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Original Article / Özgün Araştırma

The effect of schoolbag weight on cervical posture in schoolchildren

Okul çağı çocuklarda okul çantasının servikal postür üzerindeki etkisi

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ABSTRACT

Objectives: This study aims to investigate the effects of various schoolbag loads on the cervical posture during stance and after walking.

Patients and methods: Between January 2014 and June 2014, a total of 100 schoolchildren (50 boys, 50 girls; mean age 12.05±3.71 years; range 10 to 15 years) were included in the study. The craniovertebral protrusion and side bending angle of the neck were measured using the cervical range of motion instrument in the neutral position and after carrying a schoolbag with weights of 5%, 10% and 15% of body weights during stance and after walking 100 meters.

Results: There was a statistically significant relationship between sex, various backpack weights, condition, and the forward/side head postural compensation in schoolchildren. Among female students, 5%, 10% and 15% of body weight loads significantly increased the craniovertebral protrusion and side bending angle of the neck during stance and after walking. Among male students, only 10% and 15% of body weight loads significantly changed the craniovertebral protrusion and side bending angle of the neck during stance and after walking ($p \leq 0.05$).

Conclusion: Based on our study results, a schoolbag should not be more than 5% of body weight among the female students and 10% of body weight among male students. Otherwise, it will be a risk factor for postural and musculoskeletal problems either immediately or during adulthood.

Keywords: Cervical spine; posture; schoolbag; schoolchildren.

ÖZ

Amaç: Bu çalışmada duruş sırasında ve yürüyüş sonrasında çeşitli okul çantası ağırlıklarının servikal postür üzerindeki etkileri araştırıldı.

Hastalar ve yöntemler: Ocak 2014 - Haziran 2014 tarihleri arasında, toplam 100 okul çağı çocuğu (50 erkek, 50 kız; ort. yaş 12.05±3.71 yıl; dağılım 10-15 yıl) çalışmaya alındı. Duruş sırasında ve 100 metre yürüyüş sonrasında nötr pozisyonda ve vücut ağırlığının %5, %10 ve %15'i ağırlığında okul çantası taşıdıktan sonra, kraniyovertebral protrüzyon ve boynun yana bükülme açısı, servikal hareket aralığı aracı ile ölçüldü.

Bulgular: Okul çağı çocuklarında cinsiyet, çeşitli çanta ağırlıkları, duruş ve başın öne/yana postüral kompansiyonu arasında istatistiksel anlamlı bir ilişki vardı. Kız öğrencilerde vücut ağırlığının %5, %10 ve %15'i ağırlığı, duruş sırasında ve yürüyüş sonrasında kraniyovertebral protrüzyonu ve boynun yana bükülme açısını anlamlı düzeyde artırdı. Erkek öğrencilerde vücut ağırlığının yalnızca %10 ve %15'i ağırlığı duruş sırasında ve yürüyüş sonrasında kraniyovertebral protrüzyonu ve boynun yana bükülme açısını anlamlı düzeyde artırdı ($p \leq 0.05$).

Sonuç: Çalışma sonuçlarımıza göre, okul çantası kız öğrencilerde vücut ağırlığının %5'inden, erkek öğrencilerde vücut ağırlığının %10'undan fazla olmamalıdır. Aksi takdirde, kısa sürede veya erişkinlik çağında postüral ve kas ve iskelet sorunları açısından bir risk faktörü olacaktır.

Anahtar sözcükler: Servikal omur; postür; okul çantası; okul çağı çocukları.

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The use of highly loaded schoolbags among the schoolchildren has considerably increase the concern of parents on excess load on a developing spine. Students carry their educational loads mostly in backpacks without any workplace standards which have been developed for adults.[1] In general, schoolbags are heavy in 79.1% children, leading to fatigue in 65.7% and pain in 46.1%.[2] Moreover, among 16,357 participants aged 13 to 15 years, 50.9% of boys and 69.3% of girls have suffered low back pain (LBP) at least once.[3] The heavy weight of schoolbags in terms of the percentage of body weight (BW) of the children was reported to be 12.57% and 10.7% in the United States,[4] 9.6 and 9.9% in the United Kingdom,[5] 14.7% in Greece,[2] 19.9% in Italy,[6] and 14.7% in Holland.[7] The maximal loads recommended from early studies carried on adolescent varied from 25% to 40% of BW. Some authors also suggest that load requirements for females should be lower than males to account for physiological and biomechanical differences.[8] Other authors also suggest that the maximum weight limit should be 10% of BW.[9] It has been also shown that weights of greater than 10% to 15% of BW result in increased forward head postures preventing adolescents from maintaining an upright standing posture.[1,10] On the other hand, Grimmer et al.[1] was unable to find an evidence to support that backpack weight should be limited to 10% of BW.

It was shown that carrying a schoolbag is a cause of developing different symptoms of musculoskeletal disorders among the carriers.[1,11,12] Many studies have demonstrated a clear association between the schoolbag load and cardiovascular, lung volume, metabolic, and nerve function changes.[8,13,14] The daily physical distress associated with carrying schoolbags caused significantly increased forward head position and an increased forward lean of the trunk as well as changes in pelvic positions and gait patterns.[12] Asymmetrical spinal alignment during mechanical loading, disc degeneration, and back pain in 10%-30% of healthy children by their teenage years were also reported.[12,15] Due to the possibly hazardous impact of the backpack loads on the developing musculoskeletal system and diversity between the results of studies carried out in different regions and populations, we aimed to investigate the effects of different loads on the neck posture to identify the most appropriate weight for schoolchildren in Kingdom of Saudi Arabia (KSA). In this study, we have two hypotheses: *(i)* different schoolbag loads may affect the cervical posture in stance and after walking; *(ii)* there is a difference in the schoolbag load between male and female students.

PATIENTS AND METHODS

In a repeated-measures design, we investigated the cervical spine response to the school backpack weights in healthy children. Male and female students between the ages of 10 to 15 years were eligible to participate in the study between January 2014 and June 2014. The justification of the ages is to avoid the effects of the pubertal growth spurt. They were recruited to participate in the study from primary and elementary schools in the city of Hail region of the Saudi Arabia. The participation of all students was voluntary, and a written informed consent was obtained from each participant and parents. Any student with scoliosis, focal dystonia (torticollis) or other neurological disorder (cerebral palsy), and scars or skin contractures caused by spinal surgery or prior burns of the skin in the upper trunk or neck were excluded from the study. Students with pre-existing condition which prevented load carriage of a backpack using shoulder straps, or a history of neck or low back pain complaints were also excluded. Given these criteria, a total of 100 students (50 females, 50 males; mean age 12.05±3.71 years; range 10 to 15 years) were included in the study. Body weight and height were ranging from 27 to 63 kg and 127 to 163 cm, as measured using a calibrated digital scale (GIMA Pegaso Electronic Body Scale, Italy).

The study protocol was approved by the institutional Ethics Committee. The study was conducted in accordance with the principles of the Declaration of Helsinki.

Before the data collection, the procedures and steps of the study were explained to the participants. We measured the effect of schoolbag on the cervical spine posture in static stance and after walking using the cervical range of motion (CROM Deluxe, Performance Attainment Associates, Roseville, Minnesota, USA). The CROM goniometer is a lightweight frame secured with Velcro straps to monitor exactly examinee's head position in space which eliminates the positioning, zeroing, and tracking errors with acceptable reliability for measuring CROM.[16,17] While the participants were standing with easy accessible lower cervical and upper thoracic spine, the instrument was applied on the head by positioning the device to the bridge of the nose and over the ears and held firmly in place by securing the velcro straps (CROM Deluxe, Performance Attainment Associates, Roseville, Minnesota, USA) attached to the device. The participants were asked to stand as they usually do with arms by their side in neutral position and with forward horizontal gaze for measuring

Table 1. Participant characteristics (n=100)

Anthropometric data	Male students		Female students	
	n	Mean±SD	n	Mean±SD
Age (years)	50	12.2±1.6	50	11.9±1.6
Height (cm)		146.8±8.3		145.9±9.8
Weight (kg)		45.8±8.2		45.2±9.9
Body mass index (kg/m^2)		21.1±2.2		21.0±2.7

SD: Standard deviation.

craniovertebral protrusion (CVP) and side bending angle at baseline without any weights.

For measuring CVP, the forward head arm was attached to the instrument and the examiner proceeded to locate the C7 spinous process by the following procedures: palpating the most prominent spinous processes (C6 to C7) at the base of the cervical spine, while the neck was passively flexed; both C6 to C7 spinous processes were pointed with the index and middle finger tips; the participant was asked to slowly extend the head. One of the two spinous processes will vanish: the one spinous process that is still palpable will be the one of C7. Once the C7 spinous process was identified, the bottom tip of the vertebra locator pointed to it. To ensure the forward head arm was horizontal, the examiner manually adjusted the participant's head to read zero in the sagittal plane dial. The vertebra locator was adjusted so that the bubble on top of the locator was centered within the two vertical lines on the dial. The forward head arm (horizontal) and the vertebra locator (vertical) formed the right angle. This assured the tester that the vertebra locator was truly vertical. The forward head arm, marked in 0.5 cm units, indicated the horizontal distance from the bridge of the nose to the intersection with the vertebra locator. The examiner stood to the left side of the participant to read the sagittal plane dial meter of the CROM instrument. The white tape on the left side of the forward head arm screened the actual reading.

For measuring the side bending angle, the earlier procedures were repeated without the forward head arm and the reading of the horizontal inclinometer was recorded. Then, we used 5%, 10%, and 15% of BW schoolbags carried on the back for measuring the CVP and on the dominant shoulder for measuring the side bending angle in stance. The participant was asked to walk 100 meters three times, while carrying the aforementioned bags with three percentages of BW for recording the second, third and fourth measurements. Thirty minutes of rest before shifting to the higher load was used to avoid the effect of exhaustion and fatigue on the measurement. At the end of each trial, the CVP and cervical side bending angles were recorded.

Statistical analysis

Statistical analysis was performed using PASW version 17.0 software (SPSS Inc., Chicago, IL, USA). Descriptive statistics were calculated to summarize the demographic characteristics of the sample and all outcome measures at baseline (first measurement), 5%, 10% and 15% of BW load (second, third, and fourth measurement or condition) for the participants. Repeated measures analysis of variance (ANOVA) followed by the Bonferroni post-hoc pairwise comparisons to compare changes due to load were used to test for the main effect of backpack weight on the neck posture during static posture and after walking with different loads. A p value of ≤ 0.05 was considered statistically significant with a confidence interval of 95%.

RESULTS

Eligible participants and their anthropometric characteristics are reported in Table 1. A repeated measures ANOVA was used to examine the changes in CVP and side bending angle caused by various load weights (5%, 10%, 15%), followed by post-hoc pairwise

Table 2. Craniovertebral protrusion and side bending angle at each weight and condition of backpack loads

	Female students		Male students	
	CVP (cm)	Side bending (°)	CVP (cm)	Side bending (°)
Condition	Mean±SD	Mean±SD	Mean±SD	Mean±SD
Unloaded	0.4±0.5	0.2±0.6	0.5±0.4	0.3±0.6
Loaded with 5% body weight	1.2±0.6	1.8±1.3	0.5±0.4	0.3±0.6
Loaded with 10% body weight	2.0±0.7	3.8±1.7	2.0±0.7	3.5±1.7
Loaded with 15% body weight	3.9±1.0	6.4±1.8	3.8±0.9	6.2±2.0
After walking with 5% body weight	2.1±0.8	3.3±1.7	1.2±0.4	3.3±1.8
After walking with 10% body weight	3.3±1.0	6.1±2.1	3.3±0.7	6.0±2.2
After walking with 15% body weight	6.5±1.0	10.1±2.2	6.1±0.9	9.9±2.6

CVP: Craniovertebral protrusion; SD: Standard deviation.

Table 3. Craniovertebral protrusion at different conditions, weights, and sexes

Condition	Female students					Male students				
	5% of BW	10% of BW	15% of BW	F	*p*	5% of BW	10% of BW	15% of BW	F	*p*
Unloaded vs. loaded										
Mean±SD difference	0.9±0.9	1.6±0.8	3.5±1.0	218.1	0.001	0.1±0.2	1.5±0.8	3.3±0.7	281.61	0.001
Significant	0.001	0.001	0.001			0.348	0.001	0.001		
Unloaded vs. walking with load										
Mean±SD difference	1.7±0.9	2.9±1.0	6.2±1.1	262.6	0.001	0.7±0.5	2.8±0.9	5.7±1.0	562.61	0.001
Significant	0.001	0.001	0.001			0.145	0.001	0.001		

BW: Body weight; SD: Standard deviation; p= Significant at p≤0.05.

comparisons to compare changes due to weight and condition. For the unloaded condition, the mean CVP was 0.4±0.5 cm among female students and 0.5±0.4 cm among males; the mean side bending angle is 0.2±0.6° among female students and 0.3±0.6° among males. The mean CVP (cm) and side bending angle (degree) for each weight and condition are listed in Table 2. The interaction between weight and condition was significant for the CVP and side bending angle among female students (F=218.1, F=262.6, respectively; p<0.001). Among male students, the interaction between weight and condition was also significant for both forward and lateral head postures (F=281.1, F=562.61, respectively; p<0.001), indicating that there was a difference in the forward head posture and lateral deviation caused by an increased load on the back or the dominant hand (Tables 3, 4).

Among female students, pair wise comparison at baseline loading, there were immediate and statistically significant changes in CVP and side bending angle for 5%, 10% and 15% of BW backpack loads (p=0.001) during stance or after walking. On the other hand, among male students, there were statistically significant changes in CVP and side bending angle for the 10% and 15% of BW and backpack loads (p=0.001), but not for the 5% of BW load (p=0.384 and p=0.145) during stance and after walking 100 meters (Tables 3, 4).

DISCUSSION

This study identified a relationship between sex, backpack weight, condition, and the forward/side head postural compensation in schoolchildren ages 10 to 15 years. The present study also found a strong interaction of backpack weight and condition on CVP and side bending angle. Schoolbag weights had an immediate effect on forward/lateral head posture. This is consistent with the Grimmer et al. study,[1] which reported similar changes in the sagittal position of the body segments to adjust the body's center of gravity to accommodate a posterior load. Additionally, Orloff and Rapp's[18] examination of the spinal curvature and load carriage of a 13.8% of BW backpack showed significant increases in the thoracic and lumbar spinal curvatures, as the participants became exhausted while carrying the weighted backpack. Furthermore, Chansirinukor et al.[14] suggested that postural responses were sensitive to the load carriage. On the other hand, the results of the latter study contradict with our results, when the loads were less than 15% of BW or when using the student's own schoolbag. Chansirinukor et al.[14] did not report the exact weight of the student's own bag which might vary day by day according to the classes' timetable. In addition, the mean age of the students used in study was higher than that of our study.

Table 4. Side bending angle at different conditions, weights, and sexes

Condition	Female students					Male students				
	5% of BW	10% of BW	15% of BW	F	*p*	5% of BW	10% of BW	15% of BW	F	*p*
Unloaded vs. loaded										
Mean±SD difference	1.6±1.2	3.5±1.6	6.1±1.7	239	0.001	0.3±0.3	3.2±1.6	5.9±1.9	179.9	0.001
Significant	0.001	0.001	0.001			0.215	0.001	0.001		
Unloaded vs. walking with load										
Mean±SD difference	3.1±1.6	5.9±2.0	9.9±2.0	384.6	0.001	3.1±1.8	5.8±2.2	9.6±2.5	171.45	0.001
Significant	0.001	0.001	0.001			0.157	0.001	0.001		

BW: Body weight; SD: Standard deviation; p= significant at p≤0.05.

In another study, Negrini et al.[19] measured the effect of 8 and 12 kg load on the posture and suggested that these loads forced the postural system to its physiological limits without any significant difference between the used loads. These results are consistent with our results in regard to the effect of load on posture; however, we were able to detect the appropriate load in relation to the body weight in two functional tasks. Grimmer et al.[1] also reported similar changes in the sagittal position of the body segments to adjust the body's center of gravity to accommodate a posterior load. They, however, were unable to find an evidence to support or recommend the appropriate weight for schoolbags.

Furthermore, post-hoc tests using the Bonferroni correction revealed that 5% of BW elicited a slight change in CVA and side bending angles, which was not statistically significant among male students, but statistically significant among female students. For male students, our results are strongly consistent with the Lai and Jones' results,[20] which indicated that cervical and shoulder postures were influenced by both amount and duration of weight carried by a backpack and potential problems might occur from backpack weights greater than 10% of BW. Kistner et al.[21] also showed that schoolbags loads carried by schoolchildren should be limited to 10% of BW due to increased forward head positions and subjective complaints at higher loads.[21]

Based on our study results, the weight should be less than 5% of BW in female students. This can be attributed to the physiological differences between male and females. Additionally, due to many social factors, female students at that age in Hail region encounter many limitations and restriction in physical activities which may affect their muscle strength and ability to carry schoolbags with weight greater than 5% of BW.

Moreover, awareness should be increased among teachers and parents to restrict backpack load less than 5% of BW by using new technology (e-books, tablets, or iPads), school locker shelves, and need to regularly monitor the musculoskeletal problems associated with carrying heavy schoolbag loads in preadolescent children.

The main limitation to this study is the setting of the study. As this study was conducted inside the schools, we were only able to measure the cervical postural changes. The school authorities refused to transfer the students for measuring the lumbar and thoracic postural changes using the rasterstereography image for more data.

In conclusion, a school bag should not be more than 5% of BW for the female students and 10% of BW for male students. Otherwise, it will be a risk factor for postural and musculoskeletal problems either immediately or during adulthood.

Declaration of conflicting interests

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REFERENCES

1. Grimmer K, Dansie B, Milanese S, Pirunsan U, Trott P. Adolescent standing postural response to backpack loads: a randomised controlled experimental study. BMC Musculoskelet Disord 2002;3:10.
2. Negrini S, Carabalona R. Backpacks on! Schoolchildren's perceptions of load, associations with back pain and factors determining the load. Spine (Phila Pa 1976) 2002;27:187-95.
3. Kovacs FM, Gestoso M, Gil del Real MT, López J, Mufraggi N, Méndez JI. Risk factors for non-specific low back pain in schoolchildren and their parents: a population based study. Pain 2003;103:259-68.
4. Moore MJ, White GL, Moore DL. Association of relative backpack weight with reported pain, pain sites, medical utilization, and lost school time in children and adolescents. J Sch Health 2007;77:232-9.
5. Jones GT, Watson KD, Silman AJ, Symmons DP, Macfarlane GJ. Predictors of low back pain in British schoolchildren: a population-based prospective cohort study. Pediatrics 2003;111:822-8.
6. Korovessis P, Koureas G, Papazisis Z. Correlation between backpack weight and way of carrying, sagittal and frontal spinal curvatures, athletic activity, and dorsal and low back pain in schoolchildren and adolescents. J Spinal Disord Tech 2004;17:33-40.
7. van Gent C, Dols JJ, de Rover CM, Hira Sing RA, de Vet HC. The weight of schoolbags and the occurrence of neck, shoulder, and back pain in young adolescents. Spine (Phila Pa 1976) 2003;28:916-21.
8. Grimmer K, Blizzard L, Dwyer T. Frequency of headaches associated with the cervical spine and relationships with anthropometric, muscle performance, and recreational factors. Arch Phys Med Rehabil 1999;80:512-21.
9. Grimmer KA, Williams MT, Gill TK. The associations between adolescent head-on-neck posture, backpack weight, and anthropometric features. Spine (Phila Pa 1976) 1999;24:2262-7.
10. Watson DH, Trott PH. Cervical headache: an investigation of natural head posture and upper cervical flexor muscle performance. Cephalalgia 1993;13:272-84.
11. Sharan D, Ajeesh PS, Jose JA, Debnath S, Manjula M. Back pack injuries in Indian school children: risk factors and clinical presentations. Eur J Phys Rehabil Med 2008;44:33-8.
12. Pascoe DD, Pascoe DE, Wang YT, Shim DM, Kim CK. Influence of carrying book bags on gait cycle and posture of youths. Ergonomics 1997;40:631-41.

13. Adams MA, Dolan P. Spine biomechanics. J Biomech 2005;38:1972-83.
14. Chansirinukor W, Wilson D, Grimmer K, Dansie B. Effects of backpacks on students: measurement of cervical and shoulder posture. Aust J Physiother 2001;47:110-6.
15. Kanlayanaphotporn R, Lam L, Williams M, Trott P, Fulton I. Adolescent versus adult responses to vertical spinal loading. Ergonomics 2001;44:1384-91.
16. Florêncio LL, Pereira PA, Silva ER, Pegoretti KS, Gonçalves MC, Bevilaqua-Grossi D. Agreement and reliability of two non-invasive methods for assessing cervical range of motion among young adults. Rev Bras Fisioter 2010;14:175-81.
17. Garrett TR, Youdas JW, Madson TJ. Reliability of measuring forward head posture in a clinical setting. J Orthop Sports Phys Ther 1993;17:155-60.
18. Orloff HA, Rapp CM. The effects of load carriage on spinal curvature and posture. Spine (Phila Pa 1976) 2004;29:1325-9.
19. Negrini S, Carabalona R, Sibilla P. Backpack as a daily load for schoolchildren. Lancet 1999;354:1974.
20. Lai JP, Jones AY. The effect of shoulder-girdle loading by a school bag on lung volumes in Chinese primary school children. Early Hum Dev 2001;62:79-86.
21. Kistner F, Fiebert I, Roach K. Effect of backpack load carriage on cervical posture in primary schoolchildren. Work 2012;41:99-108.