Impact of backpack load on ventilatory function among 9-12 year old Saudi girls

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ABSTRACT

الأهداف: لاستكشاف نسبة وزن حقيبة الظهر التي يحملها فتيات المدارس السعوديات الذين تتراوح أعمارهم بين 12-9 سنة. لدراسة تأثير حمل حقيبة الظهر على وظائف التنفس لدى هؤلاء الفتيات. لتحديد عند أي حمل تتأثر وظائف التنفس بما في ذلك: الحجم المدّي , السعة الحيوية، السعة الحيوية القسرية، الحجم التنفسي القسري في الثانية الأولى، نسبة الحجم التنفسي القسري في الثانية الاولى الى السعة الحيوية القسرية، ذروة تدفق الزفير و التهوية الطوعية القصوى.

الطريقة: شاركت في هذه الدراسة المستعرضة غير التجريبية 91 من طالبات المدارس السعوديات اللاتي تتراوح أعمارهن بين 12-9 عام. تم استخدام مقياس التنفس لقياس وظائف التنفس في حالتين، أولاً وضع الوقوف دون حمل حقيبة الظهر، وثانياً أثناء حملها. تم قياس الوزن، والطول، وحساب متوسطهما، ووزن حقيبة الظهر ونسبتها لوزن الجسم لجميع المشاركات في العينة.

النتائج: كان متوسط نسبة حقيبة الظهر الى وزن الجسم 13.8% وهو أعلى من الحد الموصى به (10% من وزن الجسم). ووجدت الدراسة أن جميع وظائف التنفس قد انخفضت بشكل ملحوظ أثناء حمل حقيبة الظهر باستثناء نسبة الحجم التنفسي القسري في الثانية الاولى إلى السعة الحيوية القسرية. ووجدت الدراسة أن الانخفاض قد ظهر الانخفاض عند أقل وزن محمول ضمن العينة(7.4%) من وزن الجسم.

خاتمة: انخفاض كبير في جميع وظائف التنفس باستثناء نسبة الحجم التنفسي القسري الثانية الأولى إلى السعة الحيوية القسرية. وقد ظهر الانخفاض أثناء حمل حقيبة ظهر تبلغ (7.4%) من وزن الجسم. لذلك أوصت هذه الدراسة بأن الحد الأقل الآمن لحقيبة الظهر يجب أن يكون أقل من 7.4% من وزن الجسم للفتيات السعوديات الذين تتراوح أعمارهم بين 12-9 عام.

Objectives: To explore the backpack load as a percentile of body weight (BW) and its impact on ventilatory function including tidal volume (Vt), vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in one second (FEV1), FEV1/FVC, peak expiratory flow (PEF), and maximum voluntary ventilation (MVV) among 9-12 year old Saudi girls.

Methods. This is a prospective, experimental study of 91 Saudi girls aged between 9-12 years from primary schools in Riyadh, Saudi Arabia. The study took place in King Saud University, Riyadh, Saudi Arabia between April 2012 and May 2012. Ventilatory function was measured under 2 conditions: a free standing position without carrying a backpack, and while carrying a backpack.

Results: The backpack load observed was 13.8% of the BW, which is greater than the recommended limit (10% BW). All values of ventilatory function were significantly reduced after carrying the backpack (p<0.001) with the exception of FEV1/FVC (p>0.178). The reduction was observed even with the lowest backpack load (7.4% BW).

Conclusion: A significant reduction was reported for most of the ventilatory function parameters while carrying the backpack. This reduction was apparent even with the least backpack load (7.4% BW) carried by the participants. This study recommends that the upper safe limit of backpack load carried by Saudi girls aged 9-12 years should be less than 7.4% of BW.

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Backpacks are popularly used by students to carry their school belongings in many countries.[1] Therefore, serious concerns about the harmful effects of backpacks are growing. Guidelines by the American Occupational Therapy Association for safe backpack use are outlined as that a loaded backpack should never weight more than 10% of body weight (BW) while the American Physical Therapy Association recommends that backpack load to be less than 15% of the student's total BW.[2,3] In Saudi Arabia, a considerable proportion (50%) of Saudi school boys carried an over loaded (more than 10% BW) backpack.[4] The highest rate of growth for school-aged children occurs during 10-15 years.[5] Therefore, proper backpack use and safe limit should be emphasized during these ages where an excessive stress on a child's body may result in overuse injuries. Recent published studies in the literature have suggested that pulmonary function is more sensitive to backpack loading than what was previously thought. In China, it was found that there was a significant decrease in forced vital capacity (FVC) at a backpack load of 5% BW while the forced expiratory volume in one second (FEV1) decrease was found at a backpack load of 7.5% BW.[6] Obviously, the exact weight of backpacks which affect the ventilatory function is debatable. Therefore, we aim to explore what is the backpack load, as a percentage of BW that is carried by Saudi school girls aged 9-12 years and to investigate the impact of backpack load on ventilatory function including tidal volume (Vt), vital capacity (VC), FVC, FEV1, FEV1/FVC ratio, peak expiratory flow (PEF) and maximum voluntary ventilation (MVV) among 9-12 year old Saudi girls. This study hypothesized that Saudi school girls aged 9-12 years do not follow the recommended weight limit (10% BW), and there is no impact of backpack load on ventilatory function among 9-12 year old Saudi girls.

Methods. This is a prospective and experimental study of 91 healthy Saudi girls aged between 9-12 year old. They were voluntary recruited from primary schools in Riyadh, Kingdom of Saudi Arabia between April 2012 and May 2012. Geographical cluster sampling was applied as Riyadh is divided into main 5 regions (Middle, North, South, West, and East). One thousand consent forms were distributed, 681 were returned, 590 forms were excluded due to incomplete information or the subject refused to participate, or did not meet the inclusion criteria.

Inclusion criteria. Students who carried a 2 strap backpack to school daily, healthy Saudi girls without any current respiratory problems, age between 9-12 years, body mass index within the normal range for child's age (from 5th percentile to less than the 85th percentile), and using a car to go to and from school and being able to perform the spirometry maneuvers appropriately.

Exclusion criteria. Children with known current or past cardiopulmonary disorders including: congenital heart disease and upper respiratory tract infection within 3 weeks prior to data collection, orthopedic disorders involving the thorax such as scoliosis, kyphosis, history of spinal or shoulder trauma, overweight, obese, or underweight children, recent surgeries (in a period of less than 3 months) involving the thorax, abdomen, or eye, systemic disorders such as diabetes mellitus, participating in any physical activities (1/hour, 3 times/week) or formal training and organized sports.

This study was approved by King Saud University (Postgraduate and Research Committee of Health Rehabilitation Sciences Department). All the participants' parents signed the consent form before starting the study.

A purpose-designed screening form was distributed to the children and was answered by their parents. A digital weight-height scale (Detecto ProDoc, PD300 Professional Digital Column Scales) was used to measure the weight and height of each participant. Ventilatory function measurements were assessed using a spirometer (MicroLab 3300, MicroMedical Spirometer Mk 8, England) that incorporates a digital volume transducer, which measures expired volumes adjusted for body temperature and saturated vapor pressure (BTPS). The transducer is, therefore, insensitive to the effects of condensation and temperature and does not require calibration prior to each clinical application.

The examiner visited the chosen schools to meet the principals and provided the approval of the Ministry of Education. The aim of the study, inclusion/exclusion criteria and procedure were explained to each principal. In the same visit the screening form and informed consent were given to principals to distribute them among female Saudi students aged between 9-12 years to be completed and signed by their parents. At a specified day, the examiner met the participants and explained the aim of the study and procedure to them in a simple and understandable manner. They were asked whether they complained of any pain, and a physical assessment including the observation of rounded shoulders, kyphosis, and a forward bending test for scoliosis were performed for each participant to rule out any pain or deformity. Height and weight were measured by the digital weight-height scale. The body mass index (BMI) was calculated as weight in Kg/ square of height in meters before starting. All participants used their own backpacks. The BW without and with the backpack was measured by the examiner without shoes and jacket. The examiner visited the schools every day for a week to measure the weights of the backpacks. The average weight of backpacks used during the week was calculated. The participants were required to wear their backpacks for 5 minutes prior to spirometric measurements to accustom to the backpack. Ventilatory function measurements were made according to the standards proposed by the American Thoracic Society (ATS). Variables measured were; static (VC) and dynamic (FVC, FEV1, FEV1/FVC, PEF and MVV). All the variables were measured by the spirometer except for (Vt) which was calculated using the estimated tidal volume in children (Vt= 4-8 ml/kg). From a standing position the participant carried out 3 spirometry tests guided by the following instructions: a) for the static variable: breathe normally for 30 seconds, put the spirometer mouthpiece into your mouth, inhale through your nose, and exhale through the spirometer, breathing normally, b) for dynamic variables: wear the nose clip, take a deep and slow breath in, place lips around the disposable mouthpiece, exhale fully and with as much force as possible, blasting out all the air in the lungs.

The highest value of the 3 trials was recorded. The spirometric variables were measured with same instructions while in the following conditions: a free standing position without any loading for static and dynamic variables (**Figures 1A & 1B**), a standing position while carrying the backpack for static and dynamic variables. (**Figures 2A & 2B**). The spirometer, which is designed with a child incentive display screen

Figure 1 - Photograph of **A**) static and **B**) dynamic spirometic measurement without backpack.

Figure 2 - Photograph of **A**) Static and **B**) dynamic spirometic measurement with backpack.

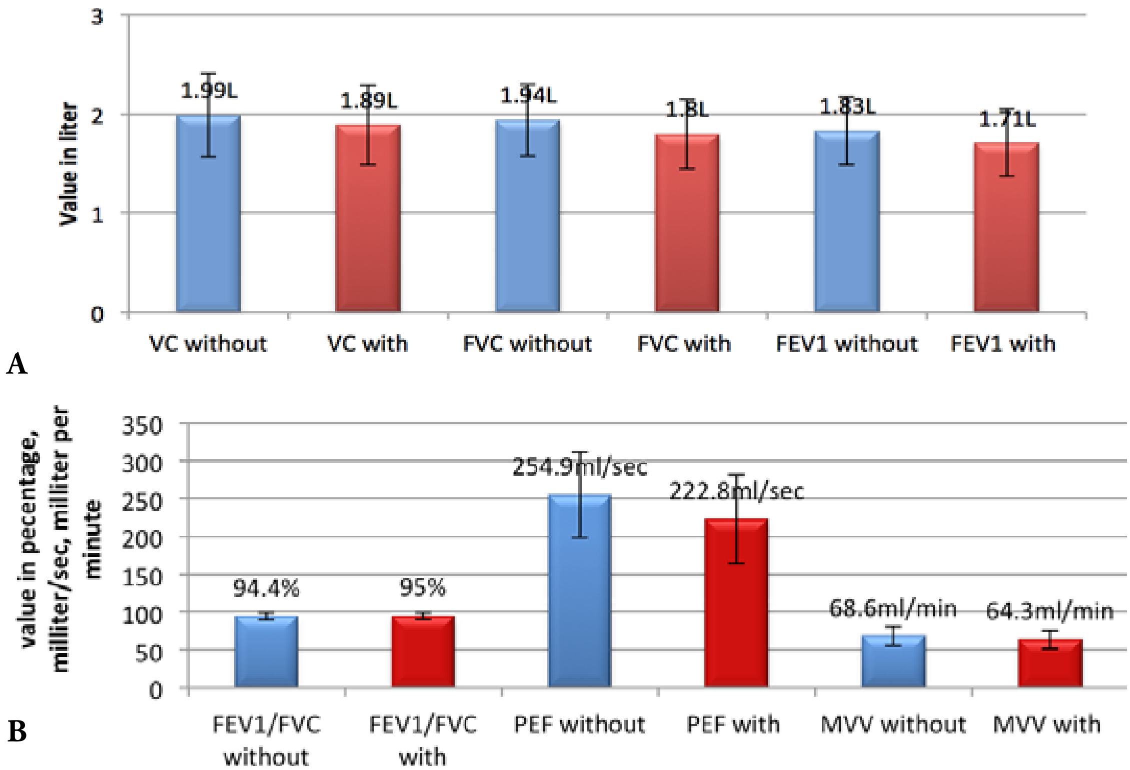

Figure 3 - Ventilatory function tests for all participants without and with backpack: **A**) ventilatory function without and with backpack: vital capacity (VC) in liter, forced vital capacity (FVC) in liter and forced expiratory volume 1 (FEV1) in liter. **B**) Forced expiratory volume to forced vital capacity (FEV1/FVC) in percentage, peak expiratory flow (PEF) in milleter per second and maximum voluntary ventilation (MVV) in milliter per minute.

and measured most lung volumes including (Vt), was unavailable during conducting the study. We therefore did not measure (Vt) rather we calculated it using the estimated tidal volume in children equation (Vt= 4-8 ml/kg). The number of participating girls was 91 participants. A thousand forms were distributed, 681 were returned, 590 forms were excluded (390 due to sudden cold or upper respiratory tract infection and 200 due to absence or failure to attend the measurement during the week of the test) also the lack of cooperation of school principals, teachers and parents had an effect on gathering more students. This study was limited to 9-12 year old due to the fact that spirometric maneuvers are effort-dependent and skills such as understanding, attention, coordination, and cooperation are required from children and therefore these skills will need a lot of effort and are time consuming for the researcher if applied on participants younger than 9 years.

Statistical analysis. Continuous data (namely, ventilatory function tests) were described as means and standard deviations. The means of backpack weights and percentages of BWs were calculated through 5 days of the week. To identify if there was a difference in ventilatory function while carrying a backpack and without, a paired t-test was used. Then to know at which backpack load (from 7.4% to ≤10%, and more than 10% to ≤30% BW) that ventilatory function was affected we used a paired t-test. All analyses were conducted using SPSS version 16 (IBM, New York, United States)

Results. The general characteristics of ninety one participating Saudi girls aged between 9-12 years old and backpack load as percentage of BW are showed in **Table 1**. There were differences in most ventilatory function tests without and with carrying backpack for all participants as showed in **Figure 3**. The paired t-test revealed that all values of different parameters of ventilatory function tests were significantly reduced with carrying a backpack ($p<0.001$) except FEV1/FVC ($p>0.178$) as shown in **Table 2**. The results revealed that there was a significant reduction in ventilatory function when carrying a backpack from 7.4% to ≤10% BW in VC, FEV1, PEF, and MVV. Also, there was a significant reduction in ventilatory function while carrying a backpack more than 10% to ≤30% BW in VC, FVC, FEV, PEF, and MVV with exception of FEV/FVC1 as shown in **Table 3**.

Discussion. The purposes of this study were; to identify the backpack load as a percentage of BW that is carried by Saudi school girls aged 9-12 years and to investigate the impact of the backpack load on ventilatory function including; Vt, VC, FVC, FEV1, FEV1/ FVC, PEF, and MVV. The findings of this study showed that the mean of backpack weight in kg among 9-12 year old Saudi girls was 4.7 kg (range between 2.6-8.7 kg). This result is comparable to most studies in the literature. Internationally, the mean school backpack weight reported ranged between 4.7-19 kg.[7] Locally, in the Kingdom of Saudi Arabia, a study found that Saudi school children carried a school bag that weighed on average 3.23 kg.[4] In addition, this result corresponded with results of neighboring countries, where it was reported that school backpacks weighed on average 3.3 kg in Iran, 3.51 kg in Palestine, and 5-19 kg in Egypt.[7-9] As regards to the percentage of backpack weight in relation to body weight (% BW), the present study revealed that the mean was 13.8% BW (ranging between 7.4-29% BW). That indicated that 9-12 year

Table 1 - General characteristics of all participating Saudi girls.

Variable	Mean	± SD	Minimum	Maximum
Age (years)	10.5	0.8	9.0	12.0
Weight (Kg)	34.7	6.5	21.80	52.10
Height (cm)	140	8.7	110.0	160.0
Body mass index (%)	17.6	1.9	13.7	21.2
Backpack weight (Kg)	4.7	1.2	2.6	8.7
Backpack as % of body weight (%)	13.8	4.0	7.4	29.1

Table 2 - The paired t-test of ventilatory function without and with carrying backpack for all participants.

Ventilatory function	Mean difference	SD	*P*-value*
Vital capacity with BP-without BP	-0.10	0.15	<0.001*
FVC with BP-without BP	-0.14	0.11	<0.001*
FEV1 with BP-without BP	-0.12	0.10	<0.001*
FEV1/FVC with BP- without BP	0.58	4.09	>0.178†
PEF with BP- without BP	-32.10	30.99	<0.001*
MVV with BP-without BP	-4.33	3.36	<0.001*

FVC - forced vital capacity, FEV1 - forced expiratory volume in one second, FEV1/FVC - forced expiratory volume in one second to forced vital capacity ratio, peak expiratory flow, maximum voluntary ventilation (MVV). *paired t test (significant p<0.001), †non-significant

Table 3 - Paired t-test among participants according to the backpack percentage without and with carrying a backpack.

Variables	No	Condition	Mean ± SD	t	P (2-tailed)*
VC (liter)	14	without BP	1.989±0.352	4.13	0.001*
		from 7.4% to ≤10%BW	1.895±0.360		
	77	without BP	1.998±0.420	6.01	0.000*
		from >10% to ≤30%BW	1.887±0.405		
FVC (liter)	14	without BP	1.866±0.290	0.32	0.750†
		from 7.4% to ≤10%BW	1.831±0.271		
	77	without BP	1.961±0.357	3.26	0.002*
		from >10% to ≤30%BW	1.977±0.363		
FEV1 (liter)	14	without BP	1.862±0.265	3.42	0 .004*
		from 7.4% to ≤10%BW	1.742±0.226		
	77	without BP	1.826±0.349	12.27	0.000*
		from >10% to ≤30%BW	1.705±0.354		
FEV1/FVC (%)	14	without BP	94.571±4.484	-1.64	0.122†
		from 7.4% to ≤10%BW	95.50±4.031		
	77	without BP	94.47±4.257	-1.02	0.311†
		from >10% to ≤30%BW	94.97±4.252		
PEF (ml/sec)	14	without BP	259.286±33.143	4.630	0.000*
		from 7.4% to ≤10%BW	223.714±35.842		
	77	without BP	254.21±58.983	9.01	0.000*
		from >10% to ≤30%BW	222.12±61.316		
MVV (ml/min)	14	without BP	69.214±14.000	4.200	0.001*
		from 7.4% to ≤10%BW	64.786±13.443		
	77	without BP	68.58±12.444	1.838	0.000*
		from >10% to ≤30%BW	64.29±12.472		

Vital capacity (VC), forced vital capacity (FVC), forced expiratory volume in one second (FEV1), forced expiratory volume in one second to forced vital capacity ratio (FEV1/FVC), peak expiratory flow, maximum voluntary ventilation (MVV), *paired t-test (significant p<0.001), †non-significant old Saudi school girls carried backpack weights more than the recommended limit (10% BW). This result was comparable with international studies that reported the backpack % BW carried by school children as ranging from 12-19.9% BW.[5,10-13]

The differences in both backpack weight in kg and backpack as % BW between studies may be produced by the differences in age, gender, grades[9] or differences in culture, school curriculum, educational system and the type of the books required in each country.[13] Other reasons may also be due to the availability of facilities such as lockers and usage of electronic systems in other schools and countries.

The current study found that most of ventilatory function parameters including; VC, FVC, FEV1, PEF and MVV were significantly reduced (p<0.001) with carrying a backpack ≥7.4% of BW with exception of FEV1/FVC. This was in agreement with results of studies in literature that were conducted to explore the effect of backpack load on ventilatory function. Bygrave et al[14] found that carrying backpacks of 15 kg was associated with decreased FVC and FEV1 values (p<0.001). Leg and Cruz[15] showed reduction in FVC (p<0.03) with 6 kg backpack. Also, Chow et al[6] found reduction in FVC, FEV1 (p<0.001) with backpack loads of 5% and 7.5% of BW. These findings can be explained by understanding the mechanics of breathing in which the main power of ventilatory function is pressure differences and thoracic cage movement, so any alteration of this mechanical process (by the carrying backpacks in this study) will subsequently affect the mechanics of breathing and reduce the ventilatory function. During normal breathing the chest is expanded in 3 diameters; vertical diameter by diaphragm download movement, transverse diameter by contraction of the external intercostal muscles (a water bucket-handle movement), and anteroposterior diameter by action of the sternomastoid muscle (pump-handle movement).[15,16] During the carrying of a backpack, the chest wall kinematics and breathing pattern will be changed in different mechanisms. The first mechanism is the production of a trunk forward lean (TFL) which results from carrying a backpack. This will lead to restriction of the downward movement of the diaphragm. In addition, the vertical diameter of the chest will decrease and this will cause a reduction in rib cage displacement and a progressive increase of abdominal contribution to tidal volume. The pressure gradients will change and as backpack loads increase, the inspiratory volumes will be limited and subsequently, expiratory volumes will be affected. This mechanism is supported by study in the literature. Brackley and Stevenson[5] stated that increased trunk forward lean (TFL) and decreased trunk angular range of motion may affect chest and abdominal respiratory muscle movement. The second mechanism that influences chest wall kinematics during the carrying of a backpack is that the side to side movement of the rib cage may be restricted by compression of both sides of the backpack on the sides of the rib cage and opposition of its movement (a water bucket-handle movement) which decreases the transverse diameter and limits the antero-posterior diameter of the chest (pump-handle movement). Then again the pressure gradient, which is responsible to move air in and out of the lungs, is affected and subsequently, the ventilatory function is reduced. The third mechanism is discussed by Bygrave et al[14] they showed that tight-fitting shoulder/chest straps of the backpack were associated with decreased FVC and FEV1 values as they oppose the expansion of the rib cage. In our current study, the only parameter that did not show reduction was FEV1/FVC (p=0.178) where it was increased with carrying a backpack. This can be explained by the fact that FEV1/FVC is reduced as a result of the narrowing of the bronchial lumen size which therefore would increase the resistance to the airflow as what would happen in obstructive dysfunctions, and this might not be produced by carrying a backpack.[17] Also, FEV1/FVC was even increased because FVC was reduced more than FEV1 in this study. This finding was consistent with previous literature in which the authors suggested that the changes in ventilatory function were characterized by a mild restrictive pattern, reducing both FVC and FEV1 without causing a reduction of FEV1/FVC.[17,18] To identify at which load the ventilatory function may be affected, we divided the participants, statistically, into 2 groups according to backpack %BW (from 7.4% to ≤10% BW and from >10% to ≤30% BW).

Our results indicated that there was a significant reduction in most of ventilatory function without and with carrying a backpack of both backpack load range (from 7.4% to ≤10% BW and from>10% to ≤30% BW). These findings are in agreement with the findings of Chow et al[6] who found that the reduction of ventilatory function was significant at a backpack load of 5% BW for FVC and at 7.5% BW for FEV1 and they suggested that pulmonary function was more sensitive to backpack loading than what was previously thought.

This study has some limitations including unavailability of MicroMedical spirometer that designed to measure all ventilatory function including Vt, drop out of a number of participants due to sudden cold or upper respiratory infection, absence of participating girls for some days within the week of measurement.

This study concludes that the mean backpack load as a percentage of BW was 13.8% which was greater than the recommended limit (10% BW); that may be due to size and type of books and unavailability of facilities such as lockers and electronic educational system in the schools. There was a significant reduction of most ventilatory function parameters including; VC, FVC, FEV1, PEF, and MVV with the exception of FEV1/FVC while carrying a backpack of 7.4% BW as result of alteration of breathing mechanics and pressure gradients by heavy backpacks. Therefore this study recommends that the maximum safe limit of backpack weight carried by Saudi school girls aged 9-12 years should less than 7.4% BW.

The important aspect of this study is to emphasize on maintaining normal ventilatory function and preventing possible further complications due to restriction of breathing mechanics by heavy backpacks among school children. However, further research is needed to explore the long term effect of excess backpack weight carried by students over a prolonged period of time.

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References

1. Brackley HM, Stevenson JM, Selinger JC. Effect of backpack load placement on posture and spinal curvature in prepubescent children. ***Work*** 2009; 32: 351-360.
2. American Occupational Therapy Association. Strategies for Successful Backpack Day Event. [Updated 2013; Accessed 30 November 2013]. Available at: http://www.aota.org/Conference-Events/Backpack-Safety-Awareness-Day/StrategiesForEvent.aspx
3. American Physical Therapy Association, 2009. Is your child's Backpack making the grade? [Updated 2013; Accessed 30 November 2013]. Available at: http://www.apta.org/Media/Releases/Consumer/2009/4/14/
4. Al-Hazzaa HM. School backpack. How much load do Saudi school boys carry on their shoulders? ***Saudi Med J*** 2006; 27: 1567-1571.
5. Brackley HM, Stevenson JM. Are children's backpack weight limits enough? A critical review of the relevant literature. ***Spine (Phila Pa 1976)*** 2004; 29: 2184-2190.
6. Chow DH, Ng XH, Holmes AD, Cheng JC, Yao FY, Wong MS. Effects of backpack loading on the pulmonary capacities of normal schoolgirls and those with adolescent idiopathic scoliosis. ***Spine (Phila Pa 1976)*** 2005; 30: E649-E654.
7. Dianat I, Javadivala Z, Allahverdipour H. School bag weight and occurrence of shoulder, hand/wrist and low back symptoms among Iranian elementary schoolchildren. ***Health Promotion Perspectives*** 2011; 1: 76-85.
8. Amro A. and Al-Faqeeh A., 2009. The effect of school bag weight on pain, posture and vital capacity of lungs of three elementary school in Bethlehem district in Palestine. Middle East Journal of Family Medicine [online]. [Updated 2009; Accessed 18 November 2012] Available at: http://www.mejfm.com/mejfmAug09_vol7-iss7/schoolbag.htm
9. Ibrahim A. Incidence of back pain in Egyptian school girls: effect of school bag weight and carrying way. ***World Applied Sciences Journal*** 2012; 11: 1526-1534.
10. Goodgold S, Mohr K, Samant A, Parke T, Burns T, Gardner L. Effects of backpack load and task demand on trunk forward lean: Pilot findings on two boys. ***Work*** 2002; 18: 213-220.
11. Whittfield J, Legg SJ, Hedderley DI. Schoolbag weight and musculoskeletal symptoms in New Zealand secondary schools. ***Iran J Public Health*** 2010; 39: 120-125.
12. 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: 232-239.
13. Kellis E, Emmanouilidou M. The effects of age and gender on the weight and use of schoolbags. ***Pediatr Phys Ther*** 2010; 22: 17-25.
14. Bygrave S, Legg SJ, Myers S, Llewellyn M. Effect of backpack fit on lung function. ***Ergonomics*** 2004; 47: 324-329.
15. Des Jardins T. Cardiopulmonary Anatomy and Physiology; Essentials of Respiratory Care. 5th ed. New York: Delmar Cengage Learning; 2008.
16. Guyton A, Hall J. Textbook of Medical Physiology. 12th ed. Philadelphia (PA): Elsevier Saunders; 2011.
17. Hillegass E. Essentials of cardiopulmonary physical therapy. 3rd ed. Philadelphia (PA): Elsevier Saunders; 2010.
18. Legg S, Cruz C. Effect of single and double strap backpacks on lung function. ***Ergonomics*** 20044; 47; 318-323.