



Influence of Varying Backpack Loads and Selected Carrying Durations on Time Elapsed Between First and Second Peak Forces of Walking Gait of School-going Boys

Rabiya Husain^{1ABCDE} and Dhananjoy Shaw^{2ABCDE}

¹University of Delhi

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Abstract

Objectives. To examine the effects of varying backpack loads and carrying durations on the time elapsed between the first peak force (FPF) and the second peak force (SPF) during the walking gait of school-going boys.

Materials and Methods. Eighty-five boys (aged 10–12 years) from the National Capital Territory of Delhi participated. Temporal gait parameters were measured using a Zebris Force Distribution Measurement pressure plate under five backpack load conditions (0%, 8%, 12%, 16%, and 20% of body weight) and five carrying durations (0, 5, 10, 15, and 20 minutes). Participants walked barefoot along a 10 m walkway with the plate positioned centrally. Data from five trials per condition were analyzed descriptively.

Results. Increasing load and duration significantly prolonged the interval between FPF and SPF, indicating an extended midstance phase. At 15–20% body weight, compensatory gait mechanisms began to fail, leading to longer intervals and greater variability, suggesting biomechanical strain and reduced walking efficiency.

Conclusions. Backpack weight and carrying duration markedly influence temporal gait parameters, particularly the FPF–SPF interval. These findings support the need for effective load management and ergonomic strategies to ensure safe backpack use in schoolchildren.

Keywords: backpack load, first peak force, gait analysis, load carriage, midstance phase, second peak force, time interval.

Introduction

Walking gait is the coordinated sequence of movements critical for locomotion, providing insights into physical health, rehabilitation, and biomechanics. The analysis of gait mechanics is particularly relevant for understanding how forces are distributed during walking. Key components of gait analysis include the first and second peak forces, which occur at heel strike and toe-off, respectively (Husain et al., 2024a). These peak forces are critical indicators of the stresses placed on the body during walking and offer valuable information on the body's balance and load-bearing capacity (Whittle, 1993; Buldt et al., 2018; Husain et al., 2024b).

Backpacks, commonly used by schoolchildren, are intended to align with the body's center of gravity to enhance stability (Pascoe et al., 1997; Sheir-Neiss et al., 2003). However, as the weight of the backpack increases, so does the strain on the body, which can alter walking mechanics (Perrone et al., 2018).

Studies have shown that carrying heavy backpacks can lead to changes in gait patterns, increased energy consumption, and potential musculoskeletal discomfort (Macias et al., 2008; Castro et al., 2013; Castro et al., 2015; Pau et al., 2015). Furthermore, carrying a backpack for extended periods can lead to fatigue, which in turn reduces walking speed and affects the overall gait cycle (Chow et al., 2005; Hong et al., 2008). Chow et al. (2005) also observed that loads exceeding ten percent of body weight notably increased demands on the hip and ankle joints, suggesting this as a critical threshold for load-induced biomechanical adaptations.

Kellis and Arampatzi (2009) highlighted that carrying schoolbags alters both temporal characteristics of gait and ground reaction forces. They found that modes of carrying, such as by hand versus on the back, influence gait efficiency, with low-back backpack positions causing fewer alterations compared to hand-carried bags. Furthermore, Hong and Cheung (2003) identified trunk inclination as a significant factor in load-bearing, emphasizing that backpacks exceeding fifteen percent body weight induce notable increases in

forward lean. While stride parameters remained stable under loads of fifteen percent body weight, prolonged carrying distances exacerbated mechanical stress.

Despite extensive research on general gait alterations due to backpack loads, studies rarely investigate the temporal dynamics between the first and second peak forces during the gait cycle. This interval is critical for understanding how the body dynamically adapts to varying loads and prolonged durations. The current study addresses this gap by exploring how different backpack weights and carrying durations influence the time elapse between these peaks in school-aged children. By examining this specific aspect of the gait cycle, this research aims to contribute to evidence-based recommendations for safe backpack use, helping to mitigate injury risks and enhance musculoskeletal health.

Based on the existing literature and preliminary observations, the current study hypothesizes that increasing backpack load and prolonged carrying duration will significantly affect the temporal dynamics of gait, specifically by increasing the time elapse between the first and second peak forces, which may indicate biomechanical stress and compensatory gait patterns.

Materials and Methods

Study Participants

A total of eighty-five school going boys from National Capital Territory of Delhi, India, age ranged between 10 to 12 years were selected randomly. Participants eligible for the study had to meet the following criteria: they were required to be male, aged between 10 and 12 years, and confirmed to be in good health. Those with acute or chronic illnesses or incomplete documentation were excluded. Additionally, participants were clearly informed of their right to withdraw from the study at any stage during the data collection process.

Study Design

The study aimed to investigate the impact of increasing backpack loads and extended walking durations on the time interval between the first and second peak forces within the gait cycle. The experimental design was utilised, where participants experienced five varying levels of backpack loads and five durations of carrying, structured in a 5x5 experimental factors. Further specifics of this research design are outlined in Table 1.

Instruments

A Zebris FDM (Force Distribution Measurement) pressure plate, measuring 40x30 cm (Figure 1), was used in the

study to evaluate the time elapsed between the first peak force and second peak force during walking gait. The Zebris FDM pressure plate functions with a sampling frequency of 120 Hz and has a measurement accuracy of $\pm 5\%$ within its calibrated range of 1–120 N/cm². It utilizes capacitive pressure sensors arranged in a matrix, enabling detailed mapping of force distribution. The Zebris FDM-S system has shown excellent internal consistency (Cronbach's alpha exceeding 0.90) for gait-related metrics, supported by a double retest protocol conducted over two consecutive days. Prior studies, such as Van Alsenoy et al. (2019), have validated the platform's reliability and accuracy in test-retest assessments. The plate operated with Win FDM-S software (Zebris GmbH, Germany), and its user manual is publicly available online (https://www.zebris.de/fileadmin/Editoren/zebris-PDF-Manuals/Medizin/Software/Alte_Versionen/Manual_zebris_FDM_1.16.x_R1_EN_web.pdf). The platform's reliability and validity for gait analysis were confirmed by Van Alsenoy et al (2019).

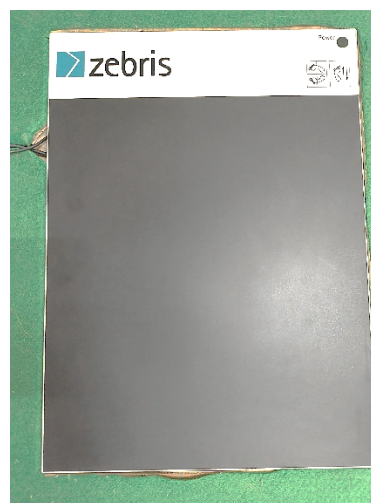


Fig. 1. The Zebris Pressure Plate

In addition, a standard backpack with double-strap, which was similar to those commonly carried by school students was used. It was filled with essential items typically carried by students, replicating realistic conditions. The total weight of the backpack was adjusted according to the experimental requirements. A calibrated weighing scale was employed to ensure the accuracy of the backpack's weight as per the body weight of each subject before each trial.

Selection of the Variables

Following variables were selected for the study:
Experimental Variables (Independent Variables)

Table 1. Backpack Load and Time Duration Protocol for Data Collection

Duration/ Backpack Load	D 0 minute	D 5 minutes	D 10 minutes	D 15 minutes	D 20 minutes
BL 0 Percent of BW	S1...S85	S1...S85	S1...S85	S1...S85	S1...S85
BL 8 Percent of BW	S1...S85	S1...S85	S1...S85	S1...S85	S1...S85
BL 12 Percent of BW	S1...S85	S1...S85	S1...S85	S1...S85	S1...S85
BL 16 Percent of BW	S1...S85	S1...S85	S1...S85	S1...S85	S1...S85
BL 20 Percent of BW	S1...S85	S1...S85	S1...S85	S1...S85	S1...S85

Note. S= Subject, S1= Subject First, S85= Subject Eighty-Fifth, BL = Backpack Load, BW = Body Weight, D = Duration

Backpack load

- Zero percent (no) backpack load of the bodyweight of the subject.
- Eight percent backpack load of the bodyweight of the subject.
- Twelve percent backpack load of the bodyweight of the subject.
- Sixteen percent backpack load of the bodyweight of the subject.
- Twenty percent backpack load of the bodyweight of the subject.

Duration of carrying the backpack load (recording time)

- At zero minute (at the start of the walking gait).
- At 5th minute of the walking gait.
- At 10th minute of the walking gait.
- At 15th minute of the walking gait.
- At 20th minute of the walking gait.

Observational Variables (Dependent Variables)

- Time elapse between first and second peak forces of the left foot (millisecond).
- Time elapse between first and second peak forces of the right foot (millisecond).

Procedure

Data collection was conducted at the Biomechanics Laboratory. The informed consent was obtained from participants’ guardians in advance. Before data collection, each subject’s body weight was measured using a calibrated scale verified with a standard weight. A 10-meter-long wooden walkway was constructed, with the pressure plate placed at its center to ensure a seamless walking path. Participants walked barefoot to allow for more accurate and clinically appropriate gait analysis.

The testing protocol began with participants starting from a designated line 4.5 meters before the pressure plate. Each participant initially stepped onto the plate with their left foot, walking naturally at a comfortable pace across the platform while wearing the backpack. Upon reaching the end of the walkway, 4.5 meters past the plate, they turned 180 degrees and walked back, stepping onto the plate with their right foot. This sequence was repeated for five trials, ensuring that each foot made contact with the pressure plate five times. The Zebris FDM-S pressure plate collected data on the selected variables, including the time interval between the first and second peak forces, which were then processed using Win FDM-S software for analysis.

This approach ensured that the data reflected real-life conditions, providing reliable and clinically relevant insights into the temporal dynamics of gait under varying backpack loads.

Statistical Analysis

The pressure platform data was exported to Excel for analysis. Descriptive statistics, including mean, standard deviation were applied to interpret the results.

Results

The Figure 2 defines several key time intervals related to gait mechanics while stepping on a pressure plate as per

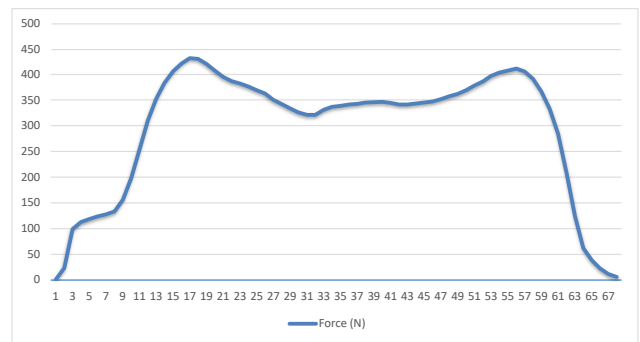


Fig. 2. Defining different Time Elapses of Right Foot and Left Foot of Walking Gait. Note. a = represents the time elapse to get the first peak force from the beginning; b = represents the time elapse to get the second peak force from the beginning; c= represents the time elapse to get the second peak force from the first peak force

the protocol of the study. The time elapse to reach the first peak force (a) represents the time duration from the beginning of the recording until the occurrence of the first peak force, which is typically associated with the initial contact and impact absorption during gait. The time elapse to reach the second peak force (b) refers to the time duration from the start of the recording until the second peak force, which reflects the propulsion phase of the gait cycle. Additionally, the time elapse (c) between the first and second peak forces is an important focus of this study, which indicates the duration of the mid-stance phase, which is critical for understanding the transition from impact absorption to propulsion.

This interval, from the first peak force to the second peak force, is a vital aspect of gait analysis. It represents the period during which the body shifts from absorbing the impact of foot contact to preparing for push-off and forward propulsion. The duration of this phase can vary depending on factors such as load distribution, balance, and muscle strength. Studying the time interval provides crucial insights into the efficiency of gait mechanics, as shorter or longer durations could indicate potential imbalances or compensatory mechanisms, especially under varying physical conditions.

In this context, understanding the time elapse between the first and second peak forces is essential for evaluating how different factors, such as varying backpack loads and carrying durations, influence gait stability and efficiency. A longer time elapse between these two peaks could suggest altered biomechanical strategies to cope with increased load, while a shorter duration might reflect an adaptive response to minimize the impact of such loads. By focusing on this temporal pattern, the current study aims to assess how these variations affect overall gait performance and to provide insights into the biomechanical implications of load carrying during walking.

The result of the study is depicted from Table 2 to Table 7.

The table 2 represents the time elapse to get the first peak force of left foot at the selected bag weights with selected recording time.

The table 3 represents the time elapse to get the second peak force of left foot at the selected bag weights with selected recording time.

The table 4 represents the time elapse to get the second peak force from first peak force of left foot at the selected bag weights with selected recording time.

Table 2. Descriptive Statistics of the Time Elapse to Get First Peak Force of Left Foot at the Selected Bag Weights with Selected Recording Time

S.No.	Bag/ Time	Time Elapse to Get First Peak Force (millisecond) of Left Foot				
		B1	B2	B3	B4	B5
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
1	T1	150.94 ± 30.65	155.18 ± 54.13	155.06 ± 28.89	150.00 ± 32.11	153.88 ± 29.44
2	T2	147.29 ± 26.52	148.12 ± 33.40	153.88 ± 26.64	144.12 ± 27.18	162.71 ± 38.93
3	T3	147.65 ± 27.59	156.35 ± 45.30	154.24 ± 28.05	147.76 ± 24.17	159.76 ± 61.16
4	T4	153.41 ± 37.75	149.29 ± 31.61	148.82 ± 26.30	147.06 ± 32.62	151.76 ± 25.87
5	T5	144.24 ± 26.20	147.53 ± 28.15	156.24 ± 32.95	147.88 ± 21.22	151.76 ± 29.16

Note: Rounded to two digits after the decimal; N=85; T1= Recording at zero minute; T2= Recording at fifth minute; T3= Recording at tenth minute; T4= Recording at fifteenth minute; T5= Recording at twentieth minute; B1= 0Percent Backpack Load of Bodyweight (No bag); B2= 8Percent Backpack Load of Bodyweight; B3= 12Percent Backpack Load of Bodyweight; B4= 16Percent Backpack Load of Bodyweight; B5= 20Percent Backpack Load of Bodyweight.

Table 3. Descriptive Statistics of the Time Elapse to Get Second Peak Force of Left Foot at the Selected Bag Weights with Selected Recording Time

S.No.	Bag/ Time	Time Elapse to Get Second Peak Force (millisecond) of Left Foot				
		B1	B2	B3	B4	B5
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
1	T1	494.00 ± 55.34	497.18 ± 71.02	505.29 ± 61.35	483.76 ± 64.73	485.88 ± 56.62
2	T2	484.82 ± 51.26	484.24 ± 59.89	491.18 ± 51.81	475.65 ± 63.76	503.18 ± 61.03
3	T3	471.41 ± 54.40	496.59 ± 68.06	500.35 ± 55.62	484.71 ± 55.52	496.12 ± 67.63
4	T4	485.18 ± 61.27	497.65 ± 69.64	492.71 ± 62.59	482.00 ± 58.18	491.65 ± 58.65
5	T5	474.59 ± 49.63	496.47 ± 58.45	504.12 ± 64.37	484.71 ± 55.84	496.71 ± 61.01

Note: Rounded to two digits after the decimal; N=85; T1= Recording at zero minute; T2= Recording at fifth minute; T3= Recording at tenth minute; T4= Recording at fifteenth minute; T5= Recording at twentieth minute; B1= 0Percent Backpack Load of Bodyweight (No bag); B2= 8Percent Backpack Load of Bodyweight; B3= 12Percent Backpack Load of Bodyweight; B4= 16Percent Backpack Load of Bodyweight; B5= 20Percent Backpack Load of Bodyweight.

Table 4. Descriptive Statistics of the Time Elapse to Get Second Peak Force from First Peak Force of Left Foot at the Selected Bag Weights with Selected Recording Time

S.No.	Bag/ Time	Time Elapse from First Peak Force to Second Peak Force (millisecond) of Left Foot				
		B1	B2	B3	B4	B5
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
1	T1	343.06 ± 24.69	342.00 ± 16.89	350.23 ± 32.46	333.76 ± 32.62	332.00 ± 27.18
2	T2	337.53 ± 24.74	336.12 ± 26.49	337.30 ± 25.17	331.53 ± 36.58	340.47 ± 22.10
3	T3	323.76 ± 26.81	340.24 ± 22.76	346.11 ± 27.57	336.95 ± 31.35	336.36 ± 06.47
4	T4	331.77 ± 23.52	348.36 ± 38.03	343.89 ± 36.29	334.94 ± 25.56	339.89 ± 32.78
5	T5	330.35 ± 23.43	348.94 ± 30.30	347.88 ± 31.42	336.83 ± 34.62	344.95 ± 31.85

Note: Rounded to two digits after the decimal; N=85; T1= Recording at zero minute; T2= Recording at fifth minute; T3= Recording at tenth minute; T4= Recording at fifteenth minute; T5= Recording at twentieth minute; B1= 0Percent Backpack Load of Bodyweight (No bag); B2= 8Percent Backpack Load of Bodyweight; B3= 12Percent Backpack Load of Bodyweight; B4= 16Percent Backpack Load of Bodyweight; B5= 20Percent Backpack Load of Bodyweight.

The table 5 represents the time elapse to get the first peak force of right foot at the selected bag weights with selected recording time.

The table 6 represents the time elapse to get the second peak force of right foot at the selected bag weights with selected recording time.

The table 7 represents the time elapse to get the second peak force from first peak force of right foot at the selected bag weights with selected recording time.

Discussion

The study highlights the significant influence of varying backpack loads and carrying durations on the temporal dynamics of walking gait, particularly the time elapse between the first peak force (FPF) and the second peak force (SPF), which reflects the midstance phase. The results indicate that both heavier loads and prolonged durations lead to a longer midstance phase, reflecting increased biomechanical stress and adaptive responses to maintain stability. These findings

Table 5. Descriptive Statistics of the Time Elapse to Get First Peak Force of Right Foot at the Selected Bag Weights with Selected Recording Time

S.No.	Bag/ Time	Time Elapse to Get First Peak Force (millisecond) of Right Foot				
		B1	B2	B3	B4	B5
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
1	T1	147.53 ± 20.17	148.90 ± 35.32	154.59 ± 49.08	146.59 ± 25.43	147.40 ± 24.11
2	T2	144.35 ± 19.55	144.50 ± 28.31	147.53 ± 24.68	146.24 ± 28.99	152.50 ± 27.60
3	T3	144.59 ± 21.58	150.70 ± 25.90	151.06 ± 25.17	143.76 ± 21.60	151.90 ± 40.28
4	T4	143.06 ± 26.05	156.00 ± 41.44	151.41 ± 25.87	145.76 ± 24.61	150.20 ± 23.40
5	T5	140.12 ± 17.89	150.70 ± 24.73	157.88 ± 40.65	143.65 ± 19.20	150.50 ± 27.38

Note: Rounded to two digits after the decimal; N=85; T1= Recording at zero minute; T2= Recording at fifth minute; T3= Recording at tenth minute; T4= Recording at fifteenth minute; T5= Recording at twentieth minute; B1= 0Percent Backpack Load of Bodyweight (No bag); B2= 8Percent Backpack Load of Bodyweight; B3= 12Percent Backpack Load of Bodyweight; B4= 16Percent Backpack Load of Bodyweight; B5= 20Percent Backpack Load of Bodyweight.

Table 6. Descriptive Statistics of the Time Elapse to Get Second Peak Force of Right Foot at the Selected Bag Weights with Selected Recording Time

S.No.	Bag/ Time	Time Elapse to Get Second Peak Force (Newton) of Right Foot				
		B1	B2	B3	B4	B5
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
1	T1	494.47 ± 51.26	498.60 ± 63.90	509.29 ± 71.01	481.88 ± 50.93	489.70 ± 49.17
2	T2	486.35 ± 46.36	483.30 ± 55.75	491.06 ± 48.23	470.94 ± 68.10	494.80 ± 52.14
3	T3	482.82 ± 43.52	502.50 ± 55.48	495.65 ± 50.41	477.88 ± 43.10	492.70 ± 55.71
4	T4	479.65 ± 55.39	502.50 ± 65.10	498.24 ± 58.31	481.06 ± 58.23	494.80 ± 51.33
5	T5	476.82 ± 41.55	499.30 ± 50.77	503.41 ± 54.89	488.24 ± 56.76	491.20 ± 47.29

Note: Rounded to two digits after the decimal; N=85; T1= Recording at zero minute; T2= Recording at fifth minute; T3= Recording at tenth minute; T4= Recording at fifteenth minute; T5= Recording at twentieth minute; B1= 0Percent Backpack Load of Bodyweight (No bag); B2= 8Percent Backpack Load of Bodyweight; B3= 12Percent Backpack Load of Bodyweight; B4= 16Percent Backpack Load of Bodyweight; B5= 20Percent Backpack Load of Bodyweight.

Table 7. Descriptive Statistics of the Time Elapse to Get Second Peak Force from First Peak Force of Right Foot at the Selected Bag Weights with Selected Recording Time

S.No.	Bag/ Time	Time Elapse to Get Second Peak Force from First Peak Force (millisecond) of Right Foot				
		B1	B2	B3	B4	B5
		Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
1	T1	346.94 ± 31.09	349.70 ± 28.58	354.70 ± 21.93	335.29 ± 25.50	342.20 ± 25.06
2	T2	342.00 ± 26.81	338.80 ± 27.44	343.53 ± 23.55	324.70 ± 39.11	342.40 ± 24.54
3	T3	338.23 ± 21.94	351.80 ± 29.58	344.59 ± 25.24	334.12 ± 21.50	340.80 ± 15.43
4	T4	336.59 ± 29.34	346.50 ± 23.66	346.83 ± 32.44	335.30 ± 33.62	344.60 ± 27.93
5	T5	336.70 ± 23.66	348.60 ± 26.04	345.53 ± 14.24	344.59 ± 37.56	340.70 ± 19.91

Note: Rounded to two digits after the decimal; N=85; T1= Recording at zero minute; T2= Recording at fifth minute; T3= Recording at tenth minute; T4= Recording at fifteenth minute; T5= Recording at twentieth minute; B1= 0Percent Backpack Load of Bodyweight (No bag); B2= 8Percent Backpack Load of Bodyweight; B3= 12Percent Backpack Load of Bodyweight; B4= 16Percent Backpack Load of Bodyweight; B5= 20Percent Backpack Load of Bodyweight.

align with studies such as Kellis and Arampatzi (2009), which reported that load carriage alters gait parameters, increasing ground reaction forces and leading to prolonged support phases. Similarly, Chow et al. (2005) noted disruptions in gait mechanics, including slower walking speed and reduced stride length, with heavier backpack loads. However, the pre-

sent study uniquely focuses on the time elapse between peak forces, a variable that has received limited attention in the literature. In comparison, Han (1993) demonstrated similar findings of increased double-support phase and forward trunk lean under heavy loads, emphasising compensatory adaptations like greater knee flexion during the weight-bear-

ing phase. Han's study complements these findings by showing how load redistribution strategies under high loads are biomechanically essential but introduces insights from joint torque and muscle activity, especially in spinal erectors.

Existing research often emphasises broader gait parameters, such as ground reaction forces (Hong et al., 2003; Sokhi et al., 2022) and plantar pressures (Pau et al., 2015; Ahmad et al., 2019; Balkó et al., 2022). While these variables provide valuable insights, they do not capture the detailed effects of load carriage on the time elapse between FPF and SPF. The current study addresses this gap, demonstrating how temporal changes (time elapse) in peak forces reflect the interplay of load and fatigue.

Interestingly, the results also reveal fluctuations in peak force timing at critical load thresholds (e.g., 15–20% of body weight). These fluctuations may indicate a biomechanical tipping point where compensatory strategies begin to falter, leading to inefficient gait patterns. Studies such as those by Knapik et al. (2004) and Harman et al. (2000) similarly observed critical thresholds beyond which load-induced strain becomes pronounced. However, unlike these studies, which primarily focus on static measures such as posture or broad kinetic metrics, the current study offers a dynamic perspective by analysing the temporal interval between peak forces, providing a more comprehensive understanding of how gait adapts over time under load. This is further corroborated by Thakurta et al. (2016), who found gender-specific sensitivity to loads, particularly in females, where stride length decreased, and stride rate increased with heavier loads.

Moreover, while previous studies (Chow et al., 2005; Paez-Moguer et al., 2019) have examined the effects of backpack weight and walking duration on posture and stride characteristics, the specific variable of time elapse between FPF and SPF remains underexplored. This temporal measure is critical because it reflects both the impact absorption and propulsion phases of gait, offering insights into load redistribution and stability. The study contributes to the growing body of evidence on load carriage by emphasising this novel variable, which has implications for injury prevention and ergonomic design. Han (1993), for example, suggested that maintaining the body's centre of mass at a lower vertical position under load was a compensatory mechanism to mitigate strain. Similarly, Figueiredo (2011) noted increased plantar pressure in specific foot regions with heavier loads, aligning with the temporal gait disruptions observed in our results.

The study highlights the underappreciated impact of backpack loads and carrying durations on the temporal dynamics of peak forces during walking gait. By focusing on a variable that has been largely overlooked in existing research, present work not only fills a critical gap in the literature but also offers actionable insights for improving the safety and efficiency of load carriage in school-aged children. These findings underscore the importance of continued exploration into load-induced biomechanical adaptations to inform guidelines and interventions aimed at promoting health and well-being. In conjunction with related studies (Han, 1993; Thakurta et al., 2016; Figueiredo, 2011) the results further reinforce the importance of dynamic gait analysis in understanding load distribution and its implications for human locomotion. The findings of the present study align with the proposed hypothesis. As predicted, increasing backpack loads and extended carrying durations significantly affected the temporal dynam-

ics of gait. Specifically, the significant increase in time elapse between the first and second peak forces observed at loads exceeding 15% body weight indicates compensatory biomechanical responses. These results suggest that excessive loads may compromise normal walking patterns, thereby increasing the risk of musculoskeletal strain in school-going boys.

Limitations of the Study

The study has certain limitations. The sample comprised only school-going boys aged 10 to 12 years from the Delhi NCR region, which may restrict the generalisability of the findings to other genders, age groups, or populations from different geographical areas. Additionally, the data was collected under controlled laboratory conditions on a wooden walkway, which might not fully replicate real-world scenarios where uneven terrain and varying surfaces could influence gait patterns.

Strengths of the Study

The study fills a critical gap in existing literature by examining the underexplored temporal interval between the first and second peak forces during the gait cycle. This unique focus provides valuable insights into how varying backpack loads and carrying durations impact the midstance phase of gait, a crucial aspect of stability and propulsion. The use of advanced instrumentation, such as the Zebris FDM pressure plate, ensures precise and reliable data collection, adding to the robustness of the findings. Additionally, well-structured 5x5 experimental framework allow for the validity of the results.

Future Implications

Future research can expand upon this study by exploring diverse populations, including younger children, adolescents and those with pre-existing musculoskeletal conditions, to increase the generalisability of the findings. It would also be valuable to examine other biomechanical variables, such as muscle activation patterns, joint torques, and angular kinematics, to gain a more comprehensive understanding of how the body compensates under different load conditions. Furthermore, conducting studies in real-world environments with varying terrains could provide deeper insights into the practical implications of load carriage. Ultimately, this research can contribute to policy recommendations for schools, parents and healthcare professionals, promoting awareness and preventive measures to safeguard children's health and well-being.

Conclusions

The study highlights the significant influence of increasing backpack loads and prolonged carrying durations on the temporal dynamics of walking gait. It highlights the extended midstance phase as an adaptive response to biomechanical stress, suggesting that load thresholds beyond 15–20% of body weight may lead to inefficiencies in gait. These findings contribute to the development of evidence-based guidelines for safe backpack use, particularly for school-aged children, and emphasise the need for ergonomic interventions to reduce potential musculoskeletal risks. Further research could

expand on this work by exploring diverse populations, additional biomechanical variables, and more dynamic environments to enhance the applicability of these insights.

Consent to Participate

Participants were assured that their participation was voluntary, with the freedom to withdraw at any time, and were continuously informed of their rights in accordance with the Declaration of Helsinki.

Data Availability

The data are not publicly available due to ethical or privacy restrictions; anonymized data may be provided upon reasonable request.

Conflict of Interest

The authors declare no conflicts of interest.

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Вплив варіації маси рюкзака та тривалості його носіння на інтервал часу між першим і другим піковими зусиллями під час ходьби школярів-хлопців

Рабія Хусейн^{1ABCDE}, Дхананджой Шоу^{1ABCDE}

¹Університет Делі, Індія

Авторський вклад: А – дизайн дослідження; В – збір даних; С – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 7 табл., 2 рис., 25 джерел.

Вступ. Підтримання стійкості та поступального руху під час ходьби — особливо з навантаженням — вимагає постійного коригування параметрів ходи.

Мета. Визначити вплив різної маси рюкзака та тривалості його носіння на інтервал часу між першим піковим зусиллям (FPF) і другим піковим зусиллям (SPF) під час ходьби школярів-хлопців.

Матеріали і методи. У дослідженні взяли участь 85 хлопців віком 10–12 років з Національної столичної території Делі. Темпоральні параметри ходи вимірювали за допомогою тискової платформи Zebris Force Distribution Measurement у п'яти умовах навантаження рюкзаком (0%, 8%, 12%, 16% та 20% маси тіла) та при п'яти тривалостях носіння (0, 5, 10, 15 та 20 хв). Учасники проходили босоніж 10-метрову доріжку з платформою, розташованою посередині. Для кожної умови виконували п'ять спроб; дані аналізували з використанням описової статистики.

Результати. Зі збільшенням навантаження та тривалості носіння інтервал між FPF і SPF суттєво зростав, що вказує на подовження середньої фази опори. При навантаженні 15–20% маси тіла компенсаторні механізми ходи починали втрачати ефективність, що проявлялося збільшенням інтервалів і варіабельності, свідчачи про біомеханічне напруження та зниження ефективності ходьби.

Висновки. Маса рюкзака та тривалість його носіння істотно впливають на темпоральні параметри ходи, зокрема на інтервал між FPF і SPF. Отримані результати підкреслюють необхідність ефективного контролю ваги рюкзака та впровадження ергономічних стратегій для безпечного його використання школярами.

Ключові слова: маса рюкзака, перше пікове зусилля, аналіз ходи, носіння навантаження, середня фаза опори, друге пікове зусилля, інтервал часу.

Information about the Authors

Husain, Rabiya: rabiyaahn70@gmail.com; <https://orcid.org/0000-0003-1434-1191>; Department of Physical Education and Sports Sciences, University of Delhi, Delhi, India.

Shaw, Dhananjay: dhananjayshaw1960@gmail.com; <https://orcid.org/0000-0002-4275-6389>; Indira Gandhi Institute of Physical Education and Sports Sciences, University of Delhi, Delhi, India.

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