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Postural Changes in Response to Unilateral Backpack Load on Dominant and Non-dominant Sides in Adolescent Females

SamahAttia El Shemy[1],Mona Nabil Ayad[2], Sara Shawki Mohammed[3]
[1]Professor at Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, Cairo University, Egypt
[2]Lecturer at Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, Cairo University, Egypt
[3]Demonstrator at Department of Physical Therapy for Pediatrics, Faculty of Physical Therapy, 6 October University, Egypt
Corresponding Author: Sara Shawki Mohammed,

Abstract: Aim: *This study aimed to investigate the effect of carrying unilateral backpack on dominant and non-dominant sides on posture in female adolescents.*

Subjects and Methods: *Seventy five adolescent female students were participated in this study. Their age ranged from 12-18 years.All students wereassessedusing formetric instrument system under three conditions;during carrying backpack on dominant,non-dominant side, and without carrying any load. The outcome measures includetrunk variables (trunk imbalance, inclination and inclination angle), pelvicvariables (pelvic tilt, torsion, rotation and inclination), spineangles (maximum kyphotic and lordotic angles) anddeviation variables (lateral deviation RMS, maximum lateral deviation and surface rotation).*

Results: *The results showed statistically significant differences in all measured variables during the three testing conditions with greater differences in loading condition on dominant than non-dominant side.*

Conclusion: *Carrying unilateral backpacks on dominant or non-dominant side has a negative effect on female adolescents' posture with more asymmetry during dominant side loading.*

Keywords: *Unilateral load, backpack, adolescent females, posture, formetric, dominant, non-dominant*

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I. Introduction

There are many types of backpack designs including shoulder bags, traditional double strap backpacks and hand carried bags. Despite warnings issued by various professional organizations regarding the harmful effects of carrying unevenly distributed heavy loads, students continue to carry shoulder bags over one shoulder of self-selected body side[1-3]. Decreased availability of school lockers as a result of security concerns, increased homework, larger textbooks, and other objects being carried to school has prompted the increased use of backpacks by school students which in turn, lead to both an increase in weight and duration of backpack carrying[4].

Adolescent school students now carry their bags over one shoulder either dominant or non-dominant although it is more harmful than carrying over both shoulders[5]. Carrying unilateral shoulder bag for prolonged periods of time can have negative effects on the human body posture. These effects include musculoskeletal misalignment, muscle spasms, spinal asymmetry. Repetitive periods of postural asymmetry can lead to asymmetric muscular activity and spinal curvature which may contribute to the development of functional scoliosis and back pain over time[6].

Asymmetric load displaces the location of the center of mass (COM) of the locomotor system towards the loaded side. To preserve dynamic balance, the loaded individual tends to shift the COM back to the limits of stability. This can be achieved by compensatory postural adjustments. The findings indicate two types of adaptation mechanism. One is active trunk flexion towards the contralateral side. The other adapted under the condition that the trunk is laterally bend towards the ipsilateral side. Both adjustments help the body to minimize the energy expenditure and increase the efficiency of walking with load. However, the postures adjusted may cause injury or reduce performance, because the natural motion of trunk is in the backward/forward direction, rather than the lateral direction[5].

During adolescence, there is a hormonal difference between females and males. The higher estrogen concentration in females may have the potential to directly affect the structure and composition of the ligaments that play an important role in maintaining stability, contributing to the higher injury risk in females, particularly, at the time of the pubertal estrogen influx [7, 8].

It was reported that the adolescent spine may be vulnerable to developing low back pain from carrying heavy backpacks during the most critical period of spinal development from 12-14 years as the spinal ligaments and muscles are not fully developed until after 16 years of age. The tissues of the human body are sensitive and responsive to tension, compression, shear and torsion of the loads that are applied to them[9].It is of great importance to identify the most important changes occurring in spinal posture and the ideal way for students to wear a single strap shoulder bag if it is the bag of choice [10]. Accordingly, this is an area that needs to be further investigated as a cause of pathology especially in female adolescents. Therefore, this study aimed to investigate the effect of unilateral loading on posture in adolescent females.

II. Subjectsand Methods

Subjects:

Seventy five adolescent female students selected from preparatory and secondary schools in Giza participated in this study. Their age ranged from 12 to 18 years. They were enrolled in this study if they had the following inclusion criteria: a) their body mass index (BMI) ranged from 1SD to -2SDaccording toBMI for age - Z score chart[11], b) all students are right handed, andc) they use unilateral backpack. They were excluded from the study if they had fixed contractures or deformities of the spine, upper or lower extremities, neurological disorders or surgical interference.

This study was performed according to the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. It was approved by the Ethics Review Committee of the Faculty of Physical Therapy, Cairo University, Egypt (No: P.T. REC/ 012/002009).

The purpose and procedures of the current study were explained to the parents of participating children and they gave signed written informed consent approving their children participation in the study. This study was conducted from August 2018 to March 2019.

Procedure:

Measurement of back geometry

The formetric instrument system represents a reliable method for three-dimensional back shape analysis and reconstruction of the spinal deformities without ionizing radiation exposure [12].

Each student data was entered in her file on the computer including date of birth, name, sex, height and weight. Students were asked to stand facing the black back ground screen at a distance of 2 meter away from the scan system either on the ground or on the blocks (according to his/her height). The horizontal line of scan system should lie below the inferior angles of scapulae. The female’s back (just above the buttocks) was completely bare to avoid disturbed image structures. Students were instructed to assume the usual natural standing attitude with chin in to improve the presentation of the vertebral prominence. They were asked to keep both upper extremities freely extended beside the body as much as possible. Height adjustment of the optical column was done before capturing to obtain the suitable image. When the camera was ready for image recording, a green horizontal line appeared on the computer screen and the projector lamp was automatically switched. During capture, each student was asked to hold on breath for a period of 40 ms. Full back shape three-dimensional analysis was recorded and printed out for each child[13].

All students were assessed using formetric instrument system under three testing conditions; during carrying unilateral backpack on dominant, non-dominant side, and without carrying any load. Unilateral backpack represents 10 % of the body weight[14]. The bag measured 46x35x15cm.Sand bags of different weights were inserted inside the school bag to represent the 10% of body weight [15].

Through one capture, the following parameters were measured; trunk variables (trunk imbalance, inclination and inclination angle), pelvic variables (pelvic tilt, torsion, rotation and inclination), spine angles (maximum kyphotic and lordotic angles) and deviation variables (lateral deviation RMS, maximum lateral deviation and surface rotation). This procedure was repeated three times and the mean value of each parameter for each student was calculated and used for analysis.

Statistical analysis

All statistical tests were performed through the statistical package for social studies (SPSS) version 22 for windows (IBM SPSS, Chicago, IL, USA). The level of significance for all statistical tests was set at $p < 0.05$. Descriptive statistics in the form of mean and standard deviation was conducted for all measured variables. One way ANOVA with repeated measures was conducted to compare the three measurement conditionsfollowed by posthoc pair wise comparisons.

III. Results

Seventy-five right handed adolescent females were included in this study. The descriptive characteristics of participated adolescents including age, weight, height and body mass index (BMI) were shown in table (1).

As shown in table (2) and (3), there were significant differences among the three testing conditions in the mean values of trunk imbalance, inclination (mm), inclination angle (degrees), pelvic tilt, torsion and rotation (p=0.0001). There were significant increase in the mean values of trunk and pelvic variables during carrying on dominant side compared with non-dominant side condition (p=0.001). Non-significant difference was observed in pelvic inclination between the three testing conditions (p = 0.16).

As illustrated in table (4) and (5), there was non-significant difference in the mean values of maximum kyphoticand lordotic angle among the three testing conditions (p =0.2) while significant differences were found in the mean values of lateraldeviation (RMS), maximum lateral deviation and surface rotation among the three testing conditions (p =0.0001).There was asignificant increase in the mean values of deviationvariables and surface rotation during carrying on dominant side compared with non-dominant side condition (p = 0.001).

IV. Discussion

This study was conducted to determine the postural changes while carrying a unilateral backpack on the dominant andnon-dominant side compared to non-loadingcondition in female adolescents.

The results of the current study showed that unilateral spinal loading either on dominant or non-dominant side always prompts postural variationsin all measured variablesin adolescent female students with greater postural asymmetry during dominant side loading thanthe non-dominant side. This could be attributed to the postural adjustment mechanism byshifting the trunk away from the loaded side toward the unloaded side.

The results of the presentstudy come in agreement withGrabiecet al.[16] who studied the influence of asymmetrical backpack carrying in primary school students. Theyreported that there is an increase in the asymmetry of the shoulders, scapulae, pelvis, and trunk which could be attributed to the trunk compensatory position due to placing too much burden on the child’s shoulders. This result is accompanied by a compensatory lateral flexion of the body in the direction opposite to the load.

These findings were also supported byConnolly etal.[17] whoreported that lateral deviation in the frontal plane occurs in response to a pack carried on one shoulder. Similarly, Konrad[18] found that unilateral loading modes created asymmetrical deviations far from the load which brought about significant greater postural asymmetrical deviations and adjustments than symmetrical loading. He added that shoulder and handheld packs delivered postural deviations in all planes which might bring about unfavorable stress and strain on spinal structures resulting in pain and progressive postural scoliosis. Carrying the load on the right shoulder fundamentally increased the thoracic lateral curvature in the frontal plane.

The results of the present study could be explained by the findings of Schlosseret al.[19]who reported that these postural deviation is due toasymmetry in spinal loading leading to asymmetry in paraspinal muscles activation which finally causesabnormal vertebral growth and remodeling of the intervertebral discs. Approximately 80% of all cases of structural scoliosis are termed idiopathic, meaning the condition has no apparent biologic or mechanical cause[20].Moreover, Marks etal.[21]found that this asymmetry in paraspinal muscle activation could lead to spinal lateral curvature (adolescent idiopathic scoliosis) which affects adolescent females four times as often as malesduring adolescent growth spurt periodespecially those experiencing a rapid growth spurt.

Haselgroveet al.[22]explainedthe postural changes during loading as the height of the loaded shoulder accompanied by counter-balancing lowering of the non-loaded shoulder. Adjustments of the spinal curvature inferable from this improper posture could be named as functional scoliosis. This occurs temporarily as the spinal column continues its right arrangement and correcting the poor posture by removing the load. Such changes of the spine might be in charge of the postural discomfort and musculoskeletal shoulders and back pain related to substantial load carriage.

The results of the present study contradict with the findings of Qureshi and Shamus [10] who reported that carrying a shoulder bag with a unilateral strap on the non-dominant shoulder draws the shoulder closer to the height of the dominant shoulder, facilitating more symmetrical posture and equalizing weight bearing through the lower extremities in static standing.

Arnsdorff[23]also reported that a single strapped bags influence posture by brought about expanded cranial thoracic spine pivot, increased shoulder rise, expanded pelvic tilt and increased trunk lateral flexion, because of weight bearing on one side of the spine. Additionally, previous studies[24-26]reported that these postural changes will probably brought about an increase in muscle activity of the back muscles in charge of adjusting the posture by keep up the area of COM over the base of support during walking. This increased muscle action had been connected with increased postural imbalance and injury.

Brandon et al.[27] studied the effect of carrying backpacks under two conditions, low on back or high on back. They found that the children alter their posture by elevating their right shoulder, thereby increasing the contact pressure and loading the right shoulder more to support the backpack load. On the other hand, Krebs et al.[28]studied the activity of trapezius, erector spinae and latissimusdorsi by electromyography during ipsilateralstrap and contralateral shoulder strap carrying load. They found thatthere was no significant difference in the muscle activityof left and right latissimusdorsi muscles during any loading conditions.

The present study has some limitations;small sample size restricts the ability to make generalization of the results. The examination procedure requires the adolescent females' back to be bare skin which was refused by some females restricting the sample size. Future study is needed including larger sample size. Also, due to gender specific postural differences, future study is needed to compare the effect of backpack carriage on posture of both sexes at different ages.

V. Conclusion

Based on the findings of this study, carrying unilateralbackpacks either on dominant or non-dominant sides could result in postural asymmetry which isgreaterduring dominant than non-dominant side loading. Bilateral back pack is more preferable as it equalizes the weight distribution on both sides.

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Conflict Of Interest
The authors reported no conflict of interest.

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Table 1. Demographic characteristics ofthe study group

	Study group (n=75) $\bar{X}$ ±SD
Age (years)	15.06 ± 2.36
Weight (kg)	55.94 ± 8.05
Height (cm)	158.97 ± 8.4
BMI (kg/m²)	22.01 ± 1.64

$\bar{X}$**: Mean**, SD: standard deviation, BMI: body mass index

Table 2. Comparison of trunk and pelvic variables among the three testing conditions

Variables	Testing conditions			f- value	p-value
	None	DS	NDS		
Trunk imbalance (mm)	6.51 ± 2.8	36.86 ± 16.36	29.31 ± 12.93	142.92	0.0001*
Trunk inclination (mm)	8.47 ± 3.34	20.01 ± 5.13	12.02 ± 3.95	149.83	0.0001*
Trunk inclination (degrees)	2.56 ± 1.06	3.73 ± 1.37	2.3 ± 1.15	36.53	0.0001*
Pelvic tilt (mm)	2.4 ± 1.15	4.65 ± 1.79	2.54 ± 1.25	96.44	0.0001*
Pelvic torsion (degrees)	1.68 ± 0.96	3.64 ± 1.29	1.89 ± 0.91	88.43	0.0001*
Pelvic inclination (degrees)	21.6 ± 6.52	22.66 ± 5.86	21.78 ± 6.98	1.86	0.16
Pelvic rotation (degree)	2.57 ± 1	4.88 ± 1.7	2.72 ± 0.98	71.75	0.0001*

Values are presented as mean± standard deviation, DS: dominant side, NDS: non-dominant side-value: ANOVA with repeated measure, p-value: probability value,*p <0.05

Table 3. Pair wise comparisons of trunk and pelvic variables among the three testing conditions

Variable	Testing conditions	Mean Difference	p-value
Trunk imbalance (mm)	None versus DS	-30.35	0.0001*
	None versus NDS	-22.8	0.0001*
	DS versus NDS	7.55	0.001*
Trunk inclination (mm)	None versus DS	-11.54	0.0001*
	None versus NDS	-3.55	0.0001*
	DS versus NDS	8	0.0001*
Trunk inclination (degrees)	None versus DS	-1.17	0.0001*
	None versus NDS	0.26	0.46
	DS versus NDS	1.43	0.0001*
Pelvic tilt (mm)	None versus DS	-2.25	0.0001*
	None versus NDS	-0.14	0.58
	DS versus NDS	2.11	0.0001*
Pelvic torsion (degrees)	None versus DS	-1.96	0.0001*
	None versus NDS	-0.21	0.54
	DS versus NDS	1.75	0.0001*
Pelvic rotation (degree)	None versus DS	-2.31	0.0001*
	None versus NDS	-0.15	0.87
	DS versus NDS	2.16	0.0001*

DS: dominant side, NDS: non-dominant side, p-value: probability value, *p <0.05

Table 4. Comparison of spine angles and deviation variables among the three testing conditions

Variables	Testing conditions			f- value	p-value
	None	DS	NDS		
Maximum Kyphotic angle (degree)	50.55 ± 14.01	48.9 ± 11.5	50.89 ± 13.55	1.61	0.2
Maximum lordotic angle (degrees)	47.98 ± 10	48.13 ± 9.37	47.02 ± 8.9	1.25	0.28
Lateral deviation RMS (mm)	6.01 ± 2.13	10.38 ± 3.61	9.3 ± 3.35	48.87	0.0001*
Maximum lateral deviation (mm)	6.64 ± 2.24	15.14 ± 5.01	10.57 ± 3.65	98.75	0.0001*
Surface rotation (degrees)	4.23 ± 1.96	8.08 ± 2.46	7.14 ± 2.89	52.09	0.0001*

Values are presented as mean± standard deviation, DS: dominant side, NDS: non-dominant side, F-value: ANOVA with repeated measure, p-value: probability value,*p <0.05

Table 5. Pair wise comparisons of spine angles and deviation variables among the three testing conditions

Variable	Testing conditions	Mean Difference	p-value
Lateral deviation RMS (mm)	None versus DS	-4.37	0.0001*
	None versus NDS	-3.29	0.0001*
	DS versus NDS	1.08	0.08
Maximum lateral deviation (mm)	None versus DS	-8.5	0.0001*
	None versus NDS	-3.93	0.0001*
	DS versus NDS	4.57	0.0001*
Surface rotation (degrees)	None versus DS	-3.85	0.0001*
	None versus NDS	-2.91	0.0001*
	DS versus NDS	0.94	0.13

DS: dominant side, NDS: non-dominant side, p-value: probability value, *p <0.05

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