = .0129$). The differences in TILT from unloaded walk to postwalk were statistically significant for all loads (10% BW: $P < .0001$; 15% BW: $P < .0001$; and 20% BW: $P < .0001$). No significance differences were observed in the postwalk TILT measures among the backpack weights ($P = .5884$). The mean TILT angle differences for each backpack weight and condition are listed in Table 2.

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Effect of Backpack Weight on Pain Severity at Different Body Regions

A significant main effect for backpack weight on pain severity was found as measured by VAS scores for the neck ($F_{2,116} = 14.57$, $P < .0001$), mid back ($F_{2,118} = 6.56$, $P = .0020$), and shoulders ($F_{2,114} = 18.73$, $P < .0001$). The pain ratings were the lowest for the 10% load and increased with heavier backpack loads for the neck, mid back, and shoulders. See Fig. 5 for the distribution of VAS pain scores by body region.

Pairwise comparisons identified differences between VAS pain score for all backpack weights. Significant differences in the VAS pain scores were noted for the neck between 10% BW and 20% BW ($P < .0001$) and between the 15% BW and 20% BW loads ($P < .0001$). Significant differences in the VAS pain scores were noted for the mid back between 10% BW and 15% BW ($P = .0011$) and between the 10% BW and 20% BW loads ($P < .0010$). Significant differences in the VAS pain scores were noted for the shoulders between 10% BW and 15% BW ($P < .0045$), between the 10% BW and 20% BW loads ($P < .0001$), and between the 15% BW and 20% BW loads ($P = .0015$). Pain severity for the low back was not significantly different between the different loading conditions. The mean VAS pain scores for each body region and backpack weight (10% BW, 15% BW, and 20% BW) are shown in Figure 5.

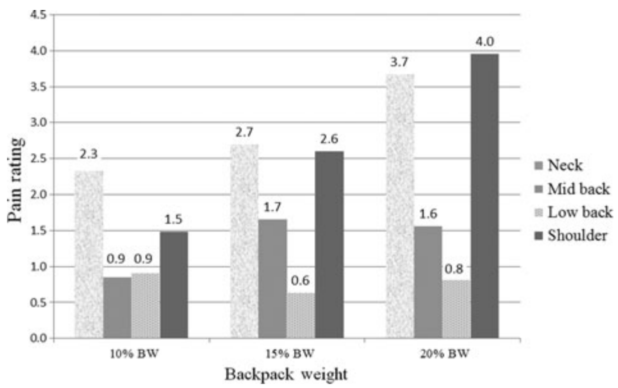

Fig. 5. Visual analog scale pain scores by body region and backpack weight. BW indicates body weight.

DISCUSSION

The results of this study indicate that backpacks weighing 10%, 15%, and 20% of a child's BW produced significant changes in children's postures upon the donning of each backpack load, as well as continued postural changes and increased pain complaints after walking with the loaded backpacks.

Upon initial loading of each backpack load condition, the children demonstrated increased forward head postures, increased FTL, and an increased anterior TILT. These measures increased further after walking for 6 minutes; an amount of time comparable to the minimal amount of time required for children to walk from a school entrance to their classroom or to walk home while carrying loaded backpacks. Greater differences in CVA and FTL were recorded after the children walked with the heavier weights.

The lightest weight tested, a backpack weighing 10% BW, resulted in statistically significant changes in all postural angles. The children demonstrated postural compensations for the backpack load by leaning forward, protracting their heads, and as suggested by the increase in TILT over time, increasing their lordosis to compensate for the weighted backpack. The VAS pain scores reported at this weight were highest for the neck and shoulder.

With the heavier 15% BW and 20% BW loads, the postural compensations progressed, with significant changes in CVA, FTL, and TILT before and after walking compared to the lighter 10% BW load. Statistically significant changes in the CVA from unloaded to initial load and to postwalk for all loads indicated the responsiveness of the children's head posture to a posterior load. The differences in the CVA from unloaded to both initial loading and to postwalk for the 15% BW and 20% BW loads closely approximate the mean differences found by Watson and Trott (4.8°)[54] and Yip (5.1°)[70] in adults with headaches, potentially putting these children at risk for headaches.[54,70] The CVA demonstrated a magnitude of change up to 13.8% from the unloaded condition (see Table 3), which puts the children at risk for headaches and musculoskeletal changes, especially at the 15% BW and 20% BW backpack loads.[51,70] The mean differences in the CVA from unloaded to postwalk for the 10% BW and 20% BW loads are greater than those found by Kistner and Roach,[40] who reported neck and mid back pain in 45% to 73% of 8- to 11-year-old children carrying 10% BW, 15% BW, and 20% BW backpack loads.

Significant responses were seen in the children's trunk posture due to the weighted backpacks. At 10% BW, the greatest FTL recorded was 9.3°. This increased to 12.51° at 15% BW and 28.2° at a 20% BW backpack load. Prior research has shown that standing just "bent forward" or when holding a 28% BW load close to the body in upright standing increases intradiscal pressures at L4-L5 by approximately 440%.[71] The forward flexed trunk angle demonstrated by these children at 20% BW has been shown to increase lumbosacral compression by at least 67% compared to unloaded posture in young adults.[35] In addition to increased intradiscal pressures, FTL also increases the shear forces within the spine due to changes in muscle tension and joint surface alignment.[72,73] Deviations in trunk posture from upright are known to affect the relative orientation of the spine and the stress distribution within the spine,[74] which may lead to strain on the body and subsequent muscle fatigue and micro trauma, potentially culminating in a musculoskeletal disorder.[73,74]

The VAS pain scores for the neck and shoulders increased with the 15% BW load. Interestingly, with the 20% BW load, the VAS pain scores for LBP did not increase despite the increase in load. The time spent carrying the

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loaded backpack may have been too short to elicit LBP in this study.

We examined these results to recommend a backpack weight limit for children and identified differences for all 3 weights tested, including increased forward head posture, increased FTL, increased TILT, and increased complaints of pain in several body regions. Although many of these measures show significant differences between the unloaded and loaded conditions when carrying backpacks weighing up to 20% of BW, there was less of an influence from the 10% BW backpack load than in the other 2 conditions. Prior suggestions from professional associations, including the American Physical Therapy Association, the American Occupational Therapy Association, and the American Chiropractic Association, have suggested guidelines for safer backpack use such as limiting backpack weight to 5% to 15% of BW and have expressed concern regarding the prevalence of heavy backpacks and incidence of back, neck, and shoulder pain, as well as the risk of brachial plexus injury in young backpack user.[75-78] An ideal recommendation would prohibit children from carrying any backpacks, but that is not realistic when 90% of children worldwide currently use backpacks. The results of this study support setting a maximum weight limit to 10% of a child's BW to minimize postural compensations and subjective complaints of pain.

Limitations

Although this study was designed to limit bias as much as possible, the participants could not be blinded to the study's purpose of examining the effects of backpacks on children. However, they were blinded to the amount of weight carried and the actual postural angles of interest. The digital analysis of the photographs was conducted by an independent researcher who was blinded to the purpose of the measurements and the study.

The postwalk pain survey did not originally contain a question about pain in the shoulders, but as the first participants reported the location of their "worst pain" to be in their shoulders, we verbally added "shoulders" as a location and asked the participants to rate the pain using the same VAS scale. The data obtained were included in the analysis and results. Only the primary researcher administered the postwalk pain survey and as such was able to maintain consistency of asking about shoulder pain after every 6-minute walk test.

CONCLUSION

Backpacks weighing 10%, 15%, and 20% of a child's BW resulted in postural changes in children both immediately and after walking for 6 minutes with the loaded backpack. In addition, reports of pain increased with increased backpack loads. Parents and clinicians need to be aware of the effect of both backpack weight and time spent carrying a loaded backpack on the posture and subjective pain complaints in schoolchildren.

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CLINICAL BOTTOM LINE

Commentary on: "Postural Compensations and Subjective Complaints Due to Backpack Loads and Wear Time in Schoolchildren"

"How could I apply this information?"

This study encourages us to minimize the weight and time that school-aged children spend carrying backpacks. To minimize body pain and postural strain, children are recommended to carry backpacks weighing no more than 10% of their body weight. Elementary school children who were healthy and who carried backpacks weighing 10% of their body weight reported neck, shoulder, and mid back pain and also exhibited postural compensations linked to increased spinal forces, tension, and fatigue. Such postural strain and body pain increased as children carried heavier backpacks, especially after walking 6 minutes (a time frame considered comparable with the minimal time children need to access classrooms). This study's findings and recommendations may be aptly integrated when screening and promoting the health, fitness, and wellness of school-aged children.

If children of school age and healthy presented with increased body pain and postural strain, we might expect that children with special needs might face greater challenges. Although children with special needs were excluded from this study, the increased physical demands these children face may lead to increased reports of pain and postural compensations. For example, while children who are healthy did not report increased low back pain despite carrying heavier backpacks, increased pain may surface in children who require greater walking time to access classrooms. If it is not possible for children who are healthy to avoid carrying backpacks or to use adaptive strategies, backpacks should be loaded to maximum of 10% of a child's body weight, to minimize postural strain and body pain. Participants in this study weighed on average 39 kg with a range of 23 to 65 kg. This indicates that a range of 5 to 14 pounds should be the maximum backpack weight children in this weight range should carry.

"What should I be mindful about in applying this information?"

Generalizing from this sample of children who are healthy to children with movement problems should be done with caution. Compensation for loads may take very different forms for different children with movement problems. Backpacks may not be a good choice for many children with special needs, even if loads are 10% or less of body weight.

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