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**ACUTE STRESS AND STRAIN DUE TO BACKPACK LOADING  
AMONG PRIMARY SCHOOL PUPILS**

By

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Submitted in part fulfillment of the requirement for the degree of Masters in Sports Science  
in the Faculty of Health Science at the University of KwaZulu-Natal

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Date Submitted : 1 December 2011

## **Declaration**

I, Sumaya Abrahams, Registration Number: 205503583 hereby declare that this dissertation,

### **ACUTE STRESS AND STRAIN DUE TO BACKPACK LOADING AMONG PRIMARY SCHOOL PUPILS**

Is a result of my own investigation and research and that it has not been submitted in part or full for any other degree or any other university.

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Signature

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Date

# DEDICATION

To my family and friends.

Thank you for your continuous love, support, patience, motivation and for always being  
proud of me.

## ACKNOWLEDGEMENTS

**I wish to record my deep-felt gratitude and appreciation to the following people and institutions, as without their assistance this thesis would not have been feasible:**

Dr T.J. Ellapen, for his impeccable supervision, insight, motivation and expertise.

Prof H.J van Heerden, for co-supervising and guiding me during this trying process.

Raeesa Vanker, for all your hard work, support, motivation, dedication and commitment as a research assistant and sister.

The Department of Education in Kwa-Zulu Natal.

The Schools and participants in the study, for their time, interest in the research and willingness to participate.

Yasmin Abrahams for her proofreading and printing.

The National Research Foundation for funding this research.

## ABSTRACT

**Introduction:** *Schoolbag carriage represents a considerable daily occupational load for children (Negrini et al., 1999). Whittfield et al., (2001) and Puckree et al., (2004) have reported that the carriage of heavy schoolbags is a suspected aetiological factor of the daily physical stress of school pupils.*

**Methods:** *One hundred and eighty-seven pupils voluntarily participated in a controlled, descriptive, epidemiological retrospective study. Subjects' biographical, epidemiological, exercise history and lifestyle information was gathered by a self-report questionnaire (adapted from Puckree et al., 2004). Subjects' body mass, stature and mass of their schoolbags were measured using a Detecto stadiometer scale. Digital images, electromyographical muscular activity and a posture profile assessments were captured in the frontal and sagittal planes whilst the pupils were in the loaded (carrying a schoolbag) and the unloaded phases (not carrying schoolbags). These images were analyzed using biomechanical software, Dartfish. The study being retrospective in nature recorded the prevalence of schoolbag carriage musculoskeletal pain over the last 12 months. Descriptive statistical tests such as mean, mode, frequency, percentages and inferential chi-square statistical test (set at a probability of 0.05) were employed to analyze the data.*

**Results:** *The result indicated that 78.99% of the cohort experience musculoskeletal pain due to schoolbag carriage ( $p < 0.0001$ ). The most prevalent anatomical sites of pain were the shoulders (37.04%), neck (20.37%), lumbar (11.73%) and thorax (10.49%) ( $p < 0.0001$ ). The mean mass of the schoolbag carried by the cohort was 5.45kg which was approximately*

*11.5% of their body mass. The predisposing factors of the musculoskeletal pain were the methods employed to carry the schoolbag (single strap (20.21%) versus double straps (76.6%), altered posture due to excessive schoolbag mass together with a reduced craniovertebral angle ( $p < 0.05$ ).*

**Discussion & Conclusion:** *The excessive schoolbag mass carried by the pupils placed strain on the immature vertebral column of these pupils thus causing postural deviations which induced musculoskeletal pain and discomfort.*

**Keywords:** schoolbag, craniovertebral angle, musculoskeletal pain

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## CHAPTER ONE: INTRODUCTION

This chapter provides a brief introduction into the major risk factors and musculoskeletal deformities associated with schoolbag carriage, international trends regarding schoolbag carriage that was identified by researchers, as well as the need for further research regarding the impact of schoolbag carriage.

### 1.1. Introduction

Back pain is commonly recognised as a problem both nationally and internationally. While considerable speculation has been directed into better understanding back pain among the adult population, comparatively little is known about the condition in children (Olsen et al., 1992; Burton et al., 1996). Musculoskeletal pain and discomfort among adolescents is a common occurrence and comprehension of the characteristics experienced by these adolescents will be beneficial for improving their quality of life (Hakala et al., 2002). There is great concern regarding the mass of adolescent schoolbags and the negative impact of these heavy loads on the developing vertebral column. There is particular concern for adolescents aged 11-14 years old, as their vertebrae are at a critical stage of development (Tanner et al., 1976).

Schoolbags are considered as a considerable daily occupational load for school children to carry (Negrini et al., 1999). By carrying a specific load during walking, it negatively encourages a disproportionate force which acts on the L5-S1 intervertebral joint (Goh et al., 1998). Schoolbag loading promotes a counter rotation of the thorax and pelvis (Lai & Jones,

2001) which causes immediate changes in spinal curvature which has a direct effect on the skeletal repositioning in an attempt to ensure stability (Chow et al., 2007). This may affect the anterior and posterior curves of the spine leading to musculoskeletal deformity of the vertebral column including cervical postural syndrome, Scheuermann's disease, pectus cavus lordosis and anterior tilting of the pelvis (Ellapen et al., 2009). Further exacerbation of these musculoskeletal deformities may lead to spondylolisthesis thereby leading to an increased risk for chronic lower back pain, nerve compression or permanent damage to the spinal nerve root which could cause weakness or paralysis of the legs (Spiegel et al., 2007). This increase in the weight of the backpack has a positive correlation to an increased risk for pain (Steele et al., 2001). These stresses on the spine are initially reflected as pain which subsequently are transformed into vertebral deformity and musculoskeletal pain (Vikat et al., 2000).

A general guideline of 10% of the body mass, initially proposed by Voll & Klimt (1977) when carrying a schoolbag, persists as an accepted rule of thumb. Exceeding this mass as well as the individuals' carrying capacity may adversely affect vertebrae growth (Ellapen et al., 2009). Excessive levels of muscular tension must certainly qualify as a physiological strain, as they can lead to muscular pain and fatigue (Chaffin, 1973) and ultimately to bone and joint disease (Bjelle et al., 1981). "Trunk forward lean" represents a dynamic emergent strategy that varies based on task demand and characteristics of the individual. Heavier backpacks exert greater forces on the spinal column and back muscles (Vikat et al., 2000). These increased schoolbag loads significantly compress the lumbar disc heights thereby significantly increasing lumbar asymmetry and lumbar curvature leading to back pain (Neuschwander et al., 2010). Research conducted by Goodgold et al., (2002) indicated that while walking with a heavier schoolbag load, the subjects adopted a compensatory trunk flexion posture to compensate for changes in inertia and centre of gravity. This spinal flexion

changed the line of action of the largest lumbar extensor muscles compromising their role to support anterior shear forces of the lumbar spine which is highly correlated to back injury (McGill et al., 2000). Spinal flexion is caused by Scheuermann's disease and it is likely that this kyphosis results in increased pressure on the vertebral end-plates anteriorly, allowing for uneven growth of the vertebral bodies with wedging as a response to Wolff's law (Lowe et al., 1990). These postural deviations may lead to vertebral subluxation (Tanner et al., 1976; Steele et al., 2001) restricting movement of the dysfunctional areas in the spine and predisposing the pupil to a number of ailments such as neck and back pain, headaches and osteoarthritis (Puckree et al., 2004).

Abnormal postural deviations are responses to heavy schoolbag loading in adolescents due to their spinal bones and muscles not being comprehensively developed. Prolonged loading duration may restrict mobility of spinal bones and may lead to spondylolithesis which has an effect on the vertebra; specifically the craniovertebral angle is altered, resulting in restricted movement which is a risk factor for back pain (Vikat et al., 2000). Other risk factors for musculoskeletal pain and discomfort associated with schoolbag carriage include: the mass, shape and size of the load in proportion to the individual, as well as, duration and position of the load on the body (Chansirinukor et al., 2001). A higher incidence of musculoskeletal pain and discomfort has been reported by females (McGrath et al., 2000; Eccleston et al., 2004). Other associated risk factors include school academic performance, which has been negatively correlated to the incidence of musculoskeletal pain and discomfort (Balahue et al., 1994; Abu-Arafeh & Russel et al., 1996) as well as a less favourable psychological disposition (Merlijn et al., 2003 & Watson et al., 2003). Literature reports that proper wearing of backpacks may positively impact the middle school aged child by improving their quality of life as noted through a decrease in reports of musculoskeletal pain by participants

(Feingold & Jacobs, 2002).

Puckree et al., (2004) confirmed anecdotal suspicions of the incidence of musculoskeletal pain and discomfort propagated by schoolbag carriage. This was the only study conducted in South Africa which researched the relationship between schoolbag carriage and vertebral pain. The researchers concluded that it was necessary to identify the risk factors for bodily pain in school children. Therefore, more in depth investigations are necessary to identify the etiology and incidence of musculoskeletal pain and discomfort, whether international risk factors associated with schoolbag carriage are congruent in South Africa, and the role of the school curriculum in contributing to this painful scenario.

## **1.2. Purpose of the study**

The purpose of this study was to determine:

- a) Postural deviations, including craniovertebral angle, whilst the subjects are in the loaded and unloaded positions.
- b) Muscular activity of the sternocleidomastoid and trapezius muscles during schoolbag loading to correlate these results with postural deviations.

Malalignments as seen in the sagittal view include, cervical postural syndrome, kyphosis, lordosis and genu recurvatum whilst malalignments as seen in the frontal view include scoliosis, genu varum, genu valgum, rear foot valgus and rear foot varus.

### **1.3. Statement of the problem**

The aim of the study was to investigate the strain on the vertebral musculature leading to postural malalignments and changes in muscular activity due to the stress associated with schoolbag carriage. Postural malalignments may be caused by repetitive loading of muscles which could possibly become pathological or lead to compensatory mechanisms to reduce tissue stress.

An additional aim was to identify risk factors associated with schoolbag loading. The purpose of the posture profile in the loaded and unloaded phase was to determine whether there was further exacerbation of postural alignment (as indicated by Neumann, 2002) (in an attempt to compensate for the excessive load). In addition to the posture profile, anatomical landmarks were identified, marked and the craniovertebral angle was measured on location using the smart tool device. The change in the craniovertebral angle was identified as the major risk factor associated with schoolbag carriage due to the immature spinal bones of pupils thus leading to back pathologies, such as spondylolisthesis, thereby leading to back pain (Pascoe et al., 1997). These results were verified using biomechanical software, Dartfish.

### **1.4. Null-Hypothesis**

There are no musculoskeletal abnormalities or risk factors in adolescents, aged 11-13 years, whilst carrying a schoolbag.

### **1.5. Delimitations**

One hundred and eighty seven (n=187) pupils between the ages of eleven and thirteen years participated in this study. The pupils were to be registered at one of the four senior primary

academic institutions, in KwaZulu-Natal, chosen for the study and participation was voluntary.

### **1.6. Limitations of the study**

Any grade seven pupil from the selected schools, who was diagnosed with a musculoskeletal condition, by a medical practitioner, was excluded from the study. Those who did not meet the inclusion criteria (i.e. age and registration at one of the four senior primary academic institutions) were also excluded from the study.

### **1.7. Definition of terms**

This section serves to give brief definition of terms used in order to lend clarity to the reader when used in the text.

#### **1.7.1. Anatomical position**

Position of an individual standing upright with feet together, arms hanging by the side with palms facing forward and thumbs pointed away from the body (Kent, 1994).

#### **1.7.2. Cervical postural syndrome**

A typical posture of protruding chin and increased upper cervical lordosis (Brukner & Khan, 2006).

#### **1.7.3. Dartfish**

Video analysis biomechanical software used to monitor deviations from the anatomical position.

#### **1.7.4. Frontal view**

An imaginary line which runs longitudinally and divides the body into right and left halves (Kent, 1994).

#### **1.7.5. Genu recurvatum**

Hyperextension of the knees (Kent, 1994).

#### **1.7.6. Genu valgum (knock knees)**

Medical term for knock knees (Kent, 1994).

#### **1.7.7. Genu varum (bow legged)**

Medical term for bow-legs (Kent, 1994).

#### **1.7.8. Load**

Resistance or load used. i.e. backpacks (Kent, 1994).

#### **1.7.9. Lordosis**

An accentuated, convex, forward spinal curvature of the lumbar region (Kent, 1994).

#### **1.7.10. Musculoskeletal disorder**

The term musculoskeletal disorder identifies a large group of conditions that result from traumatizing the body in either a minute or major way over a period of time.

#### **1.7.11. Pathological**

A condition associated with a disease (Kent, 1994).

#### **1.7.12. Rear foot valgus**

A condition in which the rear of the foot tends to curve outwards, that is, it tends to be everted at the ankle joint (Kent, 1994).

#### **1.7.13. Rear foot varus**

A condition in which the rear of the foot tends to curve inwards due to inversion at the ankle joint (Kent, 1994).

#### **1.7.14. Sagittal plane**

An imaginary line which passes through dividing the body into anterior and posterior portion (Kent, 1994).

#### **1.7.15. Scheuermanns disease**

An osteochondritis causing irregularities in the epiphysis of vertebrae (Kent, 1994).



### **1.7.16. Scoliosis**

Abnormal lateral curvature of the spine that occurs most often in the thoracic region (Kent, 1994).

### **1.7.17. Smart tool device**

Instrumentation used to measure deviations in craniovertebral angle (Lau et al., 2009).

## **1.8. Abbreviations**

This section serves to give brief definition of abbreviations used in order to lend clarity to the reader when used in the text.

<b>ACSM</b>	American College of Sport Medicine
<b>BMI</b>	Body Mass Index
<b>CVA</b>	Craniovertebral angle
<b>EMG</b>	Electromyography
<b>LBP</b>	Lower Back Pain
<b>MSP</b>	Musculoskeletal Pain
<b>PA</b>	Physical Activity
<b>PE</b>	Physical Education
<b>SCM</b>	Sternocleidomastoid
<b>SP</b>	Sport Participation

<b>SD</b>	Standard deviation
<b>kg</b>	kilogram
<b>m</b>	metre
<b>mm</b>	millimetres
<b>n</b>	Sample size
<b>p</b>	Probability

### **1.9. Summary**

This first chapter serves to clarify the need for this study and has defined the rationale of the study. The scope of the research has been clearly delimited and selected, relevant terms have been defined.

## CHAPTER TWO: LITERATURE REVIEW

This chapter provides a detailed review of the literature pertaining to schoolbag carriage among school pupils. The chapter will be discussed under the following headings: a brief introduction, schoolbag carriage in South Africa, musculoskeletal disorders, risk factors for musculoskeletal pain, the effect of schoolbags on musculoskeletal disorders, postural analysis, muscle activity, results from previous schoolbag studies, intervention studies in a school setting and a conclusion.

### 2.1 Introduction

The backpack (or rucksack) is one of several available forms of manual load carriage that is often used by school children, backpackers and the military. It is seen as an appropriate way to load the body close to the centre of gravity, while maintaining stability (Chansirinukor et al., 2001). Occupational or cultural requirements result in loads being carried on the head (African tribes), stabilized around the forehead (Sherpa's), a yoke across the shoulders or, as here, in a backpack (Attwells et al., 2006). In recent years the scientific literature has increased its focus on childhood bodily pain (Puckree et al., 2004). This is due to the fact that if school students experience a backache in their childhood, they will be exposed to worse consequences in adulthood (McCarthy et al., 2003; Lueder et al., 2007; Bauer et al., 2009). Whittfield et al., (2001) and Puckree et al., (2004) have reported that the carriage of heavy schoolbags is a suspected aetiological factor which is an overlooked daily physical stress of school pupils. Schoolbag carriage represents a considerable daily occupational load for children (Negrini et al., 1999). Presently there is growing concern regarding the mass of the

schoolbags which pupils carry and the negative consequences of such heavy loads imposed onto their immature spines (Dockrell et al., 2006).

## **2.2 Schoolbag carriage in South Africa**

South African school pupils are no different to school pupils overseas (Grimmer et al., 1999; Vikat et al., 2000). It is also not unusual to find them hauling bags that are too large and heavy for their frame (Puckree et al., 2004). The size and mass of the schoolbags has increased in recent years due the change in the South African National curriculum. The year 1997 herald, change in the South African National Curriculum which facilitated the carriage of heavier schoolbags (Puckree et al., 2004; Rooth, 2005; Lombard & Grosser, 2008). One of the hallmarks of the South African Curriculum 2005 was the implementation of the new Outcome Based Education (OBE) in which Physical Education (PE) lessons were replaced with Life Orientation lessons. The subject Life Orientation comprised of Health Education, Guidance and Physical Education, which resulted in the pupils receiving fewer PE lessons in comparison to the previous South African National Curriculum (Lombard & Grosser, 2008). It can be assumed that fewer PE lessons reduced the development of the paraspinal muscles' strength and endurance which slowed the rate of muscle and bone strengthening of the spine.

## **2.3 Musculoskeletal disorders**

The impact of daily carriage of a school backpack on the musculoskeletal health of children and adolescents has become an area of concern due to the association between backpack carriage and back pain (Negrini & Carabalona, 2002; Sheir-Neiss et al., 2003; Korovessis et al., 2005) as well as musculoskeletal deformities such as scoliosis, kyphosis and lordosis (Lai & Jones, 2001; Korovessis et al., 2005). Experimental data regarding the effects of backpack

carriage on the spine itself are relatively poorly documented (Chow et al., 2007). The method in which a pupil carries a schoolbag also has an effect on their posture. Children who use only one strap have lateral spine bending (scoliosis) and elevation of the contra-lateral shoulder; whilst pupils who employ a double strap back pack carriage method increase the prevalence of excessive thoracic vertebral flexion (kyphosis) (Pascoe et al., 1997). The forward leaning of the cervical and thoracic vertebrae predisposes the pupils to an altered craniovertebral angle, cervical postural syndrome and Schuermann's Disease (Trevelyan & Legg, 2006). The repetitive stress of carrying a heavy schoolbag may contribute to the high prevalence of musculoskeletal symptoms observed amongst secondary school students (Whittfield et al., 2001). Many studies have shown that trunk flexion, decrease in the action of erector spine muscle, increase in activation of rectus abdominis muscle and tachycardia may be caused as result of carrying over-loaded backpacks (Devroey et al., 2007). Along this line, the transition from childhood to adolescence is an important phase to evaluate the potential stability of intervention effects because of the typically mechanical and psychological demands related to adolescence (Geldof et al., 2007).

One mechanical effect of load carriage inevitably observed is an increased forward lean when carrying loads on the back (Attwells et al., 2006). Neck and shoulder pain is more frequently reported (Vikat et al., 2000) and has a strong association with psychosomatic symptoms (Puckree et al., 2004). The heavier the backpack, the more pressure it exerts on the spinal column and back muscles as these scholars will bend forward in an attempt to support the weight on the back rather than on their shoulders (Lai & Jones, 2001). These postural imbalances could often trigger a condition called vertebral subluxation (Steele et al., 2001) which leads to restricted movement of the dysfunctional areas in the spine and predisposes patients to a number of ailments such as neck and back pain, headaches and osteoarthritis

(Puckree et al., 2004). Significant increase in the trunk flexion angle with respect to the pelvis was also found with increasing backpack load, resulting in the position of C7 moving anteriorly and superiorly with respect to the pelvis (Chow et al., 2005). Furthermore, prolonged rotational motions, with high force in unsuitable postures, result in incorrect habitual behaviours which in turn may lead to skeletal disorders (Sahrmann, 2002).

### **2.3.1 Lower back pain**

Recent worldwide attention has focused on the role of backpacks in the development of adolescent non-specific lower back pain (Sheir-Neiss et al., 2003). It is known that back pain at a young age is an important factor in the risk of experiencing back pain as an adult (Brattberg, 1994; Harreby et al., 1995). Grimmer and Williams (2000), showed a strong association between lower back pain and increased time of spinal tissue loading. The carrying of heavy backpacks is common in the school-age population (Mackenzie et al., 2003; Cottalorda et al., 2004) and the occurrence of back pain in children and adolescents varies from 8% to 84.1%. The resulting strain has been associated with musculoskeletal dysfunction, head and neck aches and craniofacial and shoulder pain (Raine & Twomey, 1997).

Back pain is an epidemic in the adult population with more than 60% of adults reporting having experienced back pain (Harreby et al., 1996; Mirovsky et al., 2002; Mackenzie et al., 2003; Cottalorda et al., 2004). While considerable investment has been directed into better understanding back pain among the adult population, comparatively little is known about the condition in children (Olsen et al., 1992; Burton et al., 1996; Trevelyan & Legg, 2006). Studies have shown that reports of back pain occurring early in childhood (Troussier et al., 1994; Balague' et al., 1995; Kristja'nsdo'ttir, 1996) and that the prevalence of non-specific

lower back pain (LBP) among school children is high when estimated by survey (Balague´ et al., 1988, 1994, 2003; Legg & Trevelyan, 2003; Whittfield et al., 2005). The type, manner and load of schoolbags are believed to play a leading role in causing and sustaining back, neck and shoulder pain in children, which continues to recur in these individuals when they reach adulthood and thereafter (Taimela et al., 1997; Linton, 2000; Grimmer & Williams, 2000).

## **2.4 Risk factors for musculoskeletal pain**

Aetiological risk factors for musculoskeletal pain attributed to schoolbag carriage include gender, age, craniovertebral angle, the combined forces of the weight of the schoolbag and the gravity onto the immature spine of the pupil (Grimmer & Williams, 2000), the shape and size of the schoolbag (Chansirinukor et al., 2001), duration carrying the bag (Grimmer & Williams, 2000), the position of the schoolbag on the pupil’s torso (Malhorta & Sen Gupta, 1965) and school furniture.

### **2.4.1 Gender as a risk factor for the musculoskeletal pain experienced by school pupils**

Epidemiological schoolbag musculoskeletal pain studies have reported that girls experience more musculoskeletal pain in comparison to boys (Grimmer & Williams, 2000; Sheir-Neiss et al., 2003; Puckree et al., 2004; Mohd et al., 2010). The prevalence of non-specific back pain increases dramatically during adolescence from less than 10% in pre-teens to 50% in 15- to 16-year olds (Burton et al., 1996; Sheir-Neiss et al., 2003). The most frequent increase in prevalence of reported back pain occurs in girls aged 12-13 years and in boys aged 13-14 years (Leboeuf-Yde et al., 1999). Viry et al. (1999) noted that this period corresponds to the time of puberty and maximum linear growth. A possible explanation to the differences in

pain between the genders is the physical and physiological characteristics of males and females both differ in their muscle strength as females tend to have lower muscle strength than males, particularly in the upper limb musculature (Katzmarzyk et al., 1998). Females also have greater body awareness and lower pain thresholds (Breithecker et al., 2004) and thus tend to complain more than males. Leboeuf-Yde & Kyvik, (1998) proposed earlier maturity and the onset of puberty as a possible explanation for greater reporting of pain among females. On the other hand, Balague´ et al., (1995) theorised that the traditional image of the male led boys to underreport their back pain. Other studies which have shown gender differences in the relationship between schoolbag load and back pain have related pain to the stresses applied to the developing adolescent spine by large loads (Grimmer et al., 1999; Staff, 1999). Several other studies did not find a difference between the gender reporting patterns of back pain (Taimela et al., 1997; Kujala et al., 1999; Wedderkopp et al., 2001). Burton et al., (1996) found that the prevalence of back pain was similar in male and female 11 year olds but by age 15 years became subsequently higher in males (52.6%) than females (34.3%) ( $p < 0.01$ ). Burton et al., (1996) proposed the finding was possibly due to boys having a higher exposure than girls to more strenuous (and potentially hazardous) sports activities.

#### **2.4.2 The effect of age on musculoskeletal pain experienced by school pupils**

Grimmer & Williams, (2000) findings found that the majority of the cohort experienced musculoskeletal pain. The findings of the study was attributed to the age of the students (the cohort was younger – between 11 and 14 years of age), which affects the maturation of the adolescent spine and the associated reduced postural response to load carrying. Trevelyan & Legg, (2006) reported that a number of studies observed an increase in musculoskeletal pain relative to age (Grimmer & Williams, 2000; Wedderkopp et al., 2001; Watson et al., 2002).



An important increase in back pain after the age of 12, particularly among girls, was reported by Troussier et al., (1994) and supported by others (Olsen et al., 1992; Burton et al., 1996).

### **2.4.3 The effect of an altered craniovertebral angle (CVA) on musculoskeletal pain experienced by school pupils**

The CVA is defined as the angle formed from a horizontal line passing through the C7 spinous process and a line passing through the tragus of the ear (Grimmer et al., 1999; Chansirinukor et al., 2001; San Agustin et al., ny). The craniovertebral angle ranges from 25 to 31 degrees and indicates change in the position of the head relative to the neck. A decrease in this angle is considered to result in a 'poking chin' posture and may indicate stresses on the upper cervical spine (Moore, 2004; McEvoy & Grimmer, 2005). There is a great concern for pubescent children aged 11-14 years because their spine is at a critical stage of development. At this period of time in their young lives the mass of their schoolbags to their body mass ratio is higher than the recommended normative value, primarily due to the reason that many pupils are small in stature but carry loads similar to that of larger and older children (Hong et al., 2000; Dockrell et al., 2006). The general guideline of 10% body mass proposed by Voll & Klimt, (1977) continues to be the accepted recommended rule of thumb when carrying a backpack style schoolbag. International epidemiological surveys have documented that pupils who carry bags whose schoolbag mass to pupil body mass ratio exceed the Voll & Klimt, (1977) rule of thumb of 10% experience musculoskeletal pain (Pascoe et al., 1997; Viry et al., 1999; Grimmer & Williams, 2000; Whittfield et al., 2001; Sheir-Neiss et al., 2003; Puckree et al., 2004; Dockrell et al., 2006). The greatest changes in craniovertebral angle in response to a load occurred in the youngest students in a group aged 12 – 18 years (Mikkelsen et al., 1997; Grimmer et al., 1999).

It is believed that the backpack can pose a threat to the scholar when it does not fit properly, if it is over-packed or when it is carried incorrectly (Steele et al., 2001). Researchers have shown that the worst way to carry books is in a low-slung athletic bag or in a backpack, which is worn over one shoulder (Mikkelsen et al., 1997) which may aggravate postural misalignments and cause imbalances (Staff, 1999).

#### **2.4.4 The mass and duration of schoolbags carried by school pupils**

Schoolbag mass and time spent bearing loaded backpacks are other risk factors on musculoskeletal pain experienced by school pupils (Grimmer & Williams, 2000; Negrini & Carabalona, 2002; Szpalski et al., 2002). Consequently, loads carried by children to and from school have been the subject of recent attention (Mackie et al., 2003, 2004, 2005). Viry et al., (1999) found that these effects were larger in children who travelled to and from school on foot and in those who carried their schoolbag in their hand. Packing a load posteriorly in a limited amount of space increases the tendency to overload the bag (Tousignant, 2000; Iyer, 2001; Whittfield et al., 2001; DiJorio, 2001). Some studies have shown that more than 75% of junior students in the elementary and secondary schools of Italy and France are carrying their schoolbags in excess of 10% of their body mass (Sahrmann, 2002; Skoffer, 2007; Haselgrove et al., 2008). Viry et al., (1999) found children who carried schoolbags more than 20% of their body mass were at an increased risk of LBP requiring a physician visit. Concerns have been raised regarding the effects of schoolbag mass on adolescents, and Hong & Cheung, (2003) suggested a maximum permissible backpack load of 15% body mass based on their trunk inclination measurements. However, Goodgold et al., (2002) did not observe any mass-dependent response, and therefore suggested that care should be taken when using postural measurements as a basis for safe carrying loads. Concerns have also been raised regarding whether the recommended load limit of 15% of the body mass for normal

adolescent is acceptable (Chow et al., 2005). Some researchers suggest that the normal load of a bag is between 10% or 20% of the body mass (Devroey et al., 2007; Bauer et al., 2009), while more studies have shown the normal load of a bag is between 10-15% of the body mass (McCarthy et al., 2003; Hong et al., 2008). Grimmer & Williams, (2000) also found that children with LBP carried heavier bags relative to their body weight than those without LBP with a stronger association noted between load carrying and LBP for boys than girls.

## **2.5 The effect of schoolbags on musculoskeletal disorders**

Pascoe et al., (1997) found that the prolonged carrying of heavy backpacks could lead to symptoms of body soreness, aches, pains and tiredness in children. The child's spine differs from the adult spine in two important respects: (i) a child's skeleton has large amounts of cartilage that is susceptible to repetitive micro trauma, weakness of which decreases soft-tissue flexibility, induces muscle imbalances and can also lead to injury (Micheli & Fehlandt, 1992); (ii) the highest rate of growth occurs in school children when they are 10–15 years of age (Rowland, 1996) and they are thought to be less able to withstand the stresses that the adult spine can cope with (Grimmer & Williams, 2000). Repetitive static and dynamic loading of the spine constitutes a risk factor for lower back, shoulder and neck pain not only in adults but also in children (Balague et al., 1999; Chansirinukor et al., 2001; van Gent et al., 2003). External forces such as load carrying in the form of heavy bags may influence the normal growth, development of children and adolescents and also maintenance of alignment of their bodies. For this reason school children experience a period of accelerated growth and development of skeletal and soft tissues. Hence the spinal structures are quite different from those of adults. As the growth of the spinal structures continues over the long period of time than the other skeletal structures, there are dissimilarities in the rate of tissue development, which can pose a threat to postural integrity (Koley & Kaur, 2010). Therefore, load carrying

along with irregular spinal growth pattern can affect the adolescent posture and make the adolescent more susceptible to injury (Mohan et al., 2007).

Backpacks alter the students' unloaded posture and reposition it into a more strained or stressed improper, potentially unbalanced posture, with the addition of excessive external force (Chansirinukor et al., 2001; Grimmer et al., 2002). The developmental growing stages of the younger aged children may be more vulnerable to these external loads causing misalignments of the spine (DiJorio, 2001; Grimmer et al., 2002). These can be clinically recognised with symptoms of back, neck, and shoulder pain (Grimmer et al., 1999; Chansirinukor et al., 2001). The association of back pain with schoolbag use is controversial within the scientific literature with some studies finding no association and some finding an association (Cottalorda et al., 2004). Stresses acting on different zones of the spinal column are also of importance when considering load carriage. Vacheron et al., (1999) noted a decrease in inter-segmental mobility in both lumbar and lower thoracic regions of the spine whilst carrying a load on the shoulders. Compensation for this increased the range of motion in the cervical region, suggesting enhanced forward head posture (Attwells et al., 2006).

Between the ages of 12 – 14 years the spine is at its most critical stage of development (Tanner et al., 1976) and any stresses on the spine are reflected initially as pain and thereafter as deformity (Tanner et al., 1976; Vikat et al., 2000). Increasing schoolbag load causes a significantly increased flexion of the trunk in relation to the pelvis and extension of the head in relation to the trunk, as well as increased anteroposterior range of motion (Chow et al., 2005). While schoolbag load appears to affect balance predominantly in the anteroposterior direction, differences between groups were more evident in the medio-lateral direction (Chow et al., 2005). Viry et al., (1999) found an increased risk for LBP leading to absence from

school or sport for those children who carried their bag in one hand rather than on the shoulder harness. Grimmer & Williams, (2000) also found positive associations between longer periods of time spent carrying backpacks and LBP. A study by Pascoe et al., (1997) that considered the effect of carrying a schoolbag on the posture and gait of 11–13 year old children found that carrying a schoolbag decreased stride length, increased stride frequency and encouraged a forward lean of the trunk. Additionally, 73.4% of children used only one strap of their schoolbag to carry materials and books. One-strap bags seemed to encourage lateral spinal bending and shoulder elevation, while a two-strap back pack reduced these but significantly increased forward leaning of the head and trunk.

Fabris et al., (2004) suggested that applying a significant load to the spine for a sustained period resulted in deformation and abnormal changes to spinal tissues, which can become permanent. These changes may often result from unilateral myofascial forces acting on the musculoskeletal system, jamming spinal facet joints and irritating sensitive joint receptors. Whilst the generation of musculoskeletal pain by load carrying remains controversial (Cardon & Balague, 2004; Burton et al., 2006), abnormal postures induced by carrying a backpack have been considered as possible risk factors for musculoskeletal pain in school children (Negrini & Negrini, 2007).

## **2.6 Posture analysis**

Proper posture is considered to be a state of musculoskeletal balance that involves a minimal amount of stress or strain to the body (Griegel-Morris et al., 1992). Kendall et al., (2005) described a standard for normal sagittal alignment involving the theoretical straight line formed by the points of reference consisting of the lobe of the ear, the seventh cervical vertebra, the acromion, the greater trochanter, just anterior to the midline of the knee and

slightly anterior to the lateral malleolus. Deviation from normal alignment (i.e. postural abnormality) suggests the presence of imbalance and abnormal strain on the musculoskeletal system (Braun, 1991). Concerns have been raised regarding the effect of carrying a backpack on adolescent posture and balance (Chow et al., 2005). Human upright posture is inherently unstable and is maintained by continuous response to integrated sensory information from the visual, proprioceptive and vestibular systems (Shumway-Cook & Woollacott, 2001). Factors which have an impact on any of these sensory systems or the feedback mechanism may affect stance stability and balance (Chow et al., 2005). Posture and balance of upright stance (Kendall et al., 1983), are also influenced by external factors such as load carriage, which has been found to cause an increase in forward inclination of the trunk (Forssberg et al., 1982; Shumway-Cook & Woollacott, 1985; Karlin, 1986; Wojtys, 1987; Woollacott et al., 1989) and an increase in forward inclination of the head (Trott, 1994). While relatively little experimental data has been reported, load carriage has also been shown to affect standing balance (Chow et al., 2005). Forward head posture increased when carrying a backpack, especially one with a heavy load (Chansirinukor et al., 2001) and is found to negatively impact on the pupil's posture (by encouraging thoracic vertebral flexion), and gait (decreased in stride length and frequency) (Pascoe et al., 1997). The postural response to load is not fully developed in the child (Grimmer et al., 2000) and mobility of spinal bones, specifically the craniovertebral angle (Grimmer et al., 1999) is also altered, resulting in restricted movement, which are risk factors for back pain (Vikat et al., 2000). Part of the South Australian guidelines recommend that carrying a backpack should not significantly alter young people's posture from the sagittal and frontal view, backpacks should be worn over two shoulders and that the backpack weight should not exceed 10% of the pupil's body mass (Mackie et al., 2008).

Postural measures have been used to examine responses to schoolbag carriage (Pascoe et al., 1997; Grimmer et al., 2002; Hong & Cheung, 2003) based on the assertion that a posture that habitually deviates from gravitational alignment may be associated with spinal pain (Grimmer & Williams, 2000). Carrying heavy loads may also be a risk factor for lower back injury due to the increased stresses placed upon the back muscles and discs (Attwells et al., 2006). Based on self reports for postural behaviour, pupils who received the back posture programme in the elementary school curriculum integrated crucial sitting and lifting principles conform to biomechanical favourable postural behaviour (Geldof et al., 2007). Imbalances of the shoulder that has been affected by carrying an over-loaded bag due to the weakness of the upper trapezium (UT) muscle is a common cause of these disorders (McCarthy et al., 2003). Correct upright postures are considered to be a measure of good musculoskeletal health. Little is known about the usual variability of children's upright standing posture (McEvoy & Grimmer, 2005). Costs associated with musculoskeletal impairments in health and loss of work, have contributed to a growing interest in optimizing posture, particularly in relation to sitting positions associated with the use of visual display units (Straker & Mekhora, 2000) and standing posture in children in relation to backpack use (Steele et al., 2003).

### **2.6.1 Postural assessment**

There is no standard approach to measuring posture. Photographic observations of ideal posture have been ranked visually or simple equipment such as a tape measure, pencilled landmarks and a plumbline, have been used (Kendall et al., 1983). The linking of body landmarks has given angular measurements, allowing a more quantitative assessment of posture (Watsons & Mac Donncha, 2000). Watson & Mac Donncha, (2000) reported 85% reliability when ten aspects of adolescent photographic posture were qualitatively categorized

and rated. Straker & Mekhora, (2000) photographically evaluated sitting postures as a series of angles in adults working at visual screens. This method was reported in Straker et al., (1997) to have previously shown reliability in adults. Grimmer et al., (2002) adapted the measurements used by Straker & Mekhora (2000) to assess standing posture in adolescent high school students aged 12–18 years. Indeed the measurement of posture in children has received scant attention in the literature and little is known about the variability of children's standing posture (McEvoy & Grimmer, 2005).

## **2.7 Muscle activity**

Surface electromyography (EMG), a non-invasive method for the neuromuscular system investigation, is commonly used in ergonomic research to study the appearance of local muscle fatigue (Hagg et al., 2000; Piscione, 2006). Habibi, (2009) used a surface EMG to measure the muscle activity of the erector spinae and rectus abdominis muscles whilst carrying a schoolbag. The activity levels of erector spinae significantly decreased while carrying a backpack and increased with a shoulder bag and a front pack. Rectus abdominis revealed significantly higher EMG levels in the backpack trial. Asymmetrical activity between the right and the left part of the back muscles was clearly observed while carrying a shoulder bag with the weight at the right side of the body. The abdominal muscles revealed a slightly significant asymmetry for the shoulder bag and, surprisingly, also for the backpack. These findings suggest that the physical stresses associated with carrying book bags can be minimized by the design of a double pack. Asymmetry in muscle activity may indicate a failure of trunk stabilisation and contribute to the development of back pain (Motmans et al., 2006). EMG activity of rectus abdominis and erector spinae was recorded during 30 sec standing erect, beginning after 10 sec initial load carriage (Motmans et al., 2006). The EMG activity of erector spinae significantly decreased while carrying a backpack in a standing



position. This can be explained by two factors. With no load, the back muscles must resist a trunk flexion moment because the centre of gravity of the upper body is located somewhat forward of the lumbosacral joint. With a load on the back, the combined centre of gravity of the trunk plus the pack shifts backward. This creates an extension moment (Bobet & Norman, 1984). In order to counterbalance the weight on the back, a forward trunk lean occurs (Pascoe et al., 1997; Filaire et al., 2001). A forward displacement can already be seen with loads less than 10% the body mass (Grimmer et al., 2002). All these major shifts in body alignment can be interpreted as compensations to stabilize the whole-body centre of gravity over the feet (Bloom & Woodhull-McNeal, 1987). The net result of the back of the centre mass and the counterbalancing is a reduction in erector spinae activity. Cook & Neumann, (1987) also found a slight decrease in lumbar paraspinal EMG levels, but not significant, during the stance phase of each cycle of gait when adults carried a box of 10% and 20% body mass. According to the above theory, the rectus abdominis should work harder. Indeed, a strong increase of 54% left and 99% right occurred, compared to unloaded standing. Surprisingly, there was an asymmetry between the right and the left part of the abdominal muscle. Apparently the rectus abdominis is not used to stabilize the trunk in a standing position and fails to balance the trunk symmetrically under loaded backpack conditions. This asymmetrical pattern of muscle activity is comparable to that of patients with acute or chronic lower back pain (Finneran et al., 2003). This can be an interesting factor when considering lower back complaints (Motmans et al., 2006).

## **2.8 Results from previous schoolbag studies**

Data regarding the direct effect of backpack carriage on the spine in children appears to be limited to the work of Korovessis et al., (2005), who used a scoliometer to measure the immediate changes in lumbar lordosis and thoracic kyphosis in children when wearing their

school backpack over one shoulder as compared to the curvatures without a backpack. No immediate changes in curvature between the loaded and unloaded conditions were found (Chow et al., 2007). Grimmer et al., (2002) demonstrated that a lower backpack position in school students resulted in the least change in posture from an unloaded position. In adult studies, positioning the load in a backpack near the mid-back rather than just above shoulder level has been shown to decrease erector spinae and upper trapezius muscle activity (Bobet & Norman, 1984). Conversely, Bloom & Woodhull-McNeal, (1987) suggest that a lower load is closer to the ankles and therefore requires greater forward body rotation, in order to maintain stability. Also, in support of a high load position on the back, Stuempfle et al., (2004) found that loads carried higher on the back were more energy efficient. Bygrave et al., (2004) found that the tightness of backpack shoulder and chest straps significantly affected lung function in 12 healthy adults (Mackie et al., 2008).

Pascoe et al., (1997) investigated the impact on posture and gait kinematics of youths aged 11–13 years while carrying a 17% body mass load in a one-strap backpack, two-strap backpack and an athletic bag. A backpack promoted significant forward lean of head and trunk. When the book bag was carried over one shoulder, shoulder elevation and lateral spinal deviation away from the load was observed. A two-strap backpack reduced these stresses. Loaded walking also altered gait by decreasing the stride length and increasing the stride frequency (Motmans et al., 2006). These muscles control gross trunk movements and provide general trunk stability. The main finding was that load weight significantly affected posture, RPE and muscular strain and ability to walk and balance when the load carried reached 10% body mass. Based on these results and the rationale that posture that deviates from normal is more likely to cause MSD (Grimmer & Williams, 2000), it could be argued that carrying 10% body mass is more likely to cause MSD than carrying no load or 5% body mass.

However, for the purposes of determining a mass limit for schoolbag carriage, the postural results alone do not indicate a limit, as although the change in posture was directly proportional to mass carried, there were no disproportional change in posture at any given load that may have indicated a disproportional increase in physical strain. This finding is very similar to the proportional relationship between schoolbag mass and postural adjustment reported by Grimmer et al., (2002). It is more likely that carrying 15% body mass is the most likely condition to cause MSD as it caused the greatest change in posture (Mackie et al., 2008).

Overall, the questionnaire-based results suggest that although carrying 10% body mass was associated with a statistically significant increase in many measures, the participants did not report their load as being perceived as strenuous until they carried 15% body mass. When combined with the postural results, it could be argued that 15% body mass is excessive for schoolbag carriage (Mackie et al., 2008). In an attempt to provide objective support to schoolbag carriage recommendations, some studies have examined student's physiological (Hong et al., 2000; Lai & Jones, 2001; Li et al., 2003), postural (Pascoe et al., 1997; Grimmer et al., 2002; Hong & Cheung, 2003) and gait (Pascoe et al., 1997; Wang et al., 2001; Chow et al., 2005) responses to schoolbag carriage.

In children and adolescents, epidemiological evidence indicated lifetime prevalence for back pain varying from 13 to 51% and point prevalence ranging from 1 to 31% (Harreby et al., 1999; Jones et al., 2005). For the majority of the children, back pain experiences are non-specific and mild in nature (Jones et al., 2005) not leading to functional restrictions in their daily life (Staes et al., 2003; Jones et al., 2004). However, epidemiological research established a range of 7–27% children with recurrent lower back pain (Harreby et al., 1999). Children with recurrent or continuous back pain reported a reduced quality of life and were

found to use more medical attention and to consume more analgesics (Harreby et al., 1999). Besides, the findings of tracking studies consistently pointed out that back pain reports in childhood and early adolescence are significantly related to back pain reports in adulthood (Feldman et al., 2001; Brattberg, 2004).

Furthermore, the limited literature has indicated that the school environment exposes children to the possible loading factors with respect to prolonged poor sitting (Knight & Noyes, 1999; Murphy et al., 2004) and absence of appropriate furniture (Parcells et al., 1999; Limon et al., 2004; Milanese & Grimmer, 2004; Panagiotopoulou et al., 2004). Questionnaires have also been used to study responses to load carriage (Legg et al., 1997, 2003; Mackie et al., 2003; Stuempfle et al., 2004). Mackie et al., (2003) found significant differences in musculoskeletal discomfort (MSD) and preferred backpack when four backpacks that were intended for school use were compared using questionnaires (Mackie et al., 2008). Participants tended to respond to the increased load by flexing at the hips. Disproportionately less displacement occurred at the hip joint and the greatest changes in posture occurred approximately equally in the shoulder, C7, ear and eye (Mackie et al., 2008).

## **2.9 Intervention studies in a school setting**

The majority of intervention studies undertaken to date in a school environment have focused on comfort and involved the introduction and evaluation of school furniture (Linton et al., 1994; Aagaard-Hansen & Storr-Paulsen, 1995; Marschall et al., 1995; Taylour & Crawford, 1996; Knight & Noyes, 1999; Troussier et al., 1999). The majority of studies indicated that the standards for school furniture seemed to be inappropriate and gave evidence that the inclination of the seat should be forward and that it should be possible to adjust the tabletop to a certain non-horizontal angle. De Wall et al., (1991) compared students working at a flat desk with one that had a 10 degree inclination and found no significant difference for the

angle between the head and trunk. Linton et al., (1994) randomly assigned three classes of 10 year olds to control and intervention groups and provided those in the intervention group with ergonomic furniture. The intervention ran for a 6 month period and was assessed using comfort, posture and pain symptoms. Linton et al., (1994) found there to be a reduction of musculoskeletal disorders among the intervention group relative to the control group after the intervention ( $p < 0.05$ ) and at 5 month follow-up ( $p < 0.04$ ). The intervention group also rated their furniture as being significantly more comfortable ( $p < 0.001$ ) than the control group. Aagaard-Hansen & Storr-Paulsen, (1995) carried out a prospective study to compare three different types of furniture and found the highest tilting desk and chair to be perceived as significantly better than the other two ( $p < 0.0005$ ). Feedback regarding the tilt tabletop was overwhelmingly positive independent of the height of furniture.

Apart from intervention studies involving school furniture, few other intervention studies have been undertaken in a school environment (Robertson & Lee, 1990; Towner & Marvel, 1992; Balague' et al., 1994; Gortmaker et al., 1999; Cardon et al., 2000; Stevens et al., 2000; Feingold & Jacobs, 2002). Back care education has however received some attention. Robertson & Lee, (1990) studied the effect of back care education on students aged 10–12 years and found that instruction/training sessions on back care can have an immediate effect on students' sitting and lifting behaviours. Limitations in the study included the short-term nature of the intervention (three 1 h lessons) and the assessment process that took place at the beginning and end of each session. Feingold & Jacobs, (2002) provided education to children (mean age 12.7 years) about backpack wearing and reported an improvement in the method of carrying by the intervention group.

Cardon et al., (2002) also reported the efficacy of back care education in elementary school children. The majority of intervention studies previously undertaken in a school environment

have been of short-term duration. Results may have been influenced by the Hawthorne effect, process used for evaluation and short time period between intervention completion and evaluation. The longer-term effects of these interventions remain unknown. Mixed findings are reported particularly in interventions aimed at achieving behavioural change, thus highlighting the difficulties associated with such research. Sitting posture and load carrying are possible risk factors for both child and adult populations and should also be included in an intervention aimed at reducing back pain among school children. The intervention strategy that is proposed as a result of the present literature review has four main components. These are: school policy, school equipment and furniture, individual and family.

## **2.10 Conclusion**

There is growing concern among educators, health-care professionals, parents, and legislators that back pain is becoming a serious health issue in school-aged children due to the increased use of heavy backpacks (Wall et al., 2003). A load of 10% body mass can be carried without requiring extra muscle activity whilst standing erect (Voll & Klimt, 1977). It may be a challenge for product designers to develop a double pack as a schoolbag and reduce some practical disadvantages. The traditional backpack reduced the EMG muscle activity of erector spinae. However, rectus abdominis fails to stabilize the trunk symmetrically. A front pack showed a global higher working rate, especially for the back muscles. A shoulder bag should be avoided, because of the asymmetric muscle activity (Motmans et al., 2006).

The following are points which should be taken into consideration to alleviate musculoskeletal disorders amongst children and in turn allow them to live an improved pain free lifestyle (Trevelyan & Legg, 2006):

## **School policy**

- Sitting posture—the number of hour’s children spend sitting, i.e., length of a lesson and timetabling.
- Load carrying—school policy with respect to the provision of lockers, the aims being to minimise both the weight of schoolbags and the time that children spend carrying them.
- Education — include a programme of education in the school curriculum that includes back care advice and information about the risk factors for back pain.
- Social support—provide support system for children who have a high frequency of symptom reporting, e.g., headache, stomach ache and behavioural problems, e.g., hyperactivity, conduct and bullying.
- Consider the appointment of a school counsellor.

## **School equipment and furniture**

- Sitting posture—provide ergonomically designed furniture that meets modern specifications and is matched to student size based on the current literature.
- Lockers—encourage students to use a locker to store items while they are not required

## **Individual**

- Education—include in school programme education about sports (the positive aspects of sport with caution regarding the risks associated with competitive sports and a high level of physical activity), exercise programmes (stretching), load carrying (the recommended weight, configuration and method of packing and carrying a school bag) and sitting posture.

## **Family**

- Education—involve parents in programme—provide information regarding the prevalence of back pain among school children, risk factors associated with back pain and the action taken by the school to reduce the problem.
- Provide opportunity/forum for parents to be included in intervention programme—provide advice regarding exercise for adults and children, prevention and positive management of back pain.



## **CHAPTER THREE: METHODOLOGY**

### **3.1 Methodology**

This chapter describes the experimental design, selection of subjects, and procedures of testing. It further describes the testing procedures and instruments used in the data collection process. Ethical clearance was obtained from the Human and Social Science Ethics Committee (HSS/0184/2010 M) (Appendix G) of the University of KwaZulu-Natal.

### **3.2 Experimental design**

#### **3.2.1 Recruitment and sample selection**

The research participants in this study were from four schools around the region of eThekweni, KwaZulu-Natal. These schools were selected based on their easy accessibility and willingness to participate. One hundred and eighty seven (n=187), grade seven pupils, aged 11 - 13 years (as their bones are at a critical stage of development (Puckree et al., 2004), voluntarily participated in the study. All the pupils were requested to complete a self reported questionnaire which was adapted from Puckree et al., (2004) (Appendix B). These pupils were only identified by numbers which was assigned to each pupil at the outset of the study to ensure anonymity. Two of the four schools were chosen for the experimental study (n=82).

The recruitment and selection of subjects were undertaken in the following way:

1 Correspondence was sent to the Department of Education informing the department of the nature of the study (Appendix E). Permission was subsequently granted (Appendix H).

2 Correspondence was sent to the Board of Governors and Principals of the necessary schools to attain access to their grade seven pupils (Appendix F).

3 Correspondence and informed assent forms were then sent to parents of pupils from the respective schools to gain permission for their children to participate in the study (Appendix C and D). A power point presentation was also delivered to respective officials and parents to clarify the aims and objectives as well as the procedure for the study.

All participants read and comprehended the information document explaining the research in addition to the researcher explaining the study to the participants (Appendix C). The document outlined the risks and discomfort, responsibilities of the participant, confidentiality and freedom of consent. Subjects were reminded and given the opportunity to withdraw consent and/or discontinue participation at any time without any form of disadvantage to them. The subjects were reassured that all the data would be treated with confidentiality. Parental informed consent was obtained by all the participants before any data was collected and recorded (Appendix D).

### **3.2.2 Phases of the study**

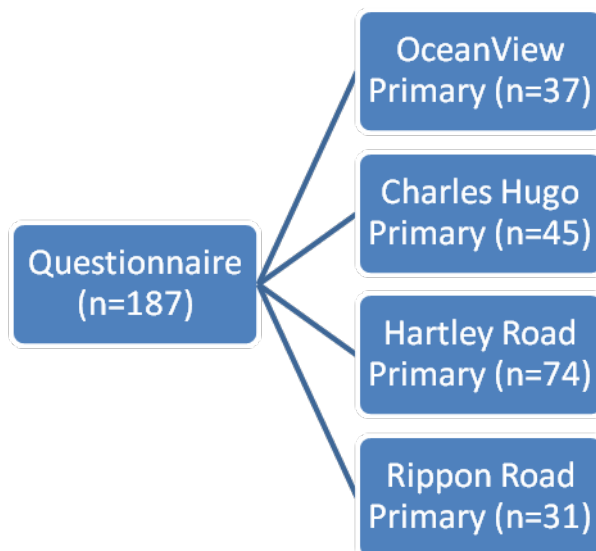
#### **Phase One**

- School visits by the researchers to inform the school principals and educators about the study.
- Training of the research assistant to assist with the testing procedure.

- PowerPoint presentation to the pupils informing them about the significance for the study and the testing procedure.

## Phase Two

- Questionnaires (Appendix B), information sheets (Appendix C) and informed assent forms (Appendix D) were administered to the pupils.



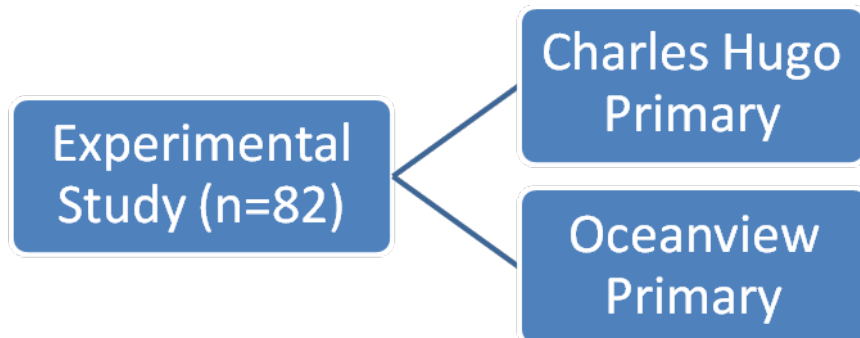
**Figure 1: Division of Questionnaire distribution**

## Phases Three

- Collection of questionnaires and completed informed assent forms signed by the parents.
- Weighing of the schoolbags of the pupils who were granted permission to participate in the study.

## Phase Four

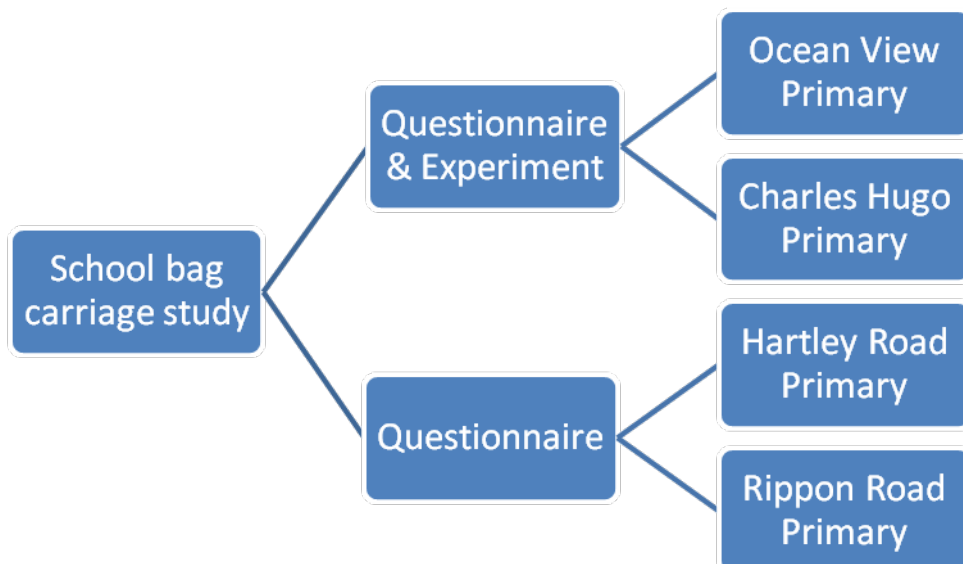
- Identification of two schools to participate in the experimental study.



**Figure 2: Identification of pupils to participate phase four (experimental study)**

## Phase Five

- Collection of experimental data from the sample (n=82).



**Figure 3: Division of the sample population**

### **3.2.3 Experimental setting and testing procedure**

The testing was completed at the school hall of the respective schools. Each test was standardised by having a single tester per station that completed all the tests throughout the study. Both graduate research assistants were thoroughly grounded with regards to the testing protocol to ensure reliability and validity of data gathered.

All equipment was calibrated prior to testing to ensure reliability and validity of the tools used. The same measuring instruments were used throughout the data collection to ensure reliability and validity of data collected. Prior to commencing the experimental study, all subjects who volunteered to participate in the study and who met the inclusion criteria, completed a self reported questionnaire adapted from Puckree et al., (2004) (Appendix B). Each questionnaire consisted of six sections, namely, personal details, medical history, school activities, activities out of school, schoolbag data and pain and discomfort pertaining to back packs. The personal details section required subjects to record their age, gender, race, grade and mode of transport. The medical history section required details of current and previous medical illnesses or medical conditions. Activities during school referred to sporting activities that the subject participated in as well as the frequency and duration of the activity while activities out of school indicated additional activities of the participant. The section on schoolbags referred to the type of schoolbag and the preferred method of carriage as well as the duration and distance of carriage. Section six which was titled pain and discomfort and required information regarding the type, frequency, intensity and duration of pain, relieving and aggravating factors and mode of treatment of pain.

The mean mass of the schoolbag of the cohort was calculated and this served to be the mass of the intervention applied to the experimental group. Upon commencing with the experimental study, all individuals were weighed using a calibrated Detecto scale and stature was measured on a stadiometer. A posture profile was then completed on all subjects in the unloaded state and digital images were then taken. Electromyographic measures were taken at this stage. The anatomical landmarks were then identified and craniovertebral angles taken. The procedure was then repeated with a load being imposed onto the shoulders of the participants.

#### **3.2.4 Data Collection**

The researcher stressed the importance of accuracy when recording stature, body mass, mass of schoolbag, the measurement of the craniovertebral angle, the position of the subject during the digital imaging, the standardization of the electromyographic readings and posture profiling. The researcher requested the help of the parents of the participating pupils to aid in the completion of the questionnaire at home and to return the document the following day.

### **3.3 The measurement of anthropometrical indices**

Specific tests were selected which were reliable and valid for the purpose of this study. Standardised methods of testing were employed conforming to criteria set by ACSM (ACSM, 2010). The test selected for the evaluation of anthropometrical indices were stature, body mass, body mass index and craniovertebral angle. The subjects were briefed and familiar with the equipment prior to testing.

### **3.4 Description of the testing protocols**

In this section the testing methods, techniques and protocols will be described for each test selected.

#### **3.4.1 Anthropometrical indices**

A brief description of the methods used in the evaluation of anthropometrical characteristics of the subjects is presented below and include: stature, body mass, body mass index, questionnaire, posture profile, electromyographic measures, digital images and measurement of craniovertebral angle.

##### **3.4.1.1 Stature (Norton et al., 1996)**

**Purpose:** To record the standing height of each pupil.

**Equipment:** A Stadiometre

**Method:** The stature of each subject was measured barefoot. The subject stood in the anatomical position with the head held in the Frankfurt plane, heels, buttocks, and upper part of the back resting against the stadiometer and with arms hanging naturally at the sides. The stature determined was the highest point of the head, looking straight ahead.

**Interpretation:** The stature was recorded in centimetres (cm) to nearest 0.5 cm.

### 3.4.1.2 Body mass (Norton et al., 1996)

**Purpose:** To record the body mass of each subject.

**Equipment:** A Detecto scale

**Method:** The subjects stood vertically in the anatomical position on the scale. All subjects were barefoot. Boys were asked to remove their school shirts while girls wore cropped tops and all pupils wore shorts to ensure limited amounts of clothing were worn and the process was standardised.

**Interpretation:** The body mass was recorded in kilograms (kg) to the nearest 0.5 kg.

### 3.4.1.3 Body mass index (Bray, 1993)

**Purpose:** To provide an indication of the relationship between body mass and stature.

**Method:** The body mass index (BMI) was computed with the following equation:

$$\text{BMI} = \frac{\text{body mass (kilograms)}}{\text{Stature (metres}^2\text{)}}$$



**Interpretation:** According to the American College of Sports Medicine, (2010) standards, BMI is classified accordingly:

**Table 1: Classifications of Body Mass Index (BMI)**

<b>Ranges</b>	<b>Category</b>
< 18.5	Underweight
18.5 - 24.9	Normal weight
25.0 - 29.9	Overweight
30.0 - 34.9	Obesity class I
35.0 - 39.9	Obesity class Ii
> 40.0	Obesity II

#### **3.4.1.4 Questionnaire (adapted from Puckree et al., 2004)**

**Purpose:** To record the prevalence of musculoskeletal disorders and pain associated with schoolbag carriage. (Appendix B)

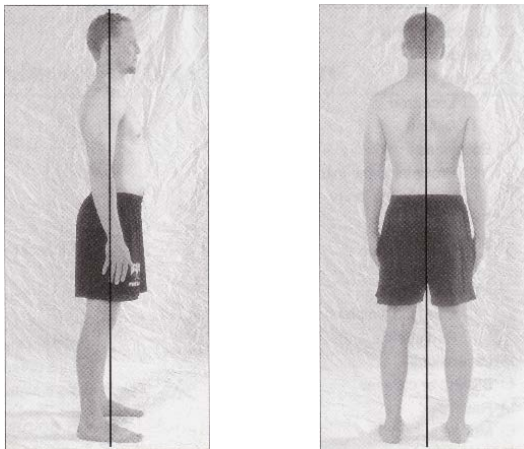
#### **3.4.1.5 Posture profile (Ellapen et al., 2009)**

**Purpose:** To identify altered postural alignment due to repetitive shoobag loading.

**Method:** Subjects stood in the anatomical position against a portable posture chart and static postural alignment was assessed in both the loaded and unloaded stances. All subjects stood

barefoot with a vest or strappy top, for females, to identify postural deviations in the frontal view which included scoliosis, genu varum and genu valgum while deviations in the sagittal views included cervical postural syndrome, kyphosis, lordosis, ptosis and genu recurvatum (Appendix A).

**Equipment:** A portable posture profile chart.



**Figure 4: Posture profiling in the Sagittal and Frontal planes**

#### **3.4.1.6 Electromyographic measures (Ellapen et al., 2009)**

**Purpose:** An EMG (NeuroTrac ETS 100) was employed to measure muscle activity of the sternocleidomastoid and upper trapezius muscles. This indicated changes in muscle activity during the unloaded and loaded phases.

**Equipment:** Electromyography machine (NeuroTrac ETS 100), electrodes and alcohol swabs.

**Method:** Alcohol swabs were used to sanitize the subject's skin and surface hair was removed so as not to interfere with conduction of the electrical current before the electrodes were placed on the appropriate muscles. The electrodes were placed on the belly of the muscle. Subject's muscle activity was measured with and without the application of the load. The average force generated by the muscle for 30 seconds was recorded. An average of 2 measures was recorded.

#### **3.4.1.7 Digital images (Ellapen et al., 2009)**

**Purpose:** To capture the changes in the frontal and sagittal planes.

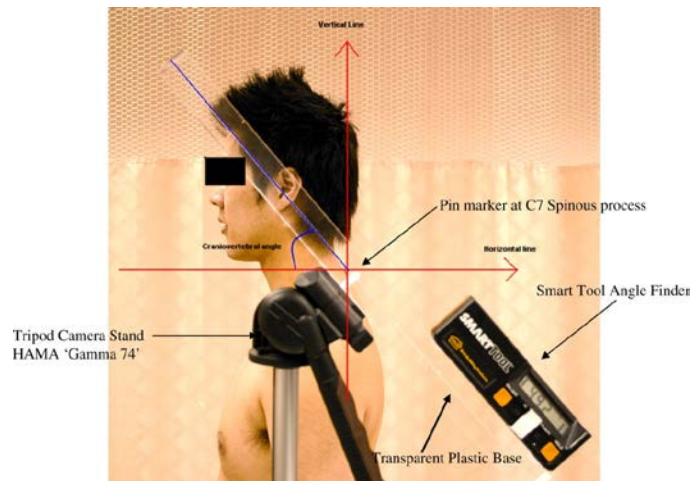
**Equipment:** Digital camera (Panasonic Lumix DMC-F3), tripod stand and Dartfish 3.0 Biomechanical Analysis Software.

**Method:** All subjects were captured in the anatomical position in the frontal and sagittal planes. This was completed during the loaded (carrying the schoolbag) and unloaded position (without a schoolbag).

#### **3.4.1.8 Craniovertebral angle (Lau et al., 2009)**

**Purpose:** To measure changes in head on neck posture.

**Equipment:** A Smart tool angle finder, tripod stand and digital camera.



**Figure 5: Measurement of the Craniovertebral Angle (CVA)**

**Method:** The smart tool angle finder was put on the standardised marking on the floor and the tripod stand was adjusted into the position until the bubble of the horizontal indicator and the central marking overlapped. The distance from the subject to the centre of the tripod stand was standardized to 0.3 m. The participants were asked to put on sportswear in order to expose their neck and the upper thoracic spine. They were also required to remove their socks and shoes. The seventh cervical (C7) spinous process was palpated and identified and an adhesive marker was attached over its midpoint of the most prominent part. The subject was then asked to stand with his/her left shoulder in front of the tripod stand. Another marker was fixed at tragus of his/her left ear. The subject was instructed to stand comfortably with their weight distribution evenly on both feet and to keep their eyes looking straight ahead. He/she was then instructed to flex and extend the head for three times and then rest it in a comfortable position. A virtual line was drawn between the two pin makers from midpoints of the tragus to C7. The reading from the Angle Finder represented the CV angle (Lau et al., 2009).

**Interpretation:** The angle was measured in degrees (°).

### **3.5 Statistical procedure**

The data was analysed descriptively and inferentially. Descriptive statistics included mean, mode, percentages and frequency. Inferential statistical analysis involved chi-square and independent t-tests ( $p < 0.05$ ).

## CHAPTER FOUR – RESULTS AND DISCUSSION

### 4. Introduction

This chapter provides analyses of the results gathered in the current study. A detailed description of the results and a discussion will be presented under the following headings:

- 4.1 Demographics of the pupils
- 4.2 Prevalence of musculoskeletal pain due to schoolbag carriage
- 4.3 Medical history
- 4.4 Type of schoolbag carried
- 4.5 Anatomical site of musculoskeletal pain due to schoolbag carriage
- 4.6 Intensity of the different types of musculoskeletal pain sensations experienced due to schoolbag carriage
- 4.7 Physical Activity (PA) and Sport Participation (SP)
- 4.8 Risk factors associated with schoolbag carriage promoting musculoskeletal pain
  - 4.9.1 The Experimental study
  - 4.9.2 Posture Analysis
  - 4.9.3 Craniovertebral Angles (CVA)
  - 4.9.4 Electromyographical Muscular activity (EMG) associated with schoolbag carriage
  - 4.9.5 Analysis of the digital images

#### 4.1 Demographics of the pupils

The demographical information pertaining to the cohort is displayed in Table 2. All demographical data was stratified into gender, race, age, and stature, body mass, body mass index (BMI) and bag mass.

**Table 2: Mean demographical data of the cohort of pupils (n=187)**

Variables	Indian		African		Coloured		Overall (n=187)
	Male (n=53)	Female (n=51)	Male (n=24)	Female (n=40)	Male (n=9)	Female (n=10)	
Age (years)	12.45	12.33	12.71	12.40	12.56	12.00	12.41
Stature (m)	1.56	1.54	1.55	1.55	1.56	1.54	1.55
Body Mass (kg)	48.55	45.42	49.01	52.9	41.33	47.25	47.41
BMI (kg/m <sup>2</sup> )	19.92	19.02	20.22	21.83	17.02	19.86	19.65
Bag Mass (kg)	6.9	6.40	4.29	5.41	4.5	5.2	5.45

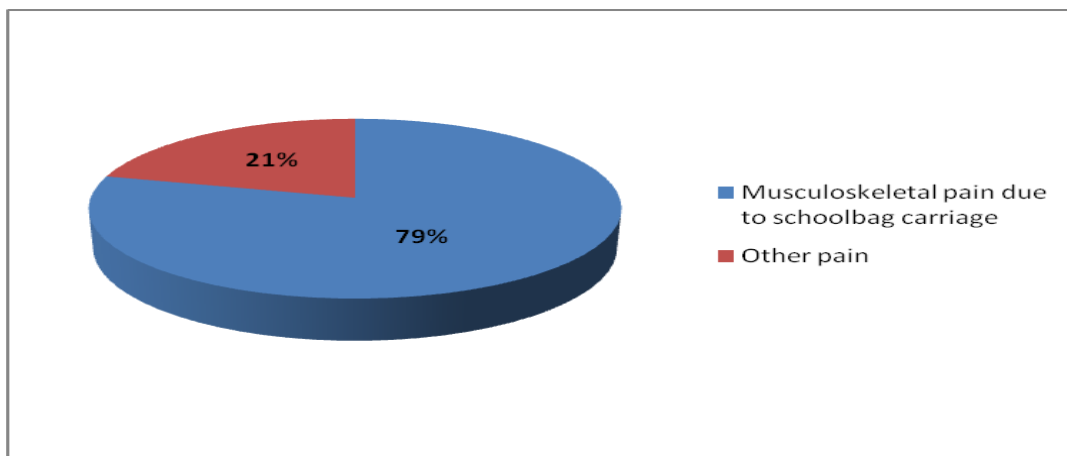
The results from the table 2 reveal that on average the cohort carried bag masses which equated to 11.5% of their body mass. The rule of thumb as proposed by Voll & Klimt, (1977) states that the bag mass should not exceeded 10% of the pupil's body mass. Iyer, (2001) found that Indian children carried schoolbags weighing 18.5% of their body mass. In the current study, Indian male and female pupils carried, on average, bag masses equating to 14.21% and 14.09% respectively of their body mass. African male pupils had the lowest (8.75%) average bag mass to body mass percentage.

One hundred and fifty two (81.28%) ( $p < 0.0001$ ) pupils indicated their preferred choices of schoolbags were to carry a double strap backpack, whilst thirty one (16.58%) a sling or single strapped bag and the remaining four (2.14%) a roller bag. This was further divided into pupils without musculoskeletal pain and pupils with musculoskeletal pain as a result of schoolbag carriage.

#### **4.2 Prevalence of musculoskeletal pain due to schoolbag carriage**

Among the 187 pupils surveyed, 119 (63.64%) experienced musculoskeletal pain of which 94 (78.99%) experienced musculoskeletal pain related to schoolbag carriage ( $p < 0.0001$ ). These findings correspond with other international injury surveys which recorded the prevalence of back pack related musculoskeletal pain (Grimmer & Williams, 2000; Whittfield et al., 2001). Puckree et al., (2004) sought to determine the relationship between schoolbag carriage and pain in scholars. The researchers wanted to link the type of bag carried, either double strap backpack or single strap bag, the manner in which it was carried, over one or two shoulders and the load that was carried, either more or less than 10% of body mass, to the pain experienced by scholars. The findings indicated that 86.9% of the pupils which participated in the study experienced bodily pain. This was indeed as a result of carrying heavy schoolbags every day.





**Figure 6: Musculoskeletal pain experienced amongst the pupils (n=119) (p<0.0001)**

### **4.3 Medical history**

Pupils were requested to indicate if they had any past or present musculoskeletal illnesses or diseases which were diagnosed by a medical practitioner. These included Scheuermanns Disease, Scoliosis, Lordosis, Osgood’s Shatters’ Disease, Sinding Larsen Johansson Disease or Severs Disease. The exclusion criterion of the study was a pupil being diagnosed with a musculoskeletal condition by a medical practitioner. The pupils indicated that n=45 (24.06%) of the cohort had a musculoskeletal pathology either at present or in the past. However, these pupils were not excluded from participation in the study due to the fact that none of the respective pathologies were diagnosed by a medical practitioner. Fifty-nine (23.98%) pupils were excluded from the study due to the pupils not meeting the inclusion criteria (i.e. age and registration at one of the four senior primary academic institutions), not gaining parental informed consent, absenteeism or inadequately completing the questionnaires.

#### 4.4 Type of schoolbag carried

Ninety-four pupils (78.99%) ( $p < 0.0001$ ) indicated that they experienced musculoskeletal pain due to schoolbag carriage. Those pupils who complained of schoolbag related MSP indicated that 76.6% ( $n=72$ ) carried a double strap backpack, 20.21% ( $n=19$ ) carried a sling or single strapped bag and 3.19% ( $n=3$ ) used a roller bag ( $p < 0.0001$ ). The pupils were requested to indicate at which time during the day they experienced the most severe pain and were given the following choices in the questionnaire: a) whilst carrying their schoolbag, b) when the schoolbag was removed or c) if they had pain all the time. More females ( $n=38$ ) (40.43%) than males ( $n=24$ ) (25.53%) indicated they experienced pain whilst carrying their schoolbag ( $p < 0.0001$ ), while 16 females (17.02%) and eight males (8.51%) experienced pain when they removed their schoolbag ( $p < 0.001$ ) and six females (6.38%) and two males (2.13%) had experienced pain all the time ( $p < 0.05$ ). These results concur with other epidemiological findings which indicated that females experienced more MSP than males (Grimmer & Williams, 2000; Watson et al., 2002; Mohd et al., 2010). This could be due to the gender differences as the physical and physiological characteristics of males and females are different and both differ in their muscle strength as females tend to have lower muscle strength than males, particularly in the upper limb musculature (Katzmarzyk et al., 1998). Females also have greater body awareness and lower pain thresholds (Breithecker et al., 2004) and thus tend to complain more than males. An explanation of the findings, Leboeuf & Kyvik, (1998) proposed earlier maturity and the onset of puberty as a possible explanation for greater reporting of pain among females. On the other hand, Balague´ et al., (1995) theorised that the traditional image of the male led boys to underreport their back pain.

The majority of the pupils ( $n=72$ , 76.6%) ( $p < 0.0001$ ) that experienced schoolbag related musculoskeletal pain carried backpack type schoolbags. However, 49 (68.06%) of the 72

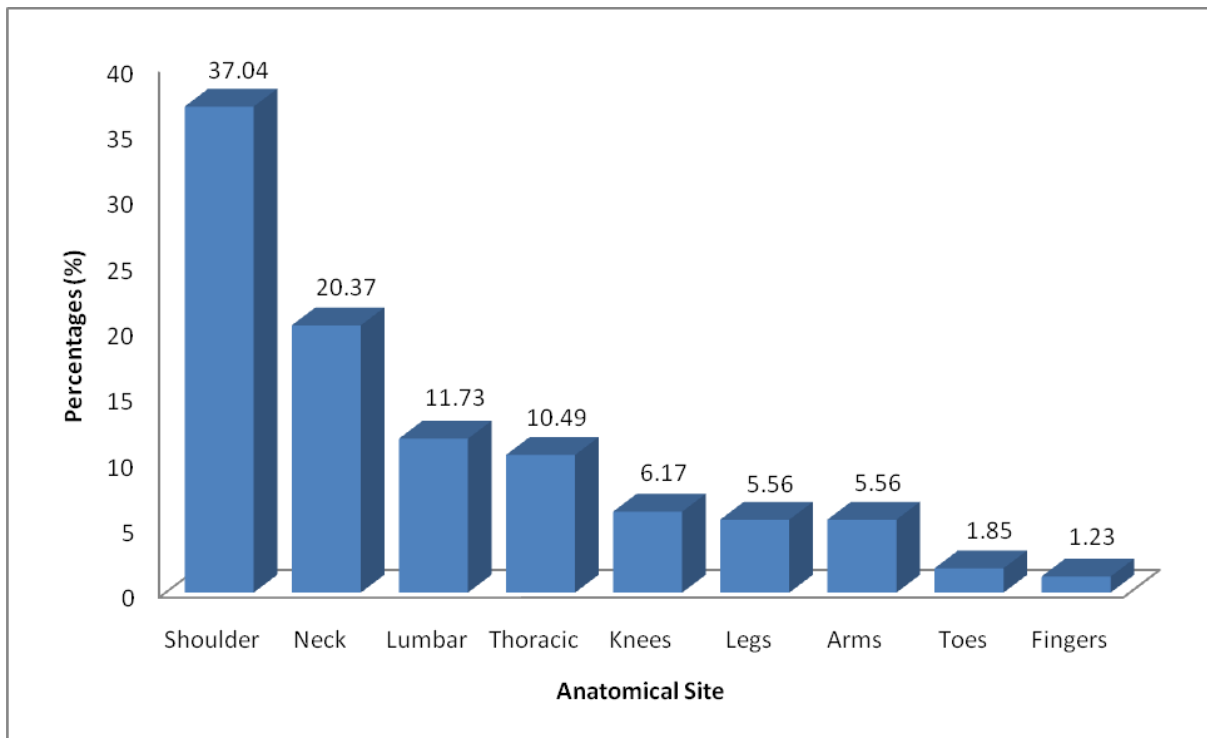
pupils who carried backpacks carried the schoolbag over both shoulders, while the other 23 (31.94%) carried the schoolbag over one shoulder (either the right or left). Nineteen (20.21%) of the pupils who experienced schoolbag related musculoskeletal pain carried a single strapped bag. These findings are similar to that of Puckree et al., (2004) whereby 60 pupils carried backpacks on two shoulders, compared to the 53 who carried single strap bags and the researchers identified that significantly fewer children ( $p < 0.05$ ) who carried backpacks on a single shoulder complained of pain. Guyer et al., (2001) and Steele et al., (2001) both showed that the type of bag carried does significantly increase the prevalence of schoolbag related musculoskeletal pain reported. The use of a backpack, which is worn over both the shoulders, caused the shoulders to become depressed as the mass of the bag is compressing on the shoulders. As an external mass is loaded onto the trunk, the pupils assumed an altered posture from their normal standing position which is seen as a kyphotic posture to balance the load placed onto their shoulders. Additionally, the pupils also assumed a forward head posture to ensure that they were able to maintain their centre of gravity over both feet to prevent themselves from falling over. However, the pupils that carried a single strapped bag presented with a depression in the ipsilateral shoulder. Simultaneously, the contra-lateral shoulder would become elevated to ensure a balanced position and again prevented the pupils from falling over. This would also cause the pupils to alter their head positions thus causing the neck muscles on the ipsi-lateral side to become lengthened while the muscles on the contra-lateral side shortened.

Additionally, 63.83% ( $n=60$ ) ( $p < 0.01$ ) of the pupils who complained of schoolbag related MSP carried an additional bag to school. The additional bags were for extracurricular sporting activities after school or to attend religious classes. This suggests that these pupils were most definitely loading their immature spinal columns with loads greater than the recommended daily allowance of 10% of their body mass (Voll & Klimt, 1977). Mackie,

(2008) confirmed that carrying a schoolbag which was 10% of the body mass was a sufficient load to induce a significant change in posture from the unloaded condition. This additional bag contributed to the increase in the load carried by the pupils which induced postural changes and an increased the risk for MSP.

#### **4.5 Anatomical site of musculoskeletal pain due to schoolbag carriage**

The most prevalent anatomical landmarks at which the pupils experienced musculoskeletal pain due to schoolbag carriage were; shoulder, neck, lumbar, thoracic, knees, legs, arm, toes and finger (Figure 7) ( $p < 0.0001$ ). This was as a direct result of loading of the spine. The results of carrying a heavy backpack mass among adolescent pupils (in excess of 10%) for prolonged periods of time precipitates muscle soreness and ligament sprains along the vertebral column and shoulders (Chansirinukor et al., 2001; Siambanes et al., 2004; Mohan et al., 2007). This extra load influences the structure of neck on upper trunk position. The altered rounded posture of the shoulder has been associated with muscle asymmetry, yielding impingement syndrome, neck pain and headache (Travell & Simmons, 1992). These results correspond to other epidemiological studies such as Mohd et al., (2010) who indicated that neck pain was the most prevalent musculoskeletal disorder among schoolchildren, followed by upper and lower back. Forward head posture is a common postural deviation among patients with neck disorders (Hickey et al., 2000). Johnson, (1998) suggested that persisted forward head posture increases loading of the cervical joints causing abnormal stresses on the posterior cervical structures and cause myofascial pain.



**Figure 7 : Prevalence of schoolbag related musculoskeletal pain at specific anatomical locations (n=94) (p<0.0001)**

The high prevalence of pain in the neck and shoulder region suggests that there was a high level of neck flexion as well as deviated standing postures (Grimmer et al., 1999). However, the occurrence of musculoskeletal disorders may also be contributed by the way the schoolbags are carried, which induced the forward leaning of the head and trunk as suggested by Pascoe et al., (1997). Posture of the head and neck has long been recognized as a factor contributing to the onset and perpetuation of cervical pain and dysfunction (Harrison et al., 2005; Persson et al., 2007). In many previous studies, investigators suggested that there were associations between the forward head posture and neck pain and disability (Griegel-Morris et al., 1992; Szeto et al., 2002). They found that those subjects with head, neck and shoulder discomfort or pain are more likely to have a smaller CV angle.

The heavier the backpack, the more pressure it exerts on the spinal column and anterior muscles as these pupils will move into a kyphotic posture an attempt to support the weight on the back rather than on their shoulders (Lai & Jones, 2001). These postural imbalances trigger a condition called vertebral subluxation (Steele et al., 2001) which leads to restricted movement of the dysfunctional areas in the spine and predisposes patients to a number of ailments such as neck and back pain, headaches and osteoarthritis. Wedderkopp et al., (2001) suggested that the spine and musculoskeletal disorders should be considered as 3 distinct entities (the neck, upper back and lower back pain). Additionally, Murphy et al., (2007) stated that when children feel uncomfortable, they may have to adopt flexed or static postures for prolonged periods of time, increasing muscular fatigue in the neck and shoulder thus leading to musculoskeletal pain. Heavy bags also cause a significant increased flexion of the trunk in relation to the pelvis and extension of the head in relation to the trunk (Chow et al., 2006). This is a possible causative factor for the onset of back and shoulder pain.

#### **4.6 Intensity and types of musculoskeletal pain associated with schoolbag carriage**

The Kee & Seo Pain Rating Scale, (2007) which ranged from 1-5, (uncomfortable = 1 and severe = 5) was used to determine the intensity of schoolbag carriage musculoskeletal pain experienced by the pupils. The findings of the intensity of schoolbag related musculoskeletal pain is described in table 3.

**Table 3: Intensity of musculoskeletal pain associated with schoolbag carriage (n=94)**  
(p<0.05)

<b>Intensity of Pain</b>	<b>Rating</b>	<b>Percentages</b>	<b>Significance (p&lt;0.05)</b>
Uncomfortable	(1)	36.17%	p > 0.0001
Manageable	(2)	28.72%	p > 0.0001
Moderate	(3)	25.53%	p > 0.0001
Severe	(4)	5.32%	p > 0.0001
Unbearable	(5)	4.23%	p > 0.01

### **Types of pain**

The pupils who experienced musculoskeletal pain were requested to indicate what type of sensations they experienced. Table 4 summarises the different types of pain experienced.

**Table 4: Types of musculoskeletal pain associated with schoolbag carriage (n=94)**  
(p<0.05)

<b>Types of Pain</b>	<b>Percentages</b>	<b>Significance (p&lt;0.05)</b>
Sharp	36.36%	p < 0.01
Dull	30.30%	p < 0.05
Pins and needles	22.22%	p < 0.05
Radiating	11.11%	p < 0.05

Results from table 4 indicate that the majority (66.66%) of the pupils experienced muscular pathologies. This was indicative of sharp and dull sensations. The remaining (33.33%) of the pupils experienced pins and needles and radiating pains which were indicative of neural pathologies.

A total 69.69% ( $p < 0.05$ ) of the pupils complained of sharp (36.36%), radiating (11.11%), pins and needles (22.22%) sensations whilst 30.30% ( $p < 0.05$ ) of the pupils who carried backpack type schoolbags reported dull aching pain (Table 4). These pupils indicated the intensity – see table 3, of the musculoskeletal pain experienced, as follows: uncomfortable (36.17%) followed by manageable (28.72%), moderate (25.53%), severe (5.32%) and unbearable (4.23) ( $p < 0.0001$ ). The pupils could not report on the prevalence of musculoskeletal injuries due to the fact that these claims of musculoskeletal injuries could not be substantiated by medical records; however the pupils identification of types of musculoskeletal pain (such as dull aching, radiating, sharp shooting, and pins and needles), intensity of pain (severity of pain according to the Kee & Seo Pain Rating Scale) and anatomical location was recorded to infer musculoskeletal injury (as stated by Hagglund et al., 2005; Fuller et al., 2006). These pupils presented with typical musculoskeletal and neural pathologies. Prentice, (2004) and Brukner & Khan, (2006) identify dull aching, sharp pain sensations as muscle pain, whilst pins and needles and radiating sensations to be neural pathology. Pain receptors in the muscles are sensitive to a variety of mechanical stimuli including pressure and stretching. Those muscles which experience pain are usually abnormally shortened, with increased tone and tension due to spasm or over contraction. This is indicative of myofascial pain which is characterised by muscles which are in the shortened or contracted state, with increased tone and stiffness and which contain trigger points. Palpation of these trigger points also cause radiating, aching pain into localized reference zones (Dorsher, 2009). Myofascial pain may become symptomatic as a result of repetitive strain, postural dysfunction or physical deconditioning. Myofascial pain can occur at the site of tissue damage or as a result of radicular damage and other neuropathic disorders at sites when pain is referred. Muscles which are affected by neuropathic pain may be injured due to prolonged spasm or mechanical overload (Gerwin, 2005). If these pathologies are left



unattended this may lead to an increase in the severity of the pain experienced over a period of time leading into a chronic pathology (Gerwin, 2005).

#### **4.7 Physical Activity (PA) and Sport Participation (SP)**

Results from the questionnaire determined PA and SP during selected time periods, namely, Life Orientation (LO) lessons; lunch-breaks; after school and club level.

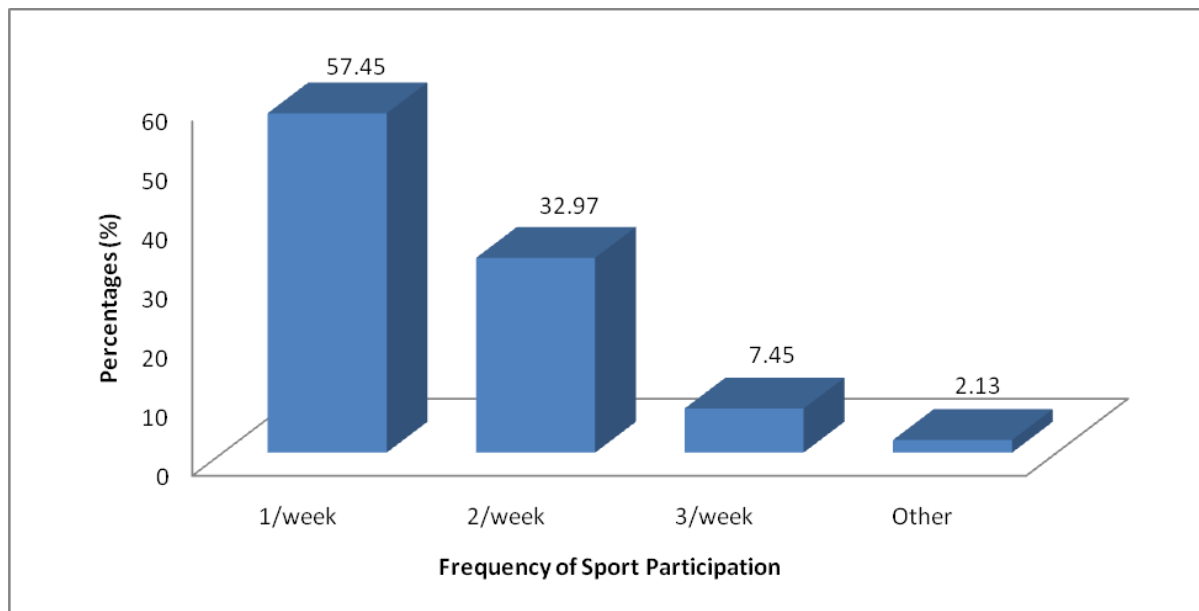
Most of the pupils in the cohort 138 (73.79%) ( $p < 0.0001$ ) travelled by vehicle to school, of which 90 (65.22%) travelled using private transport (such as a parent driven motor vehicle) whilst 49 pupils (26.20%) ( $p < 0.0001$ ) walked to school. Forty four of the pupils (89.8%) who walked to school covered a distance lesser than 2km per trip, while the remaining 10.2% walked more than 2km per trip. Pupils' modes of transport include bus, car, taxi and foot.

One hundred percent of the pupils ( $n=187$ ) indicated that they participated in sporting activities at school. This was indicative of the mandatory LO weekly lesson. The adoption of the Constitution of the Republic of South Africa (Act 108 of 1996) provided a basis for curriculum transformation and development in South Africa. In 2005 the Outcome Based Education (OBE) system was introduced into the South African curriculum and this system combined Physical Education (PE) with LO. The scope of LO session included physical well-being, citizenship education, recreation and physical activity and career choices (Department of Education, 2002b). This equipped pupils to engage on personal, psychological, neuro-cognitive, motor, physical, moral, spiritual, cultural, socio-economic and constitutional levels, to respond positively to the worlds demands and to assume responsibility and make the most out of life's opportunities (Department of Education,

2002b). However, this decreased the time to engage in physical activity. Lessons did not entail a structured PA programme which would include a warm up, sport specific skills and techniques and a cool down, but rather knowledge of healthy practices and nutrition, participation in games, recreational and leisure time activities, and an understanding of the relationship between health, physical activities and the environment can improve the quality of life and well-being of pupils (Department of Education, 2002b). This meant that the pupils were not conditioned to become fitter athletes but rather spent time learning certain codes of sport and rules and regulations associated with these sports with the emphasis on theory rather than practise. The frequency of PE lessons was also reduced to accommodate additional lessons which would be taught during the LO lesson. Van Deventer, (1999 and 2004) & Wentzel, (2001) highlighted the problem of insufficient attention paid to physical education in South African schools. It is also common practise to find a teacher taking on the responsibility to teach the lesson yet the net result is confusion, frustration, anxiety, and abandonment of the attempt. Educators lack of clarity about the innovation, their lack of skills and knowledge, unavailability of instructional material, incompatibility of organisational arrangements and lack of motivation further restricts curriculum implementation (Gross et al., 1971).

Pupils indicated inter school SP beyond their mandatory LO lessons per week, which included; netball, swimming, soccer, cricket, hockey and athletics. This lesson plan followed the same format as the LO lessons conducted during school hours. Results indicated that 45.99% of the pupils participated in soccer, 30.48% in cricket, 25.67% in netball, 24.76% in swimming, 11.76% in athletics and 0.53% in hockey which were all school based activities. Once again, these pupils were taught to better their sport specific skills in a game situation. Important factors such as muscular strength and endurance and core stability were over

looked due to a lack of time. These are vital components which the coaches and teachers need to take into consideration to eliminate musculoskeletal injury.



**Figure 8: Frequency of Sport Participation amongst the pupils who experienced schoolbag related musculoskeletal pain (n=94) (p<0.0001)**

The majority of the pupils (n=54) (57.45%) participated in sport once a week while (n=31) (32.97%) participated in sports twice a week. This indicates that the majority of the pupils (n=85) (90.42%) participated in sports twice a week or less. Eighteen (19.15%) of the pupils who complained of schoolbag related MSP exercised for 30 minutes a day, twenty seven (28.72%) for 45 minutes a day, forty (42.55%) for one hour a day, seven (7.45%) for 2 hours per day and two (2.13%) for more than 2 hours per day. Strong et al., (2005) indicated that adolescent children must partake in a structured exercise programme for 30-60 minutes per session atleast 3-4 times a week to prevent injury. The American Heart Association also advocates atleast 60 minutes of moderate intensity exercise per day. This recommendation was set not only to ensure that the youth are at a normal weight with low levels of body fat

and reduce their risk of developing diseases, such as hypertension, hypercholesterolemia, obesity and metabolic syndrome, but also to maintain a good cardiovascular base (Aerobic fitness), musculoskeletal health and fitness (Muscular strength and endurance), improve academic performance, improve bone mineral levels and reduce the risk of injuries (Strong et al., 2005).

The group of pupils who did not experience MSP (n=68) engaged in the sporting activities 1.78 sessions per week for an average of 58.01 minutes (total duration of extra-mural physical activity was 103.26 minutes/week). The group of pupils (n=94) that experienced schoolbag carriage related musculoskeletal pain played sport at a frequency of 1.54 sessions/week for an average duration of 56.97 minutes/session (total duration of extra-mural physical activity per week was 87.73 minutes/week).

The pupils who did not experience musculoskeletal pain related to schoolbag carriage participated more frequently and for longer duration in physical activity. Muscular strength and endurance increase with frequent participation in sport. It is postulated that the stronger muscles were able to withstand the stress the schoolbags placed on the vertebrae hence the pupils did not experience MSP.

#### **4.8 Risk factors associated with schoolbag carriage promoting musculoskeletal pain**

The average bag mass carried by the cohort was 5.45 kg. Statistical analysis revealed that the boys who experienced musculoskeletal pain as a result of schoolbag carriage carried a bag mass to body mass percentage of 12.53% ( $\pm 5.34\%$ ) whilst the females experiencing similar types of musculoskeletal pain due to schoolbag carriage carried a schoolbag equivalent to

12.49% ( $\pm$  4.98%) of their body mass. Guidelines recommend that carrying a backpack should not significantly alter young people's posture from the sagittal and frontal view and that the backpack mass should not exceed 10% of the pupil's body mass. Although there is sufficient evidence to suggest that the mode of carriage can affect student's posture (Voll & Klimt 1977, Pascoe et al., 1997; Motmans et al., 2006), previous research indicates that the bag mass to body mass ratio should not exceed 10% (Voll & Klimt, 1977). Mackie et al., (2008), reported that the mass of the load significantly affected posture, muscular strain and ability to walk and balance when the load carried reached 10% of the body mass. Hong et al., (2000) reported significant differences in blood pressure and energy expenditure for loads between 0 and 20% of the body mass. It was reported that blood pressure recovery was significantly longer for 15 and 20% of the body mass than for 10% body mass, which contributed to Hong et al., (2008) backpack weight recommendation of 10% of the body mass.

#### **4.9.1 The experimental study**

This phase marked the beginning of the experimental study. Initially the researchers intended on testing a single school, from the four schools that had already completed the questionnaire, which had the highest number of grade 7 pupils. However, the school which the researchers intended on selecting was an Islamic school with religious ethos and the Board of Governors' did not grant the researchers permission to continue the experimental study as they felt that photography was strictly prohibited. Therefore the researchers gained permission from two of the other schools which were willing to participate in the study. A sample of n=82 pupils were selected to participate. The results from the experimental study will be discussed under the following headings: posture analysis, craniovertebral angle, electromyography and digital images.

#### **4.9.1.1 Posture analysis**

Postural measures have been used to examine responses to schoolbag carriage (Pascoe et al., 1997; Grimmer et al., 2002; Hong & Cheung, 2003) based on the assertion that a posture that habitually deviates from anatomical alignment may be associated with spinal pain (Grimmer & Williams, 2000). The posture analysis was performed on the pupils in both the frontal and sagittal plane. Analysis of the posture was completed in the unloaded (without carrying a schoolbag) and in the loaded (carrying a schoolbag). The purpose of the posture analysis in the unloaded phase was to identify whether the pupils had a presence of any postural deviations due to their normal daily activities. The loaded posture analysis identified exacerbation of the deviated posture which may have become pathological due to carriage of an excessive weight for a prolonged period of time. The plumb line represented the line of centre which divided the body equally into right and left. The spinous processes of the vertebrae were marked to indicate lateral deviations from the plumb line in order to identify the presence of scoliosis (Kendal et al., 1983). During the postural analysis of the frontal plane, the researchers identified the following; shoulder height, hip height, greater trochanter height and ankle height. The researchers found no significant difference in these measurements during the unloaded and loaded phases. Majority of the pupils had a presence of scoliosis in the unloaded phase. This may be as a result of muscular imbalances as a result of prolonged schoolbag carriage.

#### **4.9.1.2 Craniovertebral angle (CVA)**

The craniovertebral angle is the angle formed between the tragus of the ear and a horizontal line passing through the C7 spinous process (Lau et al., 2009). The CVA during the unloaded phase was  $33.27^\circ$  and during the loaded phase became more acute measuring  $30.45^\circ$ . Raines & Twomey, (1994) and Joe et al., (2003) studied the reliability of measuring the CVA. They

also suggested that smaller CVA indicate greater protraction of the head and larger angles are more representative of 'ideal' sagittal plane head/neck alignment.

#### **4.9.1.3 Electromyographical muscular activity (EMG) associated with schoolbag carriage**

The EMG was a tool which the researchers used to measure and quantify change in the sternocleidomastoid and trapezius electromyographical activity during the unloaded and loaded phases. The aim of the EMG was to determine muscle activation and indicate stresses placed on the muscles to maintain the deviated posture, which may have exacerbated musculoskeletal pain experienced.

**Table 5: Muscular activity during the loaded and unloaded phase of the experimental study (n=82) (p<0.0001)**

<b>Muscles</b>	<b>Unloaded</b>	<b>Loaded</b>	<b>Significance</b>
<b>Sternocleidomastoid (mV)</b>	9.76 ( $\pm$ 4.39)	17.07 ( $\pm$ 15.82)	p < 0.0001
<b>Trapezius (mV)</b>	10.75 ( $\pm$ 8.29)	14.11 ( $\pm$ 10)	p < 0.0001

Both the SCM and trapezius musculature displayed significant changes in the muscle activity between the unloaded and loaded phases. During the unloaded phase the trapezius muscle exerted a stronger muscular contraction than the SCM to ensure the pupils were in the correct anatomical posture. However, when the load was imposed onto the trunk, the pupils adopted an altered posture to balance this additional load. This was evident with a significant change in the SCM muscle exerting a stronger contraction than the trapezius muscle. The pupils assumed a kyphotic posture together with a forward head posture. This was an adaptation to

ensure that the pupils maintained a standing posture and were able to maintain their balance thus preventing the pupils from falling over.

#### **4.9.1.4 Analysis of the digital images**

Ellapen et al., (2009), utilised digital images to distinguish between postural changes in both the sagittal and frontal planes during the unloaded and loaded phases. Similarly, the researcher utilised digital imagery as a means of identifying any postural deviations from the anatomical position when a load (in the form of a schoolbag) was imposed onto the trunk. In addition, the digital images were utilised to identify and measure the CVA in the sagittal plane during the unloaded (without a schoolbag) and loaded (with a schoolbag) phases (Wilmarth & Hilliard, 2003). This was an ideal tool to assist the researcher to capture exacerbation of possible postural deviations due to backpack loading. This served as raw data to be analysed using Biomechanical software such as Dartfish. Markers were placed on the participants prior to capturing the images. The researcher used these markers as a reference point during the Dartfish analysis. In the sagittal view, a vertical line was drawn, parallel to the plumbline of the posture chart, but passing through the tragus of the ear, the shoulder, hip and knee. The participants were identified as having a forward head posture when the tragus of the ear was not in line with the other anatomical landmarks. Additionally, the participants were compared to their unloaded results. The CVA was identified by measuring the angle between the tragus of the ear, the C7 spinous process and a horizontal line passing through the C7 spinous process. Once again, the results were compared to the unloaded results.

Dartfish was utilised to determine imbalances in the frontal view. This was achieved by extrapolating horizontal lines parallel to the posture chart. Altered shoulder, hip, knee and ankle heights during the unloaded phase were compared to the loaded phase. This confirmed on site evaluations.



**Table 6: Results from the unloaded posture analysis of the experimental study (n=82)**

	<b>Cervical Postural Syndrome</b>	<b>Kyphosis</b>	<b>Lordosis</b>	<b>Anterior Tilt of the Hip</b>	<b>Genu Recurvatum</b>
<b>Unloaded</b>	84.15%	56.10%	73.17%	97.56%	45.12%
<b>Significance</b>	p > 0.5	p < 0.05	p > 0.5	p > 0.5	p > 0.5

**Table 7: Results from the loaded posture analysis of the experimental study (n=82)**

	<b>Cervical Postural Syndrome</b>	<b>Kyphosis</b>	<b>Lordosis</b>	<b>Anterior Tilt of the Hip</b>	<b>Genu Recurvatum</b>
<b>Loaded</b>	90.24%	85.40%	87.80%	97.56%	54.88%
<b>Significance</b>	p > 0.5	p < 0.01	p > 0.5	p > 0.5	p > 0.5

Tables 6 and 7 indicate altered posture from the resting standing position in the unloaded and loaded phases. With the exception of the hip orientation (anterior tilt of the hip), all of the other postural conditions (cervical postural syndrome, kyphosis, lordosis and genu recurvatum) became exacerbated when a load was imposed onto the spinal column. The most significant postural change was seen in the form of kyphosis (p<0.01).

Posture is usually defined as the relative arrangement of the parts of the body. Normal or standard posture is that state of muscular and skeletal balance which protects the supporting structures of the body against injury or progressive deformity (Ghanbari et al., 2007). Analysis of digital images in the frontal plane displayed that the weight of the bag depressed both shoulders. It is hypothesized that the depression of the shoulders yielded the dull aching shoulder pain, thereby stretching and compressing the trapezius muscle. The radiating pins and needles sensations in the shoulder region were due to compression of the brachial plexus. Scoliosis is the lateral deviation of the vertebral column in the frontal plane. By marking the

vertebrae and then using these marking to identify this condition, it was found that all the pupils had scoliosis. This, even in its mildest form, can be thought to be as a result of muscular imbalances which caused some muscles along the vertebral column to be tight whilst the other muscles were weaker or elongated. Thus the presence of scoliosis was very noticeable.

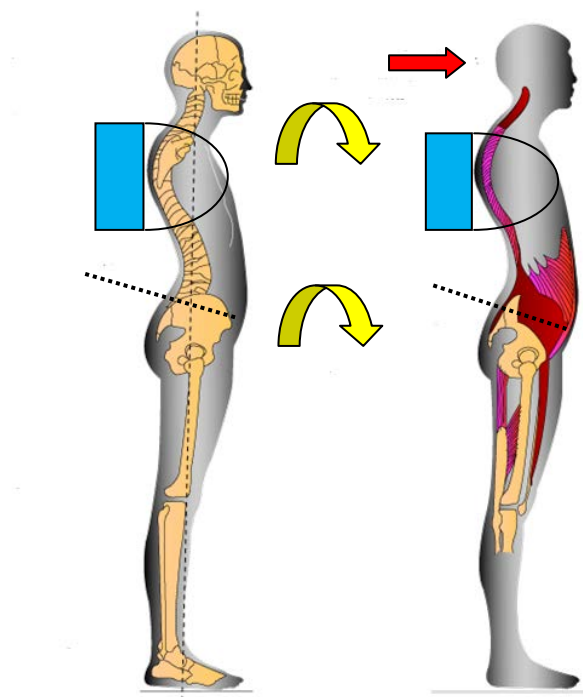
As with the frontal plane, the researchers utilised the plumb line in the sagittal plane as a line of centre to divide the body into the anterior and posterior regions. The line of centre ought to run through the auditory meatus, acromion process, anterior superior iliac spine, behind the patella and in front of the lateral malleoli. Analysis of digital images in the sagittal plane displayed forward displacement of auditory meatus from the line of centre when the pupils carried the back pack. Forward shoulder posture (FSP) or rounded shoulders (kyphosis) is one of the numerous deviations from the normal posture. This was as a result of forward displacement of the acromion process and excessive flexion of the thoracic vertebrae. The exaggerated thoracic vertebral flexion, seen in the form of kyphosis, is a musculoskeletal adaptation to balance the load of the school bag on the pubescent immature vertebral column. This abnormal thoracic vertebral flexion shortened the anterior thoracic muscles, whilst simultaneously lengthening the posterior muscles. This changed the muscle length between the anterior and posterior thoracic vertebral muscles producing an abnormal length tension relationship which adversely impacted these muscles force-couple relationship.

The EMG measured muscular activity of the anterior and posterior musculature which confirm a stronger anterior contraction (17.07 mV), than posterior contraction (14.11 mV), which indicates forward head displacement. Prolonged thoracic vertebral flexion increased the potential of muscle spasm in the anterior thoracic muscles (producing dull aching symptoms), whilst the elongation of the posterior muscles underwent the risk of muscle strains (producing sharp aching symptoms). This is supported by a change in the CVA.

The acuteness of the angle indicates possible risk factors for MSP. In a recent study, Yip et al., (2008) concluded that patients with small CV angles had a greater forward head posture and the greater the forward head posture, the greater the disability. During the loaded phase the angle became more acute as a result of excess weight loaded onto the immature spine. The activation of voluntary muscular contraction allows pupils to exert more effort in carrying a bag, adding extra forces at the vertebral structures. In a study by Motmans, (2006), the EMG activity of erector spinae significantly decreased while carrying a backpack in a standing position. This can be explained by two factors. With no load, the back muscles must resist a trunk flexion moment because the centre of gravity of the upper body is located somewhat forward of the lumbosacral joint. With a load on the back, the combined centre of gravity of the trunk plus the pack shifts backward. This creates an extension moment (Bobet & Norman, 1984). In order to counterbalance the weight on the back, a forward trunk lean occurs (Pascoe et al., 1997; Filaire et al., 2001). All these major shifts in body alignment can be interpreted as compensations to stabilize the whole-body centre of gravity over the feet (Bloom & Woodhull-McNeal, 1987). The net result of the rearward of the centre mass and the counterbalancing is a reduction in erector spinae activity. Cook & Neumann, (1987) also found a slight decrease in lumbar paraspinal EMG levels. According to the above theory, the rectus abdominis should work harder.

In an attempt to compensate, this forward trunk lean, the lumbar vertebrae underwent hyper-extension thereby facilitating the phenomenon of serial distortion of the kinetic chain. The hyper-extension of the lumbar vertebrae produced an anterior tilt of the pelvis, as seen by the anterior deviation of the anterior superior iliac spine away from the line of centre, thereby altering the normal length tension relationship between the posterior (gluteal muscles and hamstrings) and the anterior (hip flexors and quadriceps) hip muscles. The shortening of the anterior hip muscles increases the potential of these muscles to experience muscle spasms,

whilst the elongation of the posterior muscles increases the probability of these muscles to sustain muscle strains. This lumbar inter-vertebral compression yielded symptoms of pins and needles in the lumbar region (indicative of neural pathology). These results were unchanged during the unloaded and loaded phases perhaps due to the long term effects of schoolbag carriage which the participants were already experiencing, leading to permanent musculoskeletal deformity.



**Figure 9: The impact of carrying schoolbags producing serial distortion of the kinetic chain in the sagittal plane**

Six (31.58%) of the 19 subjects that carried their schoolbags using a single strap complained of symptoms of dull aching pain suggesting muscle pathology whilst the other 13 (68.42%) subjects complained of symptoms such as sharp, radiating and pins and needles which are all

suggestive of neural pathology. As stated above, Brukner & Khan, (2006) and Prentice, (2004) indicated that sharp and dull sensations were indicative of musculoskeletal pathology while radiating, pins and needles sensations were associated with neural pathology.

Analysis of digital images revealed that when pupils carried their bags using a single strap, this led to depression of their shoulder as with the backpacks. It is postulated that the weight of the bag pulled the strap against the shoulder which subsequently compressed the brachial plexus facilitating neural impingement (producing symptoms of pins and needles and radiation). The dull aching pain was attributed to the stretching of trapezius when the single strap pulled the shoulder inferiorly (producing dull aching symptoms). Pascoe et al., (1997) indicated that carrying the schoolbag on one shoulder placed an unbalanced load onto the skeleton, which led to lateral deviation of the spine (scoliosis) and elevation of the contra-lateral shoulder. Lateral deviation of vertebrae produces compression of the inter-vertebral discs which produces symptoms of pins and needles and radiating pain.

Motmans, (2006) stated that when carrying a shoulder bag with the weight at the right side of the body, the EMG values showed an increase at the contra-lateral part (left) and a decrease at the ipsilateral part (right) of the muscles. There was a clear asymmetry between the right and left part in the frontal plane. The muscles on the side contra-lateral to the load had the highest activity. The lack of back muscle synchrony, as observed in this study and the habitual changes in trunk angles to balance heavy loads are proposed to be a cause of lower back pain (Harman et al., 1992). It should be advised to avoid a shoulder bag as a schoolbag, because of the asymmetrical EMG activity. In combination with the postural deviations, these stresses may be harmful in the long term. Asymmetrical loads encourage, especially in growing schoolchildren, lateral bending of the spine by alleviating muscle and lower back

forces (Noone et al., 1993). Shoulder elevation and a deviation of the trunk away from the weight were also noted when carrying a backpack with one strap (Pascoe et al., 1997).

## CHAPTER FIVE: CONCLUSION & RECOMMENDATIONS

### 5.1 Introduction

This chapter provides a brief conclusion and overall findings of the study followed by the recommendations made by the researcher.

### 5.2 Conclusion

- Schoolbag carriage is a daily occupational habit for school children, given that, we must not overlook the negative consequences which heavy loads place on the spines of growing children. Among the 187 pupils surveyed, 119 (63.64%) experienced musculoskeletal pain of which 94 (78.99%) experienced musculoskeletal pain related to schoolbag carriage ( $p < 0.0001$ ).
- Of the 94 pupils who experienced musculoskeletal pain due to schoolbag carriage, 76.6% ( $n=72$ ) pupils carried a double strap backpack, 20.21% ( $n=19$ ) carried a sling or single strapped bag and 3.19% ( $n=3$ ) used a roller bag ( $p < 0.0001$ ).
- The average schoolbag mass carried by the pupils was 11.5% of their body mass. The rule of thumb as proposed by Voll & Klimt, (1977) states that the bag mass should not exceed 10% of the pupil's body mass. The heaviest schoolbags were carried by Indian pupils, whilst African pupils carried the lightest schoolbags.
- It was concluded that prolonged schoolbag carriage, irrespective of the type of schoolbag, produced deviation of the musculoskeletal posture which facilitated the

prevalence of shoulder, thorax and lumbar musculoskeletal pain as viewed in the sagittal plane during the loaded phase. The pupils had a prevalence of kyphosis and cervical postural syndrome. Pupils experienced the following pain sensations; dull, sharp, radiating and pins and needles. These sensations are indicative of musculoskeletal and neural pathology.

- The predisposing factors that propagated this musculoskeletal pain were the type of schoolbag carried (either a single or double strap) and the mass of the schoolbag carried expressed as a percentage of the pupils body mass. The majority of the pupils (n=72, 76.6%) ( $p < 0.0001$ ) that experienced schoolbag related musculoskeletal pain carried backpack type schoolbags. Females experienced more schoolbag related musculoskeletal pain than males. The aetiological cause of pain was the mass of the schoolbag that was imposed onto the spinal column.

### **5.3 Recommendations**

- Although the pupils exercised for the recommended duration, the frequency of SP is a factor that needs to be addressed. The pupils must engage in SP for 30-60 minutes, at least 3-4 times a week. Pupils need to become more active and partake in structured exercise programmes to ensure the development of muscular strength and endurance of the paraspinal muscles, to ensure the protection of the spinal column and eliminate the risk of injury. Additionally, parents need to take a stronger stance with their children and ensure that they are getting an adequate dose of daily exercise. This may combat not only MS pathologies but also chronic diseases, such as metabolic syndrome, diabetes and obesity in young children, which is on the rise. The parents can also set the example and display healthy eating habits and regular exercise



regimes. Alternatively, parents can partake in recreational SP with their children on a regular basis.

- Parents also need to ensure that their children are carrying only the books necessary for that day. Some of the common excuses for heavy schoolbags was “laziness” to unpack their bags and remove their unnecessary books as well as poor planning by the pupils to ensure that they have all the books required for the day. This may help to alleviate the load which the pupils have to carry around.
- LO lectures should be more structured ensuring that more practical sessions be included into the lesson plan and not just theoretical knowledge. Alternatively, the Department of Education could divide LO into PE and theoretical lessons. This way pupils would be encouraged to participate in PE more frequently and thus the teacher could concentrate on a variety of different components during the PE lesson, increasing and ensuring muscle activity and strength.
- Parents also need to pay more attention to their children when they complain of vertebral pain and ensure that they are treated and rehabilitated for the pathology in order to prevent exacerbation of the condition later on in life as they get older. If left untreated, this may impact on the academic performance of the child, increase the rate of absenteeism during the school year and possibly have this condition transform into a chronic pathology. The implications on the child as they would become an adult would be reduced productivity leading to inefficiency.
- The Department of Education should recommend that all text books be left on school property so as to decrease the mass of schoolbags. Text books may also be converted

into an electronic format and placed onto a cd or usb which may aid in the pupils utilising the book for their studies or as a reference at home.

- Schoolbags must be age appropriate. Wherever possible, carriage of schoolbags must be discouraged and the use of roller bags encouraged, which may prove to be more ergonomically friendly for growing school children. The Department of Education should also look into implementing the older desk storage system that was used in the past or locker allocations in the school setting as another option to help lighten the load of the schoolbags for the pupils.
- Although purchasing of technological equipment is not always economical (iPad), this may prove to be the way forward in future for many pupils and schools.
- Adherence to a biokinetic rehabilitation programme may be necessary when pupils are presented with pain and discomfort as a result of heavy schoolbags. Educational programmes have proved to be very beneficial to pupils in the long term as they are a tool used to educate the pupils about certain musculoskeletal pathologies and ways and means to prevent them from occurring or even to relieve one from pain.

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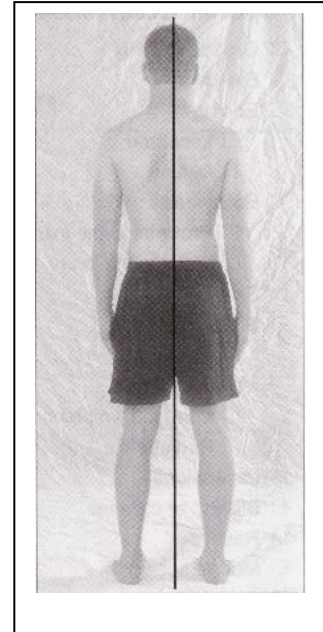
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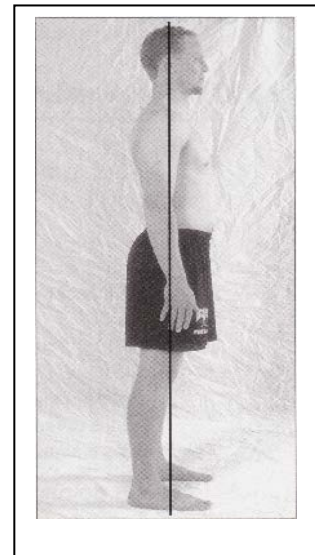
**Frontal View**      **R = right,**      **L = left**

Scoliosis		
Shoulder Height	↑ R	↑ L
Hip Height	↑ R	↑ L
Greater Troch.	↑ R	↑ L
Ankle Height	↑ R	↑ L



**Sagittal View** **Y = yes,**      **N = no**

Cervical Pos. Syn.	Y	N
Kyphosis	Y	N
Lordosis	Y	N
Hip Orientation	Anterior	Posterior
Knee Orientation	Genu Recurvatum	



**Mass** \_\_\_\_ kg      **Height** \_\_\_\_ m

**Craniovertebral angle**

Unloaded \_\_\_\_°      Loaded \_\_\_\_°



APPENDIX B  
UNIVERSITY OF KWAZULU-NATAL  
FACULTY OF HEALTH SCIENCE  
DEPARTMENT OF SPORT SCIENCE



**ACUTE MUSCULOSKELETAL STRESS AND STRAIN DUE TO BACKPACK  
LOADING IN PRE-PUBESCENT PRIMARY SCHOOL**

This questionnaire contains 6 categories (Personal Details, Medical History, School activities, Additional activities, School bag information, Pain and discomfort)

**SECTION A - PERSONAL DETAILS:**

*Fill in and tick the correct option*

Name: \_\_\_\_\_ Surname: \_\_\_\_\_

Age: \_\_\_\_\_

Gender: Male  Female

Race: African  White  Indian  Coloured

School: \_\_\_\_\_ Grade: \_\_\_\_\_

Home address: \_\_\_\_\_

Telephone Number: ( ) \_\_\_\_\_

Do you walk to and from school: Yes  No

If YES, what distance do you walk? Less than 2 km  Greater than 2 km

If NO, how do you get to school? Bus  Bicycle  Car  Taxi

**SECTION B - MEDICAL HISTORY:**

*Fill in and tick the correct option*

Do you suffer from any illness or medical condition? Yes  No

If yes, what type of illness or medical condition and for how long did you have this illness?

\_\_\_\_\_

Have you suffered from any illness or medical condition in the past? Yes  No

If yes, what type of illness or medical condition and for how long did you have this illness or condition?

---

Do you suffer or have been diagnosed with any of the following conditions:

**Scheuermanns disease** (Accentuated upper back) Yes  No



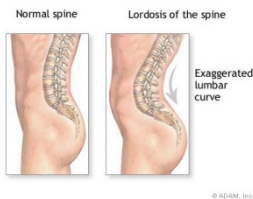
[http://cirrie.buffalo.edu/encyclopedia/images/kyphosis\\_3.jpg](http://cirrie.buffalo.edu/encyclopedia/images/kyphosis_3.jpg). Accessed 10 April 2010

**Scoliosis** (Lateral deviation of the spine) Yes  No



<http://www.spine-surgeon.org/sco.html>. Accessed 10 April 2010

**Lumbar lordosis** (Hollow back) Yes  No



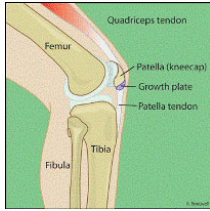
<http://www.nytimes.com/imagepages/health/adam/Lordosis.html>. Acc 10 April 10

**Osgood's Shatters'** (Pain on the shin bone) Yes  No



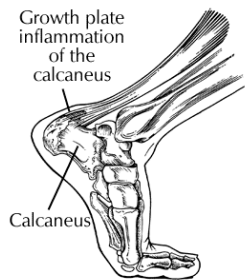
<http://www.childrens-mercy.org/pa/images/knee-osg.gif>. Access 10 April 10

**Sinding Larsen Johansson (Pain in the patella tendon)**    Yes     No



<http://www.childrensmemorial.org/sportsmedicine/images/SindingLarsenJohan.jpg>. Accessed 10 April 10

**Severs disease (Heel pain)**    Yes     No



<http://www.hughston.com/hha/severs.gif>. Accessed 10 April 2010

**Other** \_\_\_\_\_

**SECTION C – SCHOOL ACTIVITIES:**

*Fill in and tick the correct option*

Do you participate in any physical activity at school?    Yes     No

If yes, please indicate the type of activity that you participate in:

PE                           Hockey                           Other \_\_\_\_\_

Netball                           Cricket

Swimming                           Soccer

How often do you participate in these physical activities?

Once a week     Twice a week     Three times a week     Other \_\_\_\_\_

How long do you participate for?

30 mins                           1 hour                           2 hours                           Other \_\_\_\_\_

Do you carry any additional equipment or clothing on these days?    Yes     No

If yes, please explain \_\_\_\_\_

**SECTION D - ACTIVITIES OUT OF SCHOOL:**

Fill in and tick the correct option

Do you participate in any sporting activities out of school?

E.g. Soccer club? Yes  No

If yes, specify the type of activity.

---

Did you sustain any injuries during that activity? Yes  No

If yes, state the type of injury, the activity involved and when the injury occurred.

---

**SECTION E - SCHOOL BAG:**

Fill in and tick the correct option

What type of school bag do you carry?

Backpack  Single Strap  Roller bag

How do you carry your backpack?

Both shoulders  Mostly right  Mostly left

If you walk to school, how do you carry your backpack

Both shoulders  Mostly right  Mostly left

Do you rotate teachers or classrooms: Teachers  Classrooms

Mass of backpack when packed for the day: \_\_\_\_\_kg

Duration bag is carried before arriving at the classroom: \_\_\_\_\_min \_\_\_\_\_hours

Duration the bag is carried during the course of the day: \_\_\_\_\_min \_\_\_\_\_hours

Total distance the bag is carried in one day: \_\_\_\_\_m \_\_\_\_\_km

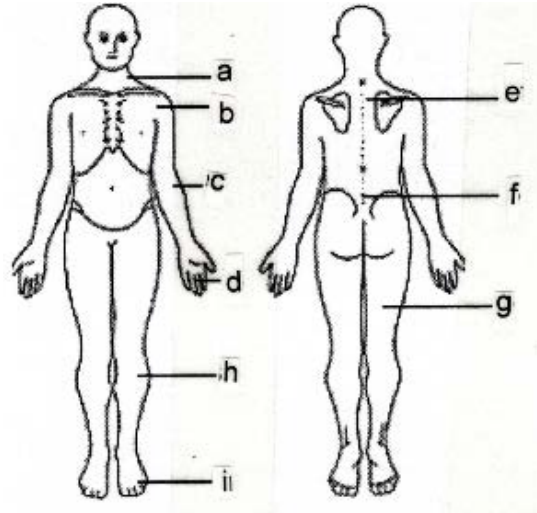
**SECTION F - PAIN AND DISCOMFORT:**

*Fill in and tick the correct option*

Do you experience pain? Yes  No

If yes, indicate the site of pain on the diagram

A	NECK
B	SHOULDER
C	ARM
D	FINGERS
E	UPPER BACK
F	LOWER BACK
G	LEGS
H	KNEES
I	TOES



Adapted from Ellapen, et al., 2009

What type of pain do you experience?

Sharp

Dull

Radiating

Pins and needles

If you experience any pain, does it run down to your fingers?

Yes  No

If you experience any pain, does it run down to your toes?

Yes  No

Is the pain related to carrying of your backpack? Yes  No

If yes does the pain:

Occur while you carry your bag

After removing the bag off the shoulders

Always remain present

If No, what do you think causes the pain?

---

On a scale of 0-5, 0 being no pain and 5 being unbearable pain, how would you rate your pain?

0 – No pain

1 – Mild pain

2- Manageable

3 – Moderate pain

4 – Severe pain

5 – Unbearable pain

What do you do to make the pain go away?

---

How often does this pain occur?

---

Does this pain cause you to be absent from school? Yes  No



If yes, how long do you stay away for?

- |        |                          |                 |                          |             |
|--------|--------------------------|-----------------|--------------------------|-------------|
| 1 day  | <input type="checkbox"/> | 4 days          | <input type="checkbox"/> | Other _____ |
| 2 days | <input type="checkbox"/> | 5 days (1 week) | <input type="checkbox"/> |             |
| 3 days | <input type="checkbox"/> | 2 weeks         | <input type="checkbox"/> |             |

How is the pain treated?

---

Have you consulted a health professional for the pain?      Yes       No

If yes, please indicate which of the following you have consulted:

- |                      |                          |                 |                          |
|----------------------|--------------------------|-----------------|--------------------------|
| General practitioner | <input type="checkbox"/> | Physiotherapist | <input type="checkbox"/> |
| Orthopedic Surgeon   | <input type="checkbox"/> | Biokineticist   | <input type="checkbox"/> |
| Nurse                | <input type="checkbox"/> | Other _____     |                          |

Do you have any suggestions with regards to our study?

---

**WE THANK YOU FOR PARTICIPATING IN OUR STUDY**



APPENDIX C  
UNIVERSITY OF KWAZULU-NATAL  
FACULTY OF HEALTH SCIENCE  
DEPARTMENT OF SPORT SCIENCE



**ACUTE MUSCULOSKELETAL STRESS AND STRAIN DUE TO BACKPACK  
LOADING IN PRE-PUBESCENT PRIMARY SCHOOL**

**Information sheet for participants and parents/guardians**

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you of any kind and we thank you for considering our request.

**Aim of the project?**

This project is being undertaken as part of the requirements for the Postgraduate Degree in Sport Science. The major aim of this project is to see what effect the backpacks have on the back and neck posture of adolescents.

**Subjects or participants of the study?**

Adolescents aged of 11-13 years will voluntarily participate in this study. Those who are in one or more of the categories listed below will not be eligible to participate in the project because, in the opinion of the researchers and the Ethics Committee of the University, it may involve an unacceptable risk to them: -

- Any adolescent younger than 11 years
- Any adolescent older than 13 years
- Any 11-13 year old adolescent that is not in grade 7

- Any adolescent that has a diagnosed musculoskeletal illness by a medical practitioner.

**Participants are required to:**

Should you agree to take part in this project, you will be asked to carry a loaded backpack. The researchers will take 2 photographs. The researchers will also measure your muscle contraction. Participants will be required to complete a questionnaire together with an examination of their posture, conducted by a researcher.

**Can Participants Change their Mind and Withdraw from the Project?**

You may withdraw from participation in the project at any time and without any disadvantage to yourself of any kind.

**What data or information will be collected and what use will be made of it?**

Data will be collected in the form of a questionnaire, posture profile with the aid of a digital image, posture profile sheet and evaluation of muscle activity in the neck and back using an electromyography. The questionnaire contains basic personal details about the subject, questions relating to the period and frequency of weight bearing as well as quality and site of pain whilst loaded. The purpose of the posture profile is to identify altered postural alignment which may be caused by repetitive schoolbag loading of muscle which could possibly become pathological or lead to compensatory mechanisms to reduce tissue stress. The researchers aim to investigate the anterior and posterior deviations in postural alignment (front and back) with the aid of a posture profile chart. The electromyography will be used to measure the muscle activity during weight bearing to link these results with postural changes. Results of this project may be published but any data included will in no way be linked to any specific participant. You are most welcome to request a copy of the results of the project should you wish. The data collected will be securely stored in such a way that only those

mentioned above will be able to gain access to it. At the end of the project any personal information will be destroyed immediately except that, as required by the University's research policy, any raw data on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed.

### **What if Participants have any Questions?**

If you have any questions about our project, either now or in the future, please feel free to contact:-

Miss S Abrahams

University of KwaZulu-Natal

Discipline of Sport Science

Telephone No: - 0768928020

- 031-2607669

Dr T.J Ellapen

University of KwaZulu-Natal

Discipline of Sport Science

Telephone No: - 031 – 260 8776



APPENDIX D  
UNIVERSITY OF KWAZULU-NATAL  
FACULTY OF HEALTH SCIENCE  
DEPARTMENT OF SPORT SCIENCE



**ACUTE MUSCULOSKELETAL STRESS AND STRAIN DUE TO BACKPACK  
LOADING IN PRE-PUBESCENT PRIMARY SCHOOL PUPILS**

**Consent form for participants or parents/guardians**

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that: -

1. My involvement in the project is entirely voluntary;
2. I am free to leave from the project at any time without any disadvantage;
3. The data photographs will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed;
4. I am aware of the discomfort and risk of this project;
5. The results of the project may be published but my anonymity will be preserved.

I agree to take part in this project.

.....

(Signature of participant)

.....

(Date)



**APPENDIX E**  
**UNIVERSITY OF KWAZULU-NATAL**  
**FACULTY OF HEALTH SCIENCE**  
**DEPARTMENT OF SPORT SCIENCE**



To whom it may concern,

I am a Masters student at the Discipline of Sport Science, UKZN Westville campus. I am currently completing a study which is titled:

**‘Acute Musculoskeletal Stress And Strain Due To Backpack Loading Among Pre-Pubescent Primary School Pupils’**

A pre-requisite before completing data collection would be consent from the Department of Education to approach the board of governors and principals of respective schools. My proposal was approved by the ethics committee at the UKZN and ethical approval number is **HSS/0184/2010 M: Faculty of Health Science.**

An explanation of the procedure used will be a posture profile, digital images, and muscle testing whilst the subjects carry a schoolbag which they will be accustomed to carrying on a daily basis. All participants will also be required to complete a questionnaire.

Should the Department grant me access to these schools I will take the responsibility to make all arrangement with the participants and respective schools. I will ensure no educator’s programmes will be interrupted and research will not take place during examination periods. No pupils, educators and schools will be identifiable in any way from the results. A brief summary of the findings will be sent to your office.

I look forward to a positive response.

Kind Regards

Miss Sumaya Abrahams

031 - 260 7669 / 076 892 8020



APPENDIX F  
UNIVERSITY OF KWAZULU-NATAL  
FACULTY OF HEALTH SCIENCE  
DEPARTMENT OF SPORT SCIENCE



To Whom It May Concern,

I am a Biokinetic Intern at UKZN-Westville and currently pursuing a Masters Degree in Sports Science. My topic is " Acute musculoskeletal stress and strain due to backpack loading among pre-pubescent primary school pupils" for which I attained Ethic Approval (Ref.: HSS/0184/2010 M).

The reason for this correspondence is to seek the permission of the Board of Governors of the school and yourself, the Principal, as I would like to be given the opportunity to gain access to your pupils who will enable me to execute data collection for my research project. The target group will consist of grade seven pupils enrolled at your school as they have been identified as a population necessary for my study.

The instrumentation to be used to gather data from the subjects' (required sample size of  $n=200$ ) is:

1. A Questionnaire
2. Anthropometric Data: Body Mass, Stature, Waist and Hip Girth Measurements
3. A Posture Profile: Visual examination of the students' posture in both the sagittal and frontal views. Postural deviations such as: cervical postural syndrome, kyphosis, lordosis, hip orientation and scoliosis will be documented. Reflective markers will be placed on anatomical landmarks and digital images of these subjects' will be captured



of the cohort in both views. This is to facilitate easy analysis of these images on Biomechanical Analysis Software, Dartfish.

4. Ergonomic Posture: Will be determined by capturing a digital image of the subjects' whilst carrying their schoolbags. These pictures will also be analyzed by Biomechanical Analysis Software, Dartfish.
5. Should the school require any clarification regarding this study, I am able to deliver a PowerPoint presentation upon your request.

It is with optimism that I anticipate your reply regarding the enlistment of a cohort for my study. Should you have any further enquiries regarding my study, do not hesitate to contact me.

Kind Regards

Miss Sumaya Abrahams

076 892 8020 / 031 260 7669

## APPENDIX G



**UNIVERSITY OF  
KWAZULU-NATAL**

University of KwaZulu-Natal  
Research Office  
Govan Mbeki Centre  
Westville Campus  
University Road  
Chiltern Hills  
Westville  
3629  
South Africa  
Tel No: +27 31 260 3587  
Fax No: +27 31 260 2384  
E-mail : [naidoo4@ukzn.ac.za](mailto:naidoo4@ukzn.ac.za)

19 April 2010

Miss S Abrahams  
c/o School of Physiotherapy, Optometry & Sports Science  
Faculty of Health Sciences  
Westville Campus

Dear Miss Abrahams

**PROTOCOL: Acute musculoskeletal stress and strain due to backpack loading among pre-pubescent primary school pupils**

**ETHICAL APPROVAL NUMBER: HSS/0184/2010 M: Faculty of Health Sciences**

In response to your application dated 16 April 2010, Student Number: **205503583** the Humanities & Social Sciences Ethics Committee has considered the abovementioned application and the protocol has been given **FULL APPROVAL**.

**PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years.**

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

**Professor Steve Collings (Chair)**  
**HUMANITIES & SOCIAL SCIENCES ETHICS COMMITTEE**

SC/sn

cc: Dr T J Ellapen  
cc: Prof. H J van Heerden  
cc: Mr S Reddy

## APPENDIX H



**kzn education**

Department:  
Education  
KWAZULU-NATAL

**S ABRAHAMS  
UNIVERSITY OF KWAZULU NATAL  
FACULTY OF HEALTH SCIENCE  
DEPARTMENT OF SPORT SCIENCE**

Enquiries: Sibusiso Alwar

Date: 11/06/2010

Reference: 0049/2010

### **RESEARCH PROPOSAL: A CUTE MUSCULOSKELETAL STRESS AND STAIN DUE TO BACKPACK LOADING AMONG PRE-PUBESCENT PRIMARY SCHOOL PUPILS**

Your application to conduct the above-mentioned research in schools in the attached list has been approved subject to the following conditions:

1. Principals, educators and learners are under no obligation to assist you in your investigation.
2. Principals, educators, learners and schools should not be identifiable in any way from the results of the investigation.
3. You make all the arrangements concerning your investigation.
4. Educator programmes are not to be interrupted.
5. The investigation is to be conducted from 11 June 2010 to 11 June 2011.
6. Should you wish to extend the period of your survey at the school(s) please contact Mr Sibusiso Alwar at the contact numbers above.
7. A photocopy of this letter is submitted to the principal of the school where the intended research is to be conducted.
8. Your research will be limited to the schools submitted.
9. A brief summary of the content, findings and recommendations is provided to the Director: Resource Planning.

...dedicated to service and performance  
beyond the call of duty.

KWAZULU-NATAL DEPARTMENT OF EDUCATION

POSTAL Private Bag X9137 Pietermaritzburg 3200 KwaZulu-Natal Republic of South Africa  
PHYSICAL Office 6/25, 188 Pietermaritz Street Metropolitan Building PIETERMARITZBURG 3201  
TEL Tel: +27 33 341 8610/8611 | Fax: +27 33 341 8612 | E-mail



**kzn education**

Department:  
Education  
KWAZULU-NATAL

10. The Department receives a copy of the completed report/dissertation/thesis addressed to:

The Director: Resource Planning  
Private Bag X9137  
Pietermaritzburg  
3200

We wish you success in your research.

Kind regards

**R. Cassius Lubisi (PhD)**  
**Superintendent-General**

*...dedicated to service and performance  
beyond the call of duty.*

**KWAZULU-NATAL DEPARTMENT OF EDUCATION**

**POSTAL** Private Bag X9137, Pietermaritzburg, 3200, KwaZulu-Natal, Republic of South Africa

**PHYSICAL** Office G26, 188 Pietermaritz Street, Metropolitan Building, PIETERMARITZBURG 3201

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**kzn education**

Department:  
Education  
KWAZULU-NATAL

**S ABRAHAMS  
UNIVERSITY OF KWAZULU NATAL  
FACULTY OF HEALTH SCIENCE  
DEPARTMENT OF SPORT SCIENCE**

Enquiries: Sibusiso Alwar

Date: 11/06/2010

Reference: 0049/2010

### **PERMISSION TO INTERVIEW LEARNERS AND EDUCATORS**

The above matter refers.

Permission is hereby granted to interview Departmental Officials, learners and educators in selected schools of the Province of KwaZulu-Natal subject to the following conditions:

1. You make all the arrangements concerning your interviews.
2. Educators' programmes are not interrupted.
3. Interviews are not conducted during the time of writing examinations in schools.
4. Learners, educators and schools are not identifiable in any way from the results of the interviews.
5. Your interviews are limited only to targeted schools.
6. A brief summary of the interview content, findings and recommendations is provided to my office.
7. A copy of this letter is submitted to District Managers and principals of schools where the intended interviews are to be conducted.

The KZN Department of education fully supports your commitment to research: **A cute musculoskeletal stress and stain due to backpack loading among pre-pubescent primary school pupils**

It is hoped that you will find the above in order.

Best Wishes

**R Cassius Lubisi, (PhD)  
Superintendent-General**

...dedicated to service and performance  
beyond the call of duty.

**KWAZULU-NATAL DEPARTMENT OF EDUCATION**

POSTAL Private Bag X9137, Pietermaritzburg 3200, KwaZulu-Natal, Republic of South Africa

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**kzn education**

Department:  
Education  
KWAZULU-NATAL

**S ABRAHAMS  
UNIVERSITY OF KWAZULU NATAL  
FACULTY OF HEALTH SCIENCE  
DEPARTMENT OF SPORT SCIENCE**

Enquiries: Sibusiso Alwar

Date: 11/06/2010

Reference: 0049/2010

**LIST OF SCHOOLS**

1. Oceanview primary school
2. Charles Hugo primary school
3. Rippon road primary school
4. Durban preparatory school
5. Hartley road primary school

Kind regards

**R Cassius Lubisi, (PhD)  
Superintendent-General**

*...dedicated to service and performance  
beyond the call of duty.*

**KWAZULU-NATAL DEPARTMENT OF EDUCATION**

**POSTAL** Private Bag X9137, Pietermaritzburg 3200, KwaZulu-Natal, Republic of South Africa

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