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The effects of backpack load and carrying duration on head forward inclination of 10-12-year old children

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Abstract

Backpacks are an advantageous route for children to convey basic instructive materials to class, however they embed different materials which builds the heaviness of backpack. The purpose of this study was to investigate the collaborations impact of load carriage and carrying durations on Head Forward Inclination and then suggestion of optimal weight limit for carrying the load of their backpacks for particular duration of walk. Six male school children, age ranging between 10 to 12 years with (Height 134.22 ± 3.61 cm & Weight 29.67 ± 2.54 kg) were selected to carry school backpacks of 0%, 8%, 12% & 16% of their own body weights on a treadmill at the 1.1 m s^{-1} to 1.4 m s^{-1} for 20 minutes. The movements of the subjects in sagittal plane were filmed; the recorded videotapes were digitized and analyzed on a motion analysis system at selected time intervals i.e. 0 minute, 5 minutes, 10 minutes, 15 minutes and 20 minutes. For each complete trial; Head Forward Inclination angle was measured in degrees. The two way repeated measures ANOVA (within-within) was used for statistical analysis of data in significant level of $p < 0.05$. The results of the study demonstrates the increased Head Forward Inclination observed in children while walking with selected load for selected duration. The greatest differences were noted as the magnitude of backpack loads goes on increasing. Significant change in Head Forward Inclination angle was found as %BW increased. When the load was increased to 12% that values didn't changed to a higher extent up to 5 minutes of walking but after that the mean Head Forward Inclination angle fell rapidly and constantly with extent of duration. Thus implying that school bag weighing 12% of body weight would be too heavy for the school children aged 10-12 years to be able to maintain their normal cervical posture alignment; thus carrying a load of 8% of body weight is suggested.

Keywords: head forward inclination, school bag, load carriage, walking time, school-aged children

1. Introduction

The carriage of backpacks has been appeared to constitute a significant day by day "word related" load on the spines of school youngsters. These activities may bring about expanded dynamic stacking of the human musculoskeletal framework. At school, a typical situation is that of school youngsters conveying their school sacks and being required to stroll amid ordinary school activities. It is generally trusted that the rehashed carriage of overwhelming school backpacks puts extra weight on the quickly developing spines of youngsters, making them more inclined to postural change, and at last prompting lower back issues. It is trusted that overwhelming weight of kids backpack brought about abundance stack into spine, and this is creating some worry for parent's and the students who need to convey them (Macki & Legg, 2008) [14]. There is specific worry for the lesser understudies in elementary schools, as the spine is at basic phase of advancement in youngsters between 12-14 year of age (Whittfield, Legg, & Hedderley, 2005) [25]. Lifting, conveying and taking care of an overwhelming backpack on the back causes forward inclining and terrible stance, which can prompt overabundance stack on the spine, and agony and distress in the neck, bears and back (Van Gent *et al.*, 2003; Hong & Li, 2005) [24, 9]. Loads conveyed by schoolchildren and their part in the advancement of musculoskeletal pain among this age assemble has been the subject of late consideration (Murphy, Buckle, & Stubbs, 2007 [17]; Javadivala, Allahverdipour, Dianat, & Bazargan, 2012) [12]. Many reviews additionally researched the impacts of conveying weight on body posture (Grimmer, Dansie, Milanese, Pirunsan, & Trott, 2002 [6]; Hong & Brueggemann, 2000 [11]; Hong & Cheung, 2003 [10]; Li, Hong, & Paul, 2003 [13]; Singh & Koh, 2009 [22]; Stacoff, Diezi, Luder, Stussi, & Quervain, 2005) [23] during level walking. As of late researchers have started to look at the impacts of conveying substantial backpacks and they noticed that conveying a backpack in this way advanced critical forward inclining of the head and trunk (Pascoe, Pascoe, Wang, Shim, & Kim, 1997) [19]. A review by (Negrini, Carabalona, & Sibilla, 1999) [18] demonstrated that 33% of Italian understudies, matured in the vicinity of 11 and 12 years, are conveying packs that measure over 30% of their body weight. After effects of a review by (Chansirinukor, Wilson, Grimmer, & Dansie, 2001) [1] uncovered that both backpack weight and time conveyed impacted cervical and shoulder act. Additionally, forward head pose expanded when they conveyed an overwhelming backpack. Many reviews have endeavoured to build up safe weight conveying limits for kids, and the rules change among nations. Stack conveying breaking points were set as 10% of the body weight in New Zealand (Whittfield *et al.*, 2005) [25]; 15% in Hong Kong

(Hong, Li, & Fong, 2008) [8], Australia (Chansirinukor *et al.*, 2001) [1], and Singapore (Singh & Koh, 2009) [22], and 20% in Turkey (Seven, Akalan, & Yucesoy, 2008) [20]. Many researchers have reasoned that the heaviness of a school back ought not to surpass 10% of the child's body weight (Goodgold *et al.*, 2002) [4]. Youngsters with heftiness expanded their trunk forward slant point, head forward slant edge, and step cycle spans in contrast with kids with ordinary body weight while conveying a backpack weight between 0 to 20% of their body weight. Therefore, the present study was undertaken with the purpose is to examine the collaborations impact of load carriage and durations on Head Forward Inclination and then suggestion of optimal weight limit for carrying the load of their backpacks for particular duration of walk.

2. Methods

2.1. Subjects

For the purpose of the study, six male school children, age ranging between 10 to 12 years with (Age 10.70 ± 0.48 years, Height 134.22 ± 3.61 cm, Weight 29.67 ± 2.54 kg) were selected from secondary school of Gwalior, India, through random sampling. All the participants were enquired about their medical history and also they were requested to report any other condition, which may cause them long term or short term problems in walking. Informed consent was obtained from the parents, and this study was approved by the Department Research Committee of Lakshmibai National Institute of Physical Education.

2.2. Backpacks, their weight and duration of carriage

A two-strap backpack that was used mostly by students was selected in this study. The backpack was carried suspended from both shoulders of the subjects, placed on the trunk, and fixed to a position (at waist level) which the subject felt most comfortable and stable. The backpacks were filled with materials usually used by students; books and other educational objects. The load of the backpack carried was expressed in terms of the different percentages (0%, 8%, 12% and 16%); backpack weight was set according to the each individual subject's body weight. The walking without backpack carriage (0% of subject's body weight) served as a control. The range of walking speed (simulated walking experimental protocol, where treadmill machine was used) was set at from 1.1 m s^{-1} to 1.4 m s^{-1} that is comfortable speed of walking for children (Wong & Hong, 1997) [27], for 20 minutes. Each subject take part in four walking trails of 20 minutes each on a treadmill with different load conditions (walking without load carriage (0% of body weight) and backpacks carriage with 8%, 12% and 16% body weight) were randomly arranged on four different days.

2.3. Measurement

In each trial, the subject's Head Forward Inclination angle was recorded by a Sony HDR-C-CX200 video camera. Camera was positioned laterally to the subject with the lens axis perpendicular to the movement plane. The frequencies of the camera was set at 30 frames /second. Subjects in standing position, 15mm reflector marker (Innovision systems Inc) was placed on the tragus and 7^{th} cervical vertebra (C7) spinous process, for the calculation of Head Forward Inclination angle; Figure 1 (Wilmarth & Hilliard, 2002) [26]. The movements of the subjects in sagittal plan were filmed and analyzed. Each testing trial was filmed throughout the walking period (20 minutes). The recorded videotapes were digitized and analyzed on a motion analysis system (Kinovea Software; version 0.8.15) at selected time intervals i.e. 0 minute, 5 minutes, 10 minutes, 15 minutes and 20 minutes. For each complete trial; Head Forward Inclination angle was measured in degrees.

Fig 1: Head Forward Inclination Angle without and with Backpack Load.

3. Data Analysis and Statistics

Two way repeated measures ANOVA (within-within) was used to compare the effect of backpack loads and durations on Head Forward Inclination. In all the statistical tests, the level of significance was set at 0.05 level, except in case of separate one way repeated measure ANOVAs where it was checked at an adjusted α level. Data were presented as mean and standard deviation. For this purpose, Statistical Package for Social Science (SPSS) version 20.0 (SPSS Inc. SPSS Statistics for Windows, Chicago: SPSS Inc.) was used.

4. Results

Two way repeated measures ANOVA are particularly susceptible to the violation of assumption of sphericity. Mauchly's test for checking assumption of sphericity for Durations, Loads and their Interaction on Head Forward Inclination values. Mauchley's test of sphericity was violated in all the three cases i.e. for Duration, Load and the Interaction (Duration * Load), since the p-value for the Mauchly's test statistic was significant at 0.05 level of significance. Thus in order to make the necessary correction the Epsilon value of Greenhouse-Geisser was considered; as the Epsilon values for all the three cases were found to be below 0.75. So, while evaluating the Within-Subjects effect (Table 1) the Row values with Greenhouse-Geisser correction was considered. The tests of within-subjects effects for durations, loads and their interactions are presented in the table below.

Table 1: Tests of within-subjects effects for durations, loads and their interactions on head forward inclination values.

Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig. (P-Value)**	**Partial Eta Squared**
Duration	Greenhouse- Geisser	359.09	1.28	280.95	193.57	0.00*	0.98
Error (Duration)	Greenhouse- Geisser	9.28	6.39	1.45			
Load	Greenhouse-Geisser	507.10	1.25	406.58	570.89	0.00*	0.99
Error (Load)	Greenhouse-Geisser	4.44	6.24	0.71			
Duration * Load	Greenhouse-Geisser	344.30	3.04	113.14	265.92	0.00*	0.98
Error (Duration*Load)	Greenhouse-Geisser	6.47	15.22	0.43			

*significant at 0.05 level of significance

In Table 1 it is evident that there was a significant main effect of walking durations and backpack loads, the p-value (0.00) was found significant at 0.05 level of significance. The results also indicate that the Interaction effect (duration * load) was significant as the p-value (0.00) is less than 0.05.

Since, interaction effect was significant the main effect does not hold much meaningful information and thus the simple effect of both the variables were analysed using Univariate repeated measure ANOVAs with corrected level of significance, though it was reported to be significant at 0.05 level of significance.

4.1 One-way rANOVA on Head Forward Inclination for analysing the effect of 'Durations' on each level of 'Load'

Repeated measure ANOVA requires the assumption of Sphericity to be fulfilled; the same was tested through Mauchly's test and the results suggest that the value of Mauchly's test statistics was insignificant for the scores of Head Forward Inclination at 8% load as the p-value is greater than 0.05 level of significance. Hence, due to insignificance of Mauchly's statistics, the assumption of sphericity has been fulfilled. While the value of Mauchly's test statistics was significant for the scores of Head Forward Inclination at 0%, 12% and 16% load as the p-value was found less than 0.05 level of significance. So, in these cases the assumption of sphericity was considered to be violated and Greenhouse-Geisser correction was considered for the purpose of later analysis.

Table 2: F-table for testing significance of duration (within-subjects) effects in each load intensities on head forward inclination.

Source		Type III Sum of Squares	df	Mean Square	F	Sig. (P-Value)	Partial Eta Squared
0 % load	Greenhouse-Geisser	0.44	1.38	0.32	0.92	0.41	0.16
Error (0 % load)	Greenhouse-Geisser	2.41	6.87	0.35			
8 % load	Sphericity Assumed	0.75	4	0.19	1.09	0.39	0.18
Error (8 % load)	Sphericity Assumed	3.44	20	0.17			
12 % load	Greenhouse-Geisser	316.06	1.20	262.66	306.06	0.00*	0.98
Error (12 % load)	Greenhouse-Geisser	5.16	6.02	0.86			
16 % load	Greenhouse-Geisser	386.14	1.62	239.08	407.72	0.00*	0.99
Error (16 % load)	Greenhouse-Geisser	4.74	8.08	0.59			

*Significant at 0.0125 level (Adjusted α value)

The results of F-Table for testing significance of Duration (Within-Subjects) Effects in Each Load Intensities on Head Forward Inclination indicates that in case of 0% Load and 8% Load, there exists no significant difference between any of the levels of duration since the obtained p-values (0% Load= 0.41 and 8% Load= 0.39) were higher than 0.0125 level of significance (adjusted α value). However, there was a significant difference in Head Forward Inclination at 12% of loads and 16% of loads as the p-values (12% Load= 0.00 and 16% Load= 0.00) is less than 0.0125 (adjusted α value).

Thus, Pairwise comparison with of means was conducted for further analysis and data were presented as mean and standard deviation, which is embedded blow.

Table 3: Head forward inclination at each load intensities with different time points.
BW= Body Weight; *, ** = 5 Minutes, 10 Minutes, 15 Minutes, and 20 Minutes duration

Backpack Load (% of BW)	Variable (Degrees)	0 Minute Duration	5 Minutes Duration	10 Minutes Duration	15 Minutes Duration	20 Minutes Duration
0% of BW	Head Forward Inclination (HFI)	56.52±2.44	56.82±2.36	56.50±2.43	56.55±2.58	56.50±2.43
8% of BW		56.62±2.44	57.02±2.17	56.58±2.25	56.67±2.34	56.80±2.32
12% of BW		56.62±2.15	56.80±2.36	53.22±2.53**	50.43±2.68**	48.68±2.55**
16% of BW		56.52±2.38	55.75±2.38*	51.65±2.48**	49.17±2.65**	47.33±2.56**

(Time Points) vs. 0 Minute duration (Time Point), p< 0.05 or p< 0.01.

The results for the selected durations at 12 % backpack load readings of Head Forward Inclination revealed that there was no significant difference found in Head Forward Inclination at 12 % load between 0 minute and 5 minutes of durations as the p-value (p=1.00) is greater than 0.05 level of significance. While, there was a significant difference in Head Forward Inclination at 12 % load between 0 minute and 10 minutes (p=0.00), 0 minute and 15 minutes (p=0.00), and 0 minute and 20 minutes (p=0.00), of durations as the p-value is less than 0.05 level of significance. From the table it is also evident that there was a significant difference in Head Forward Inclination at 16 % load between 0 minute and 5 minutes (p=0.02), 0 minute and 10 minutes (p=0.00), 0 minute and 15 minutes (p=0.00), and 0 minute and 20 minutes (p=0.00), of durations as the p-value is less than 0.05 level of significance.

4.2 One-way rANOVA on Head Forward Inclination for analysing the effect of 'Loads' on each level of 'Duration'

The value of Mauchly's test statistics was insignificant for the scores of Head Forward Inclination at 0 minute and 10 minutes as the p-value is greater than 0.05 level of significance. Hence, due to insignificance of Mauchly's statistics, the assumption of sphericity was considered to be fulfilled. While the value of Mauchly's test statistics was significant at 5 minutes, 15 minutes and 20 minutes as the p-value is less than 0.05 level of significance. So in these cases the assumption of sphericity was considered to be violated and Greenhouse-Geisser correction was considered for further analysis.

Table 4: F-table for testing significance of load (within-subjects) effects in each level of duration on head forward inclination.

Source		Type III Sum of Squares	df	Mean Square	F	Sig. (P-Value)	Partial Eta Squared
0 Minute	Sphericity Assumed	0.06	3	0.02	0.41	0.75	0.08
Error (0 Minute)	Sphericity Assumed	0.74	15	0.05			
5 Minutes	Greenhouse-Geisser	5.90	1.31	4.51	44.71	0.00*	0.90
Error (5 Minutes)	Greenhouse-Geisser	0.66	6.54	0.10			
10 Minutes	Sphericity Assumed	108.66	3	36.22	301.33	0.00*	0.98
Error (10 Minutes)	Sphericity Assumed	1.80	15	0.12			
15 Minutes	Greenhouse-Geisser	282.98	1.10	257.06	429.02	0.00*	0.99
Error (15 Minutes)	Greenhouse-Geisser	3.30	5.50	0.60			
20 Minutes	Greenhouse-Geisser	453.81	1.39	325.53	513.99	0.00*	0.99
Error (20 Minutes)	Greenhouse-Geisser	4.42	6.97	0.63			

*Significant at 0.01 level (Adjusted α value)

The results of F-Table for testing significance of Load (Within-Subjects) Effects in Each level of Duration on Head Forward Inclination indicate that in case of 0 minute duration there was no significant difference between any of the levels of load since the obtained p-value (0 Minute = 0.75) is higher than 0.01 level of significance (adjusted α value). However, there was a significant difference in Head Forward Inclination at 5 minutes, 10 minutes, 15 minutes and 20 minutes of durations as the p-values (5 Minutes = 0.00, 10 Minutes = 0.00, 15 Minutes = 0.00, and 20 Minutes = 0.00) are less than 0.01 (adjusted α value).

Thus, Pairwise comparison with of means was conducted for further analysis and data were presented as mean and standard deviation, which is embedded blow.

Table 5: Head forward inclination at each time point with different load intensities.

Duration (Minute)	Variable (Degrees)	Backpack 0% of BW	Backpack 8% of BW	Backpack 12% of BW	Backpack 16% of BW
0 Minute Duration	Head Forward Inclination (HFI)	56.52±2.44	56.62±2.44	56.62±2.15	56.52±2.38
5 Minutes Duration		56.82±2.36	57.02±2.17	56.80±2.36	55.75±2.38*
10 Minutes Duration		56.50±2.43	56.58±2.25	53.22±2.53**	51.65±2.48**
15 Minutes Duration		56.55±2.58	56.67±2.34	50.43±2.68**	49.17±2.65**
20 Minutes Duration		56.50±2.43	56.80±2.32	48.68±2.55**	47.33±2.56**

BW= Body Weight; *, ** = 8%, 12%, and 16% Load Condition vs. 0% Load Condition, p< 0.05 or p< 0.01.

The results for the selected loads at 5 minutes duration readings of Head Forward Inclination revealed that there was no significant difference in Head Forward Inclination at 5 minutes duration between 0 % load and 8 % loads (p=1.00), 0 % load and 12 % of loads (p=1.00), as the p-values is greater than 0.05 level of significance, whereas, there was a significant difference in Head Forward Inclination at 5 minutes duration between 0 % load and 16 % of loads as the p-value (p=0.00) is less than 0.05 level of significance. From the table it is also evident that there was no significant difference in Head Forward Inclination at 10 minutes duration between 0 % load and 8 % loads as the p-value (p=1.00), is greater than 0.05 level of significance. Whereas, a significant difference observed in Head Forward Inclination at 10 minutes duration between 0 % load and 12 % loads (p=0.00), and 0 % load and 16 % of loads (p=0.00), as the p-value is less than 0.05 level of significance. Also, there was no significant difference in Head Forward Inclination at 15 minutes duration between 0 % load and 8 % loads as the p-value (p=1.00), is greater than 0.05 level of significance. Whereas, a significant difference found in Head Forward Inclination at 15 minutes duration between 0 % load and 12 % loads (p=0.00), and 0 % load and 16 % of loads (p=0.00), as the p-value is less than 0.05 level of significance. The results for the selected loads at 20 minutes duration readings of Head Forward Inclination revealed that there was no significant difference in Head Forward Inclination at 20 minutes duration between 0 % load and 8 % loads as the p-value (p=1.00), is greater than 0.05 level of significance. Whereas, a significant difference in Head Forward Inclination at 20 minutes duration between 0 % load and 12 % loads (p=0.00), and 0 % load and 16 % of loads (p=0.00), as the p-value is less than 0.05 level of significance.

The graphical representation of the mean values of Head Forward Inclination at selected loads with respect to selected time points has been presented in the Figure no. 2 below.

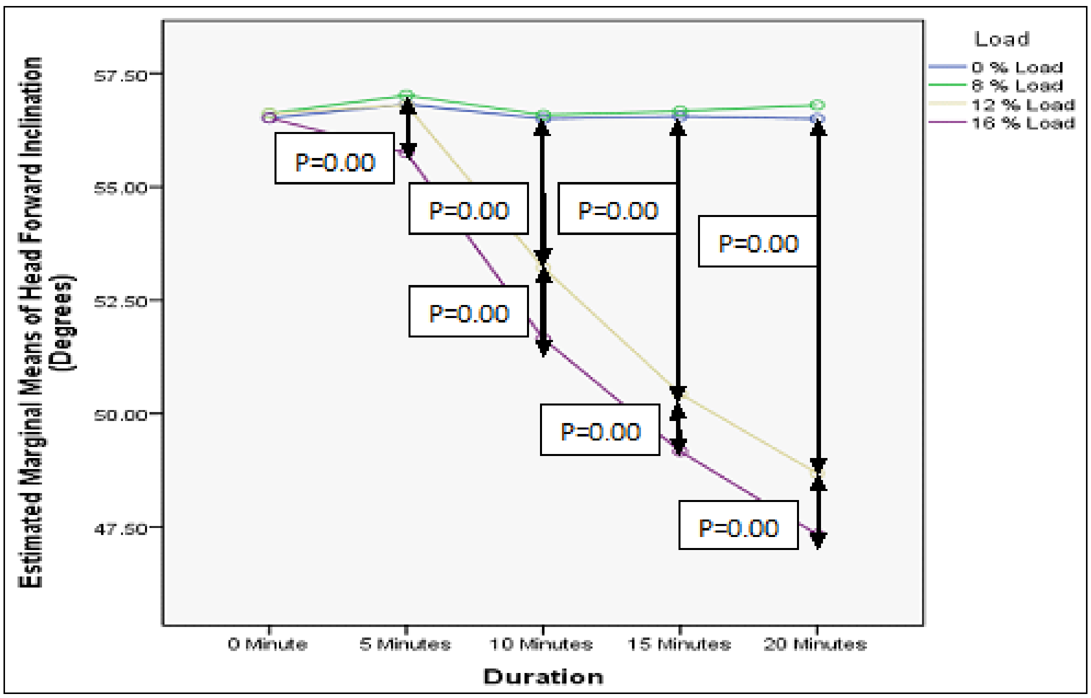

Fig 2: graphical representation of the patterns of head forward inclination at selected loads with respect to selected time points.

5. Discussion

The results of the study revealed that the Head Forward Inclination was almost unaffected when the subjects walked without any load for the selected duration. Further, when the subjects walked with 8 % load the mean Head Forward Inclination values were similar to that of the previous case. However when the load was increased to 12% that values didn't changed to a higher extent up to 5 minutes of walking but after that the mean Head Forward Inclination values fell rapidly and constantly with extent of duration. Finally in case of 16% load the values of mean Head Forward Inclination started falling from the initial phase itself. Hence, it's a serious threat to the posture of a child. These results replicates the earlier works of Mosaad & Abdel-Aziem (2015) [16], who have reported that a schoolbag weight of heavier than 7.5% of the child's body weight restrictively affects the head posture. When the backpack load increases the line of gravity keeps on shifting backward and the balance position of the body is disturbed. However, children tended to lean their heads. This reaction was conversely identified with age of the students, which proposes that as the spine develops, a more subtle head on neck response to load is invoked; thusly, the expanded Head Forward Inclination angle prompts more prominent strong strain on the cervical vertebra. A forward head posture happens when the head is arranged forward of this gravity line, Forward head position or Head Forward Inclination is the movement of forward bowing of the cervical spine. It is a position issue that is made by different factors including expanded usage of disreputable use of backpack stack, absence of created back muscle quality and nonappearance of supplements, for instance, calcium (Edmondston *et al.*, 2008) [2]. Grimmer, Williams, & Gill (1999) [7] have noted that there is a significant change in the craniovertebral angle in light of wearing a backpack. The smaller craniovertebral angle, show the Head Forward Inclination because of posterior backpack loads. A lesser Head Forward Inclination angle with expanding backpack loads found in this investigation is upheld by numerous past examinations (Grimmer *et al.*, 2002; Mayank, Upendar, & Nishat, 2006) [15]. Children have generally bigger heads and furthermore have higher center of mass at about T12, contrasted with L5-S1 in grown-ups (Shumway, 2001) [21]. When the back muscles of neck become short, tight and strained the muscles in front of our neck may become weak. Persistent head Forward Inclination could be the reasons for neck pain, shoulder pain (Yip, Chiu, & Poon, 2008) [28], headaches (Fernandez, Alonso-Blanco, Cuadrado, & Pareja, 2006) [3], expanded rate of cervical and interscapular pain and cerebral pain (Griegel-Morris, Larson, Mueller-Klaus, & Oatis, 1992) [5] of the school going children. Over a long-lasting period of time this load turns into sprain and strain injuries of the neck. General muscle pain and fatigues are the result of the Head Forward Inclination. The reappearance of Head Forward Inclination united with poor ergonomic postures and/or trauma that reason the body to adapt to forward head posture. If problem is not spotted on time, children could be identifying dischernition and it will affect the children healthy well being.

6. Conclusion

The present study the greatest differences were noted as the magnitude of backpack loads goes on increasing. Significant change in Head Forward Inclination angle was found as %BW increased. When the load was increased to 12% that values didn't changed to a higher extent up to 5 minutes of walking but after that the mean Head Forward Inclination angle fell rapidly and constantly with extent of duration. Thus implying that school bag weighing 12% of body weight would be too heavy for the school children aged 10-12 years to be able to maintain their normal cervical posture alignment. The changes in Head Forward Inclination suggest that loading more than 8% of body weight would be too heavy for the child; thus carrying a load of 8% of body weight is suggested. Parents should converse with your child about backpacks and posture and the significance of utilizing a backpack appropriately. A child who is taught right on time in life on the significance of ergonomics can apply this information in the home and office as they become more established, and will be more joyful and more advantageous subsequently.

7. Acknowledgments

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