

A HOLISTIC BACKPACK BACK PAIN MODEL FOR PREPUBESCENT  
PRIMARY SCHOOL CHILDREN

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A HOLISTIC BACKPACK BACK PAIN MODEL FOR PREPUBESCENT  
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To my parents, who raised me to know that the essence of life is to live to please our  
Creator.

To my one and only sayang, Theodora, who is a perfect embodiment of all care,  
support, encouragement, trust and forgiveness that is in an helpmeet

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## ABSTRACT

The present recommendation of the maximum bag weight to be 10-15% of body weight for schoolchildren has not been adequate as it is mainly based on biomechanical and physiological factors, without considering interaction with other risk factors associated with the subjective nature of back pain believed to be affected by psychosocial and individual characteristics of people. This serves as the basis to believe that the recommendation may not be sufficient for prepubescent primary schoolchildren, who constitute little or no part in the research leading to the initial recommendation. This research therefore aimed at developing a holistic multifactorial backpack back pain model that will provide explanation for the complex and multiple interactions associated with the back pain problem among the children. The research used mixed methodological design that employed survey, observation and objective measuring tools to investigate and understand the backpack back pain problem. A total of 662 primary schoolchildren aged 7-12 years (primary year 1-6) took part in the study. Descriptive and correlation statistical techniques were used to identify significant association among the factors. Reliability analysis and exploratory factor analysis were used for validating and reducing the variables into fitted constructs. Structural equation modelling was used for building and validating the model fit. Electromyography was used to establish the effect of age and body mass index on the trunk muscles of the children when carrying various weights corresponding to 5%, 10% and 15% of the body weight. The research established the insufficient nature of the 10-15% body weight for pain among primary schoolchildren. Most of the pain, load, anthropometric and physiological variables vary across age and racial groups. A multifactorial backpack back pain model consisting of anthropometry, pain, posture, backpack volume and rating ability was developed for better understanding of the relationship. A new safe weight recommendation based on percentage body weight and body mass index was made for the primary schoolchildren to reduce their chances of exposure to back pain. More longitudinal and control studies need to be conducted to identify appropriate percentage body weight suitable for different age groups.

## ABSTRAK

Cadangan berat beg maksimum semasa sebanyak 10-15% daripada berat badan bagi para pelajar sekolah didapati kurang wajar kerana ia secara umumnya berdasarkan faktor biomekanikal dan psikologi, tanpa mengambil kira hubungan dengan faktor risiko lain yang berkaitan dengan sifat subjektif sakit belakang yang dipercayai melibatkan ciri psikososial dan individu. Faktor ini menjadi asas dimana cadangan berat badan 10-15% tersebut tidak lagi sesuai untuk pelajar-pelajar sekolah rendah yang memainkan sedikit atau tiada peranan di dalam kajian yang membawa kepada cadangan awal. Maka, kajian ini bertujuan membangunkan satu model keseluruhan pelbagai faktor mengenai sakit belakang akibat beg galas belakang yang akan memberi penjelasan ke atas pelbagai interaksi kompleks berkenaan masalah sakit belakang di kalangan kanak-kanak. Kajian ini menggunakan pelbagai kaedah termasuk tinjauan, pemerhatian dan alat-alat pengukuran objektif bagi menyelidik dan memahami masalah sakit belakang akibat beg galas belakang. Seramai 662 pelajar sekolah rendah berumur di antara 7-12 tahun (Tahun 1-6) telah terlibat di dalam kajian ini. Teknik deskriptif dan kolerasi statistik telah digunakan untuk mengenal pasti hubungan signifikan antara faktor. Analisis kebolehpercayaan dan analisis faktor teroka telah diguna bagi mengesah dan mengurangkan ciri pemboleh ubah kepada faktor yang sesuai. Model persamaan struktur telah diguna untuk membangunkan dan mengesahkan kewajaran model. Electromiografi juga digunakan bagi mengetahui kesan usia dan indeks berat badan ke atas otot tubuh kanak-kanak apabila membawa pelbagai beban berpadanan dengan 5%, 10% dan 15% daripada berat badan. Hasil kajian ini membuktikan bahawa berat badan 10-15% tidak memadai untuk menentukan kesakitan di kalangan pelajar sekolah rendah. Kebanyakan kesakitan, beban, antropometrik dan faktor psikologikal berbeza mengikut usia dan jenis kaum. Satu model pelbagai faktor sakit belakang akibat beg galas belakang yang mengandungi antropometrik, kesakitan, postur, keberatan beg galas belakang dan kadar keupayaan telah dibuat untuk memahami hubungan ini dengan lebih baik. Satu cadangan baru beban selamat berdasarkan peratus berat badan dan indeks berat badan telah diperkenalkan bagi mengurangkan risiko sakit belakang kepada para pelajar sekolah rendah. Kajian longitudinal dan kawalan lanjut perlu dijalankan untuk mengenal pasti peratus berat badan yang sesuai bagi kumpulan usia berlainan.

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**LIST OF ABBREVIATIONS**

AGFI	Adjusted goodness of fit
AMOS	Analysis of moment structures
ANOVA	Analysis of variance
AVE	Average variance extracted
BBPP	Backpack-back pain problem
BMD	Bone mass density
BMI	Body mass index
CFA	Confirmatory factor analysis
CFI	Comparative fit index
COM	Centre of mass
CR	Comparative reliabilities
CTS	Carpal tunnel syndrome
DOF	Degree of freedom
EFA	Exploratory factor analysis
EMG	Electromyography
ES	Erector spinae
FA	Factor analysis
GFI	Goodness of fit
IED	Inter-electrode distance
MF	Median frequency
ML	Maximum likelihood
MPF	Mean power frequency
MSD	Musculoskeletal disorder
NNFI	Non-normed fit index
PASW	Predictive analytic software

PBW	Percentage body weight
REBA	Rapid entire body assessment
RMS	Root mean square
RMSEA	Root mean square approximation
RULA	Rapid upper limb assessment
SEM	Structural equation modelling
sEMG	Surface electromyography
SENIAM	Surface electromyography for the non-invasive assessment of muscles
SWL	Safe working load
TV	Television

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## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 Introduction to the Research**

This chapter provides an overview of the problem of back pain among schoolchildren with the aim of justifying the essence of the research. The application of Ergonomics and human factor principles to issues affecting schoolchildren has not been receiving enough attention among researchers (Woodcock *et al.*, 2009). This is despite evidence that children are equally exposed to problems such as musculoskeletal disorders i.e. carpal tunnel syndrome (CTS), arthritis and back pains (Smith and Leggat, 2007; Roth-Isigkeit *et al.*, 2005). This attention is justified when schools could be viewed as important work stations where children (as the worker) is surrounded by different factors that affect their productivity in learning (Grimes and Legg, 2004; Benedyk *et al.*, 2009).

Recent studies indicate that schoolchildren experience much higher degrees of discomfort and pain than had been commonly assumed (Watson *et al.*, 2002). These musculoskeletal disorders cause distractions during learning and are also responsible for absenteeism among the students when they need to rest at home or visit hospitals (Roth-Isigkeit *et al.*, 2005; Kistner *et al.*, 2013). The occurrence of such pain also triggers other actions that affect the daily living of the children and their relationship with family members and friends (Roth-Isigkeit *et al.*, 2005). Also the children may also grow with these problems as literature abounds with findings



that musculoskeletal disorders among adults have link to childhood (Roth-Isigkeit *et al.*, 2005; Watson *et al.*, 2002; Kistner *et al.*, 2013).

This stands as justification for the attention giving to the occurrence of non-specific back pain in school children (Grøholt *et al.*, 2003; Trevelyan and Legg, 2006; Bejia *et al.*, 2005; Trevelyan and Legg, 2010). Evidence has shown that this issue that was initially assumed to be non-existing among children actually cut across social, economic and political divides (Erne and Elfering, 2011). Literature provides evidence of a prevalence rate of 12-92% which has raised lot of concerns among authorities responsible for the wellbeing of children (Louw *et al.*, 2007; David, 2007; Rodriguez and Poussaint, 2010; Trevelyan and Legg, 2010; Trigueiro *et al.*, 2012; van Gessel *et al.*, 2011; Jones and Macfarlane, 2005; Gilkey *et al.*, 2010). However, the desire to ensure children are educated to be well placed to face future challenges has made education to be more demanding for the children (Grimes and Legg, 2004). The time the children spend studying and materials used have increased globally (Bauer and Freivalds, 2009; Kistner *et al.*, 2012) since school hours has increased and extra training both within and outside the schools has become a universal trend. This is because the school now serves as a safety net for parents who spend more time working (Kiecolt, 2003).

The children have to cope with sitting for a long period of time studying and also have lots of study materials which they have to transport almost on daily basis. These two activities have been identified as major cause of non-specific back pain in schoolchildren (Murphy *et al.*, 2004). Intervention and awareness programs have also been carried out to ensure that such designs and programmes achieved the objectives (Negrini *et al.*, 2004; Trevelyan and Legg, 2006; Saarni *et al.*, 2009). Yet children seems to be finding it difficult to conform to this recommendation as indicated by large number still carrying excessive weight (Dockrell *et al.*, 2013).

Hence there is need for a holistic investigation of the backpack-back pain problem. The limitation of the present recommendation may not be unconnected with

the multifactorial nature of occurrence of pain from carrying school bags as back pain is seldom caused by a single event (Smith and Leggat, 2007).

## 1.2 Background to the Research

Back pain is now recognised as a major form of musculoskeletal disorder among schoolchildren (Trevelyan and Legg, 2006). The recommendation of limiting the weight of school bags to 10-15% of body weight was arrived at from preponderance of Biomechanical and physiological analysis of load effect on children's body (Hong *et al.*, 2010). Different studies has reported the effect of backpack loading on the posture (Negrini and Negrini, 2007; Hong *et al.*, 2011; Chow *et al.*, 2007), gait (Devroey *et al.*, 2007; Hong and Li, 2005), centre of mass (Rugelj and Sevšek, 2011; Chow, Z Y Ou, *et al.*, 2010), the length and width of the feet (Drzał-Grabiec *et al.*, 2013) and feet-ground contact pressure (Pau *et al.*, 2011).

Recent studies have however highlighted the non-sufficient nature of this recommendation as there is evidence of back pain despite load conforming to the recommendation (Dianat *et al.*, 2013; Al-hazzaa, 2006; Amiri *et al.*, 2012). The failure of this recommendation has led to inconsistency and development of multiple guidelines with has not yielded the desired solution (Dockrell *et al.*, 2013). Yet, the feasibility of further downsizing the school bag is questionable as it is impossible for the children to go to school without any load. A scenario that would have fit that assertion would be the digitization of education for which educational materials will be in electronic form. This however seems to be unrealistic presently as the cost of such endeavour is high and many developing and underdeveloped countries will find it difficult to cope with as they are yet to provide the basic school necessities (Oyewole *et al.*, 2010). The developed countries will also consider household economy as parents belongs to different economic class. There is also the issue of education pedagogy as laptop or e-learning will alter the present cognitive learning development as children seems not to enjoy significant benefit or improvement in

learning outcome due to the use of e-learning or exposure to virtual learning environment despite the high financial requirement (Piccoli *et al.*, 2001; Hiltz, 1994; Hara, 2000).

The inconsistency in the methodology has also lead to the believe that the problem is being exaggerated with call for development of better systematic and evidence based guidelines thereby calling for a more stringent approach towards proffering a solution (King *et al.*, 2011; Adams and Dolan, 2005; Cardon and Federico. Balagué, 2004; Dockrell *et al.*, 2013). Most researchers have attempted to proffer solution based on findings from specific factors without considering interacting tendencies of various factors affecting human performance and behaviour. These myopic approach might be responsible for the present complex and limited understanding of the problem of backpack and back pain (Yang *et al.*, 2011; Smith and Leggat, 2007; Kurtz and Edidin, 2006) and the inability to establish the cause and effect relationship between backpacks and related syndromes (Atreya *et al.*, 2010).

### **1.3 Problems and the Research Questions**

Considering the diversities of the risk factors in determining the safe working load (SWL) across different disciplines, its application across race and age lines also need to be thoroughly investigated to justify its validity. This diversity may be the result of cultural, anthropometric, biomechanical, physiological and psychosocial factors inherent among people and since it is now widely accepted that technical approaches alone are inadequate to reduce accident rates to desired level (Paul and Maiti, 2008). This might explain why multidisciplinary researches are yet to justify the 10-15% recommendation and findings from them seem contradictory (Golriz and Walker, 2011; Bauer and Freivalds, 2009). Researches leading to these recommendations are believed either to be both subjective and limited in scope or the objective ones are from simulation rather than real life situations.

The sampling size used to draw those conclusions are also limited and the recommendations were mostly based on studies involving adolescents. Just like there is no safe or similar work limits for adults of different tasks in different countries, the generalisation of recommendations for all children need to be properly investigated since the samples used in most studies leading to the recommendations are adolescents (Smith and Leggat, 2007) who are from developed countries (Jeffries *et al.*, 2007; Dianat *et al.*, 2014).

There exists the possibility of the recommendation failing among primary school children who has tenderer spine, which is the main load carrying structure in human. Anatomically, vertebral body of younger children are more cartilaginous than bony and the spaces between their intervertebral discs are larger (Kim *et al.*, 2008). These features are expected to reverse with age (Rodriguez and Poussaint, 2010) and the spine is expected to grow sporadically until 18 years and maturing about 24 years (Grimmer and Williams, 2000). The difference in the anatomy of the spine might play a significant role in the weakness of the recommendation which has already been reported not to be beneficial to younger school children (Dianat *et al.*, 2013). Hence, back pain being a multifactorial problem (Marras, 2008) requires a multifaceted approach in arriving at a solution.

Hence, this research will seek to provide answers to the following questions:

- i. What level of interaction exists among identified factors associated with the occurrence of back pain among primary schoolchildren using backpack?
- ii. Are there significant effect and interaction of age and gender on the backpack behaviour of primary schoolchildren?
- iii. Do racial differences play a significant role in the backpack- back pain behaviour among children?
- iv. Is the ratio of bag weight to body weight sufficient to determine a safe weight for the children? Or are there other variables suitable for measurement?

## 1.4 Objective of the Research

The overall objective of this research is to critically analyse the effect of backpack usage on back pain among primary school children with the aim of confirming if the existing recommendation of safe working load is applicable to all the age groups; or if need be, to recommend an appropriate one. The specific objectives are as follows:

- a. To develop a multifactorial model describing the interaction among various factors associated with the backpack back pain problem.
- b. To establish that body mass index play a significant role in the occurrence of back pain among primary school children in order to determine if body mass index is a better criterion than percentage body weight for safe working load recommendation
- c. To develop a backpack back pain predictive model for primary school children.

## 1.5 Scope of the Research

The research will be focus on the following

- i. Prepubescent children in Primary schools. Their ages range between 7 and 12 years. Although the back pain problem cut across geographical boundaries, the study's sample population is also limited to Malaysian schoolchildren from three races of Malay, Chinese and Indian.
- ii. The study will also focus on non-specific back pain which refers to back pain without known or specific diagnosed cause. This is the commonly investigated area for non-medical personnel.
- iii. The study will also be cross sectional in design. However, a systematic approach in which both subjective and objective variables was used in identifying the effect of the backpack weight on the children's perception of back pain and related variables was utilised during the research.

## **1.6 Significance of the Research/Contribution**

The findings of this thesis will help to establish an effective backpack usage scheme among primary school children. It will also highlight the direct effect relationship between backpack safe weight and factors associating it with back pain. This thesis provides explanation for some of the complexity associated with the backpack back pain studies thereby helping to eliminate some of the misinterpretations associated with the problem. It will also enlighten parents and school authorities on the need to pay more attention on the backpack usage of the children and backpack manufacturers could also incorporate the recommended weight limits into backpack designs.

## **1.7 Organisation of this Thesis**

This thesis is made up of seven chapters. The present chapter is the first and it provides an insight into the background of the problem necessitated this research. It also contains the research questions and the objectives set out for achievement in the thesis. The chapter also highlights the scope and significance of the research. It concludes with the definition of some terms associated with the research.

The review of some of the recent findings in the literature associated with the backpack-back pain problem and various factors identified to be associated with it were presented in Chapter Two. The chapter also review the various methodologies currently employed in related studies which provides a good platform essential for proper methodological development.

Chapter Three builds on the reports in previous chapter to develop a robust conceptual model made up of constructs identified to be significantly associated with

the backpack-back pain problem. The analytical tools essential for the achievement of the objectives were also presented and justified for the research.

Chapter Four provide a detail step to step methodology followed in order to achieve the objectives laid out in the research. It also provides literature justification for the mixed methodology used in the research. The analytical procedures carried out were clearly enumerated and justification provided for them where necessary.

The results of survey and various measurements were presented in Chapter Five. It starts with the findings of the descriptive statistics needed to understand the behaviour of the sample population before presenting the univariate and multivariate findings aimed at unravelling the complexities associated with variables in the research. The chapter concludes with the result of the sEMG analysis of the effect of different weight on the muscles in the affected body regions.

Chapter Six discusses the result and uses logical reason based on related findings to recommend a new safe weight for the primary school children. Chapter seven summarises the findings in the research and the recommendations made. It also contains limitation and areas that need to be further investigated in ensuring the suitability of the modern for larger population sample.

## **1.8 Definition of Terms**

- i. Musculoskeletal disorder (MSD) refers to any abnormality in the body system arising from wrong body positioning during work.
- ii. Prepubescent refers to the childhood stage before puberty or adolescent.

- iii. Adolescent is the childhood stage before an individual is referred to as an adult.
- iv. Non-specific back pain refers to pain felt in the back without definite cause.
- v. Holistic Model: a model developed through comprehensive consideration of the various interconnected components or factors associated with it.
- vi. Erector Spinae: the group of posterior muscles that runs vertically through the back of humans and extends the vertebrae column for postural stability.
- vii. Isometric contraction: refers to muscular force generation without changes in muscle length.
- viii. Back pain Prevalence: The widespread rate at which back pain occurs within a study population or in a particular population.

## **1.9 Conclusion**

This chapter highlights the importance of this research. The present recommendations at solving the problem were identified and their limitations were highlighted. This makes it possible to set some research objectives which can lead to proffering possible recommendations that will lead to the elimination of the problem.

The next chapter provides a detailed literature review on the issues and factors associated with the backpack-back pain problem.



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