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Effect of asymmetrical backpack load on spinal curvature in school children

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Abstract.
BACKGROUND: Carrying a backpack is common among schoolchildren. The effect of backpack load on spine pain and posture defects in children is often raised in the literature. According to scientific research, the maximum backpack load that is safe for children must not exceed 10–15% of their body mass. There is a lack of scientific reports related to the effect of frequently wearing a backpack on one shoulder among children and young adults and its influence on the shape of the anterior-posterior curvatures of spine.
OBJECTIVES: The aim of this study is to evaluate body posture parameters in the sagittal plane for an asymmetrical backpack load equal to 10% of a child's body mass.
METHODS: The study was conducted using 162 primary schoolchildren aged 11–13 years. Each participant underwent three tests that examined postural parameters, including habitual posture, with the backpack on the participant's right and left shoulder. Posture was measured with the CQ Elektronik; which uses photogrammetry to make anthropometric calculations based on an image of the examined surface.
RESULTS: The asymmetrical backpack load resulted in a significant reduction of thoracic kyphosis (GKP: $p = 0.040$). The angle of thoracic kyphosis increased between the measurements. The difference (GAMMA $= 0.054$) revealed that the results were approaching significance.
CONCLUSIONS: Considering the gravity of the problem, children should be educated on ergonomics by teachers, physiotherapist or nurses, including instructions on carrying a backpack and the effects of disregarding the basic rules on body posture, as part of their school curriculum. The acceptable backpack load, which is now believed to be 10% of the child's body mass, should be carefully considered by scientists. Our own results show that even a load of 10% of the body mass may induce negative changes in spinal posture.

Keywords: Spinal load, back pain, asymmetric loading, children

1. Introduction

Carrying a backpack is common among schoolchildren. Nowadays, approximately 90% of children in developed countries carry a backpack [1]. The effect of backpack load on spine pain and postural defects in children is often questioned in the literature [2,3].

According to scientific research, the maximum backpack load that is safe for children must not exceed 10–15% of their body mass [4]. Several studies have found that a backpack load exceeding 15–20% of a child's body mass increases the risk of spine pain, posture and gait disorders [5–7]. Another study found that the maximum backpack load must not exceed 20% of a child's

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body mass in the case of a symmetrical load and 10% of a child's body mass in the case of an asymmetrical load [8]. Studies on symmetrical backpack load have been widely reported in the scientific literature and their results are largely unambiguous. Most of these studies have focused on evaluation of the acceptable weight of the backpack [6,9], and the impact of backpack load on posture, gait [7,8] and back pain [1,9–11].

It is still not clear, however, what the acceptable load should be when the backpack is carried asymmetrically [12,13], despite the fact that most children (72.3%) prefer to carry their backpack on one shoulder [14]. For this reason, we aimed to test the hypothesis that a backpack load of 10% of the child's mass carried asymmetrically negatively influences spinal curves.

2. Aim of the study

The aim of this study was to evaluate postural parameters in the sagittal plane for an asymmetrical backpack load equal to 10% of a child's body mass.

3. Materials and methods

After obtaining family consent and child assent to participate, 162 primary schoolchildren (82 girls and 80 boys) aged 11–13 years were included in the study. Each participant underwent three tests that examined postural parameters.

To keep testing procedures reliable and reproducible, testing was routinely carried out at the same time of day (in the morning hours), using the same testing equipment operated by the same researcher. The first test was carried out in the habitual standing posture without backpack (measurement I). The first measurement was used as a baseline for the measurements with asymmetric load. The second test was carried out with the backpack on the subject's right shoulder (measurement II) and the third test with the backpack on the participant's left shoulder (measurement III). In the second and third tests, the mass of the backpack equalled 10% of the child's body mass. The load was fixed immediately before the test, after establishing each child's body mass with electronic scales (within an accuracy of ± 0.1 kg). Each measurement was performed using each participant's own backpack. Body posture was measured with the "CQ Elektronik". This equipment uses photogrammetry to make anthropometric calculations based on an image of the examined surface. A spatial image is obtained by the equipment displaying lines of strictly defined parameters on each participant's back. When the lines fall on the participant's back at a specific angle, they become deformed. The obtained image is then rasterised and the result of the process is a contour map of the examined surface [9–11,15]. The photograms were analysed without participants. The study utilised the parameters presented in Table 1.

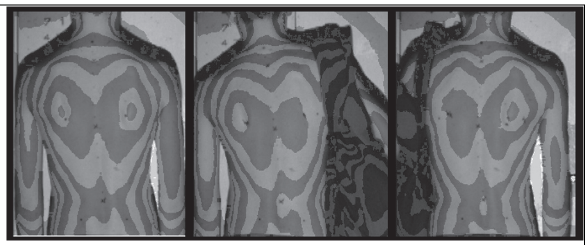

Fig. 1. An example of a photogrammetric test.

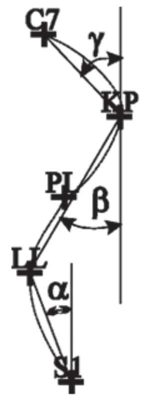

Fig. 2. Angles of inclination of different sections of the spine relative to the vertical.

Consent to conduct the tests was obtained from the Bioethics Commission of Rzeszow University, Poland. An example of a photogrammetric test is presented in Fig. 1.

Angles of inclination of different sections of the spine relative to the vertical are presented in Fig. 2. All tests were conducted in January 2013.

4. Statistical methods

To conduct statistical analysis of the collected data, the analysis of variance (ANOVA) Friedman test was applied. This test analyses the differences in more than two measurements of the dependent variables. Differ-

Table 1
Parameters applied in the study

Parameter	Description
ALPHA	Inclination of the lumbosacral section of the spine. The angle calculated between S1 and the deepest place of lordosis.
BETA	Inclination of the thoracolumbar section of the spine. The angle is calculated between the transition lordosis and kyphosis at the peak of kyphosis.
GAMMA	Upper thoracic region angle. The angle between C7 and the peak of kyphosis.
KPT	Sagittal inclination of the trunk. Referred to the deviation of line C7-S1 "forward" or "backward"
KKP	Angle of thoracic kyphosis. KKP = 180 − (BETA + GAMMA)
GKP	Depth of thoracic kyphosis calculated between the top of kyphosis and kyphosis moving into lordosis
KLL	Angle of lumbar lordosis. KLL = 180 − (ALPHA + BETA)
GLL	Depth of lumbar lordosis calculated between transition of between kyphosis in lordosis and the deepest point of lordosis
GKS	Depth of cervical spine calculated between C7 and external occipital tuberosity

Table 2
Comparison of parameters for the anterior-posterior-spinal curvatures-in the habitual posture (measurement I), with the backpack on the participant's right shoulder (measurement II) and the with the backpack on the participant's left shoulder (measurement III). Comparisons are for measurements I and II and for measurements I and III

Variable	Measurement I		Measurement II		Measurement III		Friedman test	
	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	x^2 ANOVA	P
ALPHA	12.00	17.26	15.50	19.82	14.46	20.73	$x^2 = 1.55$	0.461
BETA	7.65	3.13	7.30	2.89	8.69	6.43	$x^2 = 0.77$	0.679
GAMMA	25.54	23.76	26.58	22.57	25.61	22.09	$x^2 = 5.86$	0.054
KPT	−8.52	16.64	−9.38	17.31	−6.48	18.44	$x^2 = 4.01$	0.133
KKP	146.86	23.89	146.20	22.03	146.34	22.45	$x^2 = 4.28$	0.118
GKP	11.50	6.14	10.17	6.12	11.45	8.33	$x^2 = 9.13$	0.040
KLL	170.72	21.38	172.00	24.74	173.06	25.72	$x^2 = 0.50$	0.778
GLL	−12.10	5.92	−10.90	5.94	−16.55	28.04	$x^2 = 4.41$	0.110
GKS	11.69	7.04	11.81	7.52	12.80	8.10	$x^2 = 1.54$	0.462

statistically significant difference ($p < 0.05$).

ences in the means of three measurements from the same group of participants were determined. The non-parametric test was chosen due to the failure to meet the assumptions of parametric tests for dependent variables concerning the compliance of the distributions of all tested variables with the normal distribution. The compliance of the distributions with the normal one was verified using the Shapiro-Wilks test. In the case where the occurrence of significant differences between the three measurements was noted, a post-hoc test was carried out. The test verifying the results between each of the three measurements (each pair of results separately: I with II, I with III and II with III) was the Wilcoxon signed-ranks test. The level of statistical significance, also in the case of the last test, was < 0.05.

The arithmetic mean and standard deviation, the chi-squared ANOVA test value and the p-value were calculated for each parameter, where $p < 0.05$ denoted statistical significance.

5. Results

The results of this study point to an increase in the lumbosacral region angle (inclination of the lumbosacral section of the spine – ALPHA) during carriage of an asymmetrical load for both measurements II and III, when compared to the measurement conducted in the habitual posture (I), although this difference was not statistically significant ($p = 0.4607$). The asymmetrical backpack load resulted in a significant reduction of thoracic kyphosis (GKP: $p = 0.040$). The post-hoc test for parameter GKP showed differences between the measurements I and II ($p = 0.021$). Detailed results are shown in Table 3. The thoracic kyphosis angle (KKP) and parameters for lumbar lordosis (KLL, GLL) did not reveal any significant changes during asymmetrical load. The cervical spine depth increased, but the increase in this parameter was not statistically significant (GKS: $p = 0.462$). The upper thoracic region angle increased between the measurements. The difference (GAMMA = 0.054) identified a trend; however, this difference was not statistically significant.

6. Discussion

The results of our study revealed a significant flattening of thoracic kyphosis when the backpack was worn on the participant's right shoulder. There was a

Table 3
Post-hoc test Wilcoxon signed-ranks test for GKP parameter

TKD	Measurement I	Measurement II	Measurement III
Measurement I	–	0.0021	0.3042
Measurement II	0.0021	–	0.2304
Measurement III	0.3042	0.2304	–

Statistically significant difference ($p < 0.05$).

tendency for deepening of cervical lordosis; however, the difference was not statistically significant. Other parameters did not reveal any clear differences between measurements I, II and III.

An asymmetrical backpack load equal to 10% of body mass resulted in a tendency for an increase in the upper thoracic spine curvature and to move the head forward in our study population, creating flattening of thoracic kyphosis.

The effect of backpack load has been discussed by numerous authors [5,13]. However, most authors have studied the effect of symmetrical load [1,6,14–16], even though most children declare that they carry their backpack asymmetrically [17]. Only a few studies regarding the problem of influence of backpack load on spine have been published. Negrini et al. found that an asymmetrical backpack load of 8 kilograms leads to an increase in the thoracic kyphosis angle and lumbar lordosis angle in comparison to a symmetrical load, which, in practice, means the flattening of these curves [19]. Flattening of the physiological curvature of the spine reduces the amortisation function of the spine, which may lead to degenerative changes in the intervertebral disc in the future and pain during adulthood [20,21].

Our study is the first to measure the dimensions of all anterior-posterior curvatures, the curvature angles and the bending of the whole trunk. In addition, our study required children to use the same backpack that they carried on an everyday basis, rather than substitutes provided by the study. The substitutes would load the spines similarly, but would not create an identical biomechanical situation as an everyday backpack would.

Postural disorders and postural changes are very common in schoolchildren [6,22,23]. The causes of trunk deformations are still ambiguous and therefore all studies of the various effects on spinal biomechanics of the spine appear to be legitimate. Backpack overload is also common [24,25]. Our results show that even a backpack load equal to 10% of body mass leads to negative postural changes. In recent years, one of the most common sagittal plane changes in children has been the flattening of thoracic kyphosis and forward bending of the head due to several factors. These changes can be observed during physiotherapy and during the screening process. In the scientific literature, to date, no study has proven the reasons behind such changes. One can only assume that this is related to the sedentary lifestyle and gradual decrease in physical activity in children. Our study shows that carrying the backpack asymmetrically increases both of these changes, irrespective of whether the backpack is carried on the left or right shoulder. Korovessis et al. [26] noted a statistically significant correlation between carrying a backpack and thoracic spine pain in children; however, they did not find any connection between symmetrical and asymmetrical load and spine pain. The phenomenon of the flattening of thoracic kyphosis has been increasingly observed in young patients visiting orthopaedists with thoracic and lumbar spine pain. The flattening of the curvatures may lead to an increase in forces affecting the spine and a decrease in the spine biomechanical endurance. The flattening of thoracic kyphosis is a risk factor for scoliosis [27]. However, this issue requires further research. It should be remembered that it is not just the backpack load, but also the length of time spent carrying the backpack that plays an important role [24]. Authors in previous studies have not taken into consideration changes in postural parameters over time. The continuation of existing research will broaden their examination of changes in body posture under the influence of time and the effect of time spent with the load on the spine on those parameters characterising the behaviour of the body. Our research will continue to measure the chosen postural parameters with a decreasing load starting from 10% of body mass, to establish what kind of load is safe for the spine. In addition, future studies should compare the impact of asymmetric and symmetric loads. The results of this study, along with conclusions drawn by other authors, show that tolerance limits for carrying loads for children must be set more carefully.

In many countries, children carry excessive loads in their backpacks on a daily basis. In most schools, students are not able to leave their textbooks and school items at school, meaning that they are required to carry them to school every day. The distance that the children walk daily with a backpack is very long, especially for children residing in rural areas who cannot reach their schools by bus. The cost of purchasing cabinets for schools is very low in comparison with the amount that must later be spent from the national budget to remedy the consequences of carrying excessive loads for prolonged periods of time; that is, to treat postural deformities and spinal pain among children. It is also necessary to introduce educational programs for both children and teenagers, informing them about the rules of ergonomics and how to adhere to them in a school environment, as well as providing information regarding the negative consequences of not adhering to those rules [28,29]. Primary schools should introduce regular screening for the assessment of posture and weight of the backpack, which should be carried out by qualified physiotherapists. This should also involve providing a series of educational programs for students, parents and teachers who should monitor the efficiency and effectiveness of these educational programs during the school year.

7. Conclusions

Considering the gravity of the matter, children should be educated on ergonomics as a part of their school programme, including instructions on carrying a backpack and the effects of disregarding the basic rules on body posture. The acceptable backpack load, which is currently believed to be 10% of the child's body mass, should be carefully considered. Our own results show that even a small load may induce negative changes in body posture.

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