# Work load evaluation of the school bag carrying of primary students based on biomechanical approach

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## Abstract

Nowadays, a problem of Thai primary students is to carry a heavy school bag relatively to the student weight. The school bag carrying task can be classified as a carrying workload. This workload was evaluated based on a biomechanical static model. 346 primary students (178 boys and 168 girls) aged between 6 to 12 years old were recruited voluntarily for the research. Average school bags weight was 11.76% of the body weight (BW). The results showed that the body weight is not significantly relate to the body strength ($R<0.5$), then student weight should not be used as an indicator to set safe of the school bag weight. The compressive force on the lower back while carrying the school bag was about 18% of maximum voluntary compressive force on the lower back calculated from the composite strength test.

## 1. Introduction

The muscle strength is an important factor to assign any safety workload. The muscle-strength data is useful to prevent muscle pain and injury. In the present days, a problem of Thai primary students is to carry a heavy school bag relatively to their body weight. According to the survey of the school bag weight compared to the weight of children in primary school year 1-6 from Child Safety Promotion and Injury Prevention Research Center [1], it found that there are more than 80% of the sample sizes carried the heavy school bags which weight more than 10% of the body weight. The school bag carrying is one of the tasks in school activities which can effect the spine shape [2] if this task is assign to be a heavy workload. The carrying weight was recommended to be at 10% of the student body weight which was set as an acceptable safety level [3] [4] [5]. Commonly in Ergonomics Design any workload assign was set by comparing to the subject strength. In healthy person, the amount of strength which is directly relative to the number of muscle cells can be measured by the body weight. Nevertheless, there was a report about a change in Thai children proportion. Ministry of Public Health of Thailand reported that the present Thai children have been overweight [6]. Since the overweight in children may be caused by the fat cell, the body weight should not be relative to the body strength. Therefore body weight in Thai primary students may not use as an indicator to assign the school bag weight. The first objective of this research is to find the relationship between the primary student strength and their body weight. The second objective is to evaluate the school bag carrying task based on a biomechanical static model. This task was compared the compressive force on the lower back to the individual composite strength capacities.

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## 2. Literature review

### 2.1 The load acting on the lower spine

Ekholm et al. [7] studied the effect of mass acting on the lower spine while lifting heavy objects. The forces and moments acting on the lower spine were separated into 3 sources which are 1. the force from body weight above the lower spine, 2. the force from objects weight during transport and 3. the force resulting from Extensor Erector Spinae contraction. The Erector Spinae muscle serves to extend the back by contracting a force parallel to the spine which has a distance approximately 4 cm. from the center of L5/S1 Intervertebral disc [8] as shown in figure 1.

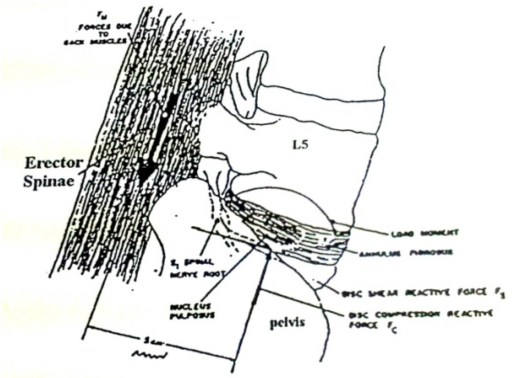


**Figure 1** The distance between the contraction force of the Extensor Erector Spinae and the center of the L5/S1 Intervertebral disc [9].

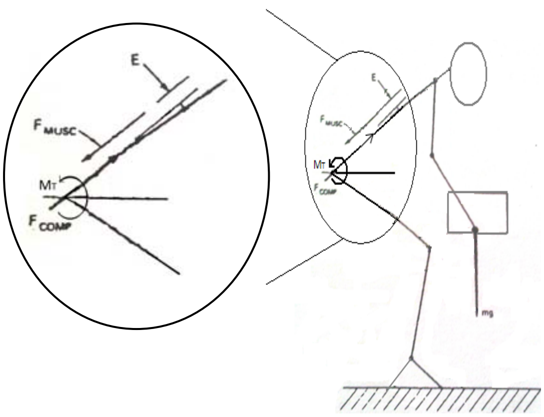


**Figure 2** the moment and forces acting on the lower back.

While lifting or lowering objects, the moment and forces acting on the lower back is shown in figure 2. NIOSH [10] concluded that the compressive force ($F_C$) on lower back over 3,400 N may result in the fracture of lower spine. Moreover, the compressive force ($F_C$) on lower back over 6,400 N may result in damage of the spinal cord.

### 2.2 Workload evaluation during operation

Kroemer and Grandjean [11] concluded that average voluntary contraction during dynamic activity for long period of time should not be more than 20% of the maximum ability of the muscle contraction and average voluntary contraction during static activity should not be more than 15% of the maximum ability of the muscle contraction.

## 3. Methodology

A maximum voluntary contraction of muscle in static model is used as the maximum ability of the muscle contraction. A static measurement of Maximum Voluntary Composite Strength (MVCS) in figure 3 is a kind of strength test under the guidance of Kitti [12].

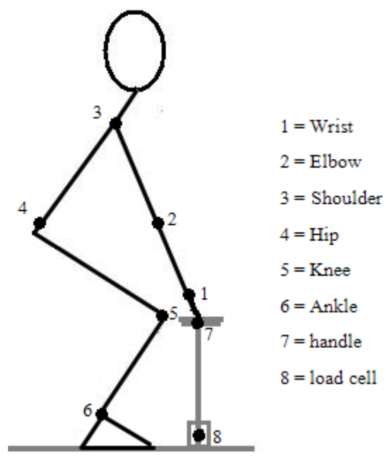


**Figure 3** The subject posture while measuring a static composite strength. The subject takes a semi-squat

position, both hands hold a handle. The feet remain flat to the platform. After that, the subject pulls the handle in vertical direction for at least 5 seconds.

### 3.1 Participants

178 boys and 168 girls from Chulalongkorn University Demonstration primary school (age between 6-12 years). The consent forms with all necessary information were given to the subjects and their parents to allow them to join the research.

### 3.2 Instrumentation

The static strength measurement equipment

- Tension/Compression load cell model no.616,
- Digital display model pax-1/8 din analog input panel meters,
- Weight scale,
- Digital camera IXAS 120 IS.

### 3.3 Procedure

3.3.1 Measurement of static composite strength and 2D digital images were taken during measurement.

3.3.2 The joint co-ordinations were calculated from 2D digital images to approach of biomechanical static model which are under the following assumptions:

- Center of mass (COM) is constant,
- Bilaterally symmetric body,
- The segment mass and the position of COM were estimated from the references of Kitti [12].

A static measurement of Maximum Voluntary Composite Strength (MVCS) is shown in figure 4.

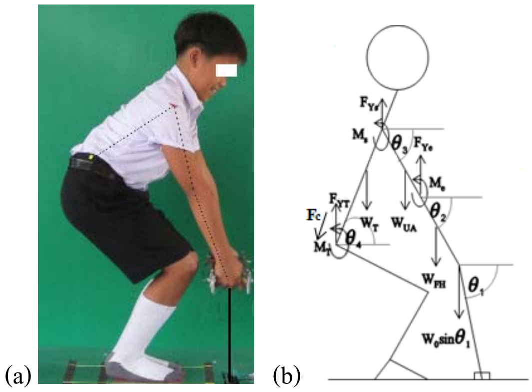


**Figure 4** (a) Subject posture while testing (b) Free body diagram of the composite strength test

$W_0$ = Force of a static composite strength test,

W = Weight of the body parts,

$F_Y$ = Resultant force in vertical direction on the joint,

M = Moment acting on the joint,

$F_C$ = Compressive force on the lower back.

3.3.3 The side-view image while subject carrying a school bag (figure 5.) was used to estimate the compressive force on lower back in sagittal plane.

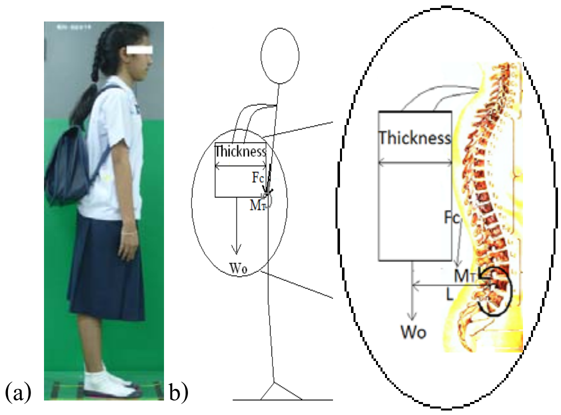


**Figure 5** (a) Subject carrying a school bag

(b) Free body diagram of the school bag carrying

$W_0$ = Weight of school bag which its COM was assumed to locate in the middle of the school bag,

L = Length from the middle of the school bag to the lower back is 14 cm.

Length was estimated from summation of 1. Half of thickness of the school bag is 8 cm., 2. the distance from the lower back skin to the center of lower spine is 6 cm.

$M_T$ = Moment acting on the lower back,

$F_C$ = Compressive force on the lower back.

3.3.5 Biomechanical Models were calculated to estimate the compressive force on the lower back. The compressive force on the lower back while carrying the school bag was compared to it while MVCS.

## 4. Results

The anthropometric data of subjects were consisted of age, number of subjects, body weight, school bag weight, static composite strength as shown in Table 1.

**Table 1** Anthropometric data of subjects

| Age (years) | N | Weight (kg.) | Schoolbag weight(kg.) | MVCS (kg.) |
|---|---|---|---|---|
| 6 | 36 | 24.03(4.33) | 2.34(0.45) | 12.10(3.85) |
| 7 | 72 | 26.55(5.58) | 2.92(0.55) | 15.13(5.74) |
| 8 | 59 | 30.20(6.94) | 3.26(0.89) | 19.36(7.41) |
| 9 | 56 | 33.61(8.56) | 3.79(0.75) | 19.82(6.08) |
| 10 | 67 | 36.87(8.69) | 4.02(0.76) | 22.93(7.60) |
| 11 | 34 | 45.89(10.9) | 4.51(1.15) | 28.74(9.98) |
| 12 | 17 | 44.22(8.09) | 4.85(1.35) | 30.91(10.17) |

Values are average (SD); N= Number of subjects.

The basic statistical analysis of the compressive force on the lower back from MVCS is shown in figure 6.

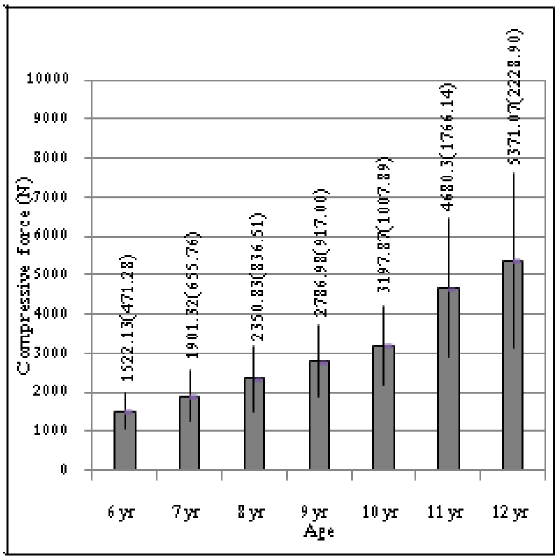


**Figure 6** Basic statistical data of compressive force on the lower back from MVCS.

Figure 6 shows that both average values and the standard deviation of compressive force on the lower back from MVCS increase along the age. The increase of the variation may be caused by the differences in daily activities and nutrition. Both factors (daily activities and nutrition) may effect to the body weight and strength of student. Moreover, the survey result found that there were more than 60% from all participant students carried their school bags which were heavier than 10% of the body weight. In order to evaluate the school bag carrying task, the compressive force on the lower back ($F_C$) while carrying was compared to that from the individual strength capacities. In this research, the Fc of school bag carrying task was compared to $F_C$ of:

1. the light workload in common activity which is standing without load carrying,

2. the moderate workload in common activity which is the acting as MVCS testing with no contraction force on the handle (the back bending posture)

3. the safe-level workload which is the acting as MVCS testing with a contraction force on the handle at 15% of MVCS [11] (a semi-squat lifting).

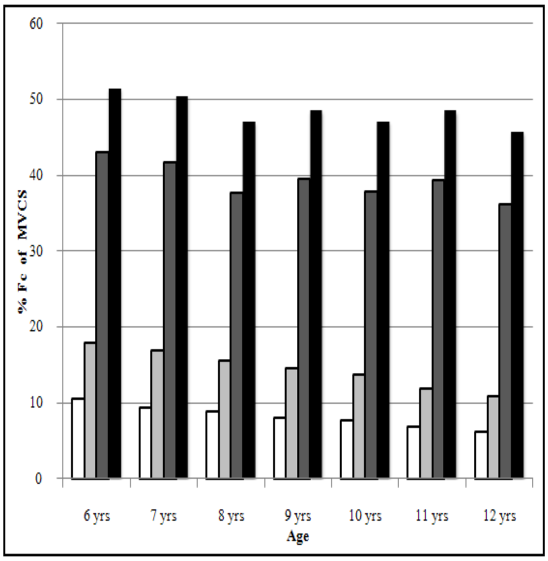


**Figure 7** Comparison of compressive force on the lower back in four conditions.

$F_C$ while standing without load carrying (Bar 1)

$F_C$ while carrying their school bags (Bar 2)

$F_C$ while acting as the strength test without any exertion: 0% of MVCS (Bar 3)

$F_C$ while acting as the strength test with 15% of MVCS (Bar 4)

Figure 7 shows the comparison of Fc of school bag carrying task among other three conditions. Bar 1 represents the lowest compressive force on lower back calculated from the standing posture without any load carrying while Bar 4 represents the safe-level of Fc calculated from the strength test posture (back bending posture) with 15% of MVCS exertion.

## 5. Conclusions and Discussion

The correlation coefficient test between the maximum voluntary strength and the body weight found that both of them have no significant relationship. Commonly, workload assignment especially carrying task should be considered based on the subject strength capacities. Hence the student weight should not be used as an indicator to set the acceptable weight of school bag because the body weight did not relate to the individual strength capacities. In addition, the Fc while carrying the school bag decrease along the age relatively to those from MVCS. The decreasing occurrence caused by the student strengths increase along the age while the bag weights are still not change along their ages. The Fc while carrying the school bag is closer to the Fc while standing without load carrying than both Fc calculated from MVCS. This result agrees to the previous studies [3] [4] [5] which the bag weight at 10% of body weight should not effect to the student physiology and psychophysics comparing to standing without load carrying. The concept of workload assignment of the previous studies might be classifying the school bag carrying task as a common living task which should be minimize as much as possible. However the workload assignment in working task concept commonly is designed based on the strength capacities at the safe level (15% of MVCS). In this research, the school bag carrying task with weight at 10% of body weight was evaluated at about one-third of the safe level, and then this task might be low based on the concept of working task assignment. Moreover, the load carrying for a long period of time might effect to muscle fatigue. Based on the activity monitoring from Hamish's research [5], the cumulative carrying activities of students might spend approximately two hours to carry their school bags in each day. The bag weight at 10% of body weight might be recommended for the long period carrying especially for the students who are confront with the traffic jam while traveling between home and school. However the recommended weight of school bag can be set heavier than 10% of body weight and not exceed 15% of their strength capacities in the case of short period carrying. Until now, there is no explicit report that shows the cause of the abnormal spine shape related to the school bag carrying. However the assignment for school bag load would help everyone consider the importance of quality of life in school activities. Future research should focus on using the dynamic test and the dynamic conditions to calculate compressive force on lower back in order to obtain suitable results and should increase the number of schools and number of samples that are interested in participating in research studies to provide wider population coverage.

## 7. Acknowledgment

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