Malaysian Journal of Medicine and Health Sciences Vol. 1 (1) January 2005: 21 - 31

School Bag Load and Its Effect on *Erector spinae* Muscle and Low Back Pain Among Primary School Children in Malaysia

Tamrin SBM, LP Ai, Hamzah R, Abdullah MY & Hanafi SS

Department of Community Health, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia

ABSTRACT

Objective: A cross-sectional study was conducted to determine and evaluate the effects of schoolbag load on electromyography (EMG) activity of the erector spinae muscle. **Methods:** Eighty-four primary schoolchildren were selected from two national medium primary schools in Seri Kembangan, 42 from Primary Two (P2) and 42 from Primary Five (P5), aged 8 and 11 respectively. Data were collected through interviews, anthropometrics measurements, the weight of schoolbag load and surface electromyography (SEMG) of the erector spinae using Muscle Tester ME3000P®. Surface Ag-AgCl electrodes were used to measure: unloaded standing and walking, and loaded standing and walking. **Results:** The study revealed that the erector spinae was found to be more efficient in loaded standing probably due to other trunk muscle co-activity compared to unloaded standing ($p<0.05$). However, the erector spinae was less efficient when loads were carried on the back while walking, compared to unloaded walking. When the schoolbag was carried over both shoulders, forces generated by the erector spinae were reduced and resulted in a more efficient use of the erector spinae compared to other asymmetrical carrying methods ($p<0.05$). **Conclusions:** Bending slightly forward when carrying schoolbag was found to reduce the forces generated by the erector spinae compared to normal sagittal posture ($p<0.05$), however no significant difference was found between the different frontal postures. A significant inverse relationship ($p<0.01$) between the weight of schoolbag load and the average electromyography (AEMG), showed that the significance of the erector spinae muscle was reduced when a heavier schoolbag load was carried, owing to other trunk muscles co-activity. The study also revealed that apart from age of schoolchildren, family history of back pain, exposure to environmental tobacco smoke (ETS), weight of the schoolbag and method of carrying schoolbag also play important role as risk factors for back pain.

Keywords: Electromyography, schoolbag, primary school, back pain

INTRODUCTION

Low back pain in children is becoming a concern as studies show a rising prevalence rate.[1, 2, 3, 4, 5, 6, 7, 8, 9, 10] Several factors have been associated with non-specific low back pain in children. These include gender,[8] family history of low back pain,[8] muscle strength,[8] load carrying,[8] maintaining asymmetry body postures such as forward flexion or bending, lateral bending and twisting of the trunk[11,12] and even exposure to the environmental tobacco smoke (ETS).[13]

Carrying heavy schoolbags may result in biomechanical stresses imposed on the children's musculoskeletal system as it is well established that manual load carrying is a major cause of musculoskeletal injuries.[14] Carrying excessive weight can have serious repercussions in a child's developing posture,[14] growth and coordination[14] and thus a recommendation guideline was introduced that schoolchildren should not carry more than 10% to 15% of their body weight.[15] However, in Malaysia, although there has been much concern by parents, teachers and the Ministry of Education on this problem, to the authors' knowledge, no proper and scientific studies have been conducted on the back pain of the schoolchildren in relation to the weight of the schoolbag they carry, method of manual load carrying, gender of the students, exposure to environmental tobacco smoke or parents with family history of low back pain. Thus, there is a need to conduct such a study in Malaysia. Furthermore, this study also intends to determine the load carried in schoolbags with the effect on electromyography (EMG) of the erector spinae muscle of the children.

MATERIALS AND METHODS

Healthy subjects from primary 2 (P2) and primary 5 (P5) were selected from two schools. A total of 84 subjects with informed consent participated in this study, comprising 42 (P2) and 42 (P5) schoolchildren, who have an average age of 8 and 11 years respectively, and 34 males and 50 females. Questionnaires were distributed to their parents to obtain the personal and family background data related. The students were interviewed on a one-to-one basis by the same investigator to make it consistent, based on a coded questionnaire to find out about their schoolbag carrying practices, lifestyles and physical activities. Questions were also asked on low back pain among the children. All the questionnaires were pre-tested on 10 subjects to make sure that all subjects fully understood all the questions given.

Anthropometrics measurements refer to comparative measurements of the human body. In this study, measurements were carried out to obtain the subjects' body heights and body weights. Body heights were measured using Bodymeter Seca® 208 cm and body weights were measured using the Tanita® weighing scale. Subjects' schoolbag loads were also weighed using the same Tanita® weighing scale. The measurement procedure was as recommended by Gordon [16].

Surface electromyography (SEMG) of the erector spinae muscle in the lumbar region (L4-L5) was performed using Muscle Tester ME3000P System and surface Ag-AgCl electrodes. SEMG was carried out at a sampling rate of 1000Hz using two channels for four tasks with durations of about 30 seconds for each task as recommended by Mega Electronics Limited.[17] The four tasks were unloaded standing and walking, and loaded standing and walking. Gross observations were recorded on the methods of schoolbag carrying and the types of both sagittal and frontal postures adopted when the subjects were standing with schoolbags. These posture recordings were made based on the classified degree of deviation from the normal posture.

The surface electromyography (SEMG) data were analysed using the Muscle Tester ME3000P System Software® Version 1.3. The analysis includes averaged electromyography (AEMG) that measures average force used by the muscle and the median frequency (MF) values that indicate the level of muscle fatigue for each task performed. All data obtained in

this study were then analysed using the Statistical Package for Social Sciences (SPSS)® Windows Version 9.05 at p value of 0.05 (confidence interval of 95.0%).

RESULTS

Prevalence of Low Back Pain

The study showed that the overall prevalence of low back pain among schoolchildren was 59.5%. The prevalence of low back pain among p5 was higher (64.3%) compared to p2 (54.8%). 58.3% of the subjects reported having experienced low back pain while carrying their schoolbags.

Anthropometric Measurements

The anthropometrics data showed that the p2 schoolchildren have significantly lower mean ($p<0.05$) body height (121.8 ± 8.8 cm) and body weight (24.4 ± 6.8 kg) compared to p5 schoolchildren with mean body height of 141.1 ± 7.2 cm and a mean body weight (35.9 ± 9.4 kg). The schoolbag load carried by the p2 schoolchildren was significantly lighter ($p<0.05$) (3.7 ± 1.3 kg) compared to p5 schoolchildren who carried an average of 5.5 ± 1.2 kg. The average load carried by both Primary 2 and Primary 5 was 15% of their body weights. Based on observation, 84.5% of the subjects carried their schoolbags over both their shoulders, while 15.5% of them used other methods of carrying including over one shoulder, in one hand or pulling with trolleys.

Averaged Electromyography (AEMG) and Median Frequency (MF)

The SEMG data for all four tasks performed by the subjects are tabulated in Table 1. The MF values were significantly ($p<0.01$) lower among females in the loaded positions (standing and walking) compared to males, with AEMG values were nearly the same ($p>0.05$) with male schoolchildren (Table 2). The AEMG values were significantly higher ($p<0.01$) for p2 compared to p5 schoolchildren in all AEMG measurements either standing or walking but with no different values ($p>0.05$) in all MF measurements (Table 3). Table 4 showed that there were overall reductions in both the AEMG and MF values when the schoolbag was carried over both shoulders compared to other methods of carrying but only the MF values were significantly reduced ($p<0.05$) when the schoolchildren carried their schoolbags in the standing position.

In Table 5, the result of Pearson's Correlation showed that body height had a weak inverse correlation with AEMG values when walking freely for both left (r=-0.352) and right side (r=-0.385)], loaded standing also showed a weak inverse relationship for both left (r=-0.276) and right side (r=-0.369). Loaded walking showed much higher inverse relationship for both left (r=-0.486) and right side (r=-0.530). Body weight showed an inverse relationship with AEMG for both free walking [r=-0.397 (left)] and [r=-0.433 (right)] and loaded walking [r=-0.499 (left) and [r=-0.590 (right)]. In term of relationship between AEMG values with school bag weight, the result showed an inverse relationship for both standing and walking with schoolbag while no relationship was observed using median frequency for both standing and walking with schoolbag (Table 6).

Table 1. Frequency analysis of averaged electromyography (AEMG) and median frequency (MF) for all four task

SEMG measurements	Primary 2 N = 42 (50.0%)			Primary 5 N = 42 (50.0%)			Total N = 84 (100%)		
	Mean	SE	SD	Mean	SE	SD	Mean	SE	SD
Free stand									
AEMG-L (μv)	14.9	1.1	7.3	12.8	1.6	10.0	13.8	1.0	8.8
AEMG-R (μv)	14.6	1.0	6.4	10.5	0.7	4.6	12.6	0.6	5.9
MF-L (Hz)	96.7	5.1	32.7	93.7	4.9	31.9	95.2	3.5	32.1
MF-R (Hz)	87.0	5.1	32.8	84.4	5.6	36.0	85.7	3.7	34.3
Stand with bag									
AEMG-L (μv)	13.0	1.2	7.7	8.3	1.0	6.2	10.6	0.8	7.3
AEMG-R (μv)	12.6	0.8	5.3	9.0	0.9	6.0	10.8	0.7	6.0
MF-L (Hz)	80.4	4.1	26.8	78.7	5.7	37.0	79.5	3.5	32.1
MF-R (Hz)	76.1	4.5	29.1	65.2	5.2	33.4	70.7	3.5	31.6
Free walk									
AEMG-L (μv)	21.4	1.0	6.8	18.0	1.1	7.4	19.7	0.8	7.2
AEMG-R (μv)	22.8	1.1	7.2	17.9	1.2	7.4	20.4	0.8	7.7
MF-L (Hz)	90.5	2.9	18.6	89.2	3.1	20.1	89.8	2.1	19.2
MF-R (Hz)	90.5	3.2	20.6	89.1	3.5	22.9	89.8	2.4	21.7
Walk with bag									
AEMG-L (μv)	21.7	1.1	7.3	16.6	1.1	7.00	19.2	0.8	7.6
AEMG-R (μv)	22.8	1.1	7.1	16.6	1.1	6.9	19.7	0.8	7.6
MF-L (Hz)	81.2	2.8	18.0	78.9	2.9	18.7	80.1	2.0	18.3
MF-R (Hz)	81.6	2.9	18.5	76.6	3.3	21.3	79.1	2.2	20.0

Table 2. Independent samples t-test for averaged electromyography (AEMG) and median frequency (MF) between males and females

SEMG measurements	Gender		t	p (95% CI)
	Males N = 34 (40.5%)	Females N = 50 (59.5%)		
Loaded standing				
AEMG-L (μv±SD)	11.6 ± 7.3	10.0 ± 7.3	1.019	0.311 (-1.58-4.89)
AEMG-R (μv±SD)	10.4 ± 5.5	11.1 ± 6.3	-0.488	0.627 (-3.29-1.99)
MF-L (Hz±SD)	91.7 ± 34.4	71.3 ± 27.9	2.998	0.004** (6.88-34.01)
MF-R (Hz±SD)	81.2 ± 35.0	63.5 ± 27.3	2.470	0.016* (3.34-31.87)
Loaded walking				
AEMG-L (μv±SD)	21.7 ± 7.6	17.5 ± 7.1	2.600	0.011* (0.99-7.46)
AEMG-R (μv±SD)	21.4 ± 8.5	18.6 ± 6.6	1.720	0.089 (-0.45-6.21)
MF-L (Hz±SD)	89.4 ± 19.1	73.7 ± 14.8	4.045	<0.001***(7.94-23.49)
MF-R (Hz±SD)	90.2 ± 18.8	71.6 ± 17.2	4.675	<0.001*** (10.67-26.47)

L = Left, R = Right

Table 3. Independent samples t-test for averaged electromyography (AEMG) and median frequency (MF) between Primary Two and Primary Five

SEMG measurements	Class Standard		t	p (95% CI)
	P2 N = 44 (50%)	P5 N = 42 (50%)		
Loaded standing				
AEMG-L (μv±SD)	13.0 ± 7.7	8.3 ± 6.2	3.047	0.003** (1.61-7.67)
AEMG-R (μv±SD)	12.6 ± 5.3	9.0 ± 6.0	2.975	0.004** (1.22-6.16)
MF-L (Hz±SD)	80.4 ± 26.8	78.7 ± 37.0	0.240	0.811 (-12.35-15.74)
MF-R (Hz±SD)	76.1 ± 29.1	65.2 ± 33.4	1.602	0.113 (-2.65-24.56)
Loaded walking				
AEMG-L (μv±SD)	21.7 ± 7.3	16.6 ± 7.0	3.263	0.002** (1.99-8.20)
AEMG-R (μv±SD)	22.8 ± 7.1	16.6 ± 7.0	4.069	<0.001*** (3.18-9.25)
MF-L (Hz±SD)	81.2 ± 18.0	78.9 ± 18.7	0.577	0.566 (-5.66-10.28)
MF-R (Hz±SD)	81.6 ± 18.5	76.6 ± 21.3	1.160	0.249 (-3.61-13.71)

L = Left, R = Right

Table 4. Independent samples t-test for averaged electromyography (AEMG) and median frequency (MF) between two methods of carrying schoolbag

SEMG measurements	Method of carrying		t	p (95% CI)
	Over both shoulders N = 71 (84.5%)	Other methods N = 13 (15.5%)		
Loaded standing				
AEMG-L (μv±SD)	9.6 ± 5.8	16.4 ± 11.5	-2.080	0.058 (-13.87-0.26)
AEMG-R (μv±SD)	10.1 ± 5.1	14.8 ± 8.4	-1.943	0.073 (-9.90-0.50)
MF-L (Hz±SD)	75.9 ± 31.3	99.3 ± 30.4	-2.488	0.015* (-42.09-(-4.69)
MF-R (Hz±SD)	67.7 ± 30.1	86.9 ± 36.1	-2.054	0.043* (-37.86-(-0.61)
Loaded walking				
AEMG-L (μv±SD)	18.2 ± 6.1	24.8 ± 11.9	-1.950	0.073 (-13.90-0.70)
AEMG-R (μv±SD)	19.4 ± 6.7	21.5 ± 11.5	-0.650	0.527 (-9.25-4.96)
MF-L (Hz±SD)	78.0 ± 16.4	91.2 ± 24.2	-1.880	0.081 (-28.09-1.84)
MF-R (Hz±SD)	78.0 ± 19.2	85.2 ± 23.6	-1.207	0.231 (-19.22-4.70)

L = Left, R = Right

Table 5. Pearson correlation test between anthropometrics data and the averaged electromyography (AEMG) and median frequency (MF) of the *erector spinae*

Electromyography measurements	Body Height		Body Weight	
	R value	p value	r value	p value
Free standing				
AEMG-L	-0.183	0.096	-0.204	0.063
AEMG-R	-0.346	0.001**	-0.334	0.002**
MF-L	0.004	0.971	-0.067	0.547
MF-R	0.007	0.947	0.006	0.957
Free standing				
AEMG-L	-0.352	0.001**	-0.397	<0.001***
AEMG-R	-0.385	<0.001***	-0.433	<0.001***
MF-L	-0.012	0.915	-0.121	0.272
MF-R	-0.007	0.951	-0.053	0.633
Standing with schoolbag				
AEMG-L	-0.276	0.011*	-0.179	0.103
AEMG-R	-0.369	0.001**	-0.338	0.002**
MF-L	0.039	0.722	0.015	0.891
MF-R	-0.129	0.242	-0.039	0.722
Walking with schoolbag				
AEMG-L	-0.486	<0.001***	-0.499	<0.001***
AEMG-R	-0.530	<0.001***	-0.590	<0.001***
MF-L	-0.025	0.821	-0.087	0.432
MF-R	-0.120	0.277	-0.164	0.137

N = 84 (100.0%)
L = Left, R = Right

Table 6. Pearson correlation test between schoolbag weight and the averaged electromyography (AEMG) and median frequency (MF) of the *erector spinae*

Electromyography measurements	Schoolbag weight	
	r value	p value
Standing with schoolbag		
AEMG-L	-0.278	0.011*
AEMG-R	-0.268	0.014*
MF-L	-0.366	0.276
MF-R	-0.398	0.101
Walking with schoolbag		
AEMG-L	-0.120	0.001**
AEMG-R	-0.180	<0.001***
MF-L	-0.158	0.151
MF-R	-0.175	0.111

DISCUSSION

Justification of AEMG and MF in Muscles Activity

A part of the questionnaire to determine low back pain, SEMG (AEMG and MF) is used to determine forces and fatigue that arise from muscle activities. In fact, Marras[18] has stated the need for electromyography as a tool to determine the above parameters. The AEMG value gives the basic information on whether the muscles measured were in use during an exertion. This measure simply relates how active the muscle was during exertion and represents the force generated.[18]

The median frequency (MF) signals the basic information regarding localised muscle fatique and characterised in frequency that linked with fatigue.[19] The median frequency obtained from this study indicated that frequency was divided into high frequency component and low frequency component. When a muscle experiences fatique, MF value will show decline of high frequency components while low frequency component will increase gradually.[20]

Prevalence of Low Back Pain

The present study showed a high prevalence rate in low back pain among primary schoolchildren. The 59.5% prevalence rate of low back pain is considered very high and this may not be the true scenario as it is only a general perception obtained by the schoolchildren. The trend shows an increase in prevalence of low back pain from 54.8% among p2 schoolchildren up to 64.3% among p5 schoolchildren. Our findings agree with earlier reports[1] on prevalence of low back pain increasing with age.[1]

Many factors can contribute to low back pain, and one of these would be load carrying.[2,11,21] One of the important findings in this study was that as high as 58.3% of the schoolchildren reported having low back pain associated with carrying heavy schoolbags. A high prevalence of low back pain associated with heavy load can be associated with the fact that most of the schoolchildren were carrying a schoolbag with a weight of 15% of their own body weight, which is the upper recommendation limit by many health practitioners.[15]

Surface Electomyography Values

Differences in Electromyography between Gender and Age

Gender is an important factor to be considered in load carrying among schoolchildren, whereby the MF values generated by female were significantly lower than the males with AEMG values remaining the same. The finding shows that females children are less efficient in carrying loads on their backs, females are supposed to utilise bigger erector spinae muscles compared to males, which can lead to faster rate of muscle fatigue and increase the risk of low back pain in the future as suggested by Holewijn[22] and Alpaugh.[23] In term of schooling years, p2 schoolchildren who were much younger had to generate more muscle activity (AEMG) compared to p5 schoolchildren who had lower AEMG values. This shows that younger children's ability to carry loads is less efficient (in terms of energy used to carry the load) compared to older children who tend to use their muscles efficiently to carry loads on

their backs. Therefore, it can be said that it is hard work for children to carry schoolbags. Our results agreed with the findings of other authors who stated that younger children do have a problem carrying heavy schoolbags.[24,25]

Differences in Electromyography

The study showed that with reduced SEMG values, the erector spinae muscles are being utilised efficiently especially in standing position when the schoolchildren carry their schoolbags on their backs. This is due to co-activity by other trunk muscles such as the rectus abdominis, internal and external oblique abdominal muscles as suggested by Neuman[24] and Bobet.[26] Our study showed that when one walks with a load, there is a reduction in MF values compared to when one walks without any load. It indicates that carrying a load while walking will utilise larger fibers of the erector spinae muscle compared to free walking with no significant changes in the forces generated.

The method of carrying a schoolbag is also a factor to be considered in terms of SEMG values. It had been shown that when one is carrying a load over both shoulders (symmetrical method), the efficiency of the erector spinae muscles is increased compared to carrying over one shoulder (asymmetrical method). In fact, Lin [27] and Neumann [24] stated that carrying the bag over both shoulders will slow the rate of muscle fatigue compared to other asymmetrical methods. The reason is the bilateral load carrying method will significantly reduce force generated by the muscle.[24]

Relationship between Electromyography with School Bag Weight

The present study also showed that, when the weight of the schoolbag increases, the AEMG values of the erector spinae muscles will decline, which suggested that an increase in schoolbag load will result in a more efficient use of the erector spinae muscle as the increased load tends to cause forward bending sagittal posture thereby increasing trunk muscle co-activity and reducing erector spinae activity.[26] However, in this study, the threshold limit of the schoolbag weight was not observed as it was not part of the objective. However, the study was able to identify that an increase in body height or body weight resulted in more efficient use of the erector spinae muscle as there are larger muscle fibers to provide for the total muscular demands.[28]

Factors Contributing to Low Back Pain Among Schoolchildren

The history of low back pain in the family is also one of the risk factors considered in this study. Salminen *et al.*[8] earlier reported that school children with low back pain in the latter years have a history of back pain in the family. In our study, as high as 56% of the children with back pain have parents with history of low back pain. In fact, Burton *et al.*[5] in their study reported a much higher prevalence of 60%. Gunzburg *et al.*[2] even stated that 64% of the schoolchildren who reported experiencing low back pain had at least one of their parents suffering from or complaining of low back pain. This study supported the finding of Gunzburg *et al.*[2] with much higher prevalence of 76%.

In our study, we found that the method of manual load carrying was one of the important factors of children complaining of low back pain especially with improper manual load carrying and our study complemented the earlier studies.[2, 11, 21,29,30] Burger[29] has already stated that the improper carrying of the schoolbag could cause a lot of muscle problem with higher SEMG values. Moreover, Kujala *et al.*[21] in their earlier study had established a link between musculoskeletal loading and future back pain problem.

Other possible risk factors include exposure to environmental tobacco smoke (ETS). Furthermore, Burdof and Sorock[13] had stresses that ETS was one of the risk factors for the back disorders. In our study we found that 25% of the schoolchildren with back pain are exposed directly to ETS. However, the study failed to prove any significant association ($p>0.05$) between exposure to passive smoking and prevalence of low back pain as shown in Table 7.

Table 7. Chi square analysis between low back pain and passive smoking

Low back pain	Passive smoking		Total	χ^2	P value
	Yes N(%)	No N(%)	(%)		
Yes	13(61.9)	37(58.7)	50(59.5)	0.066	0.797
No	8(38.1)	26(41.3)	34(40)		

CONCLUSION

In conclusion, there is a high prevalence of low back pain among primary schoolchildren compared to the older counterpart who are taller and have heavier bodyweight. Therefore, revisions should be evaluated concerning the need to carry any loads at all for these young children, as they are faced with the risk of low back pain in the future. Each schoolchild should be asked whether the bag is heavy before carrying it. If schoolbag carrying is necessary, it is important that schoolchildren be taught the proper method of carrying the bag and proper bags should be used. This involves the adoption of carrying over shoulders (symmetrical carrying) with the adoption of mild forward bending, and the avoidance of a combination of forward bending and lateral bending or twisting and other awkward postures. In addition, it should be recommended that back pack is considered the least risky for schoolchildren as it promotes symmetrical loading as well as keeps the two hands free for other use.

Our study also revealed that apart from the age of the schoolchildren, gender, family, history of back pain, exposure to environmental tobacco smoke (ETS), the weight of the bag and method of carrying the bag also are risk factors for back pain.

REFERENCES

[1] Phelip X. Why the back of the child? European Spine Journal 1999;8 : 426-428.

[2] Gunzburg R, Balague F, Nordin M, et al. Low back pain in a population of school children. European Spine Journal 1999;8 : 439-443.

[3] Balague F, Troussier B, Salminen JJ. Non-specific low back pain in children and adolescents: risk factors. European Spine Journal 1999;8 : 429-438.

[4] Salminen JJ, Erkintalo MO, Laine M, et al. Low back pain in the young. Spine 1995;20(19) : 2101-2108.

[5] Burton AK, Clarke RD, McClune TD, et al. The natural history of low back pain in adolescents. Spine 1996;21(20): 2323-2328.

[6] Kristjansdottir G. Prevalence of self-reported back pain in school children: a study of sociodemographic differences. European Journal of Pediatrics 1996;155 : 984-986.

[7] Newcomer K, Sinaki M. Low back pain and its relationship to back strength and physical activity in children. Acta Paediatrica 1996;85 : 1433-1439.

[8] Salminen JJ, Erkintalo MO, Pentti J, et al. Recurrent low back pain and early disc degeneration in the young. Spine 1999;24(13) : 1316-1321.

[9] Olsen TL, Anderson RL, Dearwater SR, et al. The epidemiology of low back pain in adolescent population. American Journal of Public Health 1992;82(4) : 606-608.

[10] Mierau D, Cassidy JD, Yong-Hing K. Low-back pain and straight leg raising in children and adolescents. Spine 1989;14 : 526-528.

[11] Harreby M, Nygaard B, Jessen T, et al, Lindahl A. Risk factors for low back pain in a cohort of 1389 Danish school children: an epidemiologic study. European Spine Journal 1999;8 : 444-450.

[12] Chaffin DB, Andersson GBJ, Martin BJ. Occupational biomechanics. New York: John Wiley, 1999.

[13] Burdorf A, Sorock G. Positive and negative evidence of risk factors for back disorders. Scandinavian Journal of Work, Environment and Health 1997;23 : 243 56.

[14] Genaidy AM, Karwowski W, Christensen DM, et al. What is 'heavy'. Ergonomics 1998;41(4) : 420-432.

[15] Negrini S, Carabalona R, Sibilla P. Backpack as a daily load for schoolchildren [letter]. Lancet 1999;354(9194) : 1974.

[16] Gordon CC, Chumlea WC, Roche AF. Stature, recumbent length and weight. In: Lohman TG, Roche AF, Martorell R (eds). Anthropometric standardization reference manual. Champaign Illinois: Human Kinetic Books, 1991: 3-8.

[17] Mega Electronics Limited. Muscle tester ME3000 Professional User's manual V1.3. Kupio Finland: Mega Electronics, 1995.

[18] Marras W. Overview of electromyography in ergonomics. In: Soderberg GL, (ed.). Selected topics in surface electromyography for use in the occupational setting: expert perspectives. Iowa: National Institute for Occupational Safety and Health, 1992:2-3.

[19] Gerleman DG, Cook TM. Instrumentation. In: Soderberg GL, (ed.). Selected topics in surface electromyography for use in the occupational setting: expert perspectives. Iowa: National Institute for Occupational Safety and Health, 1992:44-68.

[20] LeVeau B and Andersson G. Output forms: Data analysis and applications. Interpretation of the electromyographic signal. In: Soderberg GL (ed.). Selected topics in surface electromyography for use in the occupational setting: expert perspectives. Iowa: National Institute of Occupational Safety and Health 1992:70-102.

[21] Kujala UM, Taimela S, Viljanen T, et al. Physical loading and performance as predictors of back pain in healthy adults: a 5-year prospective study. European Journal of Applied Physiology 1996;73 : 452-458.

[22] Holewijn M. Physiological strain due to load carrying. European Journal of Applied Physiology 1990;61 : 237-245.

[23] Alpaugh EL. Temperature extremes. In: Plog BA, Benjamin GS, Kerwin MA (eds.). Fundamentals of Industrial Hygiene. USA: National Safety Council, 1988.

[24] Neumann DA, Cook TM, Sholty, RL, et al. An electromyographic analysis of hip abductor muscle activity when subjects are carrying loads in one or both hands. Physical Therapy 1992;2(3) : 207-217.

[25] Jonsson B. The value of electromyographic measures in the assessment of muscular load and fatigue in work place tasks. In: Winter DA, Norman KW, Wells RP, et al. (eds.). Biomechanics IX-B. Proceedings of The Ninth International Congress of Biomechanics. Waterloo, Canada. Champaign, Illinois: Human Kinetics 1983:3-8.

[26] Bobet J, Norman RW. Effects of load placement on back muscle activity in load carriage. European Journal of Applied Physiology 1984;53 : 71-75.

[27] Lin CJ, Dempsey PG, Smith JL, et al. Ergonomic investigation of letter carrier satchels: part II: biomechanical laboratory study. Applied Ergonomics 1996;27(5) : 315-319.

[28] Oborne DJ. Ergonomics at work: human factors in design and development. Chichester: John Wiley, 1995.

[29] Burger B. Backpacks – is your child's spine at risk? 2000. Online. Available. http://www.mtnconnection.com/health.com. 10 July 2000.

[30] Mays PJ. Students feeling the strain of 'Heavy' academic loads. 1998. Online. Available. http://www.onlineathens.com/1998/110898/1108.a2students. html. 12 July 2000.