INFLUENCE OF SCHOOL BACKPACK LOAD ON PLANTAR FOOT PRESSURE DURING WALKING IN 9–11 YEARS OLD GIRLS

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SUMMARY

Objective: This study aimed to assess the relative load of the midfoot and the metatarsals of both feet when schoolchildren walked with backpacks of different loads.

Methods: A group of 12 healthy girls (9.9 ± 0.8 years; 33.8 ± 6.7 kg, 1.40 ± 0.10 m) walked barefoot to assess plantar pressures during gait without load (L0%) and with a loaded backpack equal to 10% (L10%) and 20% (L20%) of their body weight. A Footscan® system (RSscan International, Belgium) was used to determine the contact area and relative pressure impulse in the midfoot and metatarsals on the dominant (DL) and non-dominant legs (NL).

Results: The effect of load was significant for the contact area of the midfoot for both NL ($p = 0.013$) and DL ($p = 0.001$). In the metatarsals, there was significantly greater relative impulse during L10% compared to L0% in the first ($p = 0.041$) and second ($p = 0.050$) metatarsals of the DL. Comparing the NL and DL showed significantly greater relative impulse on the DL in the fourth metatarsal during L10% ($p = 0.023$), greater contact area in the fifth metatarsal during L0% ($p = 0.050$), and greater impulse in the midfoot during L20% ($p = 0.028$) on the NL.

Conclusions: The school backpack load influences relative plantar pressure distribution, especially in the midfoot. Further, our findings suggest greater propulsion of the DL and supporting function of the NL.

Key words: gait, kinetics, health, biomechanics, overload, laterality

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INTRODUCTION

School backpacks that weigh as little as 10–15% of a child's weight can affect the locomotor system, and the child can become at risk of fatigue or musculoskeletal injury when carrying a heavy backpack for long periods of time (1, 2). With the weight of a school backpack, the ground reaction forces and plantar pressure in the foot-ground contact area increase (3). This can result in the longitudinal arches flattening, which is considered to be a source of plantar fasciitis development (4–6). It is also known that changes in walking associated with a flat foot can ultimately negatively affect torso position (7, 8). Therefore, as backpack load increases, there may be a greater risk of injury in children when walking.

It is well documented that greater loads result in increased plantar pressures; however, it is not clear whether this effect is similar for different parts of the foot or between dominant and non-dominant feet. Only a few studies have considered the effect of lateral preference on the movement of children during walking with different backpack loads (9, 10). Also, other authors (11) draw attention to this problem and recommend that the laterality of the lower limbs should be taken into account in gait research. Since laterality of the lower limbs is presented as one of the main causes of functional differences between the limbs, it may be one of the reasons for gait asymmetry (12). Some authors have claimed that lateral preference may affect the plantar pressure of the lower limbs in contact with the ground (9, 10) while the results of other studies show the opposite (13–15). Other research found that school age children transfer the weight of their body more on the right leg when standing (16), which is likely the dominant leg. Similarly, other authors found differences in the plantar pressure distribution in the midfoot, forefoot, and toe between the left and right legs in relation to the increasing load of the school backpack (17). However, the authors of this study were focused on the assessment of differences in pressure distribution between left and right feet, which may not be related to functional differences between lower limbs (12). Some authors (9, 10) suggest that that the propulsion phase of the stance phase is more controlled by the dominant limb and the non-dominant limb is more important for providing of support.

Taken together, there is a lack of evidence concerning the effect of school backpack load on the load of various areas of feet with regard to functional differences between limbs, especially in girls. Thus, the aim of this study is to assess the effect of backpack load on relative plantar pressures and contact areas of the dominant and non-dominant limbs in 9- to 11-year-old girls. We chose this age category, as in other studies (1, 3, 7, 8), because at this age the weight of the school backpack can increase significantly due to the increase of the volume of the school supplies and learning materials that students carry to and from school on a daily basis. We hypothesized that the increasing weight of the backpack would affect the pressure parameters of the foot differently in relation to providing support and propulsion.

MATERIALS AND METHODS

Participants

Twelve healthy girls (9.9 ± 0.8 years; 33.8 ± 6.7 kg, 1.40 ± 0.10 m) participated in this study. They were healthy and were not medially diagnosed with flat arches. Three test subjects had to be excluded from the statistical processing of the data in order to comply with the body weight criterion. All children voluntarily participated in the testing after being informed of the purpose of the study and after obtaining the written consent of the parents. All procedures performed in this study were in accordance with the ethical standards of the institutional and with the Helsinki declaration and its later amendments or comparable ethical standards. The research project was approved by the Ethics Committee of the Faculty of Education in Jan Evangelista Purkyně University in Ústí nad Labem under reference number (3/2016/4).

Procedures

The average weight of the school backpack that the children actually used on a daily basis was measured three times during the week before laboratory measurements. The weight of the school backpack was expressed as a percentage of participant's body weight (BW), and the average of three measurements was 15.7 ± 3.3% BW.

Children reported to the laboratory on two separate days. During the first day, the children's BW and height were measured. Then, two tests were performed to determine lower limb laterality: rolling a ball along a straight line and kicking the ball into a small goal. The leg chosen by the child for these tasks (right or left) was considered as the dominant/preferred leg (DL) and the opposite leg as the non-dominant leg (NL) (11, 18).

On the second day, gait was measured in the laboratory (22 °C, between 9 a.m.–3 p.m.) under three different barefoot walking conditions: walking without a school backpack (L0%), walking with a school backpack loaded to 10% of the child's BW (L10%), and walking with a school backpack loaded to 20% of child's BW (L20%). The school backpack was adjusted for each participant individually, and only the load of the backpack was changed. Before the measurement, each child walked with a backpack for 5 minutes to get used to the required walking speed and the measuring system.

Next, three valid attempts for each load (in order L0%, L10%, L20%) were measured. A successful record of both feet during normal smooth walking was considered as a valid measurement. Although previous research has shown that the typical self-selected walking speed of 10-year-old children is approximately 5 km/h (19), we suspected that the heavy backpacks would result in slightly slower speeds. We also suspected that some of the girls would have self-preferred walking speeds that were below the average of 5 km/h. Therefore, the speed of the walk was controlled to approximately 3.5 to 4.5 m/s, and each participant was measured separately.

Instrumentation and Data Processing

The Footscan® system (RSscan International, Olen, Belgium) with a platform size of 2.0×0.4 m and a measurement frequency of 125 Hz was used for the gait testing. This method is considered as reliable for testing walking performance (20). A runway was built in front of and behind the measuring platform to eliminate the height difference between the platform and the floor. Thus, the total length of the walkway was 7 m. Using the manufacturer's software, the following parts of the foot were evaluated in the stance phase: the midfoot (MDF) and the 1st–5th metatarsals (MT1–5) (Fig. 1). In these areas, the following variables were measured: contact area (CA) expressed in cm^2 and pressure impulses ($N \cdot s/cm^2$). Lastly, relative impulse (RI) was calculated as the quotient of the impulse of specific area of the foot relative to the impulse of the whole foot (without toes), which was expressed as a percentage, i.e. [the measured part of foot impulse/the whole foot impulse] ×100 (21, 22).

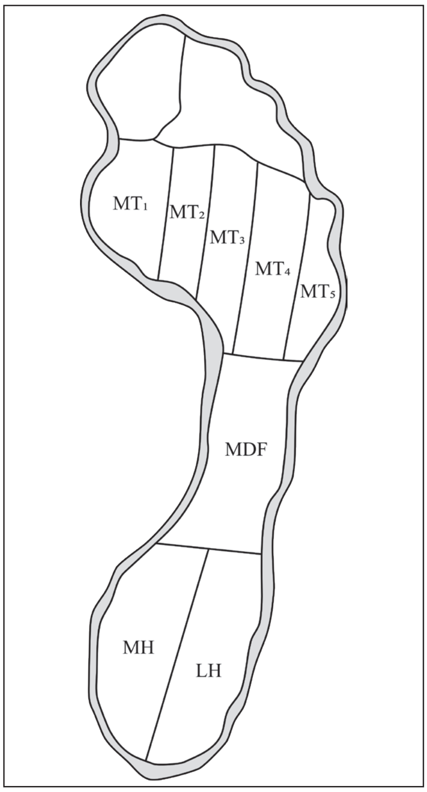

Fig. 1. *Individual parts of the foot.*

MT1–MT5 – first to fifth metatarsals; MDF – midfoot; MH – medial heel; LH – lateral heel

Statistics

Data processing was performed using Statistica (version 13, Tibco software, Palo Alto, USA). The data was not normally distributed (Shapiro-Wilk test); therefore, the following nonparametric statistical analyses were used: Friedman's test, post-hoc Wilcoxon test, and effect size r ($r=0.10$–0.29 small; $r=0.30$–0.49 moderate; $r>0.50$ large) (23, 24). From the three valid attempts, the median was used as the input value for statistical analysis. Differences between various loads and DL vs. NL were tested. The level of statistical significance was determined at $p<0.05$.

RESULTS

The magnitudes of relative impulses and contact areas at all observed areas are presented in Table 1.

In the metatarsals, there was no significant effect of load. Pairwise comparisons showed significantly greater relative impulse during L10% compared to L0% in M1 ($p=0.041$; $r=0.42$) and M2 ($p=0.050$; $r=0.40$) of the DL. When comparing the NL and DL, relative impulse was significantly greater on the DL in the M4 during L10% ($p=0.023$; $r=0.46$), and the contact area was significantly greater on the NL in M5 during L0% ($p=0.050$; $r=0.40$).

In the midfoot, there was a significant effect of backpack load on the contact area on the NL ($p=0.013$; $r=0.51$) and DL ($p=0.001$; $r=0.57$). On the NL, contact area was significantly greater in L20% compared to L10% ($p=0.023$; $r=0.46$), while on the DL, contact areas were significantly greater in L20% compared to L10% ($p=0.012$; $r=0.51$) and L0% ($p=0.015$; $r=0.50$), and L10% compared to L0% ($p=0.050$; $r=0.40$). In addition, there was significantly greater relative impulse on the NL compared to DL in L20% ($p=0.028$; $r=0.45$).

DISCUSSION

Although many studies have shown that increased load results in greater plantar pressures (1, 2, 25), it is not clear if this load is distributed equally to all foot parts and equally to both limbs. For these reasons, we focused on variables that describe relative changes in loading (relative impulse) and changes of plantar morphology (contact area) while also evaluating the effect of load on plantar loading asymmetry.

Table 1. *Effect of school backpack load on plantar foot pressures*

Foot area	Variable	Foot	L0%			L10%			L20%		
			Median	LQ	UQ	Median	LQ	UQ	Median	LQ	UQ
M1	RI (%)	NL	6.7	5.9	7.6	6.7	5.8	8.5	7.1	5.9	8.9
		DL	6.9	5.1	7.6	7.7*	6.2	9.5	7.7	4.5	11.3
	CA (cm^2)	NL	10.4	9.7	11.3	10.5	9.7	11.7	10.8	10.1	11.4
		DL	10.5	9.6	11.6	10.7	9.3	11.5	11.7	9.4	13.7
M2	RI (%)	NL	15.8	11.4	17.9	16.3	13.9	17.7	16.2	14.6	18.4
		DL	14.3	12.5	16.9	16.6*	15.9	18.2	16.5	12.8	17.7
	CA (cm^2)	NL	10.3	9.1	11.3	9.8	8.4	10.9	9.7	8.5	11.3
		DL	9.7	9.5	10.8	10.0	9.0	10.9	9.9	9.1	10.9
M3	RI (%)	NL	17.3	15.9	20.6	17.2	14.0	20.9	16.8	14.1	19.2
		DL	20.4	16.1	22.5	18.8	16.6	19.5	19.0	16.6	20.8
	CA (cm^2)	NL	8.4	7.5	9.6	8.3	7.4	9.0	8.5	7.2	9.3
		DL	8.4	7.0	9.0	8.2	7.3	8.8	8.3	6.8	9.0
M4	RI (%)	NL	13.4	11.8	15.4	13.8	11.8	14.4	12.8	10.1	15.3
		DL	15.5	13.7	18.1	16.8#	13.1	17.6	15.0	12.7	16.7
	CA (cm^2)	NL	8.2	7.7	9.2	8.7	6.9	9.9	8.6	7.9	9.9
		DL	8.6	7.6	9.6	8.4	7.3	9.2	8.3	7.3	9.4
M5	RI (%)	NL	5.4	3.0	8.7	6.3	3.8	9.3	4.1	3.3	6.0
		DL	4.3	3.4	5.8	5.3	2.9	6.7	4.4	3.8	6.2
	CA (cm^2)	NL	10.3	7.2	11.7	10.1	8.5	11.3	10.0	8.4	12.3
		DL	8.8#	7.8	10.0	8.9	7.7	9.6	9.1	8.4	9.8
Midfoot	RI (%)	NL	3.5	3.0	4.8	3.5	2.8	4.9	4.7	3.0	5.2
		DL	3.4	2.5	4.3	3.1	2.5	4.2	3.4#	2.5	4.4
	CA (cm^2)	NL&	29.6	23.6	30.1	27.6	23.9	31.9	31.0§	23.4	33.1
		DL&	26.3	22.1	27.6	27.5*	24.1	29.4	27.8*§	25.9	30.8

NL – non-dominant leg; DL – dominant leg; L0% – without load; L10% – load of school backpack of 10% BW; L20% – load of school backpack of 20% BW; M1–M5 – first to fifth metatarsals; RI – relative impulse in %; CA – contact area in cm^2; LQ – lower quartile; UQ – upper quartile; & – significant effect of load, * – significantly different than L0%, § – significantly different than L10%, # – significantly different than non-dominant foot.

Our results showed a significant effect of school backpack load on the contact area of the midfoot in both DL and NL. With heavier backpack load, the contact area was larger. This is consistent with other studies where the contact area in the middle of the foot increased by 4.3% when walking with a load of 16% BW (1), and by 8.8% with a load of 17% BW (25). In these cases, it may be that with heavier loads and increased muscle fatigue, the arch of the foot deforms, resulting in the enlargement of the midfoot area (26). This suggests that long-term exposure to heavy loads can be one of the contributing factors to the damage to the natural arch of the foot and the onset of plantar fasciitis (6). In the metatarsals area, there was no significant effect of the load on contact area.

Relative impulses showed changes in plantar pressure distribution between various parts of the foot. In our study, significantly greater relative pressure was found in M1 and M2 at L10% compared to L0%, but only on the DL, which suggests a certain transport of weight on medial part of the foot.

Another part of our study focused on evaluating the differences between DL and NL during different loads. Our results showed greater relative impulse on the DL in M4 during L10%, while in the midfoot, relative impulse was greater on the NL during L20%, indicating that there are certain functional differences between the lower limbs (12). The explanation of these findings could be associated with different phases of the stance (braking, propulsion). In healthy subjects, the maximum load can be seen in 40–50% of the stance duration for the midfoot and in 70–90% of the stance duration for the metatarsals (22). From this point of view, it can be expected that the maximum load for the midfoot occurs in the braking phase, and the maximum load for the metatarsals occurs in the propulsion phase of the stance. In fact, several authors have stated that the propulsion phase of the stance is controlled more by the dominant limb while the non-dominant limb creates rather support (9, 10). Thus, the non-dominant limb could have a larger effect on maintaining of stability during walking (27), which has been supported by Pau et al. (4). Conversely, the dominant leg is significantly involved in the distribution of force while moving (10). This finding is also supported by the results of another study (28), which showed higher values of plantar foot pressures on the dominant limb compared to non-dominant limb during running. A third difference between the DL and NL in our study was that the contact area in M5 was greater on the NL than the DL, suggesting its involvement in stabilizing the foot.

One important aspect of our study is the load of the backpack. Previous studies have also shown that approximately half of children wear a school backpack heavier than 15% of their BW (1, 29). In all of these studies, the average backpack load was near the upper limit of the recommended load of 10–15% BW (30). The weight of the school backpack exceeding 15% BW and its long-term effect during school attendance is one of the factors affecting the health of youth (1, 2). The average weight of children in our study was 33.8 ± 6.0 kg, and their actual school backpacks that they used every day were 5.1 ± 0.4 kg, which equates to an average of about 16% of their BW. This implies that around half of the children wear a school backpack heavier than is recommended. On the other hand, it is claimed that the load of the school backpack can be considered as a form of regular physical activity and can have a positive effect on children's health. The results show a significant effect of the L20% school backpack load on changes in the measured variables. In practice, this information is very important and is related to the individual body weight of the child. Children from the same class are loaded with approximately similar weight of the school backpack, which represents different influence on the body system for children with lower and higher BW. For example, a girl from the tested group weighing 23 kg loaded by an actual school backpack weighing 5.1 kg represents a load of 22.2% of her BW, but for a girl weighing 43 kg, it is only 11.8% of her BW and for this child, walking with a school backpack can be considered as a positive stimulus for the locomotor system unlike the previous example. Therefore, the long-term exposure of the heavy school backpack on individuals with lower BW may cause a higher risk of negative changes in their musculoskeletal system than children with higher BW. In practice, a fundamental question arising in connection with the weight of a school backpack is optimizing the weight of the school backpack in relation to BW. For children with low BW, it would be advisable to minimize the backpack load so that it does not exceed 10% of their BW. In the case of individuals with greater BW, the usual load of a school backpack of about 5–6 kg is adequate and around 10% of BW can be considered as a positive stimulus for the development of the body. Higher loads, which may adversely affect the development of the locomotor system, are the primary risk for children with lower BW, i.e., the youngest age category where the weight of a school backpack can reach or exceed 20% of BW. The higher weight of the school backpack can also cause a change in "usual" gait patterns, which is manifested by inappropriate loading of the lower limbs and individual parts of the leg. With the current technological progress, it is possible to consider reducing the weight of the school bag thanks to e-books and interactive applications that could replace some school supplies.

Although the geographical and socioeconomic factors play a role, one current trend is to drive children to school by car, and Adeyemi et al. (29) quantifies this situation to more than 50% of cases. This transport to a school may reduce the negative consequences of carrying heavy school backpacks on the development of the musculoskeletal system. On the other hand, school backpacks with adequate load may increase the natural stimuli for walking development.

One limitation of our study can be considered small sample size ($n = 12$). Greater variability of measured variables and non-normal distribution of measured data required the use of non-parametric statistical procedures. On the other hand, all significant differences showed a medium to large effect. Additionally, it is possible that leg-length discrepancies can play a role in gait data, but leg length was not measured in the present study. Nevertheless, we did not observe any limping, favouring to one side, excessive lean, etc., leading us to believe that the girls all had normal gait patterns.

CONCLUSIONS

In conclusion, our results suggest that school backpack load influences not only the absolute load placed on the feet, but also affects relative plantar pressure distribution. Specifically, greater backpack loads resulted mainly in the increase of load in the midfoot. In addition, our study confirmed the existence of some differences between the loading pattern of the dominant and non-dominant limbs. In the dominant limb, there was greater loading during propulsion, while in the non-dominant limb, loading was greater during the braking phase, which suggests greater propulsive function of the dominant limb and supporting function of non-dominant limb. When using a school backpack, it is important to take into account not only the ever-decreasing level of children's posture but also different individual body weight of children who carry equally heavy school bags.

Conflicts of Interests

None declared

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REFERENCES

1. Pau M, Mandaresu S, Leban B, Nussbaum MA. Short-term effects of backpack carriage on plantar pressure and gait in schoolchildren. J Electromyogr Kinesiol. 2015;25(2):406-12.
2. Perrone M, Orr R, Hing W, Milne N, Pope R. The impact of backpack loads on school children: a critical narrative review. Int J Environ Res Public Health. 2018;15(11):2529. doi: 10.3390/ijerph15112529.
3. Mosaad DM, Abdel-Aziem AA. Backpack carriage effect on head posture and ground reaction forces in school children. Work. 2015;52(1):203-9.
4. Pau M, Corona F, Leban B, Pau M. Effects of backpack carriage on foot-ground relationship in children during upright stance. Gait Posture. 2011;33(2):195-9.
5. Schulze C, Lindner T, Woitge S, Finze S, Mittelmeier W, Bader R. Effects of wearing different personal equipment on force distribution at the plantar surface of the foot. Sci World J. 2013;2013:827671. doi: 10.1155/2013/827671.
6. Wearing SC, Smeathers JE, Urry SR, Hennig EM, Hills AP. The pathomechanics of plantar fasciitis. Sports Med. 2006;36(7):585-611.
7. Hong Y, Cheung CK. Gait and posture responses to backpack load during level walking in children. Gait Posture. 2003;17(1):28-33.
8. Shasmin HN, Abu Osman NA, Razali R, Usman J, Wan Abas WAB. The effect of load carriage among primary school boys: a preliminary study. J Mech Med Biol. 2007;7(3):265-74.
9. Peters M. Footedness: asymmetries in foot preference and skill and neuropsychological assessment of foot movement. Psychol Bull. 1988;103(2):179-92.
10. Mayolas Pi C, Arrese AL, Aparicio AV, Masià JR. Distribution of plantar pressures during gait in different zones of the foot in healthy children: the effects of laterality. Percept Mot Skills. 2015;120(1):159-76.
11. Maupas E, Paysant J, Datie AM, Martinet N, André JM. Functional asymmetries of the lower limbs. A comparison between clinical assessment of laterality, isokinetic evaluation and electrogoniometric monitoring of knees during walking. Gait Posture. 2002;16(3):304-12.
12. Sadeghi H, Allard P, Prince F, Labelle H. Symmetry and limb dominance in able-bodied gait: a review. Gait Posture. 2000;12(1):34-45.
13. Bosch K, Gerss J, Rosenbaum D. Development of healthy children's feet - nine-year results of a longitudinal investigation of plantar loading patterns. Gait Posture. 2010;32(4):564-71.
14. Forczek W, Staszkiewicz R. An evaluation of symmetry in the lower limb joints during the able-bodied gait of women and men. J Hum Kinet. 2012;35:47-57.
15. Zverev Y. Laterality and plantar pressure distribution during gait in healthy children: comment on Mayolas Pi, Arrese, Aparicio, and Masià (2015). Percept Mot Skills. 2016;123(1):121-6.
16. Wojtków M, Szkoda-Poliszuk K, Szotek S. Influence of body posture on foot load distribution in young school-age children. Acta Bioeng Biomech. 2018;20(2):101-7.
17. Rodrigues S, Montebelo MIL, Teodori RM. Plantar force distribution and pressure center oscillation in relation to the weight and positioning of school supplies and books in student's backpack. Braz J Phys Ther. 2008;12(1):43-8.
18. Niu W, Chu Z, Yao J, Zhang M, Fan Y, Zhao Q. Effects of laterality, ankle inversion and stabilizers on the plantar pressure distribution during unipedal standing. J Mech Med Biol. 2012;12(3):1250055. doi: 10.1142/S0219519412005113.
19. Lythgo N, Wilson C, Galea M. Basic gait and symmetry measures for primary school-aged children and young adults. II: walking at slow, free and fast speed. Gait Posture. 2011;33(1):29-35.
20. Xu C, Wen XX, Huang LY, Shang L, Yang Z, Yan YB, at al. Reliability of the Footscan® platform system in healthy subjects: a comparison of without top-layer and with top-layer protocols. Biomed Res Int. 2017;2017:2708712. doi: 10.1155/2017/2708712.
21. Hallemans A, D'Août K, De Clercq D, Aerts P. Pressure distribution patterns under the feet of new walkers: the first two months of independent walking. Foot Ankle Int. 2003;24(5):444-53.
22. Orlin MN, McPoil TG. Plantar pressure assessment. Phys Ther. 2000;80(4):399-409.
23. Pallant J. SPSS Survival manual. A step by step guide to data analysis using IBM SPSS. 5th ed. Berkshire: Open University Press; 2013.
24. Tomczak M, Tomczak E. The need to report effect size estimated revisited. An overview of some recommended measures of effect size. Trends Sport Sci. 2014;21(1):19-25.
25. Kasović M, Zvonar M, Gomaz L, Bolčević F, Anton V. Influence of schoolbag carriage on pattern changes in plantar pressure during walking among first-grade schoolchildren. Kinesiology. 2018;50(2):188-93.
26. Mueller S, Carlsohn A, Mueller J, Baur H, Mayer F. Influence of obesity on foot loading characteristics in gait for children aged 1 to 12 years. PLoS One. 2016;11(2):e0149924. doi: 10.1371/journal.pone.0149924.
27. Matsusaka N, Fujitta M, Hamamina A, Norimatsu T, Suzuki R. Relationship between right and left legs in human gait, from a viewpoint of balance control. In: Winter DH, Norman R, Wells R, Hayes K, Patla A, editors. Biomechanics IX-A. Champaign, IL (USA): Human Kinetics Publishers; 1985. p. 427-30.
28. Jandová S, Volf P, Vaverka F. The influence of minimalist and conventional sports shoes and lower limbs dominance on running gait. Acta Bioeng Biomech. 2018;20(3):3-9.
29. Adeyemi AJ, Rohani JM, Rani AM. Back pain arising from schoolbag usage among primary schoolchildren. Int J Ind Ergon. 2014;44(4):590-600.
30. Brackley HM, Stevenson JM. Are children's backpack weight limits enough? A critical review of the relevant literature. Spine (Phila Pa 1976). 2004;29(19):2184-90.

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