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Evaluation Of Postural Changes In School-Going Children With Straps In Traditional Backpack

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Abstract

Background*: Backpacks commonly contribute to musculoskeletal issues and postural changes in school children. The purpose of the current study was to see the postural alteration with and without adjustable chest and waist straps in traditional backpack.*

Method: *This study was conducted on 61 healthy adolescents (Age- 12–14 years, Male=42, Female=19). There were four experimental conditions: no backpack (unloaded), backpack with 15 % of body weight in three conditions (loaded) no straps, with chest strap only and with waist and chest strap respectively. Sagittal plane photographs were taken in unloaded and standing posture under the three experimental conditions after placing anatomical markers. In posture analysis cranio-vertebral angle (CVA), forward trunk lean angle (FTLA), pelvic tilt angle (PTA) and sagittal shoulder posture angle (SSPA) were calculated using a software (AutoCAD 2016). The statistical software SPSS version 16 was used to obtain results. The differences between conditions were determined using repeated measure analysis of variance models (ANOVA) with $p<0.05$ considered significant.*

Results: *All the 4 angles changed significantly in loaded conditions when compared with unloaded condition (p value = 0.01). However, there was no significant change within the loaded conditions. The SSPA was found to alter significantly with addition of both waist strap and chest strap combined as compared to chest strap alone with a mean difference of 4.3^0 (p value = 0.01) .*

Conclusion*: Carrying backpack changes all the postural angles. Shoulder posture measured with SSPA reduced when both straps were tied. However other angles did not change significantly with addition of straps.*

Keywords*: Chest Straps, Craniovertebral angle, Posture, Waist Straps*

INTRODUCTION

The rise in posture related problems among school-going children has become a common health concern, with one of the main contributors being the use of traditional backpacks (1). The school going children between the age group of 12 to 14 are susceptible to musculoskeletal problems especially spinal related issues (1–4). Studies show that 10%-30% of children experience back pain, while 28.4% report neck pain by their teenage years, along with joint pain in other areas (5). Carrying heavy school bags, especially those with non-adjustable straps, can lead to poor weight distribution, resulting in musculoskeletal strain and postural deviations. Children are particularly vulnerable to these effects due to their developing musculoskeletal systems commonly it has been seen that the tissues transform from cartilage to bone through the process of ossification and any abnormal loading during these years may have a detrimental effect on the development of the spine (1,5).

Common causes of musculoskeletal disorders are bad posture, obesity, psychosomatic impacts, inappropriate classroom furniture along with problems with school bags (1–3,6). Research suggests that kids must wear backpacks that should not exceed 10- 15% or 10-20% of their total body weight (1). Postural modifications may result from a backpack's design, positioning on the spine, and manner of carrying (4).

Studies have demonstrated that load bearing can cause changes in posture that could indicate possible tissue injury. These changes in posture are frequently assessed using angles such the cranio vertebral angle (CVA), forward trunk lean angle (FTLA), pelvic tilt angle (PTA) and sagittal shoulder posture angle (SSPA) (7,8). Body segments being connected and part of kinetic chain the changes can impact the head and neck, spine, pelvis, and lower limbs. Although earlier research has looked at how school children who use regular backpacks or those with extra waist straps alter their posture, there is a dearth of literature about how traditional backpacks with additional adjustable chest straps affect the overall posture (7,8).

This study aims to assess the impact of adding adjustable straps to traditional backpacks on the postural alignment of school-aged children. Through quantitative analysis, this research will explore whether adjustable backpack straps alter the posture or not. The study can play a preventive role in posture-related issues, thereby informing safer backpack design for children. The hypothesis of the study was adding adjustable straps will lead to significant differences in the postural angles measured.

MATERIALS AND METHODS

The study was approved by Research Review Committee and Ethical Committee of Indian Spinal Injuries Center, New Delhi (Ref ISIC/IIRS/RP/2015/103).

Subjects

The pre-test post and test experimental study design included healthy subjects of 12-14 years of age (7,9) of both the genders (male= 42, female= 19) who themselves and their parents voluntarily given consent for their children to participate in the study. The subjects who had any diagnosed musculoskeletal, neurological, systemic and cognitive disorders were excluded.

Equipment

We used one backpack for all our tests. The backpack was made of nylon, with zipper compartments having double shoulder straps. Additional chest and waist strap was added to this backpack. Height and weight of the subjects were measured by wall mounted measuring tape and weighing machine (accurate up to 0.1 kg). Measures of the static sagittal posture are accurately measured by photographs. Static photographs provide posture measures which can be quantified as the position of landmarks on the body against standard references. One Pentax K 50 DSLR was used to take the pictures which was mounted at the tripod stand at 170 cm (as the mean height of our subjects was 150.16 $\pm$ 10.27) height to the right side of the subject in order to obtain full height of the subject (10).

Procedure

Subjects were given black stretchable shorts and sleeveless t-shirt top to get full exposure of the markers as much as possible. Lateral anatomical landmarks were marked by adhesive beads at the right side of the body. They comprised the tragus of the ear, C7 spinous process, mid acromion of the shoulder, anterior superior iliac spine, posterior superior iliac spine and greater trochanter of the femur. A randomized predetermined sequence was used for conditions to prevent subject bias. The different conditions were randomly tested on each subject. Photographs were put in the AutoCAD 2016 (v 20.1) software and the angles were calculated. Sagittal Photographs were taken 4 times of each participant in 4 different conditions. The bag pack weight used was fixed to 15% of body weight as this is said be within safe limits(1). External mettalic weights were kept in the bag for loaded conditions. The subjects were photographed in the following conditions- (i) Unloaded condition: subjects were photographed in their normal standing position. (ii) Loaded condition: subjects were given a traditional backpack (15% BW). (iii) Loaded with chest strap only: the chest strap was buckled at the level of the axilla, and the picture was taken. (iv) Loaded with both chest and waist straps: both straps buckled (Figure 1, 2, 3, 4 respectively). The position of the backpack was adjusted according to their height and it was placed at the center of the waist. The measurement of unloaded condition was taken as baseline measure and their values were used for comparisons. Four angles were calculated to determine posture at cervical, shoulder, trunk and pelvis regions. The sagittal images were analyzed using software AutoCAD 201 (v 20.1, Autodesk, Inc. California, U.S) (9).

CVA - It is the angle formed at the intersection of horizontal line through the spinous process of C7 and line of tragus of ear. This provide an estimation of neck on upper trunk positioning (7) . (Figure 5)
SSPA - It is the angle formed at the intersection of horizontal line through C7 and line between the midpoint of greater tuberosity of humerus and posterior aspect of acromion is measured (7). (Figure 5)
FTLA - It is the angle formed by the intersection of the line from the acromion to the greater trochanter and a vertical reference line. This provide an estimation of body leaning forward (8). (Figure 6)
PTA - It is the angle formed between a line joining the ASIS (anterior superior iliac spine) and the PSIS (posterior superior iliac spine) with the horizontal line shows the anterior pelvic tilt. This provide an estimation of the sacral inclination and lumbar lordosis (8). (Figure 6)

Statistical analysis

Repeated measures ANOVA models were applied to test differences between the unloaded to the loaded condition. Further the comparison was done between the backpack having chest strap only, and the backpack having both chest and waist strap.

RESULTS

A total of 61 subjects in the age group of 12-14 years were selected for the study. The mean height & mean weight of the subjects were 150.2 ± 10.3 cm and 37.82 ± 7.9 kg respectively. The mean BMI of the subjects was found to be 16.8 ± 2.2 kg/m^2. Baseline values were obtained by analysing the CVA, FTLA, PTA, SSPA in unloaded condition (no backpack), using the software AutoCAD 2016 (v 20.1, Autodesk, Inc. California, U.S). The impact of backpack loading on normal posture and additional changes brought about by the usage of chest and waist straps in the backpack were examined using a paired sample t-test, which compared baseline measurements to those obtained following the intervention ($p<0.05$). The paired sample statistics revealed that the baseline angles in unloaded condition were significantly altered in the backpack environment ($p<0.05$) where the average values of CVA, FTLA, PTA, and SSPA (in degrees) were found to be 49.98 ± 6.32, 6.03 ± 3.14, 16.17 ± 7.27, 60.41 ± 17.07 respectively. The descriptive average values of all angles are shown in Tables 1.

The main effect on CVA with carrying a backpack was found to be significant as tested by repeated measures analysis of variance (ANOVA) (f = 22.9, df = 3, p-value < 0.05). In between comparison of chest strap versus chest and waist strap combined was done using ANOVA for SSPA. Interestingly, according to the values obtained, addition of waist strap increased the load over shoulder causing a significant reduction in SSPA ($p<0.05$). Post hoc analysis of angles between loaded with chest strap and loaded with both chest and waist strap condition values are depicted in Table 2. Additionally the FTLA, PTA and SSPA also reflected similar picture. Post hoc testing for pair-wise comparison using Bonferroni underscored the effect of backpack on CVA, however there were no differences across the loaded, loaded with chest strap and loaded with both chest and waist strap conditions.

Table 1: Variations of all angles (mean and standard deviation) in different conditions

Angles	Unloaded (no backpack) (Mean ± S.D)	Loaded with backpack (Mean ± S.D)	Loaded with chest strap (Mean ± S.D)	Loaded with chest and waist strap (Mean ± S.D)
CVA	53.6 ± 5.7	50 ± 6.3	50.6 ± 7.0	49.7 ± 6.3
FTLA	3.6 ± 2.2	6.03 ± 3.1	6.5 ± 3	6.1 ± 3.2
PTA	13.9 ± 6.1	15.3 ± 7.3	15.6 ± 7.2	15.4 ± 7.3
SSPA	52.3 ± 15.8	60.4 ± 17.1	56.6 ± 16.5	59.3 ± 16.5

Table 2: Post hoc analysis of angles between loaded with chest strap and loaded with both chest and waist strap condition.

Conditions	CVA	p-value	FTLA	p-value	PTA	p-value	SSPA	p-value
Loaded with chest strap	49.8 ± 6.3	0.40^{NS}	5.1 ± 3.1	0.70^{NS}	15.3 ± 7.3	1.00^{NS}	60.4 ± 17.1	0.01*
Loaded with both chest and waist strap	50.4 ± 6.3		5.6 ± 2.3		15.6 ± 7.2		56.1 ± 16.5*	

* Significant at $p \leq 0.05$

Figure 1: Subject standing without backpack (Unloaded)

Figure 2: Subject standing with traditional backpack (Loaded)

Figure 3: Subject standing with traditional backpack with chest strap (Loaded)

Figure 4: Subject standing with traditional backpack with chest and waist strap (Loaded)

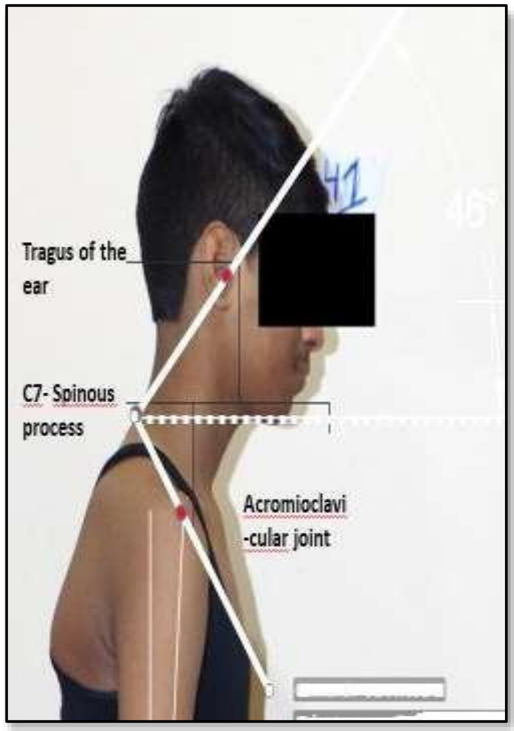

Figure 5: Picture shows anatomical landmarks and Postural angles for CVA, SSPA

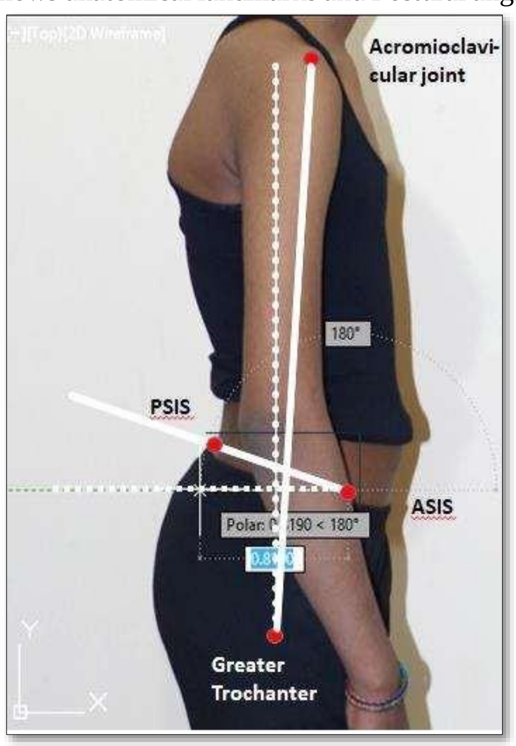

Figure 6: Picture shows anatomical landmarks and Postural angles for FTLA and PTA

DISCUSSION

The study's findings shed important light on how human posture adjusts to external pressures through compensatory and adaptive mechanisms. Four different postural angles were used to measure them. In particular, our results show that school-going children's static posture is considerably impacted by backpack wearing. Significant changes were found when this study compared the immediate pre- and post-changes in all four scenarios.

CVA: Craniovertebral angle (CVA) provides an estimation of head on upper back where a small angle indicates more forward head position. In our study, it was found to be significantly decreased in all three loading conditions namely loaded with traditional backpack, loaded with only chest strap fastened in traditional backpack and loaded with both waist and chest strap fastened in traditional backpack respectively, as compared to unloaded condition. The load was 10-15% of body weight as per the justified safe limits. These findings are advocated by Shivananda et al(7)who found significant reduction in CVA with backpack weighing 15% of body weight both in static and dynamic loading when compared to without backpack. The reduction in CVA corresponds to increased forward head posture, characterised by flattening of lower cervical spine and increased thoracic kyphosis. These postural changes lead to shortening of sternocleidomastoid and scalene muscles on one side and lengthening of levator muscles on the other side resulting in abnormal muscle imbalances. This in turn signifies the importance of different backpack design on alteration in posture.

The reduction of CVA in loading condition was found in accordance with findings by Mathur et al who found reduced CVA with addition of waist strap to traditional backpack in both static and dynamic loading condition (11). However, no significant differences between the three different loading conditions indicate that addition of chest strap or chest strap with waist strap on traditional back pack has no beneficial effect on cervical posture.

Further it is seen that greater the duration of carrying the load, greater is the increase in forward head and trunk posture (8). It is found that loading the bag more than 10% of body weight is considered too heavy for the child to maintain normal cervical and shoulder posture alignment (9,18). Thus, it becomes imperative to consider load in terms of body weight to prevent musculoskeletal impairments.

FTLA: This angle provides an estimation of leaning of trunk in forward direction. In our study, FTLA was found significantly associated with increased load carriage in all the three loading conditions. This finding was consistent with Kistner et al's who investigated effects of carrying increasing weighted backpacks upto 20% of body weight on Forward trunk lean. They found shift in FTL even at 10% body weight with greater increase in trunk lean with heavier backpack load with an additional increase in the FTL angle for all weight conditions after 6-minute walk(8).This was comparable to findings of our study.

In addition to bag weight and design, the placement of the backpack impacts trunk leaning. For the purpose of this study, backpacks were positioned at the centre of the spine, specifically spanning the vertebral levels T12 to L3, to control for confounding variables related to trunk inclinations or the other postural deviations, thereby allowing for an isolated assessment of the biomechanical impacts of the auxiliary support straps in a traditional backpack (19). When burdens are positioned higher on the spine (centre of the backpack at T7), tilting of trunk is found to be increased when compared to placement of load at T12 or L3(4). This is contradicted by Maj. Joseph et al. who stated that, while loads are carried low on the spine it requires more forward body rotation about hips and ankles to bring the backpack back to the centre of mass over the feet (12,18).

Load induced forward inclination of the trunk and pelvis, along with increased hip flexion extension serves to maintain dynamic stability and counterbalance movement of the lower limbs. However, the excessive and prolonged anterior lean, particularly without supportive elements like a hip belt or chest strap may lead to sustained eccentric activations of the hamstring and semispinalis muscles predisposing adolescents to lumbar strain and postural discomfort (18). The backpack with only chest strap was found to have highest displacement of FTL ($F = 24.202$, $p < 0.001$) when compared to other backpacks. However, no statistically significant difference was seen between the three loading conditions. This suggests that the chest strap, or a combination of the two straps, may modify the FTL, but its impact on posture requires longer-term study to remark on angular variations.

PTA: A neutral pelvis is the one in which ASIS and sympysis pubis is at the same vertical plane. A neutral pelvis is one in which the ASIS and sympysis pubis are located in the same vertical plane. As a result, if the line connecting ASIS and PSIS is horizontal, it implies no tilt. Although this is not the best posture for the pelvis. People typically stand with an anterior pelvic tilt of 11-13 degrees. An anteriorly tilted pelvis creates a higher angle between ASIS and PSIS, which increases sacral inclination and lumbar lordosis (13).

In our study, the pelvic tilt increased with the backpack in all loading conditions significantly ($F = 6.516$, p value < 0.001). This result is similar to findings of Kistner et al, where increased anterior tilt was seen with all loaded backpack with significant progression of postural compensation in terms of increased tilt seen with backpacks weighing heavier than 10% body weight before and after walking (8). This result contradicts the findings of Borhani et al where no significant difference in pelvic tilt was seen between no bag and conventional backpack with 17% load. Further they found load of 25% body weight for Conventional bag showed the greatest increase in angular pelvic tilt indicating mere addition of strap was not sufficient to alter the pelvic tilt (14).

In addition, pelvic tilting is also found to be associated with neck reposition sense in case of subjects with forward head posture. Lee et al found that higher the pelvis side tilting angle, the worse was the head repositioning accuracy value of lateral neck flexion (15). Thus, it is important to consider pelvic postures when movement is limited in Forward head posture due to vitiation of the proprioceptive sense of the neck.

SSPA: This provides an estimation of the position of shoulder in relation to head in sagittal view by measuring shoulder protraction. In our study, the SSPA was found to increase significantly in all the loaded conditions as compared to unloaded condition ($F = 11.604$, p value < 0.001). This is in consistent to findings by Hundekari et al (9) where increase in SSPA was found corresponding to increased percentage of backpack load. The enlarged SSPA when carrying a loaded backpack in our study is supported by Shivananda et al, where the increased SSPA values when carrying a backpack was attributed to more anterior head position (7). A significant reduction in SSPA was found in our study with the addition of chest straps in the backpack compared to unloaded condition (p value <0.005). On the other hand, addition of combined waist strap and chest strap to the traditional backpack was found to be statistically significant when compared to chest strap alone ($p= 0.13 > 0.05$) wherein the angle increased in chest strap alone and decreased when both straps are buckled. The lowered values of SSPA in case of addition of only chest strap in backpack suggests that it can result in reduced shoulder protraction while carrying loads making it imperative to be considered in choosing the right backpack.

As quoted in previous research by Hundekari et al in 2013, the pressures exerted on the shoulders by backpacks with varying weights cause significant increases in scapular and superior shoulder pressures. It is to note that backpacks relying primarily on shoulder support elicit higher pressure readings compared to designs that distribute weight to the hips via a wide waist belt(9). This distinction underscores the importance of backpack design in mitigating shoulder-related discomfort and potential long-term musculoskeletal consequences. In the study of Wen Ling et al (16) and Maj Joseph et al (12), the results showed that including a waist belt in the design of a backpack greatly increases the efficiency of load carrying in adult females. Even at higher load levels, significant improvements in gait characteristics and centre of gravity stability were noted (17).

The sample's unbalanced male and female participant distribution made statistical comparisons less meaningful, avoiding firm conclusions about gender-based disparities. Only static posture assessment was done, therefore, future studies can target on equal \male female posture along with dynamic postural assessment.

Literature on the effect of adjustable combination of chest and waist strap in a traditional backpack on student’s whole-body posture is scarce. The effect of bag placement, amount of load and the duration of load carriage might provide a better knowledge about the effect of supporting straps in a backpack, as students carries backpack for a certain duration that might induce exertion and affect the posture.

CONCLUSION

The study can be concluded stating that a small but significant differences were found when comparing posture while carrying a backpack under different conditions, for the CVA, FTLA, PTA, and SSPA. Significant differences were not observed when the chest and waist straps were compared for different angles accept the sagittal shoulder posture that was found to be increasing. This indicated that the shoulder protraction might decrease when only chest strap was fastened. A significant reduction in CVA was found while carrying backpack weighing 15% of body weight over both the shoulders indicating increased forward head posture with backpack. There was no significant alteration in PTA and FTLA implying that chest and waist straps might not affect the trunk leaning forward and pelvic kinematics with backpack of 15% of body weight. Though in an ideal scenarios the actual backpack weights are much higher and duration of carriage can intensify the deviations in posture.

REFERENCES

1. Ahmed NA, Ahmed MM, Ahmed NA, Shahid A, Mittal G. Schoolchildren's Musculoskeletal Pain and Backpack Weight Impact on Posture: A Short-Term Study. Journal of Pharmacy and Bioallied Sciences. 2024 Jul 1;16(Suppl 3):S2497-9.
2. Panicker R, S S. Prevalence of musculoskeletal pain in school going adolescents using school bags - A co-relational research. Int J Ther Rehabil Res. 2014;3(4):23.
3. Yamato TP, Maher CG, Traeger AC, Wiliams CM, Kamper SJ. Do schoolbags cause back pain in children and adolescents? A systematic review. British Journal of Sports Medicine. 2018 Oct 1;52(19):1241-5.
4. 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 Apr 17;3:1–10.
5. Guessogo WR, Assomo-Ndemba PB, Ebal-Minye E, Mekoulou-Ndongo J, Bika-Lélé CB, Mbang-Bian W, Djuine-Soh EL, Ondoa JB, Mandengue SH, Temfemo A. Effect of Schoolbag Weight on Musculoskeletal Pain among Primary School Children in Yaounde, Cameroon: A Cross-sectional Study. International Journal of Medical Students. 2020 Aug 31;8(2):96-101.
6. Kumar DK., Putti BB, Bindhu S, Manjula S. Prevalence of Mechanical Low Back Pain in School Children of Adolescent Group - an Observational Study. J Adv Res Biol Sci. 2012;4(7):213–8.
7. Shivananda SV, Sasidhar V, Yakub S BM. Analysis of cervical and shoulder posture in school Children using backpack experimental study. Int J Physiother Res. 2013;2:36–41.
8. istner F, Fiebert I, Roach K, Moore J. Postural compensations and subjective complaints due to backpack loads and wear time in schoolchildren. Pediatr Phys Ther [Internet]. 2013;25(1):15–24.
9. Jagdish Hundekari JH. Does alteration in backpack load affects posture of school children? IOSR J Dent Med Sci [Internet]. 2013;7(4):71–5.
10. Z Hazar GK. Reliability of photographic posture analysis of adolescents. J Phys Ther Sci. 2015;27:3123–6.
11. H M, A D, SA K. To Determine the Efficacy of Addition of Horizontal Waist Strap to the Traditional Double Shoulder Strap School Backpack Loading on Cervical and Shoulder Posture in Indian School going Children. Int J Phys Med Rehabil. 2017;05(06).
12. Knapik JJ. Soldier Load Carriage Historical, Physiological,. Mil Med. 2004;169:45–56.
13. Kewis CL, Laudicina NM, Khuu A, Loverro KL. The Human Pelvis: Variation in Structure and Function During Gait. Anat Rec. 2017;300(4):633–42.
14. Borhani M, McGregor A, Bull A. The effect of backpack load on pelvic kinematics. Brazilion Congr Biomech. 2013;(1):1–5.
15. Lee HS, Chung HK, Park SW. Correlation between Trunk Posture and Neck Reposition Sense among Subjects with Forward Head Neck Postures. Biomed Res Int [Internet]. 2015;2015:1–6.
16. Ling W, Houston V, Tsai YS, Chui K, Kirk J. Women ' s Load Carriage Performance Using Modular Lightweight. Mil Med. 2004;169:914–9.
17. Huang L, Xu Y, Fekete G, Gu Y. Effect of Waist Strap Reinforcement in Backpacks on Children Gait Parameters During Walking and Running: A Randomized Cross-Over Prospective Study. InMaterial Strength and Applied Mechanics 2024 (pp. 538-545). IOS Press.
18. Oberhofer K, Wettenschwiler PD, Singh N, Ferguson SJ, Annaheim S, Rossi RM, Lorenzetti S. The influence of backpack weight and hip belt tension on movement and loading in the pelvis and lower limbs during walking. Applied bionics and biomechanics. 2018;2018(1):4671956.
19. Chen YL, Mu YC. Effects of backpack load and position on body strains in male schoolchildren while walking. PloS one. 2018 Mar 21;13(3):e0193648.