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ORIGINAL ARTICLE

The Effect of an Overweight Backpack towards Comfortability and L5s1 among Primary School Student

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The issue of overweight pupils' school bag has been a subject of vast of discussion by the parents which may associate to back pain. This paper presents the effect of the weight of the backpack towards the lumbosacral joint (L5/S1) and conformability among primary student. A total of 10 respondents from the primary school students were involved in this study. Questionnaires of psychophysical experience with eight areas of body surveys were distributed as to obtain the comfortable feedback. The participants were required to perform three activities; standing without load; standing and climbing with load. The pupils are required to carry a backpack in symmetrical manner. These three activities will be recorded by using a digital camera. Due to safety measure during COVID-19 pandemic, the ImageJ Software was used to measure the joint angles and gait parameters. Based on the data measured by the software, a static and dynamic analysis were applied to calculate the torque and force for the trunk muscle, compressive and a shear force acting on the lumbosacral joint. Based on the result, It was found the student to carry 17% of their body weight, which is beyond of the 10-15% recommendation threshold. The survey shows, 40% of the students feel very uncomfortable especially at their low back, shoulder, head, and neck area due to heavy backpack. It shows the compression force on L4L5 during climbing slightly exceed the recommendation limit by NIOSH, while the others within the acceptable level. The related stakeholder should provide solutions, which conducive in order to prevent and control the occurrence of low back pain among primary student.

Keywords: Low back pain, Schoolbag weight, Pupils, L5S1

1.0 INTRODUCTION

The attention of the community has been called related to school bag load issue. As the year past, the weight of backpack has roses significantly due to the necessity of carrying academic materials. The problem has been discussed seriously since 2007 which may cause negative effect to the school children [1]. As the overweight school backpack is a common issue in Malaysia, Education Ministry recommended several strategies as to lighten the load in 2018 [2]. The overload bag problem may cause postural deviations, erector spine muscle and spinal pain [3]. It was reported the student with average 40 Kg of body weight has to carry every day with a backpack weighing 6.4 kg [4]. According to studies by [5], they stated that a child's school bag weight should be less than 10% of the student weight. Most guidelines recommend the bag-study body weight ratio should less than 1:10 [6]. For example, a girl or a boy that weight around 50kg, the maximum recommended weight for the backpacks should be 5kg. However the recommendation by The American Academy of Pediatrics quite lenient where the tolerance of child's backpack should weigh no more than 10 to 20 percent of their body weight [7], [8].

Postural deviations are considered as a significant public health issue, as it could cause a permanent or temporary impairment to the school children. A study depicted that the low back pain prevalence among children and adolescents ranges between 11% and 52.1% [9]. With unnecessary materials up to 2Kg, study done by [4] reported that 87%, 68% and 66.7% of back pain issue recorded from national school, Chinese medium school and Tamil medium school respectively.

Backpack with two straps is the most suitable for primary student due to symmetrical manner in carrying schoolbag with two shoulders. This design is ergonomically friendly. The load exerted on the shoulders more than force along the low back [10]. However some students use only one strap which is asymmetry in load distribution. Carrying schoolbag over one shoulder is inefficient method and discomfort, where it consumes energy double than two straps [11]. Moreover, research done by [12] reported that carrying a 6 kg backpack with single strap may effect on ventilator impairment in lung function more severe than double strap backpack.

This paper reported on the comfortability survey during carrying the school bag in several activities. The calculation associated backpack load toward L4L5 and L5S1 were presented and to be compared with the NIOSH Guideline.

2.0 METHODOLOGY

2.1 Questionnaires and Survey

A total of 10 students randomly selected from grade 1 to grade 6 of male and female primary schools. A set of questionnaires were distributed to the participant to fill out complaints due to heavy school bag. Explanation has been given as to ensure the students fully understand every question in the questionnaires. Eight areas of comfortable surveys to be answered; leg and foot, knee; thigh; buttock; low back; arm shoulder and head and neck. The students were asked to note their comfort level of psychophysical experience using Likert scale. It was ranked from 1 to 5 which represent very uncomfortable, uncomfortable, neutral, comfortable, and very comfortable.

The height and body weight, the schoolbag weight of each students were measured. During testing, each of the students will performed three type of activity which is standing with no load, standing with load and climbing the stairs with load. These three types of activities have been recorded by cameras. The angle of trunk flexion will be measured through the recorded media by using the ImageJ software.

2.2 Static Equilibrium Analysis

The use of a static model assumed equilibrium; the net forces and torques were summed to zero in two sagittal plane directions, and unknown values were determined. First, the sum of the moments at the lumbosacral joint as shown on free-body diagram in **Figure 1** was set at zero, summing up all the torques. Three equations were used to calculate the lumbar load variables, all based on the assumption of a static equilibrium. The lumbosacral joint-moments can be calculated by eq. 1. This provided the value of muscle torque, which was divided by a 6 cm of muscle moment arm to equal the value of muscle force. The second equation added forces in the y direction to provide the joint compressive reaction force and the third equation added forces in the x direction to provide the joint reaction force for the shear.

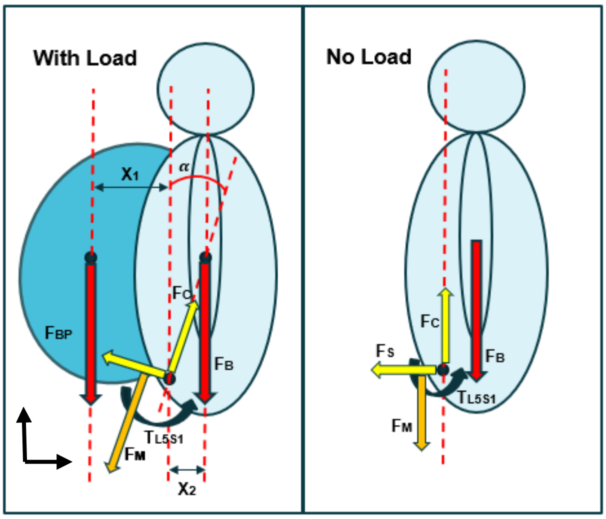


Figure 1 Free body diagram

$$\Sigma\, T = T_M + T_{BP} - T_B \quad (1)$$

$$\Sigma\, F_y = F_C - F_M - F_{BP}\, sin\,(90 - a) - F_B sin(90 - a) \quad (2)$$

$$\Sigma\, F_x = F_S - F_{BP}\, cos(90 - a) - F_B cos(90 - a) \quad (3)$$

Where; TM is muscle torque, TBP Torque of backpack, TB torque of body, Fc reaction force at L5S1, Fs is L5S1 shear force, FBP Force weight of backpack, FB Force weight of body, α Angle of forward lean, X1 Distance between spine to center of mass of the bag, X_2 Distance between spine to center of mass of the body

2.3 Dynamic Equilibrium Analysis

Figure 2 shows free-body diagram of lumbosacral joint. Even though, some of the backpack's weight was distributed on the shoulders, it was assumed that the force of backpack acts primarily as moment at the lumbosacral joint. The reaction forces, Fc and Fs are the most important unknowns at the lumbosacral joint. The spinal angle; α, changes during bending based on posture. For backpack load, it corresponds to the forward lean angle. The weight of the upper body acts at a distance of 37.4% of the spine length. From the free body diagram below, the equation of dynamic equilibrium can be created and used to solve the unknown forces.

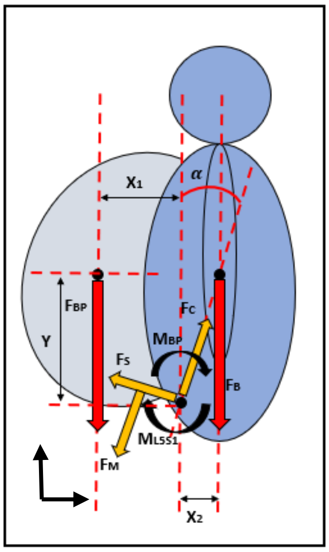


Figure 2 Free-body diagram of body in dynamic condition

$$M_{L5S1} = M_{BP} - [0.374L_S \cos(90 - \alpha)(W_B)] \quad (4)$$

$$M_{BP} = W_{BP}[X_3 \cos\alpha - Y_1 \sin(90 - \alpha)] \quad (5)$$

$$F_y = F_C \cos\alpha + F_S \cos(90 - \alpha) - W_B \quad (6)$$

$$F_x = F_C \sin\alpha + F_S \sin(90 - \alpha) \quad (7)$$

Where; W_B weight body weight; W_{BP} backpack weight; F_C reaction force at L5S1, F_S shear force at L5S1; F_{BP} force weight of backpack; F_B force weight of body; M_{BP} moment of backpack; α angle of forward lean, LS length of spine; X distance between spine to center of mass; Y distance up the spine between L5S1 to center mass . The maximum compression and shear value are 3400N and 1000N as recommended by NIOSH [13]

2.4 Assessment of Compression Using 3DSSPP

Based on the posture imposed by the student in the **Figure 3**, the posture were simulated and analysed by using 3DSSPP. This software will show either the compression force exerted on the L5S1 is safe enough for the student or action need to be taken to decrease the force acting on it. 3DSSPP will be used to analyse the strain existed on the lumbar portion of the spinal column (segment L5/S1).

Figure 3 Angle of trunk flexion when carrying backpack.

3.0 RESULT AND DISCUSSION

The school that participates in this survey is Gong Badak Primary School in Kuala Terengganu. All the measurements were conducted using the bag's weighing scale, body weighing scale and measuring ruler. The questionnaires were handed to each respondent. The questionnaires were focusing on their psychophysical (feeling of pain) during and after carrying the school bag and the way they preferred to carry their schoolbag. From the observation on the 10 students as shown in Figure 4 with the body weight between 26.42 kg to 42.75 kg and the total of the average is 32 kg. The average schoolbag found to be 5.5 kg. The average weight of the backpack is 17% of their body weight. The result shows that the average weight is more than recommendation bag-body weight ratio (10%).

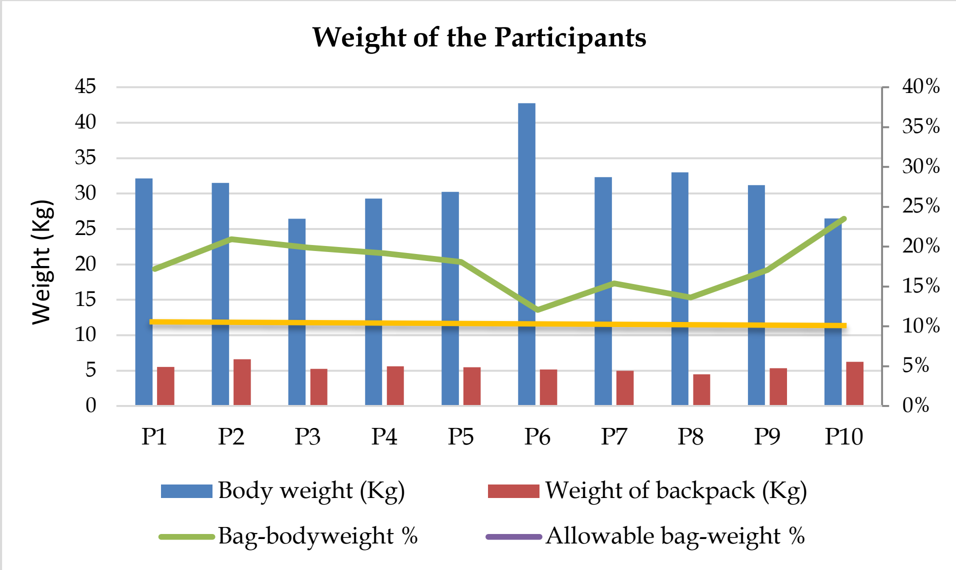


Figure 4 Weight of the participants

3.2 Questionnaires Responds Analysis on Psychophysical Experience

Based on the survey, the results in Figure 5 indicated that 5 out of 10 students claimed that they feel the very uncomfortable at their low back, head, and neck area due to heavy bag pack. Around of 40% of the respondents claimed that they feel uncomfortable at their foot, thigh, buttock, and low back. On the other side, most of the students agreed that they feel comfortable at their buttock and knee area. The rest of 80% of the students stated that they feel comfortable at their buttock area.

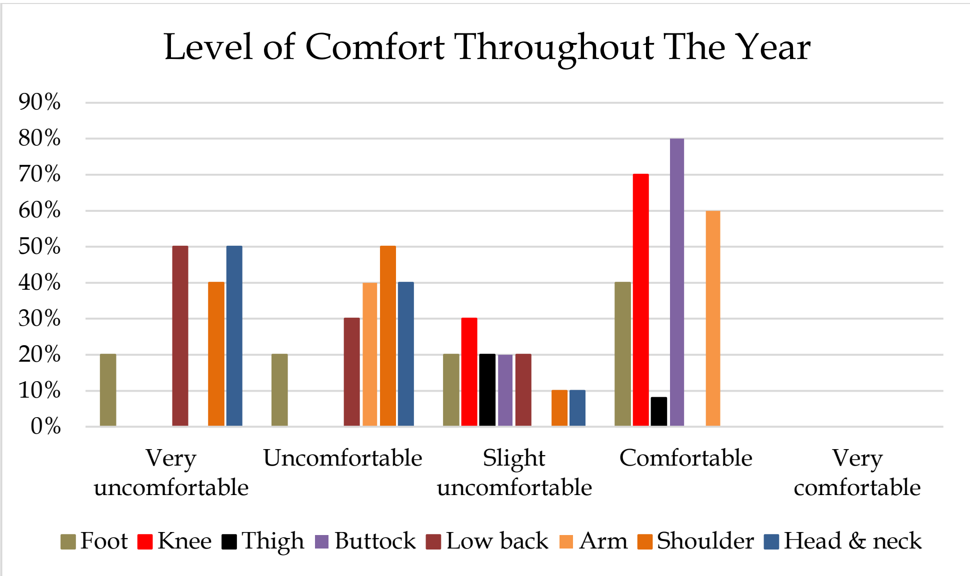


Figure 5 Psychophysical experiences of the participants

3.3 Comparison of Trunk Flexion Angle

The trunk flexion of the students as shown in Figure 6 increased from standing with no load to standing and climbing the stairs while carrying a backpack. The trunk was measures as the most vertical when there is no load carry by the students. The trunk flexed the most when the students were climbing the stairs while carrying the backpack with an average of 24.92°. The measurement methods for trunk flexion angle as shown in the Figure 7 during climbing stairs were taken multiple times and the average was used for the comparison for all conditions. The average trunk flexion angle for condition where the students are standing while carrying a backpack is 14.05 deg.

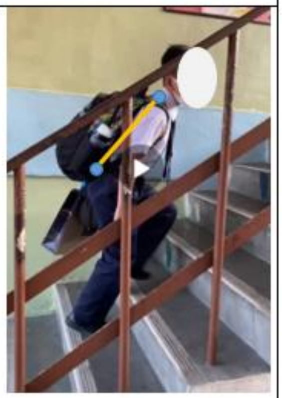
Trunk flexion when carry no load	Trunk flexion when carry a backpack	Trunk flexion when climbing stairs
		

Figure 6 Comparison of trunk flexion angle between three conditions

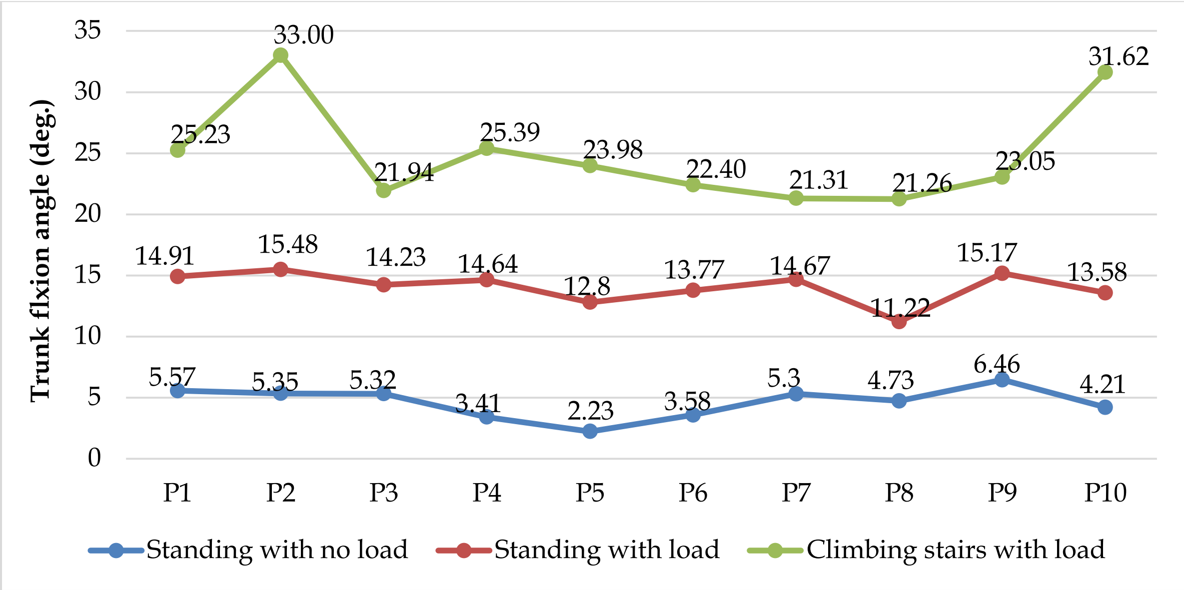


Figure 7 Trunk flexion angle for all three conditions (deg)

3.4 Comparison of compression forces at L5S1

Static equilibrium as in the Equation 1-3 was used to calculate the shear and compression forces exerted at the L5S1 joint. ImageJ software was utilized to determine the forward lean angle of the body while carrying the backpack. This comparison of compression force is illustrated in Figure 8. The compression force was the least during the no load condition. It was expected at the early stage as the only load supported in this condition was the body weight themselves.it is also logical that the compression force increased from holding the backpack while standing to carrying backpack while climbing the stairs. The differences of the compressive value between the conditions were affected by the differences in muscle force and the trunk flexion angle. The greater muscle force would contribute to a greater compressive force acting on the L5S1 joint.

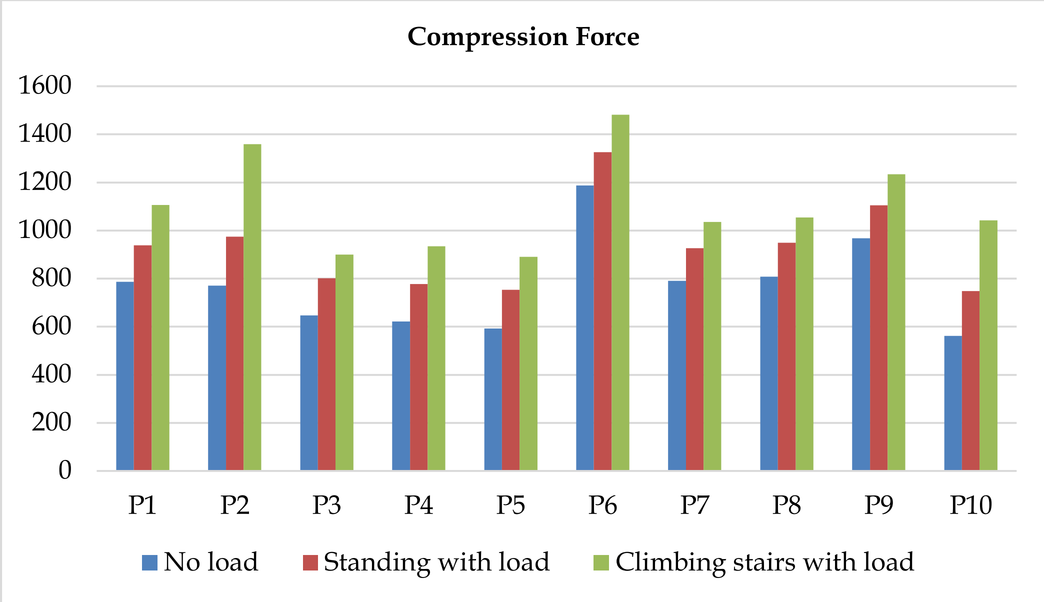


Figure 8 Comparison of compression force acting at L5S1

3.5 Comparison of shear forces at L5S1 Joint

As the result in Figure 9, the shear force for the condition when climbing the stairs with backpack has the highest value compared to the other conditions. The average shear forces acting at L5S1 during climbing the stairs is 254 N. With the addition of the backpack, the shear reaction force increased by approximately by 88 N from no load to carry a backpack during standing. However, the value still within the limit of 1000N as recommended by NIOSH.

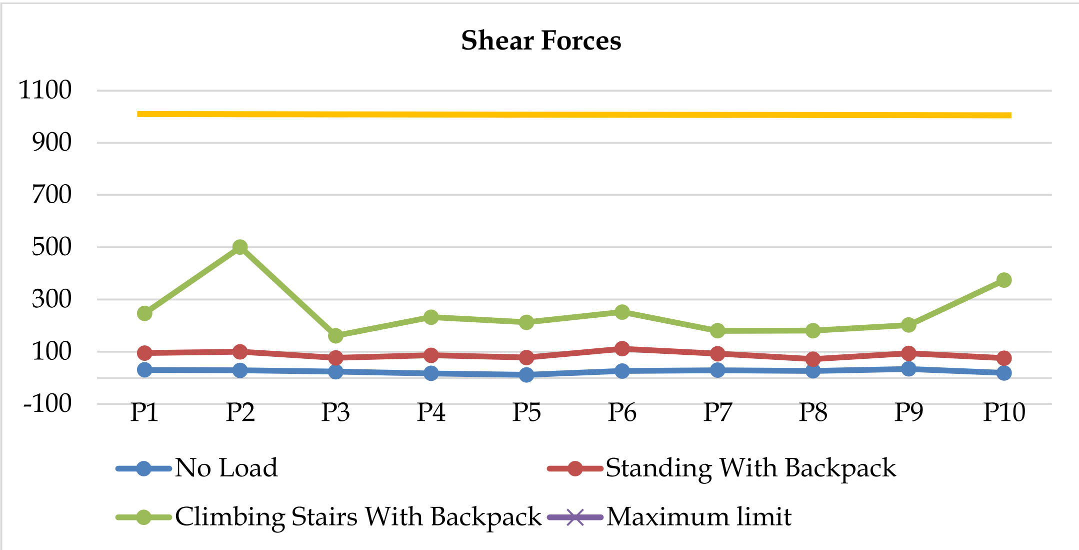


Figure 9: Comparison shear forces for all three conditions

3.6 Standing While Holding Backpack

The L5S1 disc compression force and sheer force of Respondent 1 for this activity is 1052 N and 297 N respectively, the different load with different participant can be seen in Table 1. Based on the 3D low back compression, the average compression force of 991 and 986 at L5S1 and L4L5 respectively are within the limit of NIOSH guideline (<3500N). The result shows the minimum risk of musculoskeletal injury during standing.

Table 1 The 3DSSPP results on the compression force during standing

Participant	Compression at L5S1 (N)	Shear Force (N)	Compression at L4L5 (N)
1	1052	297	958
2	1021	293	1117
3	844	298	891
4	816	298	860
5	822	301	853
6	1205	301	1217
7	1120	292	1150
8	948	290	897
9	1291	282	1163
10	789	154	749

3.7 Climbing Stairs While Carrying Backpack

Table 2 shows the results of the 3DSSPP of compression force produced during climbing. The average compression force on L5S1 of 1069 is still within the limit. However, the average compression force at L4/L5 quite alarming since the average value of 3617 greater than 3400N that recommended by NIOSH. It has been shown by the simulation where the 3D low back compression value falls within yellow region. It was associated with the student tends to bend forward and creates more pressure exerted toward both L4L5 and L5S1 rather than during standing.

Table 2 The 3DSSPP results on the compression force during climbing

Participant	Compression at L5S1	Shear Force	Compression at L4L5
1	1025	237	3595
2	989	249	3544
3	881	279	3389
4	917	269	3440
5	934	263	3464
6	1380	261	4011
7	978	251	3526
8	997	246	3552
9	1482	278	4145
10	1106	246	3513

4.0 CONCLUSIONS

This study indicates that the trunk flexion angle increased respectively from standing with no load to climbing stairs with load. The study found that most of the student carry a backpack that weight 17% of their body weight which requires appropriate solution. Both the compression and shear forces for the climbing stairs with load found to be higher than standing. All the forces exerted on L5S1 and L4L5 are within the recommendation limit of 3400N except the force on L4L5 during climbing (3617N). Even though, some of the results are acceptable, the student complained on uncomfortable especially on low back, shoulder and head neck area.

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