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## Effect of back pack loads carried for extended time durations on mean pressure on the plantar aspect of the foot of school going children's gait (A descriptive approach)

**Sandeep Singh Sokhi, Dhananjay Shaw, Deepak Singh and Syed Murtaza Hussain Andrabi**

### Abstract

**Background:** Backpack load carriage has proven to have negative impact on the musculoskeletal health of school going children. Therefore, it is imperative to examine the compensatory changes that may exist with backpack load during gait on mean foot pressure distribution.

**Objective:** To examine the effect of various backpack loads carried for extended periods of time on the mean pressure of school going children's gait.

**Participants:** A total number of 85 school going children from Delhi NCR participated in this study.

**Method:** The mean pressure of the children was recorded with a pressure platform (ZebrisInc; Germany (40x30 cm), supported with Win FDM-S software, Germany) at various backpack load and exposure time recordings.

**Statistics used:** To analyse the data we used a descriptive approach (mean, standard deviation, and coefficient of variation) and the findings have been illustrated with the help of line diagram (two dimensional).

**Results:** The results showed changes in mean pressure when a backpack load was carried for an extended periods of time, and changes were observed when the backpack load increased.

**Conclusion:** The change in mean pressure signifies acute changes in the foot structure of the children which may have implications for foot disorders and postural (musculoskeletal) deformities for developing children.

**Keywords:** Back pack, plantar aspect, children's gait, foot pressure distribution

### Introduction

Backpacks are the most convenient way to carry things from one location to the next. School children use the backpack mostly to carry books and notebooks around. A survey conducted on the school children of Pune and Hyderabad reported that 77.2% of school children carried a heavy backpack load of up to 20% of backpack load [1]. A recent study suggested that an excessive backpack load could lead to the collapse of Medial Longitudinal Arc (MLA) [2] which could have implications for foot injuries and foot disorders for developing children [3].

Studies have documented that carrying backpack load can modify gait kinematics [4], kinetics [5], muscle activity [6] as well as plantar pressure distribution [7] in school going children. Pressure distribution has often been studied as it can provide valuable insight into human gait and foot function.

Research that has looked into the pressure distribution of the foot have reported significant increase in contact areas [7, 8] contact time [9], pressure [7, 8] and force loading [8] with the increase of backpack load. These findings are confirmation of modification in foot loading patterns with external load. Upon reviewing the literature, it is consistent that the subjects use a forward lean to offset the load of backpacks. This strategy accentuates the foot loading towards the anterior of the foot as a balancing mechanism in the sagittal plane [7].

A further look into literature reveals that the contact area in the mid-foot increases up to 10% as the backpack weight increased [7]. This implies that with the heavier backpack load there is an increasing amount of foot-group contact possibly due to collapse of MLA.

Yet, many other facets remain unclear such as children carry backpacks for a duration of time from home to school and school to home. Research done so far has examined the acute effect of backpack load carriage [3-9]. Therefore, the objective of this study were to describe the effect of backpack loads carried for extended periods of time on mean pressure on the plantar aspect of male school going children.

As the children carry their backpack, with time (duration of carrying backpack) there will be an onset of fatigue especially in the intrinsic foot muscles that may lead to changes in foot strike pattern as well as acute deformation of the foot structure and thereby effecting pressure distribution. So our primary hypothesis was that with the progression of time there will be changes in mean pressure of the right and left foot for the same external load. We also expected that with the progression of time and increase in backpack load there would be a possible interaction of two factors which will increase the effect of fatigue on the selected gait parameter (mean pressure).

**Methods**

**Sample of the study:** The subjects of this study were 85 male school going children of Delhi NCR, age ranging from 10 to 12 years.

**Tools used for measurement (pressure plate):** The portable pressure measurement platform from ZebrisInc; Germany (40x30 cm), supported with Win FDM-S software (Germany) was used to collect the data on subjects over five trails for each foot.

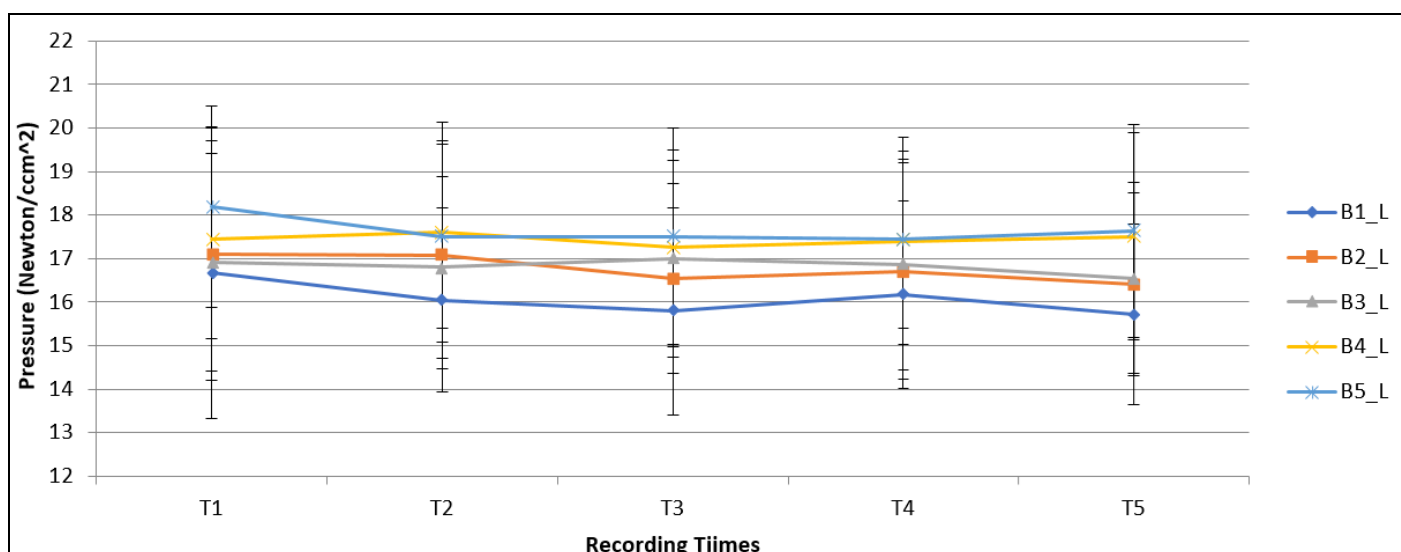
**Back pack load and Gait protocol:** The subjects were exposed to five backpack load conditions (B1; Backpack load of 0% of Body Weight (No bag); B2; backpack load of 8% of Body Weight; B3= backpack load of 12% of Body Weight; B4= backpack load of 16% of Body Weight; B5=backpack load of 20% of Body Weight) which were carried for extended periods of time with the purpose of recording the pressure distribution at specific periods of time(T1= Recording at 0 minute; T2= Recording at 5 minutes; T3= Recording at 10 minutes; T4= Recording at 15 minutes; T5= Recording at 20 minutes).

**Data analysis:** The data recorded with the pressure platform was exported to excel for further data analysis. Statistics used: For the purpose of this study were used mean, standard deviation, and coefficient of variation to interpret the data.

**Table 1:** Descriptive Statistics of the Mean Pressure of Left Foot at the Selected Bag Weights with Selected Recording Time

S.no	Bag Time	Mean Pressure (N/cm <sup>2</sup> ) of Left Foot																		
		B1			B2			B3			B4			B5		Mean	S.D	COV		
		Mean	±	S.D	Mean	±	S.D	Mean	±	S.D	Mean	±	S.D	Mean	±				S.D	
1	T1	16.67	±	3.36	17.10	±	2.90	16.92	±	2.51	17.43	±	2.27	18.20	±	2.31	17.26	2.67	15.30	
2	T2	16.05	±	2.12	17.08	±	2.62	16.80	±	2.08	17.62	±	2.53	17.51	±	2.12	17.01	2.29	13.27	
3	T3	15.79	±	2.38	16.54	±	2.19	16.99	±	2.26	17.27	±	2.24	17.49	±	2.52	16.82	2.32	13.72	
4	T4	16.17	±	2.15	16.71	±	2.49	16.87	±	2.42	17.41	±	2.38	17.44	±	2.04	16.92	2.29	13.68	
5	T5	15.72	±	2.07	16.42	±	2.10	16.55	±	2.20	17.51	±	2.38	17.63	±	2.44	16.77	2.24	13.31	
		16.08		2.41	16.77		2.46	16.82		2.29	17.45		2.36	17.65		2.29				
	CV	15.01			14.66			13.63			13.51			12.94						

**Note:**  
 Values have been rounded to two digits after the decimal; N=85  
 T1= Recording at 0 minute; T2= Recording at 5 minutes; T3= Recording at 10 minutes; T4= Recording at 15 minutes; T5= Recording at 20 minutes.  
 B1; Backpack load of 0% of Body Weight (No bag); B2; backpack load of 8% of Body Weight; B3= backpack load of 12% of Body Weight; B4= backpack load of 16% of Body Weight; B5=backpack load of 20% of Body Weight



The table-1 displays the descriptive statistics of the mean pressure of left foot for selected back pack weights (B1= 0% of Body Weight (No bag); B2= 8% of Body Weight; B3= 12% of Body Weight; B4= 16% of Body Weight; B5= 20% of Body Weight) and selected recording times (T1= Recording at 0 minute; T2= Recording at 5 minutes; T3= Recording at 10 minutes; T4= Recording at 15 minutes; T5= Recording at 20 minutes). the descriptive statistics of B1(0% body weight) along with the progression of time was mean=16.08, SD=2.41, the data fluctuated with a CV of 15.01, which is not very homogenous nor heterogeneous.

In regard to B2(8% of body weight), along with the progression of time the mean and SD values were 16.77 and 2.46 respectively, the data

fluctuated with a CV of 14.66 which is not very homogenous nor heterogeneous.

In regard to B3(12% of body weight), along the progression of time the mean and SD values were 16.82 and 2.29 respectively, the data fluctuated with a CV of 13.63, which is not very homogenous nor heterogeneous.

In regard to B4(16% of body weight), along with the progression of time the mean and SD values were 17.45 and 2.36 respectively, the data fluctuated with a CV of 13.51 which is not very homogenous nor heterogeneous.

In regard to B5(20% of body weight), along with the progression of time the mean and SD values were 17.65 and 2.29 respectively, the data fluctuated with a CV of 12.94 which is not very homogeneous nor heterogeneous.

It was observed that along with the addition of back pack loads the CV is linearly reduced.

In regard to T1(recording at 0 minute), through selected backpack loads (B1,B2,B3,B4 and B5) the mean and SD values were 17.26 and 2.67 respectively with a CV of 15.30.

In regard to T2(recording at 5 minutes), through selected backpack loads (B1,B2,B3,B4 and B5) the mean and SD values were 17.01 and 2.29 respectively with a CV of 13.27.

In regard to T3(recording at 10 minutes), through selected backpack loads (B1,B2,B3,B4 and B5), the mean and SD values were 16.82 and 2.32 with CV reported to be 13.72.

In regard to T4(recording at 15 minutes), through selected backpack loads (B1,B2,B3,B4 and B5), the mean and SD values were 16.92 and 2.29 respectively with a CV of 13.68.

In regard to T5(recording at 15 minutes), through selected backpack loads (B1,B2,B3,B4 and B5), the mean and SD values were 16.77 and 2.24 respectively with a CV of 13.31.

It was observed that with the progression of recording times the CV linearly reduced.

Along with the progression of recording time and increase of Back pack loads, the data demonstrated a reduction of CV

**Fig 1:** Pressure on Left Foot at Selected Bag Loads with respect to Selected Recording Times

**Table 2:** Descriptive Statistics of the Mean Pressure of Right Foot at the Selected Bag Weights with Selected Recording Time

S. No	Bag Time	Mean Pressure (N/cm <sup>2</sup> ) of Right Foot															Mean	S.D	CV
		B1			B2			B3			B4			B5					
		Mean	±	S.D	Mean	±	S.D	Mean	±	S.D	Mean	±	S.D	Mean	±	S.D			
1	T1	16.22	±	2.63	16.37	±	2.02	16.35	±	2.26	17.02	±	2.31	17.99	±	2.34	<b>16.72</b>	<b>2.31</b>	<b>13.83</b>
2	T2	15.51	±	2.22	16.25	±	2.39	16.71	±	2.03	17.62	±	2.26	17.51	±	2.79	<b>16.72</b>	<b>2.34</b>	<b>14</b>
3	T3	15.70	±	1.98	16.18	±	2.20	16.70	±	2.49	17.21	±	2.66	17.70	±	2.44	<b>16.70</b>	<b>2.35</b>	<b>14.09</b>
4	T4	15.59	±	2.07	16.59	±	2.65	16.53	±	1.95	16.86	±	2.13	17.39	±	2.20	<b>16.58</b>	<b>2.20</b>	<b>13.25</b>
5	T5	15.61	±	2.17	16.28	±	2.09	17.07	±	2.38	17.33	±	2.50	17.36	±	2.62	<b>16.79</b>	<b>2.35</b>	<b>14.01</b>
		<b>15.73</b>		<b>2.21</b>	<b>16.34</b>		<b>2.27</b>	<b>16.67</b>		<b>2.22</b>	<b>17.21</b>		<b>2.37</b>	<b>17.59</b>		<b>2.48</b>			
	<b>CV</b>	<b>14.07</b>			<b>13.90</b>			<b>13.33</b>			<b>13.78</b>			<b>14.08</b>					

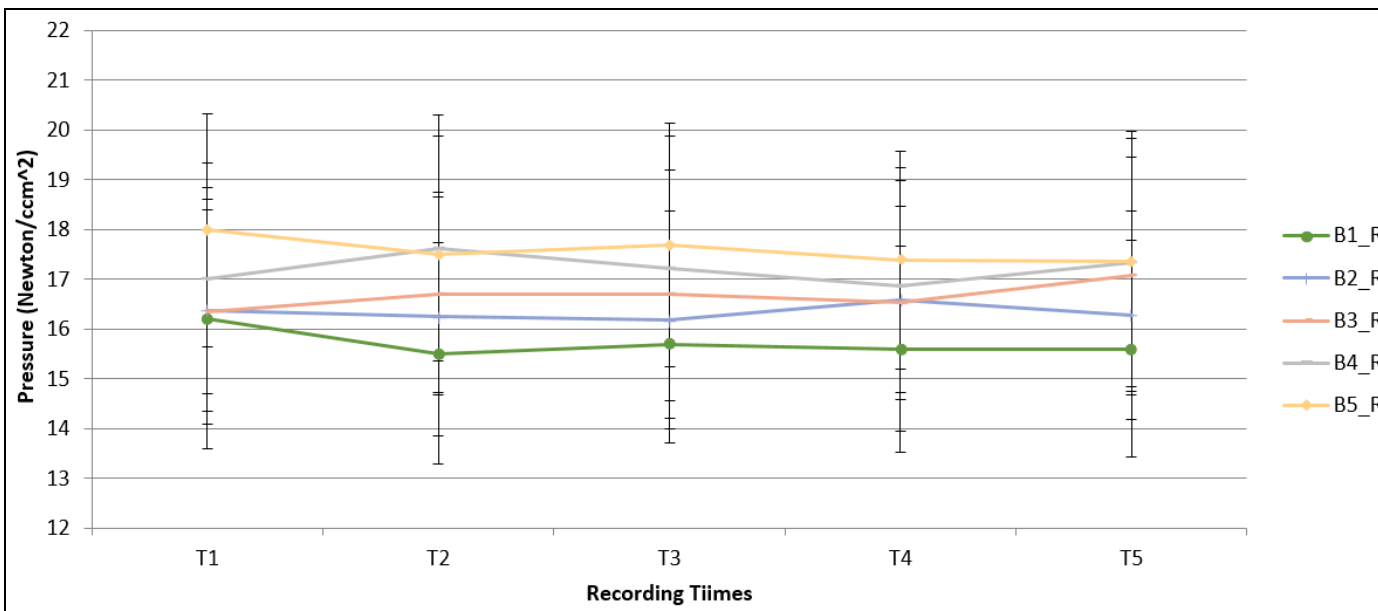
**Note:**

Values have been rounded to two digits after the decimal; N=85

T1= Recording at 0 minute; T2= Recording at 5 minutes; T3= Recording at 10 minutes; T4= Recording at 15 minutes;

T5= Recording at 20 minutes.

B1; Backpack load of 0% of Body Weight (No bag); B2; backpack load of 8% of Body Weight; B3= backpack load of 12% of Body Weight; B4= backpack load of 16% of Body Weight; B5=backpack load of 20% of Body Weight



The table-2 displays the descriptive statistics of the mean pressure of right foot for selected back pack weights (B1= 0% of Body Weight (No bag); B2= 8% of Body Weight; B3= 12% of Body Weight; B4= 16% of Body Weight; B5= 20% of Body Weight) and selected recording times (T1= Recording at 0 minute; T2= Recording at 5 minutes; T3= Recording at 10 minutes; T4= Recording at 15 minutes; T5= Recording at 20 minutes). The descriptive statistics of B1(without a backpack) along with the progression of time was mean=15.73, SD=2.21, the data fluctuated with a CV of 14.07, which is not very homogenous nor heterogeneous.

In regard to B2(backpack =8% of body weight), along with the progression of time the mean and SD values were 16.34 and 2.27 respectively, the data fluctuated with a CV of 13.90 which is not very homogenous nor heterogeneous.

In regard to B3(backpack =12% of body weight), along the progression of time the mean and SD values were 16.67 and 2.22 respectively, the

data fluctuated with a CV of 13.33, which is not very homogenous nor heterogeneous.

In regard to B4(backpack =16% of body weight), along with the progression of time the mean and SD values were 17.21 and 2.36 respectively, the data fluctuated with a CV of 13.51 which is not very homogenous nor heterogeneous.

In regard to B5(backpack =20% of body weight), along with the progression of time the mean and SD values were 17.65 and 2.37 respectively, the data fluctuated with a CV of 13.78 which is not very homogeneous nor heterogeneous.

It was observed that along with the addition of backpack loads the CV is linearly reduced.

In regard to T1(recording at 0 minute), and selected backpack loads (B1,B2,B3,B4 and B5) the mean and SD values were 16.72 and 2.31 respectively with a CV of 13.83.

In regard to T2(recording at 5 minutes), and selected backpack loads (B1,B2,B3,B4 and B5) the mean and SD values were 16.72 and 2.34 respectively with a CV of 14.

In regard to T3(recording at 10 minutes), and selected backpack loads (B1,B2,B3,B4 and B5), the mean and SD values were 16.70 and 2.35 respectively with a CV of 14.09.

In regard to T4(recording at 15 minutes), and selected backpack loads (B1,B2,B3,B4 and B5), the mean and SD values were 16.58 and 2.20 respectively with a CV of 13.25.

In regard to T5(recording at 15 minutes), and selected backpack loads(B1,B2,B3,B4 and B5), the mean and SD values were 16.79 and 2.35 respectively with a CV 14.0.

It was observed that with the progression of time extended to carry selected backpack loads the CV reduced linearly.

Along with the progression of recording times and increase of Back pack loads, the data demonstrated a reduction of CV ie. Increment in homogeneity.

**Fig 2:** Pressure on Right Foot at Selected Bag Loads with respect to Selected Recording Times

## Discussion

The study set out to observe the effect of backpack load carried for extended periods of time on school going children's gait. Our study found that with the load carried for extended periods of time the mean pressure decreased in both of the feet (figure 1; figure 2). This implies that as the time progresses the contact area of the foot with the ground is increased. One possible explanation to this is the deformation of the MLA (medial longitudinal arc). The MLA is a deformable structure that can flatten up to 10mm and alter its length by 4 mm during the mid-stance of the gait. This structure is primarily supported by two muscles namely tibialis anterior and tibialis posterior<sup>[10]</sup>. Any inadequacy in the magnitude of muscle tension production due to onset of fatigue of these muscles has implications for the deformation of the MLA. Consequently, increasing the contact area of the foot during the stance phase (mid-stance) of the gait. As the MLA deforms and comes down, the greater contact area reduces the mean pressure under the foot. Indeed, a study reported a significantly decreased mean pressure after high intensity running exercise to exhaustion<sup>[10]</sup> which is consistent with our finding.

Castro observed more pressure in the medial mid-foot and toes and lower values in the lateral rare-foot region under loaded condition, this behaviour of pressure loading is suggestive of increased foot pronation under loaded conditions<sup>[11]</sup>. Subsequently, increasing the contact area of the foot (forefoot and mid-foot) which is mostly attributed to soft tissue deformation<sup>[12]</sup>. Our study showed increase in mean pressure with the addition of backpack loads which is consistent across studies<sup>[8, 11]</sup>.

The change in the pressure distribution pattern leads to number of postural (musculoskeletal) deformation<sup>[13]</sup>, which are detrimental for proper growth, development, organic functions and personality of the growing children<sup>[14]</sup>.

Further statistical analysis like two way repeated measure design and/or MANOVA (Multivariate Analysis of Variance) are strongly recommended for further discourse of the cause and effect in the future study.

## Conclusions

- This study found that with the increase of backpack load the mean pressure increased for the right and the left foot.
- We also found that with the progression of time at every backpack load the mean pressure decreased for the right as well as the left foot.

- The change in mean pressure signifies acute changes in the foot structure of the children which may have implications for foot disorders for developing children.

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