Impact of Backpack on Static and Dynamic Balance among School Going Adolescents

Khushi Saxena[1], *Sapna Dhiman[2], Dishti Narang[3]

[1]School of Physiotherapy, Delhi Pharmaceutical Sciences and Research University, New Delhi, India

[2]Assistant Professor, School of Physiotherapy, Delhi Pharmaceutical Sciences and Research University, New Delhi, India

[3]School of Physiotherapy, Delhi Pharmaceutical Sciences and Research University, New Delhi, India

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ABSTRACT

Improper backpack usage, particularly when it involves excessive loading, has been associated with altered biomechanics that can negatively affect posture and balance in school-going adolescents. This issue remains largely under-recognized despite its potential long-term implications on musculoskeletal health. The present study aimed to evaluate the influence of backpack load on both static and dynamic balance in adolescents, with the goal of providing evidence-based insights to support clinicians, educators, parents, and students in preventing and managing these adverse effects. A total of 84 school children between the ages of 13 and 18 years participated in the study. Balance was assessed using the Single Leg Stance Test (SLST) for static balance and the Functional Reach Test (FRT) for dynamic balance. Each participant was tested under two conditions: with and without their school backpack. Statistical analysis was conducted using the paired t-test to determine the significance of differences in balance scores. Results revealed that 50% of the participants carried backpacks exceeding 15% of their body weight, which is the commonly recommended safe threshold. The mean SLST time decreased significantly from 37.05 ± 15.26 seconds without a backpack to 23.98 ± 12.69 seconds with a backpack. Similarly, the FRT score dropped from a mean of 29.72 ± 5.43 cm without a backpack to 24.18 ± 5.92 cm with a backpack, with both findings being statistically significant ($p < 0.001$). These results indicate that carrying a heavy backpack has a significant negative impact on both static and dynamic balance in adolescents. The findings highlight the importance of raising awareness and implementing proactive strategies to reduce backpack-related risks during school-age development.

Keywords: backpack, balance, school children, adolescence

INTRODUCTION

The backpack is an omnipresent and highly favoured bag, particularly among various groups in society, notably the students. Research shows that the backpack is a popular choice for carrying school books and stationery items (Khouli et al., 2020). Students' daily school bags often contain a diverse array of items, including books for multiple subjects and individual notebooks, pencil boxes, calculators, specific sportswear, lunch boxes, and full water bottles (Perrone et al., 2018). This increase in the amount and size of items being carried has resulted in a significant load being borne by students (Shaikh et al., 2020).

It's important to note that when heavy backpacks are carried improperly, it could pose health risks to students, with the potential for musculoskeletal disorders, balance problems, and postural deviations (Ganesh et al., 2023 & Lewis et al., 2009). Many students carry a load far exceeding the recommended 10-15% of their body weight, with some carrying up to 30% (Atreya et al.,2010).

The consequences of heavy backpacks include musculoskeletal issues and balance problems, leading to permanent postural deviations and impaired postural balance control (Bahiraei et al., 2015). This is particularly concerning given the changing current circumstances, where children may be commuting to school alone, facing heavy traffic, and busy surroundings, increasing the risk of falls (Shaikh et al., 2020). The weight of the backpack shifts the center of gravity, causing children to adjust their gait and posture to maintain balance

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(Zhou et al., 2018). Proper positioning of the backpack is important for load-carriage methods and ergonomic schoolbag design, with a higher position being generally recommended (Orloff et al., 2004).

Balancing is a critical aspect of our usual daily activities, with the center of mass needing to remain within the boundaries of the base of support (BOS) to maintain stability. There are two types of balance: static, where the body is at rest, and dynamic, which involves maintaining stability while body parts are in motion (Sharma et al., 2024).

The developmental stage of teenagers' muscles, ligaments, and bones, particularly between ages 6 and 14, makes them more prone to injuries, and heavy backpacks can exacerbate these risks (Bahiraei et al., 2015). The harmful effects of heavy backpacks, such as kyphosis, scoliosis, and forward head posture, can lead to balance issues in students. While research supports recommended weight limits, further investigation is needed to understand the relationship between backpack use, injuries, design of the backpack, individual characteristics, level of physical fitness, and adaptations required (Bahiraei et al., 2015).

The sight of young children burdened by heavy backpacks, along with an increasing incidence of non-specific back pain in schoolchildren, has raised serious concerns among parents and the community (Perrone et al., 2018). The collective uneasiness surrounding this issue highlights the growing recognition of the potential long-term effects of heavy backpacks on children's health and highlights the need for proactive steps to address the situation. Hence this study was aimed to determine the impact of backpack load on the balance and the results of this study will shape future research in this area and help in forming risk management strategies for managing the weight of school backpacks.

METHODOLOGY

Participants and study design

This cross-sectional observational study was conducted between April 2022 and May 2023, following approval from the Institutional Ethics Committee. The sample size was initially calculated as 92 school children using G Power software. However, due to 8 dropouts, the study was completed with a final sample of 84 students. Participation was voluntary and anonymous, with informed consent obtained from the parents.

Eligibility criteria

The inclusion criteria included school-going students of any gender, aged 13 to 18 years.

Exclusion criteria included children with a history of spinal cord injury, lower limb soft tissue injuries, or bone fractures within the past six months; those with deformities or neurological conditions; those unable to follow commands; and those with pre-existing conditions that either prevented them from carrying a backpack or caused low back pain limiting backpack use.

Procedure

A sample of 84 students was selected using convenience sampling. All the subjects were given thorough explanation about the procedure and the tests were demonstrated.

Demographic data was obtained and the height and weight were measured for all participants and the BMI calculated. The weight of backpack was also measured. Balance was measured- Static balance, by Single leg stance test and Dynamic balance, by Functional Reach test.

Each participant executed the tests initially without backpack, followed by a subsequent performance with the backpack. A five-minute rest period was provided between each test.

Outcome measures

1. **Static balance:**

Single leg stance test (SLST): The participants stood barefoot two feet from a wall, focusing on a fixed point 20 feet away at eye level. They balanced on one leg, flexing the other leg at 90° at the hip and knee, with hands on their hips. Timing began when the leg was lifted and stopped if the stance leg moved, the foot touched down, gaze shifted, or the lifted leg hooked onto the stance limb despite two warnings. A five-minute rest was given between repetitions, and the mean of three readings was recorded as the final result (Shaikh et al., 2020).

2. Dynamic balance:

Functional Reach Test (FRT): The participants stood wearing shoes with feet positioned on marked spots for consistency. The examiner stood behind to observe. Participants extended one arm forward at 90° flexion, with the elbow fully extended and wrist neutral, aiming to reach as far as possible without lifting their heels, holding the stretch for three seconds. The mean of three measurements was recorded as the final result (Duncan et al., 1990).

Statistical analysis

Data normality was evaluated using the Shapiro–Wilk test, which revealed the normal distribution of the data ($P \geq 0.01$). To analyze and draw conclusions from the data, we used paired t-test and the level of significance for analysis was set at $p \leq 0.05$. Statistical analysis was conducted using Statistical Package for the Social Sciences (SPSS) software version 24. Data was summarized as mean ± SD and analyzed.

RESULTS

Participants

Initially, the study included 92 participants aged 13-18 years. After 8 fallouts, due to various reasons (as given in Fig 1) a total of 84 participants were assessed further, comprising 43 girls (52%) and 41 boys (48%). The mean (SD) age was 15.21 (1.60) years, with age distribution depicted in Graph 1. The participants' demographic attributes are presented in Table 1.

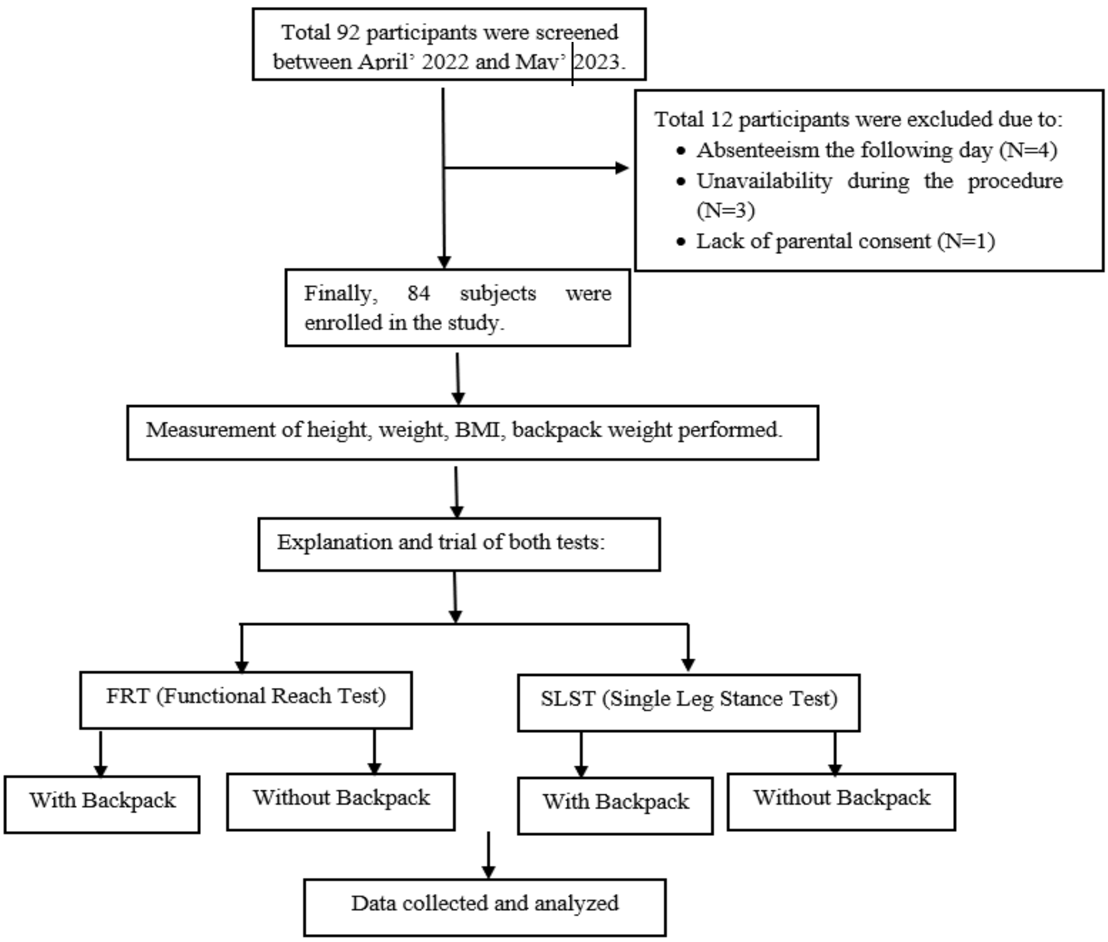

Fig 1. Cross-sectional analysis of backpack weight on balance in adolescence

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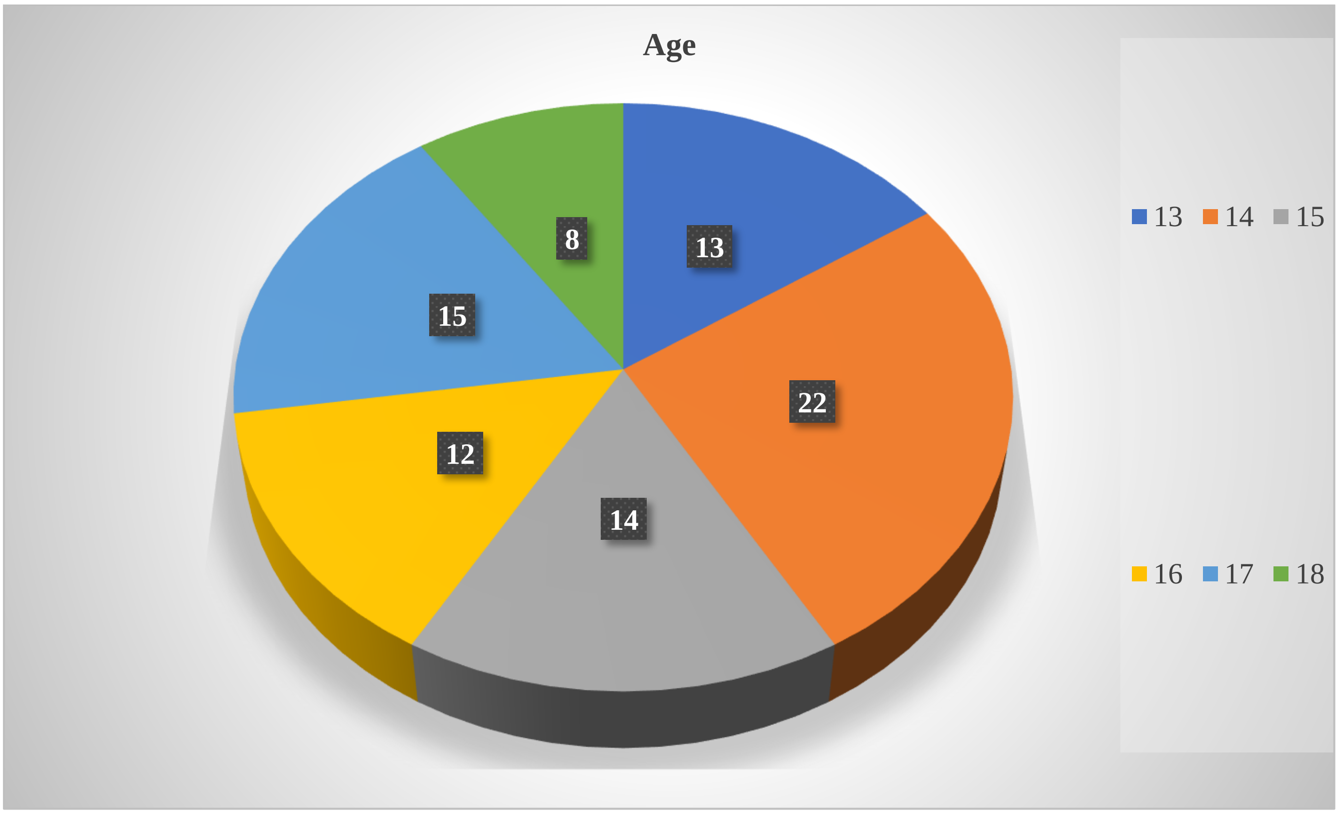


Graph 1. Age distribution of participants

Table 1. Demographic and general attributes

Gender	**Boys**	**Girls**
Number of participants N (%)	41 (48.81)	43 (51.19)
Age (years) Mean (SD)	15.65 (2.26)	14.64 **(**1.46)
BMI (Kg/m^2) Mean (SD)	19.98 (3.94)	19.25 (3.67)
Weight of Backpack (Kg) Mean (SD)	7.23 (1.28)	7.07 (0.95)
Grade in school N (%)		
7th	5 (12.19)	7 (16.28)
8th	17 (41.46)	8 (18.60)
9th	8 (19.51)	10 (23.26)
10th	4 (9.76)	6 (13.95)
11th	4 (9.76)	8 (18.61)
12th	3 (7.32)	4 (9.30)

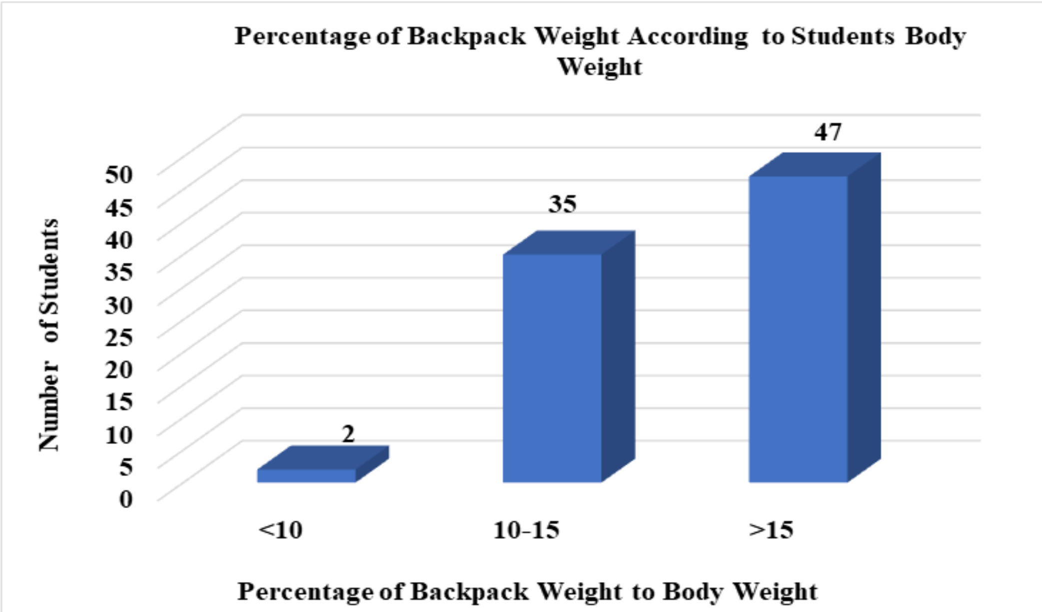
SD: Standard Deviation; %: Percentage; Kg: Kilogram

Backpack load

In order to evaluate the influence of various loads on balance, participants from various age groups and grade levels were included to ensure diversity in the study. Out of 84 students, there were 12 students in 7th grade, 25 in 8th grade, 18 in 9th grade, 10 in 10th grade, 12 in 11th grade, and 7 in 12th grade thus providing a range of backpack loads for assessment.

The backpack loads varied across different grade levels, with students in the 10th grade carrying the highest loads, which exceeded 7.5 kgs.

Upon measuring the percentage of backpack weight according to students' body weight, it was found that 50% students carried a backpack of more than 15% of their body weight (Graph 2).



Graph 2. Percentage of backpack weight to body weight.

Impact of backpack on static and dynamic balance

The scores of SLST and FRT in both situations, with and without backpack are summarized in Table 2. The results indicated that during the SLST and FRT, students demonstrated better performance without a backpack. They were able to maintain balance for a longer duration and achieve greater reach distances in the absence of a backpack compared to when carrying one.

Table 2. Comparison of static and dynamic balance with and without backpack

Test	State	Mean (SD)	t-value	P-value
Single Leg Stance Test (Seconds) [SLST]	**Without Backpack**	37.05 (15.26)	8.368	<0.001
	With Backpack	23.98 (12.69)		
Functional Reach Test (Centimetres) [FRT]	**Without Backpack**	29.7 (5.43)	16.281	<0.001
	With Backpack	24.18 (5.92)		

SD: Standard Deviation

Overall, a statistically significant difference was observed between the two conditions- wearing and not wearing a backpack, on both static and dynamic balance. ($P < 0.05$)

DISCUSSION

In vast number of studies, major emphasis has been given to postural changes and pain, resulting from the use of backpack, but balance alterations have been comparatively ignored, hence this study was designed with the objectives of assessing and comparing balance scores. Along with this, the effects of backpack on balance seen particularly in school going adolescent students post-covid era have not been explored greatly. This study mainly focuses on the adolescent population because adolescent school children undergo a phase of rapid growth and development in skeletal and soft tissues, resulting in distinct spinal structures compared to adults. Children have proportionally larger heads and a higher center of mass around T12, unlike adults who have it around L5-S1. The extended growth period of spinal structures, relative to other skeletal tissues, introduces potential challenges to postural integrity due to incongruities in the rate of tissue development (Chansirinukor et al.,2001). Therefore, there is a need to study the impact of backpack on static and dynamic balance among school going adolescence in detail.

84 students (mean age of 15.21 ± 1.60 years, weight of 48.20 ± 9.63 kg) were randomly selected. The average weight of the backpack was 7.15 ± 1.04 kg with the Backpack percentage to body weight being 15.40 ± 0.03

%. The findings indicate a significant statistical disparity between the two groups- with and without backpack. ($P < 0.05$)

Based on recommendations previously provided by APTA (American Physical Therapy Association) and ACA (American Chiropractic Association), it is advised that the weight of a child's backpack should range from 5% to 15% of their body weight. In this study, backpack percentage to body weight was 15.40 ± 0.03%, with only 2% of participants carry a bag weight less than 10% of their body weight, 42% carry a load equivalent to 10 to 15% of their body weight, while 56% carry a load exceeding 15% of their body weight.

Participants in our study demonstrated significant decline in balance performance when they carried backpacks. This was evident in both static and dynamic balance assessments, measured through the single-leg stance test and the functional reach test where participants performed markedly worse while carrying a backpack ($p < 0.05$). These findings highlight the destabilizing effect of backpack-induced load on postural control.

The underlying mechanism for this decline in balance performance can be attributed to biomechanical compensations. Carrying a backpack causes the COG (center of gravity) to shift forward and upward, which requires increased muscle activity, particularly from the anterior trunk and lower leg muscles to maintain postural alignment. This added demand can strain musculoskeletal structures and compromise proprioceptive feedback. The resultant restriction in joint range of motion and impaired coordination likely influenced the decreased reach distance observed in the functional reach test (Shaikh et al., 2020).

Several supporting studies have reinforced these biomechanical implications. For example, Bahiraei et al., 2015 found that children aged 11 to 13 demonstrated a forward-bending posture under loads exceeding 17% of their body weight. Similarly, other studies reported increased velocity in the movement of the center of pressure when external loads were applied, suggesting decreased postural stability. In terms of gait, carrying backpack loads of 20% body weight has been associated with reduced walking speed, shorter cadence, and prolonged double support time—markers of gait instability and compensatory mechanisms aimed at minimizing fall risk (Singh et al.,2009).

The findings of the Maharashtra studies have mirrored our findings, further validating the prevalence and impact of excessive backpack loads among school children. They discovered that half of the students carry backpacks equivalent to 10-15% of their body weight, with 31.17% carrying loads surpassing 15% of their body weight. The consistency in these results highlights the need for early intervention strategies and ongoing monitoring of students' load-bearing habits (Kafle, 2020).

Carrying heavy backpacks can result in various disorders affecting the head, shoulders, spine, and joints. Frequently, these disorders are linked to shifts in neuromuscular control strategies and balance irregularities. These changes escalate the forces exerted on joints, ligaments, and muscles, potentially resulting in injuries. Additionally, defects in proprioception and joint position, muscle weakness, and limited range of motion can further contribute to imbalance. If the center of gravity is not adequately maintained within the supporting plane, it can lead to abnormal forces on the limbs, potentially causing subsequent injuries (Hong *et al.*,2008).

Limitations

The study's limited duration was a constraint in assessing the long-term effects of the intervention. The current study focused solely on the immediate effects of carrying a backpack. Secondly, the influence of external factors, such as backpack design, carrying habits, environmental conditions, and physical activity levels, was not controlled Also, in addition to the chosen measures to assess balance, advanced laboratory equipment such as posturography can be utilized for a thorough evaluation of tasks performed while carrying a backpack.

Future scope of study

Future research should aim at longitudinal studies to understand long-term musculoskeletal outcomes and assess the efficacy of targeted intervention strategies in improving balance and posture among school-going children. It is important to implement awareness programs for students, parents, and school staff regarding ideal backpack weight and carrying methods. Encouraging the use of ergonomically designed backpacks with padded straps and waist belts, promoting regular posture screening in schools, and introducing posture correction exercises as part of physical education could help minimize the burden of musculoskeletal issues in adolescents.

CONCLUSION

This study shows that many adolescents carry schoolbags heavier than the recommended limit, impacting their balance abilities. Carrying heavy backpacks led to reduced balance scores during tasks due to altered body mass distribution and increased strain on the musculoskeletal system. Addressing this issue is crucial. Raising awareness among students, parents, and schools about weight limits is important. Regular monitoring and adjusting backpack weight can enhance safety. Implementing ergonomic designs, proper storage, and educational programs can help reduce negative effects on balance. In conclusion, proactive measures are needed to combat heavy backpacks in adolescents. Promoting awareness, implementing supportive measures, and adhering to weight limits can protect students' balance abilities, overall well-being, and reduce health concerns.

Declarations:

Ethical Statement

The study was approved by the Research Review Development Committee of the School of Physiotherapy, Delhi Pharmaceutical Science and Research University (DPSRU), New Delhi, India (Reference No.: 10/801/PT/DPSRU/2022/20310).

Conflict of Interest

We declare no conflicts of interest associated with this publication, and there has been no significant financial support for this work that could have influenced its outcome.

Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author.

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