# Development of Instruments to Assess Physiological and Physical Neck Pain Risk Factors

by

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# Abstract

Neck pain has the potential to result in altered afferent input to the central nervous system which may thereby result in altered sensorimotor integration and eventually further disability. One "at risk" population for neck pain may be university students, particularly given the growing use of laptop computers in the university setting. This thesis presents two pilot studies which aim to develop and assess instruments to use as screening tools for risk factors associated with neck pain.

The first study explores the environment in which university students utilize their laptop computers and the relationship to known risk factors for neck pain. A new questionnaire, The Student Laptop Use and Neck Pain Risk Questionnaire (SLUNPRQ) was created to measure the presence of risk factors known to increase the risk of developing neck pain. This questionnaire was piloted for reliability using test- retest measures. Results indicated that the SLUNPRQ had good reliability based on Cohen's Kappa scores. A modified questionnaire was developed based on questions with either low reliability or ambiguous answers and is ready for further testing.

The second study sought to determine if dual somatosensory evoked potential (SEP) ratios changed with long term chiropractic care. This was part of the overall goal of finding neural markers that could identify those who are at risk for developing neck pain. This study sought to determine the feasibility of using dual SEPs to evaluate changes in neural markers of sensorimotor integration after 12 weeks of chiropractic care and demonstrated that dual SEPs shows potential as a marker to screen individuals at risk of neck pain as the SEP markers showed improvement after long term chiropractic care.


**Keywords:** Laptop Use, Reliability, Laptop Questionnaire, Neck Pain, Dual SEPs

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◊

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# Contribution of Authors

## Manuscript I

Diana Gray conducted the literature review, focus group, developed the Student Laptop Use and Neck Pain Risk Questionnaire (SLUNPRQ) and completed the manuscript as well as initial editing and formatting.

Dr. Bernadette Murphy revised the SLUNPRQ, as well as manuscript I prior to submission. Dr. Murphy also provided feedback and guidance when necessary.

Dr. Pierre Côté provided contacts for the expert review panel for the initial development of the SLUNPRQ and aided in the revision of the SLUNPRQ as well as the manuscript prior to submission.

## Manuscript II

Diana Gray completed the literature review, conducted data collection sessions, completed data analysis and completed the manuscript as well as initial editing and formatting.

Dr. Heidi Haavik-Taylor provided guidance with SEP peak picking for the data analysis portion of the manuscript.

Dr. Bernadette Murphy provided guidance with data analysis for SEP peak picking, edited and revised the written manuscript.

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## Chapter Five

# List of Abbreviations

| | |
|---|---|
| APB: | Abductor Pollicis Brevis Muscle |
| ADM: | Abductor Digiti Minimi Muscle |
| CI: | Confidence Interval |
| CNS: | Central Nervous System |
| EEG: | Electroencephalography/ Electroencephalogram |
| FDI: | First Dorsal Interosseous Muscle |
| FHD: | Focal Hand Dystonia |
| HVLA: | High Velocity Low Amplitude (Spinal manipulation) |
| IFCN: | International Federation of clinical Neurophysiologists |
| IRR: | Incidence Rate Ratio |
| KPeCs: | Keyboard Personal Computer Style Instrument (Questionnaire) |
| M1: | Primary Motor Cortex |
| MSD: | Musculoskeletal Disorder |
| NDI: | Neck Disability Index |
| OR: | Odds Ratio |
| RR: | Risk Ratio |

S1: Primary Somatosensory Cortex

SCNP: Sub Clinical Neck Pain

SE: Standard Error

SEP: Somatosensory Evoked Potential

SF-MPQ: Short Form McGill Pain Questionnaire

SMA: Supplementary Motor Area

SMI: Sensorimotor Integration

# Chapter One Introduction

## 1.1 Background and Rationale

Musculoskeletal pain has become a substantial issue worldwide, and contributes greatly not only to the disability of many but to immense global economic cost as well. Musculoskeletal disorders (MSDs) encompass a wide array of musculoskeletal tissue injuries, some of which are work related (Green, 2008). These disorders affect many areas of the body such as the neck, upper extremities or back. In particular, upper limb pain has been shown to be very common in the general population, with 36% of men and women in Britain reporting pain within the upper extremities in any given week (Walker Bone, Palmer, Reading, Coggon, & Cooper, 2004). This is further supported by outcomes based on a cohort study conducted in Saskatchewan, Canada where 54% of the studied population experienced neck pain in the previous 6 months and 5% considered it disabling (P. Côté, Cassidy, & Carroll, 2003). Of particular concern are those people for whom neck and upper limb pain become chronic. The annual prevalence of neck pain ranges from 27.1% in Norway to 47.8% in Quebec, while in Canada, the annual prevalence of neck pain interfering with daily activates is 14.1% within the general population of workers (P Côté et al., 2009). Finally, MSDs have had a considerable influence on economic costs internationally. In the year 2000 alone, $500 million was spent on MSDs in Quebec, Canada while between $45- $54 billion is spent annually in the United States (Denis, St-Vincent, Imbeau, Jette, & Nastasia, 2008). High prevalence coupled with enormous economic cost has evidently resulted in a widespread burden requiring much attention.

With the continuing development of information technology and the move towards service sector oriented employment, there has been an increase in the incidence and prevalence of neck pain (P Côté, et al., 2009). The rise in MSDs may be influenced, at least in part, by an increase in sedentary work as well as occupational and recreational computer use. This is supported with a demonstrated 12-month prevalence of neck pain of 45.5% in office workers (Cagnie, Danneels, Van Tiggelen, De Loose, & Cambier, 2007). Recent reports have also shown that the one year prevalence of neck pain ranges from 17.7% to 63% in office workers across different countries (P Côté, et al., 2009).

The increasing demand within the service industry has led to a shift toward increasing computer based tasks and daily computer use (Cagnie, et al., 2007). In order to respond to such a demand, some educational institutions have focused on technology enhanced learning and skill acquisition and have even included laptop-based education to prepare students for the workplace. It has been noted that notebook computer use by university students has increased from 52.8% in 2005 to 75.8% in 2007 (Jacobs et al., 2009). With such an increase in the use of laptop computers, comes the need to assess the possible risk for the development of MSDs associated with their adoption. Extensive research has been done on computer and work related MSDs which have found associations between desktop computer use and increased risk of reporting MSD symptoms yet research on laptop computer use in the work area is limited. There is minimal work on student populations, although one study found that 41% of university students reported experiencing musculoskeletal pain while using a computer (Katz et al., 2000). However, this study did not differentiate between desktop and laptop computer use. There are important differences between the way a desktop and a laptop computer are used. Desktop workstations are often adjustable whereas laptop computers as used by students, often have to be used in crowded lecture theatres where seat and desk height cannot be adjusted. Additionally, student laptop users generally do not use computer peripherals (keyboard, mouse, monitor, and riser). This means that laptop users have postural stresses that are different than desktop users. It is clear that university student populations are potentially at risk for developing neck and upper limb pain (Katz, et al., 2000). With the growing use of laptops by students and even laptop based universities, it is essential that the potential risks of developing MSDs in relation to laptop use are well understood to allow for appropriate precautions to be taken. This demographic is in need of attention and the development and piloting of a questionnaire to assess neck pain risk factors in student laptop users is one focus of this thesis.

## 1.2 Disordered Sensorimotor Integration

Laptop use by students often involves awkward postures in confined spaces in lecture theatres not ergonomically set up for their use. Prolonged postural alterations represent a form of altered afferent input to the central nervous system which has the potential over time to lead to alterations in the way that the central nervous system (CNS) processes all subsequent input. Recent work has postulated that one possible consequence of prolonged periods of altered afferent input is disordered sensorimotor integration (SMI) (H Haavik-Taylor & Murphy, 2007a, 2007b, 2010a, 2010b; Murphy, Haavik-Taylor, Wilson, Oliphant, & Mathers, 2003; Tinazzi, Priori, et al., 2000; Tinazzi et al., 2004; Tinazzi et al., 1998). SMI is the process by which the nervous system coordinates incoming sensory (afferent) information from different parts of the body and integrates with the motor system to control movement. The sensorimotor system continuously monitors afferent information and addresses such input by modifying the connectivity and strength of synaptic connections within the nervous system (Moller, 2001). With these continual alterations within the sensorimotor system, there is potential for long lasting plastic changes to emerge. These changes may be adaptive but they also have the potential to be maladaptive.

A key component of typical SMI is sensory filtering. Sensory filtering is the ability of an individual to suppress or attenuate the processing of multiple afferent peripheral inputs. It reflects “surround-like” inhibition, which in healthy individuals, allows for the contrast between stimuli to remain high by suppressing the processing of input from surrounding areas. In the visual system for example, surround inhibition works similarly to a camera focussing in on the object of interest while other objects become “fuzzy”, allowing the object of interest to be clearly perceived. In the somatosensory system, such inhibition allows for the body to perceive stimuli as separate and process them accordingly (Tinazzi, Priori, et al., 2000). This filtering process has been found to be altered in individuals with neck pain, after repetitive muscular activities such as typing as well as other MSDs such as Dystonia (H Haavik-Taylor & Murphy, 2007a, 2010a, 2010b; Tinazzi, Priori, et al., 2000). This phenomenon can be measured using dual somatosensory evoked potentials (dual SEPs).

## 1.3 Chiropractic Care and SMI

Examples of altered afferent input which could potentially lead to disordered SMI include prolonged postural alterations, repetitive activity, or even removal of inputs or deafferentation such as occurs in carpal tunnel syndrome or anaesthetic block. Joint dysfunction also represents a form of altered afferent input, as proposed by Haavik-Taylor, Holt and Murphy (H Haavik-Taylor, Holt, & Murphy, 2010). These authors adopted a theoretical framework proposing that dysfunctional joints will lead to altered afferent input to the CNS, thereby leading to altered SMI and eventually altered motor control which then promotes pain and disability in a self perpetuating cycle (H Haavik-Taylor, et al., 2010). A particular focus of their work are patients with subclinical neck pain (SCNP), which refers to individuals with "recurring neck dysfunction such as mild neck pain, ache, and/or stiffness with or without a history of known neck trauma." (H. Haavik-Taylor & Murphy, 2011). These authors state that individuals with SCNP do not display continual symptoms and have not sought treatment of their neck pain (H. Haavik-Taylor & Murphy, 2011). Individuals with neck pain are assessed and often found to have dysfunctional joints by chiropractors and other manual therapists. It may be that the presence of underlying but asymptomatic joint dysfunction represents a form of altered afferent input that can lead to disordered SMI and ultimately cause SCNP to become chronic.

Joint dysfunction, defined as tenderness to palpation and reduced intersegmental range of motion (Hubka & Phelan, 1994; Jull, Treleven, & Versace, 1994) is typically treated by chiropractors and other manual therapists, using joint manipulation, a type of physical treatment that is known to change SMI in the short term, typically for at least 20 minutes after manipulation (H Haavik-Taylor & Murphy, 2007b, 2010a, 2010b). This suggests that in some cases, altered SMI may be able to be addressed with targeted therapeutic interventions. The hypothetical framework provided above suggests that the treatment of neck pain and dysfunction will then lead to improved SMI and a reversal of the chronic neck and/or upper limb pain. One criterion in a identifying a potential marker of disordered SMI and neck pain risk would be its ability to respond to treatment. Therefore, a pilot study to determine if dual SEPs is a feasible technique to show changes of SMI with 3 months of chiropractic care is essential to determine if the dual SEP technique can be a screening tool for those individuals with neck pain and is the second focus of this thesis.

It has been found that the most reliable indicators for spinal dysfunction are tenderness to palpation of the dysfunctional joint and observed intersegmental range of motion (Hubka & Phelan, 1994; Jull, et al., 1994). Therefore, for the purposes of this thesis, joint or spinal segment dysfunction will thereby be defined as the presence of both reduced intersegmental range of motion and tenderness to palpation of the dysfunctional joint.

## 1.4 Thesis Aims

This thesis focuses on two potential screening methodologies that pertain to the risk of developing neck and upper limb pain. The first relates to assessing the risk associated with laptop computer use and the incidence of neck and upper limb pain in university students with the development and piloting of a questionnaire. The second focuses on the potential use of dual SEPs as an instrument to measure the role of disordered sensorimotor integration (SMI) in the development of chronic neck pain. For the purposes of this thesis, chronic pain will refer to pain lasting > 3 months in accordance with the International Association for the Study of Pain (Harstall & Ospina, 2003) while the term acute pain will refer to pain lasting <3 months.

## 1.5 Hypotheses for Questionnaire Development Study

1) The piloting and test-retest reliability of the Student Laptop Use and Neck Pain Risk Questionnaire (SLUNPRQ) will yield good reliability as denoted by high Kappa values (K >0.8).

## 1.6 Hypotheses for Sensorimotor Integration Study using Dual SEPs

1) Individuals with neck pain will have improved SEP markers of neural processing and sensorimotor integration after 12 weeks of chiropractic care as denoted by reduced MU/M+U ratios in cortical and subcortical peaks.

2) Participants will show improvement in the Neck Disability Index (NDI) and Short Form McGill Pain Questionnaire (SF-MPQ) after 12 weeks of chiropractic care that mirror the improved SEP ratios.

## 1.7 Presentation of Information

This thesis is comprised of two literature review chapters and two manuscript sections. Chapter 2 reviews the anatomy of the somatosensory system, mechanisms of neural plasticity and methods of measuring such phenomena. Chapter 3 reviews the literature on risk factors for neck pain and the currently available questionnaires that measure these risk factors. Chapter 4 is the original manuscript for the development of a questionnaire on neck pain risk factors in student laptop users and Chapter 5 is the original manuscript for the feasibility of using dual peripheral somatosensory evoked potentials in measuring the long term effects of chiropractic care on disordered sensorimotor integration of the neck and upper limb. Finally, Chapter 6 is the summary of findings and future directions.

# Chapter Two Literature Review on Sensorimotor Integration

The central nervous system (CNS) is continuously reorganizing itself in response to the afferent input that it receives. Accurate sensorimotor integration (SMI) is essential to allow for that information to be processed and utilized effectively; thereby resulting in the precise and appropriate execution of motor tasks. Although typical neural reorganization may be beneficial in many ways to allow for learning and day to day function, there remains an opportunity for maladaptive plastic changes to occur. In order to provide further insight into this topic, the somatosensory system and ways in which to evaluate such neural processing must be well understood. This chapter reviews the anatomy of the somatosensory system, SMI, the method and mechanisms behind somatosensory evoked potentials (SEPs) and recent evidence on the mechanisms behind neural plasticity in regards to sensorimotor integration.

## 2.1 The Somatosensory System

The CNS is comprised of the spinal cord and the brain. Sensory information from various parts of the body enters the CNS through the dorsal root ganglion region of the spinal cord (Kandel, Schwartz, & Jessell, 2000). This information then begins to ascend through subcortical and finally cortical regions until it reaches the somatosensory cortex.

Sensory information obtained through limb proprioception or tactile sensation ascends ipsilaterally through large diameter dorsal root ganglion axons to the cuneate nucleus within the Medulla. It is at this point, that the axons decussate and the information begins to ascend contralaterally toward the thalamus. This pathway is known as the dorsal column-medial lemniscal system. Meanwhile the sensation of pain or temperature ascends contralaterally through smaller diameter axons, promptly decussating at the level of the spinal cord and ascending to the thalamus via the anterolateral system (Kandel, et al., 2000). These pathways are shown below in Figure 1.

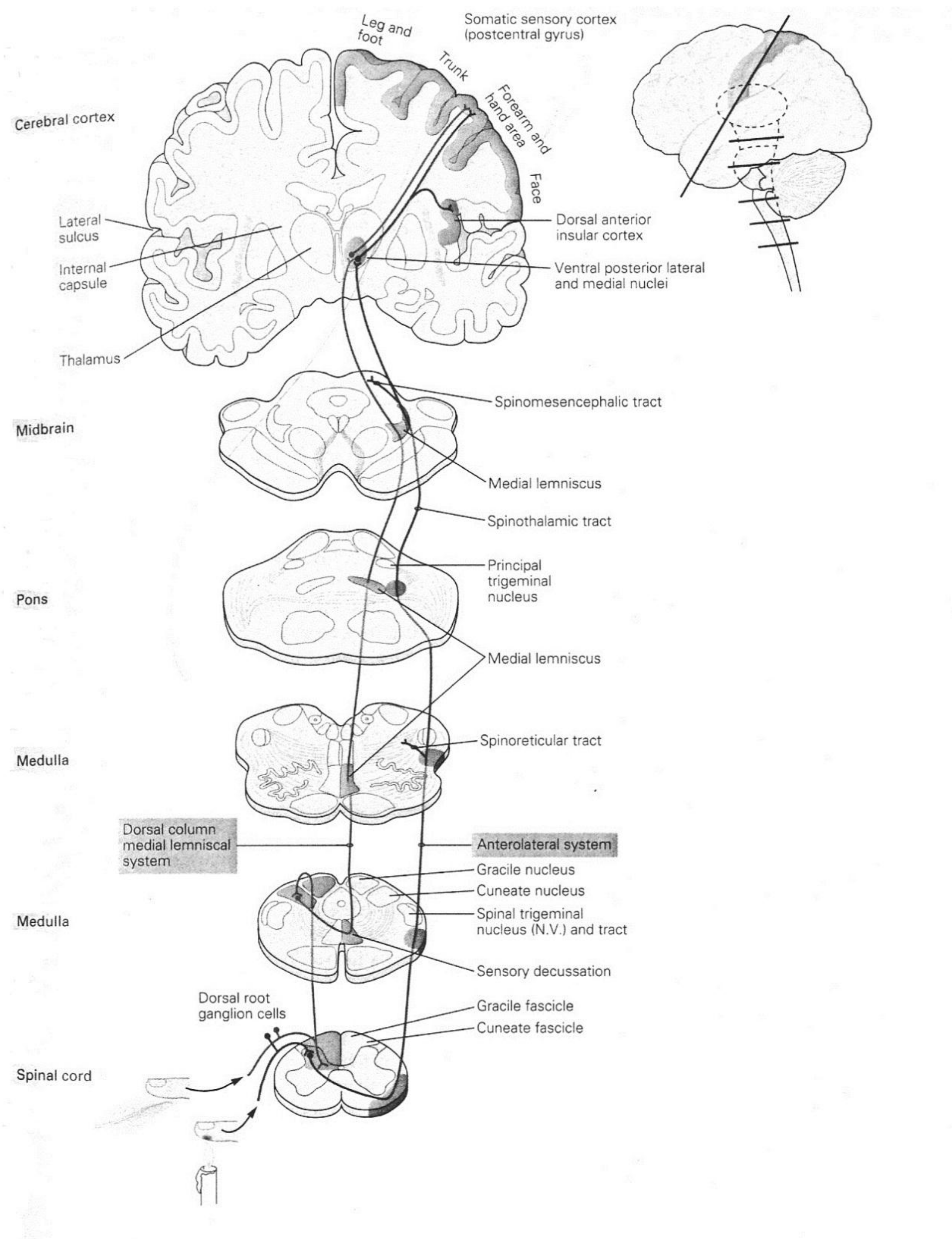


**Figure 1: The Dorsal Column Medial Lemniscal system (left) and the Anterolateral system (right) pathways. Printed with permission from McGraw-Hill, (Kandel, et al., 2000) on page 447.**

Somatotopic organization is widespread within the CNS. This is observed not only with axonal distribution within the dorsal columns of the dorsal horn but with the organization of cortical regions such as the thalamus and somatosensory cortex. Axons entering the CNS from lower areas of the spinal cord are distributed in different areas of the dorsal horn than those entering from higher segments of the spinal cord. Axons entering from the sacral region are located within the midline of the dorsal columns, while axons entering higher up in the spinal cord are distributed in more lateral orientations (Kandel, et al., 2000). At the higher levels of the spinal cord, this organization is maintained. The dorsal columns in higher levels of the cord are split into two fascicles; the gracile and cuneate fascicles. The gracile fascicle (located medially) contains fibers ascending from the ipsilateral sacral, lumbar and lower thoracic regions eventually terminating in the lower medulla in the gracile nucleus. The cuneate fascicle (located laterally) contains fibers from the upper thoracic and cervical regions of the spinal cord and terminates in the lower medulla in the cuneate nucleus (Kandel, et al., 2000).

The segregation of areas distributed within the CNS allows for sensory maps of the body to be created. This allows for the integration of information from adjacent areas of the body (such as the arm and hand) (Kandel, et al., 2000). The somatotopic organization within the motor and somatosensory cortex is maintained as above. Lower regions such as the legs are represented closer to the midline of the cortex, where higher regions such as the arms and face are located more laterally. Motor and sensory homunculi may be seen in Figure 2.

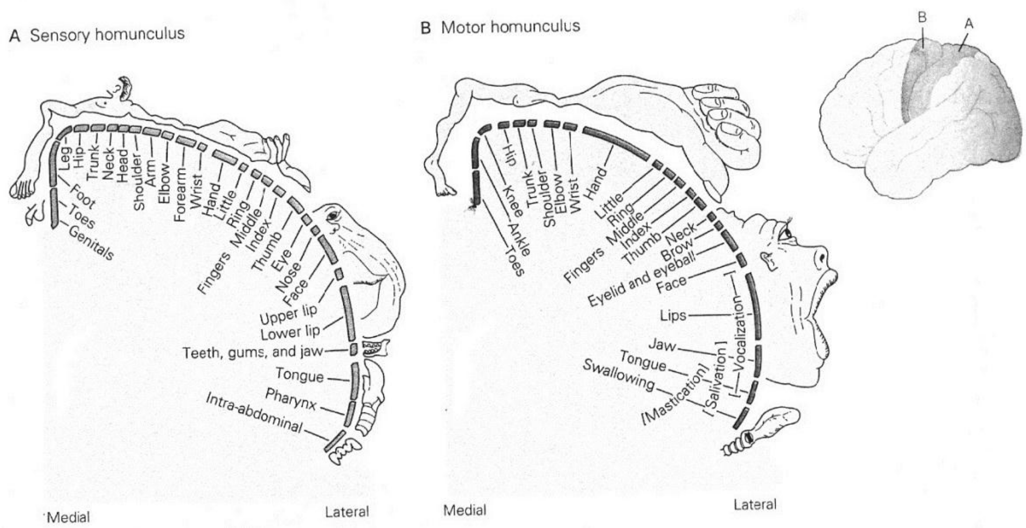


**Figure 2: The sensory and motor homunculi. The location of limb representation within the cortex is seen here. The amount of cortical area dedicated to a certain region is represented by the size of the image, reflecting their degree of innervations. Printed with permission from McGraw-Hill, (Kandel, et al., 2000) on page 344.**

Once somatosensory information travels through the brainstem, it is relayed through the ventral posterior lateral nucleus of the thalamus to the primary somatosensory cortex (S1) (Kandel, et al., 2000). S1 is located within the post-central gyrus of the parietal lobe (see Figure 3) and consists of four main areas; Broadman's areas 3a, 3b, 1 and 2. Although thoroughly interconnected, Broadman's areas 3a and 2 receive proprioceptive information from muscles and joints while areas 3b and 1 receive information from receptors within the skin (Kandel, et al., 2000).

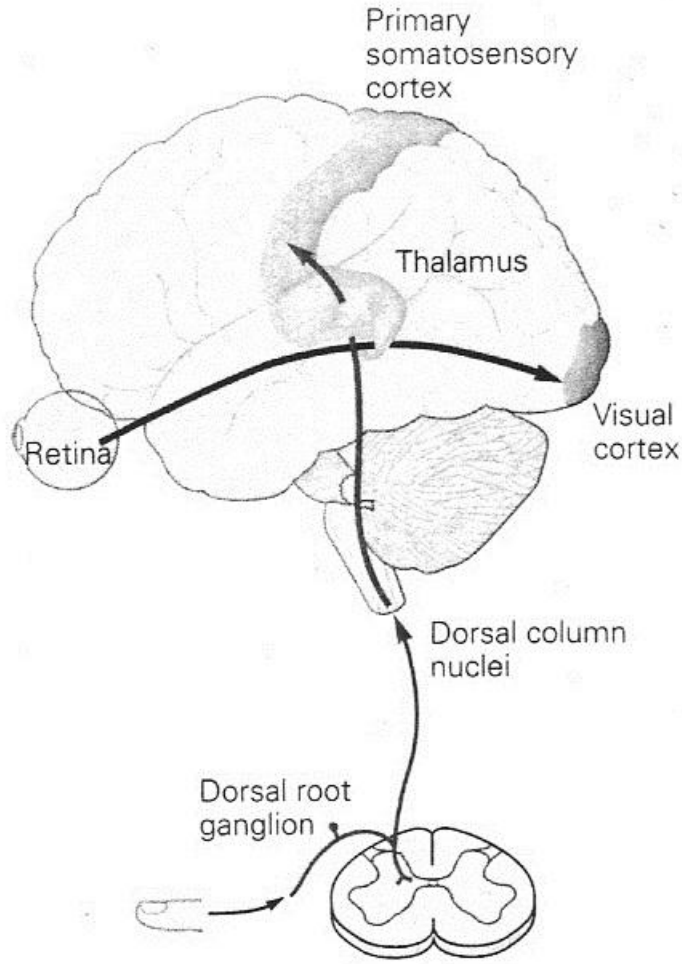


**Figure 3: The primary somatosensory cortex (S1). Printed with permission from McGraw-Hill, (Kandel, et al., 2000) on page 343.**

## 2.2 Sensorimotor Integration (SMI)

As described earlier, SMI involves the process of integrating afferent information from various parts of the body with the motor system to control movement. Precise and appropriate integration of such afferent input with the motor system is essential for executing accurate motor tasks. However, there is recent evidence to suggest that there are abnormalities within SMI processing in various MSDs, particularly in some movement disorders such as focal hand dystonia (Abbruzzese & Berardelli, 2003; Tinazzi, Priori, et al., 2000), as well as in patients with neck pain (H Haavik-Taylor & Murphy, 2010a). Pain itself has also shown to be a factor in affecting neural markers of SMI, particularly in clinical cases of trigeminal neuralgia (Tinazzi, et al., 2004). Chronic and transient deafferentation have recently been shown to alter neural markers of SMI both in clinical populations with median nerve compression due to carpal tunnel syndrome (Tinazzi, et al., 1998) and in experimental trials with transient deafferentation of the radial nerve (Murphy et al., 2003; Tinazzi, Rosso, Zanette, Fiaschi, & Aglioti, 2003). Experimental results have also shown that increases in afferent input due to repetitive muscular activity such as 20 minutes of typing are able to alter neural markers of SMI lasting at least 20 minutes after the activity (H Haavik-Taylor & Murphy, 2007a, 2010b; Murphy, Haavik-Taylor, Wilson, Oliphant, et al., 2003). These abnormalities could lead to maladaptive plastic changes within the CNS, potentially providing an opportunity for impaired motor function and pain to arise. Sections 2.4 through 2.5 discuss these findings in further detail.

The phenomena of SMI can be measured through many ways, such as transcranial magnetic stimulation (TMS), functional magnetic resonance imaging (fMRI) or somatosensory evoked potentials (SEPs). Evidence for disordered SMI and potential improvements in SMI may be evaluated by using these techniques. For the purposes of this dissertation, the SEP methodology will be reviewed in detail as it pertains to the methodology of the experiment carried out within this thesis.

## 2.3 Somatosensory Evoked Potentials

One way of measuring SMI at various levels of the CNS is through the use of somatosensory evoked potentials (SEPs). A SEP is an electrical potential elicited by either physiological, or electrical stimulation of somatosensory receptors, or their axons (Angel, Boylls, & Weinrich, 1984; Cohen & Starr, 1985). These SEPs may be recorded over the spinal cord and scalp through the cutaneous stimulation of a peripheral nerve. The most common upper limb nerves stimulated are the median, ulnar and radial nerves while the most common lower limb nerves stimulated are the tibial and peroneal nerves. As long as the stimulus intensity is not significantly over motor threshold, then large diameter myelinated afferents (i.e.: Ia and Ib fibers which have the fastest conduction velocities) are depolarized. In contrast, A delta and C fibers (conveying pain and temperature sensation) which are slower conducting and require longer stimulus durations to excite their receptors, are not part of the volley that elicits early SEPs at non painful stimulus intensities (Burke, Skuse, & Lethlean, 1981).

A unique feature of SEPs are that they allow one to determine in what level of the medial lemniscal pathway changes are occurring based on the elicited peak that is affected. In order to bring out these waveform peaks a multitude of stimuli, often 1000 - 2000 sweeps (Mauguiere et al., 1999) must be averaged to obtain a representative waveform since the electroencephalographic (EEG) signal is small. The resulting waveforms are named based on the direction of their deflection (positive or negative) and their latency in milliseconds, beginning at the time of initial nerve stimulation. There are two ways of labeling SEP waveforms; upward deflections labeled as negative (denoted with an N) or positive (denoted with a P). The resulting waveform label would then appear as either a N30 or a P30 for example, depending on the labeling convention used. In accordance with the International Federation of Clinical Neurophysiology (IFCN), the nomenclature for SEP waveforms utilized in this dissertation will be that of upward deflections as 'negative' (N) and downward deflections as 'positive' (P) (Mauguiere, et al., 1999; Nuwer et al., 1994).

One adaptation of this SEP technique is upper limb dual SEPs which is measured the same way but involves the stimulation of two nerves of interest. For the purposes of this dissertation, the technique that stimulates the median nerve and ulnar nerves will be described. This technique would involve the stimulation of the median (M) and ulnar (U) nerves both separately (M+U) and simultaneously (MU). This provides insight into the interaction between these two nerves demonstrated through an MU/M+U ratio. MU in this case represents the amplitude value of both nerves being stimulated at the same time, while the M+U value is the arithmetic sum of the two nerve amplitudes when stimulated separately. The MU values are typically lower than M+U values. This is seen because M and U values are not attenuated as much compared to when both nerves are being bombarded by stimuli simultaneously (Tinazzi, Priori, et al., 2000). With this knowledge, one can determine that an increased MU value is not favorable (Tinazzi, Priori, et al., 2000). The phenomena of sensory filtering is able to be assessed using this technique and is discussed further on in this chapter.

### 2.3.1 Neural Generators of SEP Waveforms

Different SEP waveform peaks that occur at typical latencies are known to represent central neural processing by specific parts of the brain and spinal cord, as described below. In order for SEPs utilization to provide meaningful data, the neural generators of each peak must be clearly understood. A neural generator is the proposed cerebral region thought to generate the electrical activity producing the SEP waveform of interest. Typically, SEP peaks prior to 100 ms are known as short latency SEPs and they reflect the arrival and pre-cognitive processing of incoming somatosensory information. The peaks of interest with respect to this thesis are the N9, N11, N13, P14, N18, N20, P22, P25 and N30 peaks, and the neural generators of each will be viewed here. A visual representation of the waveform peaks has been provided in Figure 4 and has been adapted from recent IFCN guidelines.

Originally, the neural generators of SEP peaks were determined by various techniques such as direct cortical recording during brain surgery (Allison et al., 1989; Wood et al., 1988) or by their absence in people with confirmed lesions in certain cortical areas (Mauguière, Desmedt, & Courjon, 1983). Recently, commercially available software using whole head EEG and complex mathematical modelling has been used to infer the "neural source" of some of the aforementioned SEP peaks (Baumgärtner, Vogel, Ohara, Treede, & Lenz, 2010; Buchner et al., 1996; Cebolla, Palmero-Soler, Dan, & Cheron, 2011). Such techniques are referred to as dipole source localization or standardized Low Resolution Brain Electromagnetic Tomography, to name a few. The evidence for the likely neural generators of the peaks of interest is presented and discussed in sections 2.3.2 to 2.3.10.

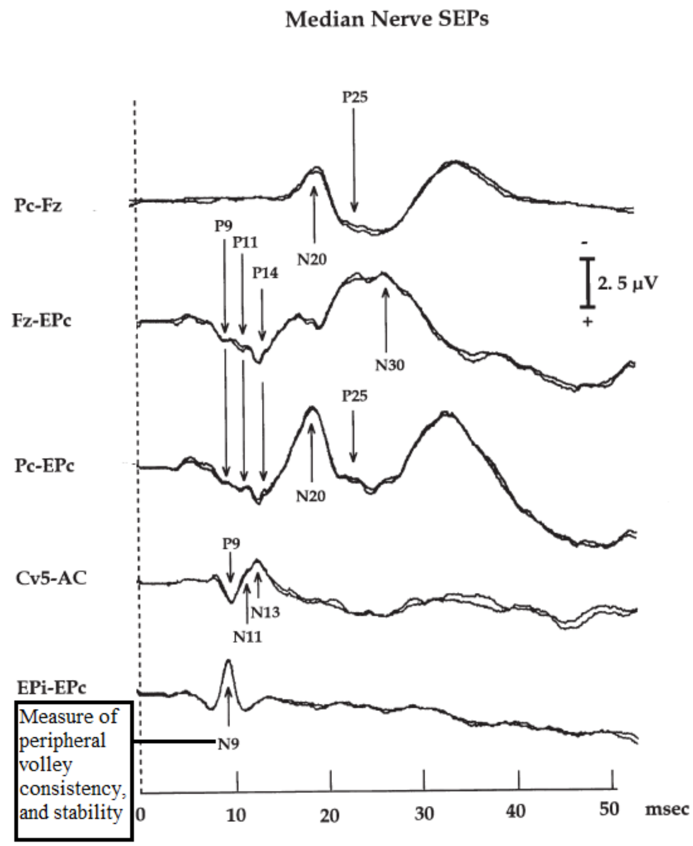


**Figure 4: Graphic representation of SEPs elicited from the median nerve. Waveform peaks N9 through N30 may be seen here. Modified from: (Mauguiere, et al., 1999).**

### 2.3.2 The N9 Peak

The N9 is a short latency evoked potential recorded over Erb's point, which is located in the supraclavicular fossa. This peak is recorded ipsilateral to the stimulation site. This peak is widely accepted as reflecting activity within the brachial plexus trunk (Mauguiere, et al., 1999), representing the peripheral ascending volley prior to entering the CNS.

### 2.3.3 The N11 Peak

The N11 is a small negative peak recorded best over the 5th cervical spinous process (C5) of the spinal cord (Mauguiere, et al., 1999). This peak is now widely accepted as reflecting the ascending peripheral nerve volley at the cervical level of the spinal cord, specifically through the dorsal columns (Mauguiere, et al., 1999). This peak therefore represents the peripheral afferent volley as it is ascending the spinal cord.

### 2.3.4 The N13 Peak

The N13 is a negative peak best recorded again over the C5 of the spinal cord (Mauguiere, et al., 1999). Typically seen as an inflection off of the N11 component, the origin of this particular peak has been debated. Previously proposed as originating in the cuneate nucleus as measured from the C2 spinous process (Sonoo, Shimpo, Genba, Kunimoto, & Mannen, 1990), this peak is now accepted as originating within the interneurons of the dorsal horn gray matter of the cervical spinal cord (Desmedt & Cheron, 1981; Mauguiere, et al., 1999).

### 2.3.5 The P14 Peak

The P14 is a positive peak best recorded using a scalp electrode, referenced to the contralateral earlobe (Mauguiere, et al., 1999). Originating from the lower brainstem, IFCN guidelines suggest that this peak is generated within the cervico-medullary junction (Mauguiere, et al., 1999). This is further supported by the presence of P14 potentials in patients with lesions of midbrain and upper medullary origin, suggesting that the origin of this peak is below the upper medulla (Noël, Ozaki, & Desmedt, 1996). The neural generator of this peak has therefore been concluded to reflect activity within the caudal medial lemniscus (Noël, et al., 1996).

### 2.3.6 The N18 Peak

The N18 is a negative peak immediately following the P14 peak. The IFCN guidelines suggest that the origin of the N18 is below the thalamus but above the foramen magnum (Mauguiere, et al., 1999). Clinical evidence suggests that the origin of the N18 is within the brainstem, specifically the dorsal column nuclei and/or the accessory olives (Noël, et al., 1996). Evidence stems from the preservation of the N18 peak with medial lemniscus lesions at the midbrain and upper medulla levels (Noël, et al., 1996).

### 2.3.7 The N20 Peak

The N20 is a negative peak recorded on the parietal region of the scalp contralateral to the stimulus site. This peak reflects activity within the primary somatosensory cortex (S1) within the posterior wall of the central fissure, specifically area 3b and is in accordance with recommendations from the IFCN (Allison, et al., 1989; Mauguiere, et al., 1999; Namiki et al., 1996). This neural origin is widely accepted, reflecting the earliest cortical activity within S1.

### 2.3.8 The P22 Peak

The P22 is a positive peak best recorded over the contralateral frontal scalp. Previously, the P22 has been suggested as originating in the motor cortex (M1) (Mauguière, et al., 1983). This was based on the fact that the P22 and N30 were still present in patients with parietal lesions, while earlier SEP components became absent (Mauguière, et al., 1983). Recent evidence for the origin of the P22 peak now suggests that the origin is not in M1, but in S1. It has been found using dipole source localization that the P22 originates from the postcentral gyrus, specifically Broadman's area 1 (Buchner, et al., 1996). This study also found that the P22 was abolished in a case of a postcentral lesion in area 1 where the N20 peak was preserved (Buchner, et al., 1996). This indicates that the N20 and P22 peaks have independent neural generators. Similar findings were acquired in 2010 using dipole source localization. Authors suggested that the P22 again originates in Broadman's area 1, stating that the origin of M1 is a less likely case (Baumgärtner, et al., 2010). These cases suggest that the P22 is actually located within Broadman's area 1 of the somatosensory cortex, rather than within the motor cortex.

### 2.3.9 The P25 Peak

The P25 is a positive peak best recorded over the contralateral parietal scalp region. Although labelled in this dissertation as the P25, this peak has great variation in latency and has been distinguished as either the P25 (Mauguiere, et al., 1999; Namiki, et al., 1996) or P27 (Tinazzi, Priori, et al., 2000; Tinazzi, et al., 1998) by various authors. The precise origin of this peak is still up for debate, although thought to originate somewhere in S1 (Mauguiere, et al., 1999). Recent evidence suggests that the P25 originates from the crown of the post central gyrus, specifically Broadman's areas 1 and 2 (Namiki, et al., 1996).

### 2.3.10 The N30 Peak

The N30 is a large negative peak, consistently recorded over the contralateral medio-frontal scalp region (Mauguiere, et al., 1999). Evidence suggests that there is not one single neural generator but many for this particular peak. The N30 has been suggested as originating in area 3b of S1(Allison, et al., 1989), but more recent evidence suggests that this peak represents activity of a complex cortico-subcortical loop incorporating the basal ganglia, thalamus, premotor and supplementary motor areas (SMA) as well as the primary motor cortex (M1) (Abbruzzese & Berardelli, 2003; Mauguière, et al., 1983; Pierantozzi et al., 1999; Rossini et al., 1989; Waberski et al., 1999). This peak is thought to represent SMI (Rossi et al., 2003).

Evidence of N30 originating, at least in part, within the SMA, basal ganglia and M1 has been seen in the past. One study found that the N30 peak was absent in a subject with a meningioma of the falx, resulting in unilateral SMA compression (Rossini, et al., 1989). This indicates that the SMA has some part to play in the generation of the N30. A more recent study found that when using a deep brain stimulation technique, patients with Parkinson's disease had an increase in the N30 representation (Pierantozzi, et al., 1999). Authors suggested that this increase in amplitude could be due to an improvement in SMA function (Pierantozzi, et al., 1999). Finally, evidence to support the contribution of M1 in the generation of N30 has been seen in a recent study using dipole source localization. These authors determined that the N30 was situated within area 4 of M1 (Waberski, et al., 1999). The most recent evidence to suggest that N30 generator involves an array of neural structures was found using event related potentials (similar in concept to SEPs). Using standardized Low Resolution Brain Electromagnetic Tomography on averaged data, authors reinforced that the N30 generators appear to be within the motor, pre-motor and pre-frontal cortices, again all areas thought to be important for SMI (Cebolla, et al., 2011).

## 2.4 Evidence of Neural Plasticity with Altered Afferent Input

Neural plasticity has been described as "a morphological or functional change in neuronal properties such as strength of internal connections, altered representational patterns or a reorganization of neuronal territories" (Boudreau, Farina, & Falla, 2010). There is recent evidence that such neural reorganization may occur due to pain (Tinazzi, Fiaschi, et al., 2000; Tinazzi, et al., 2004), as well as increases in peripheral afferent input as seen with repetitive muscular activity (Byl et al., 1997; H Haavik-Taylor & Murphy, 2007a; Murphy, Haavik-Taylor, Wilson, Oliphant, et al., 2003), increases in sensory input as seen in blind braille readers (Dayananda, Roopakala, Sprinivasa, & Rajeev, 2008) and in cases of reduced peripheral input such as transient or chronic deafferentation (Murphy, Haavik-Taylor, Wilson, Knight, et al., 2003; Tinazzi, et al., 2003; Tinazzi, et al., 1998). These neural changes may develop quickly as seen after some cases of repetitive muscular activity (H Haavik-Taylor & Murphy, 2007a, 2010b; Murphy, Haavik-Taylor, Wilson, Oliphant, et al., 2003) or may develop over the long term as seen in cases of chronic deafferentation due to carpal tunnel syndrome (Tinazzi, et al., 1998). Rapid neural plastic changes are thought to represent an unmasking of latent cortico-cortical connections that were previously inactive (Moller, 2001; Murphy, Haavik-Taylor, Wilson, Oliphant, et al., 2003) while changes developed over the long term are thought to reflect an increase in the synaptic efficiency of pre-existing synapses and development of new connections by the branching/sprouting of axons (Merzenich et al., 1983; Moller, 2001).

### 2.4.1 Neural Plasticity due to Pain

In recent research, it has been found that neural markers of plasticity have been known to change due to the presence of both chronic and acute pain. Utilizing somatosensory evoked potentials, evidence of plasticity was shown in a population with trigeminal neuralgia susceptible to chronic facial pain on one side (Tinazzi, et al., 2004). Researchers found that SEPs obtained from the median nerve (unaffected by the condition) at the wrist taken on the painful side elicited greater cortical SEP peaks than on the opposing non-painful side. Patients were pain free at the time of data acquisition. This demonstrates that although pain is specific to one region (in this case the trigeminal nerve), neural plastic changes may occur in adjacent representations of the brain in response (in this case, median nerve or hand). The proximity of the hand and face representation within the cortex may be seen in the homuncular illustration in Figure 2. Since patients were pain free at the time of data acquisition, it provides evidence that chronic pain can induce persistent neural plastic changes within the cortex.

The presence of pain at the time of recording leads to different changes within the CNS. One study found that patients experiencing pain in the right thumb due to a protrusion of an intervertebral disk had altered cortical SEP markers (Tinazzi, Fiaschi, et al., 2000). Patients were in pain at the time of data acquisition and yielded greater N13, N20 and N30 SEP peaks on the painful side compared to the non-painful side (Tinazzi, Fiaschi, et al., 2000). The results from these studies would indicate that pain results in alterations at multiple levels of the somatosensory system, specifically subcortical and cortical areas of the central nervous system.

### 2.4.2 Neural Plasticity due to Repetitive Muscular Activity

Recent evidence has revealed the potential for neural plastic changes to occur due to repetitive muscular activity in both human and animal models (Byl, et al., 1997; H Haavik-Taylor & Murphy, 2007a, 2010b; Murphy, Haavik-Taylor, Wilson, Oliphant, et al., 2003). In fact, repetitive motor activity for only 20 minutes has been shown to induce neural plastic changes in subcortical and cortical structures. One study used a clever design where SEPs were recorded from the median nerve at the wrist, which would mainly be carrying afferent fibers from the thumb musculature while participants performed 20 minutes of repetitive typing with the three middle fingers. SEPs acquired from the median nerve demonstrated attenuation of the N13, P14-N18 and N30 complexes persisting for 20 minutes after the typing task (Murphy, Haavik-Taylor, Wilson, Oliphant, et al., 2003). This indicates that although the motor training occurred in the three middle fingers, the way in which the CNS was processing the afferent information from the thumb was altered for some time after the intervention.

Dual SEPs have demonstrated similar findings. In a recent study, it was found that the cortical N20 and N30 MU/M+U ratio values increased after a 20 minute typing task. This indicates that after a mere 20 minutes of repetitive typing with the thumb, plastic changes occurred at the cortical level, possibly reflecting a release of inhibition and/or a reduced ability to effectively filter or integrate dual peripheral input (H Haavik-Taylor & Murphy, 2007a). Since these elevations were seen at the N20 and N30 peaks, one can deduce that fast neural plastic changes have been induced at the level of S1 as well as subcortical and cortical loops within the brain. Similar findings were found by the same authors where MU/M+U ratios for the N20 and N30 SEP components were elevated after 20 minutes of typing in neck pain patients prior to a chiropractic intervention (H Haavik-Taylor & Murphy, 2010b). These studies have shown that just 20 minutes of repetitive muscular activity has the potential to alter the ability to process or filter afferent input appropriately, outlasting the repetitive movement itself. Interestingly, the increased SEP ratios seen with repetitive activity appear to mirror the increased SEP amplitudes seen in people who were in pain at the time of recording (Tinazzi, Fiaschi, et al., 2000). It seems that the typing task appears to provide a window into the silent plastic changes that may exist in SCNP patients.

In addition, it has also been demonstrated in animal models that cortical neural plasticity can occur due to repetitive muscular activity, specifically overuse. In this study, two owl monkeys were trained to complete a pellet retrieving task over 20 weeks, averaging 300-400 trials per day. One monkey used a hand squeezing technique while the other developed a more variable pulling technique to retrieve the food through the hand grip apparatus. After the 20 weeks of motor training, the monkey adapting the hand squeezing technique developed a significant decline in motor function of the limb involved in the task (Byl, et al., 1997). Both monkeys were also assessed through cortical mapping and demonstrated a significant degradation of the previously sharply defined hand representation in area 3b of the somatosensory cortex, as measured by increased size, distribution and overlap of receptive fields (Byl, et al., 1997). This degradation was less pronounced in the monkey utilizing the arm pulling technique. These results demonstrate that highly articulated, repetitive movement (in this case hand squeezing) is capable of producing lasting neural plastic changes within the somatosensory cortex of owl monkeys. This illustrates that the homuncular representations of the body are adaptable and are continuously in reorganization to emulate the amount of use within the body, further supporting that repetitive muscular activity has the ability to induce neural plastic changes.

The findings seen above elucidate the fact that both short and long term repetitive muscular activity has the potential to elicit maladaptive plastic changes within the cortex. These changes could lead to motor dysfunction as seen in the primate study above (Byl, et al., 1997).

### 2.4.3 Neural Plasticity due to Altered Peripheral Input

As stated earlier, neural plasticity may occur due to changes in peripheral afferent input. These changes may represent an increase or decrease of peripheral input as seen with Braille readers (Dayananda, et al., 2008), as well as in cases of transient or chronic deafferentation (Murphy, Haavik-Taylor, Wilson, Knight, et al., 2003; Tinazzi, et al., 2003; Tinazzi, et al., 1998). Recent research on the congenitally blind has shown increases in somatosensory cortical activity compared to normal sighted subjects (Dayananda, et al., 2008). Using median nerve SEPs, it was found that N20 peak amplitudes in blind participants were enlarged. Due to the blind individual's reliance on tactile and non visual sensory cues, this could reflect neural reorganization in response to such an increase in sensory input.

Furthermore, reduced peripheral input to the somatosensory system can lead to neural adaptations and has been examined by way of transient deafferentation. In 2003, authors conducted a study by inducing radial nerve anaesthetic block and elicited median nerve SEPs ipsilateral to the blocked nerve. SEP recordings found that the cortical N30 peak amplitudes were increased during the nerve block, eventually returning to baseline values after the blockade had worn off (Murphy, Haavik-Taylor, Wilson, Knight, et al., 2003). Since this finding was a short term change, it could reflect an unmasking of pre-existing cortico-cortical connections (Murphy, Haavik-Taylor, Wilson, Knight, et al., 2003). Similar findings were seen in radial nerve block, in relation to the first dorsal interosseous (FDI) muscle. The cutaneous territory over the FDI is innervated by the radial nerve, while the muscle itself is innervated by the ulnar nerve (Tinazzi, et al., 2003). This unique feature allowed for authors to examine the effects of radial nerve block on SEPs elicited from muscle afferents in the FDI muscle. Authors demonstrated that cortical SEP peak amplitudes increased during anaesthetic block. The N20, P27 and N30 SEP peak amplitudes were greatest when under complete anaesthesia and returned back to baseline values after it had worn off (Tinazzi, et al., 2003). This demonstrated that short-term plastic changes can occur at different submodal levels (proprioceptive and cutaneous afferents) within the same body part. Again, these changes were short term, likely indicating an unmasking of pre-existing previously inactive connections.

Finally, a reduction of peripheral input due to chronic deafferentation from unilateral carpal tunnel syndrome (median nerve compression) has been shown to induce neural plasticity within many levels of the somatosensory system. Patients experiencing unilateral carpal tunnel syndrome for 11-25 months were shown to have increased cortical and subcortical SEP peak amplitudes when taken from the ulnar nerve ipsilateral to the deafferented median nerve (Tinazzi, et al., 1998). Amplitudes of the N13, P14, N20, P27 and N30 components were all elevated compared to the non affected side as well as to healthy controls (Tinazzi, et al., 1998). Authors suggest that the changes seen in the subcortical regions such as the brainstem could in fact be the underlying cause of in changes seen in S1. Authors also state that the unmasking of connections and increases in synaptic strength could result in the ulnar SEP changes seen in this study (Tinazzi, et al., 1998).

The above findings demonstrate that altered afferent peripheral input, either in the form of increased or reduced input can lead to neural plastic changes within many levels of the somatosensory system and may occur rapidly or over long periods of time. These changes could represent long lasting maladaptive plastic changes.

## 2.5 Evidence for Altered Sensory Filtering

As previously mentioned, “surround-like” inhibition is enhanced in healthy individuals, allowing for contrast between stimuli to remain high by suppressing surrounding input and reflects normal sensory filtering. Evidence for abnormalities of sensory filtering have occurred following periods of repetitive muscular activity (H Haavik-Taylor & Murphy, 2007a, 2010b), as well as in certain MSDs or movement disorders such as focal hand dystonia (FHD) and neck pain (Tinazzi, Priori, et al., 2000). FHD is a movement disorder characterised by excessive co-contraction of agonist and antagonist muscles during fine motor tasks such as writing or playing instruments (Wu et al., 2010). Recent research has found that patients with FHD have reduced surround-like inhibition, or impaired sensory filtering. This is seen with an increase in the MU/M+U ratio (described initially in section 2.3 of this thesis) using dual SEPs, indicating a reduced ability to suppress and filter afferent information (Tinazzi, Priori, et al., 2000). These authors believe that this increased ratio would be due to a defect in “surround-like” inhibition in those with FHD.

Impaired sensory filtering is characterized by increased MU/M+U ratios, reflecting a reduction in “surround like” inhibition. This phenomenon has also been seen due to repetitive muscular activity. It has been recently found that after only 20 minutes of repetitive typing, MU/M+U ratios have been increased in healthy individuals as well as in patients with neck pain, again demonstrating an inability to appropriately filter dual peripheral input (H Haavik-Taylor & Murphy, 2007a, 2010b). These authors have proposed that persistence of such a finding could lead to possible desegregation of the somatosensory maps within the brain and could lead to maladaptive plasticity in susceptible individuals. Such a desegregation could resemble findings in the primate cortex (Byl, et al., 1997). It has been found that these values are increased after repetitive muscular activities. This may simply reflect disinhibition which is fundamental for motor learning. Alternately, it could reflect an inability to properly filter or inhibit the sensory information coming in. Furthermore, a positive correlation has been associated with increased cortical peaks evoked from median nerve SEPs with impaired somesthetic temporal discrimination threshold in patients with FHD (Tamura et al., 2009). These findings are important because it links a sensory deficit in these patients to the SEP measures of altered SMI.

The studies described above provide evidence that sensory filtering (a key component of SMI) is altered in not only in individuals with MSDs such as neck pain and FHD but after short periods of repetitive muscular activity such as typing. Altered sensory filtering could potentially represent the initial stages of maladaptive plastic change which over time could lead to potential desegregation of sensory maps within the cortex, eventually leading to abnormal motor control, pain or disability.

## 2.6 Improvement of SMI Following Spinal Manipulation

As mentioned in the introduction, in order to develop an effective neural marker of neck pain risk, the marker needs to be able to change in response to treatment. Recent studies have shown that one treatment which is able to improve SMI is spinal manipulation of dysfunctional cervical joints. One study investigated the effects of spinal manipulation on neural markers of SMI in patients with subclinical neck pain (SCNP). Researchers found that the cortical N30 component MU and MU/M+U ratio values after spinal manipulation were reduced from baseline values (H Haavik-Taylor & Murphy, 2010a). This indicates that individuals with recurring neck pain are already unable to appropriately attenuate dual peripheral input, but that manipulation can normalize their SEP markers of SMI. Similar findings were found using a single SEP technique, where the cortical N30 component elicited from the median nerve were decreased after spinal manipulation (H Haavik-Taylor & Murphy, 2007b). This again indicates that the neck pain population has higher SEP markers of SMI but is able to be normalized after treatment.

More importantly, spinal manipulation delivered prior to the performance of a motor task appears to improve the SMI of that task in a people with recurrent neck pain (H Haavik-Taylor & Murphy, 2010b), suggesting that they may have disordered SMI. Initially researchers demonstrated that twenty minutes of repetitive muscular activity produced a decrease in sensory filtering by increasing MU values, as well as MU/M+U ratios for the N20 and N30 components in people with recurrent neck pain (H Haavik-Taylor & Murphy, 2010b). In an experiment performed at least four weeks apart, participants with subclinical neck pain and current neck joint dysfunction as assessed by a registered chiropractor, completed the same 20 minutes of repetitive motor activity but first had their neck treated by a registered chiropractor using spinal manipulation. In this experiment, the decrease in MU amplitude values and MU/M+U ratios seen in previous work was confirmed (H Haavik-Taylor & Murphy, 2010a). Furthermore the effect persisted even following the 20 minutes of repetitive activity. This reduction in MU or the MU/M+U ratio values would indicate a restoration of “surround-like” inhibition, or sensory filtering which was able to persist when individuals had to perform a motor task. Since the N20 represents S1 and N30 represents activity in cortical circuits relevant to

SMI, the authors concluded that alterations in sensory filtering occurred at the level of the somatosensory cortex, subcortical and cortical loops. This would indicate an improvement or normalization of SMI when spinal manipulation is delivered to dysfunctional joints in advance of repetitive motor activity. These results persisted for up to 20 minutes after the manipulation intervention. However they were not measured beyond this time frame and hence the effects of manipulation cannot be generalized to long-term alterations of SMI.

To be clinically useful, it is important to know whether the effects of altering SMI are long term and this is a knowledge gap that this thesis seeks to fill.

## 2.7 Chapter Two Summary

Based on the findings from chapter two, there is evidence to suggest that the CNS is constantly reorganizing itself in response to altered afferent input. This has been shown whether or not that is due to pain (Tinazzi, Fiaschi, et al., 2000; Tinazzi, et al., 2004), both increases and decreases of peripheral afferent input (Dayananda, et al., 2008; Murphy, Haavik-Taylor, Wilson, Knight, et al., 2003; Tinazzi, et al., 2003; Tinazzi, et al., 1998) as well as both long and short term repetitive muscular activity (Byl, et al., 1997; H Haavik-Taylor & Murphy, 2010b; Murphy, Haavik-Taylor, Wilson, Oliphant, et al., 2003). These changes may develop over long periods of time (Byl, et al., 1997; Tinazzi, et al., 1998) or over the short term (H Haavik-Taylor & Murphy, 2007a, 2010b; Murphy, Haavik-Taylor, Wilson, Oliphant, et al., 2003).

One marker of neural plasticity that is essential to the phenomena of SMI is sensory filtering. Reduced sensory filtering is seen as the inability to appropriately attenuate more than one peripheral input. One example of this is the ability to attenuate processing of input following electrical stimulation of peripheral nerve bundles, as seen in patients with FHD as well as neck pain (H Haavik-Taylor & Murphy, 2010a; Tinazzi, Priori, et al., 2000). It is thought that chronic alterations in afferent input could lead to maladaptive plasticity within the brain. Such plasticity could lead to a desegregation of the somatosensory maps within the brain potentially leading to further maladaptive plasticity in susceptible individuals (H Haavik-Taylor & Murphy, 2010b). In an effort to address such impaired sensory filtering, spinal manipulation has been assessed as a potential treatment. Spinal manipulation has been shown to improve SEP markers of SMI and the filtering of dual peripheral input for at least 20 minutes after the treatment but has yet to be investigated over long periods of time. The experiment described in manuscript II aims to address this issue, specifically over a timeframe 12 weeks to determine if these beneficial changes can be maintained over the long term.

# Chapter Three Risk Factors for Neck Pain and Appraisal of Questionnaires

As previously mentioned in section 1.1, the rising use of information technology coupled with increases in service sector oriented employment have coincided with recent increases in the incidence and prevalence of neck pain (P Côté, et al., 2009). This rise in neck pain (or other MSDs) may be partially influenced by an increase in sedentary work as well as occupational and recreational computer use.

In order to meet the current service sector demand for technology based skills, some post-secondary institutions have developed technology enhanced learning programs. In such cases, students within these programs may be provided with their own personal laptop. Because laptop use may represent a significant neck pain risk factor in a young population about to embark on their working life, it was important to develop measures to assess the way in which laptops are being used by students, and how this relates to the known risk factors for neck pain.

Initially, the literature was searched to identify a suitable instrument to provide further insight into laptop use within student populations. However, there were no adequate tool identified at the time of the initial literature search that encompassed laptop use and its relationship to neck pain in student populations.

This chapter reviews the recent literature on the risk factors for upper extremity and neck pain as it pertains to computer and laptop use. A recent review of the literature on neck pain from the 2000-2010 Bone and Joint Decade Task Force on Neck Pain and its Associated Disorders played a significant role in developing sections 3.1 to 3.2.11 of this chapter (P Côté, et al., 2009; Hogg-Johnson et al., 2009). This chapter identifies those risk factors for neck pain that also apply to laptop use in student populations and reviews currently available questionnaires on the use of computers or laptops to determine whether they measure the identified risk factors for neck pain. Issues that are specific to laptop use requiring incorporation into future instruments are discussed in sections 3.3 and 3.4. The chapter concludes with recommendations for the use and development of a multi-dimensional questionnaire to be administered to student laptop users.

## 3.1 Non-Modifiable Risk Factors Associated with Neck Pain

The non-modifiable risk factors for neck pain are discussed in sections 3.1.1 to 3.1.5. Non modifiable risk factors are those that cannot be altered, but are still significant for the potential development of neck pain. Risk factors for neck pain are reviewed and their relevance for inclusion for student laptop users is discussed.

### 3.1.1 Age

There has been a great deal of evidence in the literature regarding the association between age and the risk of developing neck pain. A recent study found that the risk of neck pain increased with age until the age of 50, where it began to decrease (Cagnie, et al., 2007; Hogg-Johnson, et al., 2009). This is supportive of recent findings from the Bone and Joint Task Force which reported that older workers were more likely to develop neck pain than their younger counterparts, with risk peaking in the fourth and fifth decades of life (P Côté, et al., 2009; Hogg-Johnson, et al., 2009).

### 3.1.2 Gender

Many studies have shown differences in the risk for developing neck pain between genders. The Bone and Joint Decade Task Force found preliminary evidence for women being at higher risk than men (P Côté, et al., 2009). There has been further evidence of such a trend, seen in female workers who use video display units. A Finnish cross-sectional survey found that, female workers had a correlation almost three times greater for neck pain when compared to men (OR=2.9 1.3± 6.7) (Korhonen et al., 2003). A similar trend was seen in a study where female office workers had a correlation that was almost twice as high of developing neck pain than men (OR=1.95, 95% CI 1.22±3.13), paired with higher prevalence rates of neck pain among women (at 18%) than in men (at 11%) (Cagnie, et al., 2007). Female students were also found to be more likely to report limitation in student activities due to musculoskeletal discomfort than male students and reported having pain in the neck (70% vs. 44%) and shoulder (52% vs. 29%) more than male students (Hupert et al., 2004). Therefore, the current evidence suggests that being of female gender is associated with neck pain.

### 3.1.3 Ethnicity

There has been varying evidence on the association between neck pain and ethnicity. One study found that racial/ethnic minority students were more likely than non minority students to report upper extremity symptoms associated with computing (52% vs. 37%) and were more likely to develop symptoms faster, with a significant portion reporting symptoms just after computing for one hour or less compared to non-minority counterparts (Hupert, et al., 2004). In contrast, it has also been found that non-white workers had a lower incidence of neck pain than whites (Gerr et al., 2002). Ethnicity may or may not present an increased risk for neck pain; further research may elucidate this topic in the future. Collecting data on ethnicity can be difficult and ethically challenging and there is no evidence to suggest that this is an independent risk factor for neck pain in laptop users. Given the equivocal nature of the evidence, there is not sufficient justification to include ethnicity as a risk factor in the analysis of questionnaires pertaining to student laptop use.

### 3.1.4 History of Musculoskeletal Pain

Recent reviews of the literature have demonstrated an increase in risk for the development of neck pain associated with prior history of musculoskeletal pain (P Côté, et al., 2009). It was found that experiencing neck pain in the past (RR= 1.7, 95% CI, 1.2-2.5) and a history of low back pain (RR= 1.7, 95% CI, 1.3-2.1) increased the risk of developing neck pain in an adult general population (Croft et al., 2001; Hogg-Johnson, et al., 2009). Similar findings were seen in a population of nurses, where the risk of developing neck or shoulder pain was increased in those individuals who had reported previous pain within the neck/shoulder or low back (Smedley et al., 2003). The available evidence suggests that a history of musculoskeletal pain can increase the risk of future neck pain, and should therefore be included on instruments measuring the risk of developing neck pain.

### 3.1.5 Job Security

As reported by the 2000-2010 Bone and Joint Decade Task Force on Neck Pain and its Associated Disorders, job security is associated with neck pain (P Côté, et al., 2009). This is supported by one high quality study that found workers reporting job insecurity had a slightly increased risk of neck pain (G. Ariëns et al., 2001). This is an important risk factor for workers and should therefore be included on surveys specifically for workers since it is a pertinent issue for that population. However, it is not a relevant issue for student laptop users and will not be included for the analysis of questionnaires pertaining to student laptop use.

## 3.2 Modifiable Risk Factors for Neck Pain

The modifiable risk factors for neck pain are discussed in sections 3.2.1 to 3.2.11. Modifiable risk factors are those that have potential to be altered and are significant for the potential development of neck pain. Risk factors are discussed below if they were deemed to be potentially relevant to student populations, laptop and/or computer use.

### 3.2.1 Smoking

There is some evidence that cigarette smoking may be associated with the risk of developing neck pain (P Côté, et al., 2009). One study found that current smokers had a risk ratio of 1.2 (95% CI, 0.9-1.5) in comparison to those who had never smoked but did not report an association between smoking and neck pain incidence (Croft, et al., 2001; Hogg-Johnson, et al., 2009). This was also supported by findings from a more recent study. Based on evidence from a cross-sectional survey, it was found that current/ex-smokers had a correlation almost twice as high of developing neck pain compared to those who had never smoked (OR= 1.9, CI 0.8±4.3) (Korhonen, et al., 2003). This suggests that smoking, both past and present, may contribute to the development of neck pain in the future and should be included as an item on current as well as future questionnaire pertaining to the study of neck pain.

### 3.2.2 Job strain

There has been a great deal of evidence surrounding the effects of job strain on health. A large amount of evidence suggests that high amounts of job strain and low job control can increase the risk and incidence of neck pain (P Côté, et al., 2009). An example of this is seen in a recent study where high job strain was found to interact with high perceived muscle tension, demonstrated by an incidence rate ratio (IRR) of 4.0 (95% CI, 1.6-10.0) to increase the risk of developing neck pain (Wahlström, Hagberg, Toomingas, & Wigaeus Tornqvist, 2004). High job strain was also found to interact with high physical exposure as a risk for neck pain, with an IRR of 2.7 (95% CI, 1.2-5.9)

(Wahlström, et al., 2004). Similar findings were seen with high amounts of quantitative job demands (RR, 2.14; 95% CI, 1.28–3.58) (G. Ariëns, et al., 2001).

Although job strain may not be an issue for student populations, there has been evidence that psychosocial factors such as stress do have an impact among high school students. This is supported by an apparent positive association found between stress and neck and shoulder symptoms among adolescents, particularly in high school girls (Niemi, Levoska, Rekola, & Keinanen-Kiukaanniemi, 1997). Stress is a potential risk factor in programs which are highly demanding or competitive and is certainly worth further investigation. An appropriate and equivalent measure of this risk factor needs to be included in future musculoskeletal surveys of students. However, this may require a separate questionnaire altogether. The development of such a questionnaire requires psychological expertise that is beyond the scope of this thesis and will therefore not be included when analyzing current laptop/computer based questionnaires.

### 3.2.3 Social support

There is evidence demonstrating that low social support at work from co-workers or superiors may influence the risk of neck pain (P Côté, et al., 2009). An example of this is seen in female computer users where low social support was found as a risk factor for the development of musculoskeletal symptoms (Jensen, 2003). Similar results were found that low co-worker support was related to neck pain in workers (RR, 2.43; 95% CI, 1.11–5.29) (G. Ariëns, et al., 2001). If social support at work is a risk factor, then social support at school could be a factor in student populations and should therefore be included on surveys targeted towards this demographic, as it may represent a potential risk factor. Although beyond the scope of this review, an appropriate measure of psychosocial risk factors and social support needs to be identified and/or developed for a student population, ideally combined with the measures of job strain discussed in section 3.2.2.

### 3.2.4 Sedentary Position

There is a large body of evidence to suggest that working in a sedentary position for prolonged periods of time is associated with increased risk of developing neck pain (P Côté, et al., 2009). It has been reported that workers who sit for more than 95% of the time have greater than twice the risk of acquiring neck pain (RR= 2.34, 95% CI, 1.05-5.21) (G Ariëns et al., 2001). The same authors also reported that individuals who remained in a sitting position for longer than 1% of their working time were at higher risk for neck pain than those who rarely adopted a sitting position. These authors attribute this to a continual static load to the neck muscles when in a sitting position for prolonged periods (G Ariëns, et al., 2001). A more recent study is in line with these findings, as it found a significant association between cumulative hours of computer use with participants reporting *any, moderate and greater* musculoskeletal symptoms (Menendez et al., 2008). This suggests that working in a sedentary position for prolonged periods of time may increase the risk of developing neck pain. This is of particular concern for student laptop users, and should be included within questionnaires intended for the assessment of neck pain within this population.

### 3.2.5 Neck Posture

There is evidence for an increased risk of neck pain due to extended amounts of time with the neck in forward flexion. In a study done on office workers, it was found that working with the neck in flexion at a minimum of 20˚ for greater than 70% of the time was a risk factor for developing neck pain (G Ariëns, et al., 2001) . In the same study, it was found that working with the neck in flexion at a minimum of 45˚ produced lower risk ratios for developing neck pain. These authors did not find any association between neck pain and neck rotation at 45˚ for more than 30% of the working time (G Ariëns, et al., 2001). It is clear that producing an angle of 20 ˚ or more during neck flexion for prolonged periods of time may increase the risk of developing neck pain among computer users. This is of concern in laptop users due to the potential lack of appropriate workstation that comes with a typical desktop computer setup. As stated in a recent study, when a laptop is used without external monitors, keyboards, risers or other accessories and is placed on a desk or table, the keyboard is usually too high while the monitor is too low (Jacobs et al., 2011). A high keyboard leads to a forward slumped posture with the forearm/wrist area usually resting on the hard edge of the desk. The low monitor means that the head and neck need to be flexed forward to see it rather than maintaining a neutral neck posture. This means that neck flexion will commonly exceed 20° for laptop users (Jacobs, et al., 2011). This is an important factor to consider when assessing the risk of neck pain in future studies. This risk factor should be included within musculoskeletal assessment tools for student laptop users.

### 3.2.6 Upper Extremity Posture, Keyboard and Mouse Position

As reported in the Bone and Joint Decade Task Force review of the literature, upper extremity posture in relation to keyboard and mouse position can affect the risk of developing neck pain. A study done on computer users found that those who maintained an inner elbow angle greater than 121˚ while using their keyboard were less likely to develop neck and shoulder pain (Marcus et al., 2002). The same study found that elbow height lower than the “J” key on a keyboard would increase the risk of developing neck and shoulder symptoms and disorders twofold. In terms of mouse position, the literature tends to vary. It was found that utilizing a mouse which created an angle of shoulder flexion greater than 25˚ increased the risk of developing neck and shoulder pain, peaking at 35˚ and 44˚ of flexion (Marcus, et al., 2002) but has yet to be supported by other work to date.

The study of keyboard and mouse position is an important area to investigate but since external mouse utilization does not apply to the majority of student laptop users, it should be asked as an additional or separate question when targeting a student laptop user population. These results suggest that using a laptop that creates an inner elbow angle less than 121˚ and which results in having the elbow lower than the “J” key on the keyboard may increase the risk of developing neck and upper extremity pain. The results seen here emphasize the need for the inclusion of these factors within current and future neck pain assessment tools, as they are pertinent to laptop use within the majority of users.

### 3.2.7 Chair Armrests

Evidence has shown that the use of chair armrests was associated with lower risk of developing neck pain. This was supported by one study which demonstrated a reduced risk of developing neck and shoulder disorders compared to those who did not utilize chairs with armrests (P Côté, et al., 2009; Marcus, et al., 2002). This has yet to be supported by another study and should be further investigated. Nonetheless, this should be incorporated into a questionnaire assessing risk of neck pain among laptop users.

### 3.2.8 Head Posture

As reported in the Bone and Joint Decade Task Force, it has been found that working with a computer monitor that creates a tilted angle of greater than 3˚ at the head can increase the likelihood of developing neck and shoulder symptoms by 50% (P Côté, et al., 2009; Marcus, et al., 2002). The utilization of external monitors is not common practice among student laptop users due to the adjustable nature of the laptop screen; however the laptop is almost always below the level of the student's head necessitating neck flexion. The position of the head relative to the neck in student laptop users needs further investigation as it is not yet clear whether head position represents a risk factor in laptop users. This should be included in future surveys pertaining to laptop use to be determined if it is in fact a risk factor for this demographic.

### 3.2.9 Daily Computer Use

Evidence has been found to support the cumulative effects of daily computer use on the risk of neck pain. In fact, university students report musculoskeletal symptoms after only one hour of computing (Hupert, et al., 2004). A recent cross-sectional study supported these findings, demonstrating that compared to no computer use, computing for just one to two hours was associated with reporting *any* musculoskeletal symptoms within a university student population (Menendez, et al., 2008). These authors created categories for perceived musculoskeletal symptoms ranging from *none, mild, moderate*, *severe* and *very severe.* This study found that computing for periods of nine and 14 hours was associated with *moderate* and *greater* musculoskeletal symptoms of the upper extremity. Generally, the odds ratios for the reporting of musculoskeletal symptoms increased with increasing computer exposure time (Menendez, et al., 2008). This is important considering that on average, university students are using a computer for 21.3 hours per week for recreational work and academic related purposes (Smith, Salaway, & Caruso, 2009). Moreover, 8.8% (n= 30,270 students) spend >40 hours per week on their laptop (Smith, et al., 2009). Daily computer usage could be a valuable indicator for determining risk of developing musculoskeletal symptoms and should be included within questionnaires pertaining to student laptop users.

### 3.2.10 Length of Rest Breaks

There is evidence suggesting that taking short breaks during computer use may reduce the risk of reporting musculoskeletal symptoms associated with neck pain. It has been found that taking breaks for less than 15 minutes was negatively associated with university students reporting *any* musculoskeletal symptoms when using a computer (Menendez, et al., 2008). The same authors found that breaks of greater length were all associated with reporting musculoskeletal symptoms, and suggest that shorter breaks may be effective when computing. Length of rest breaks should be included within computer and laptop based questionnaires to assess risk for developing neck pain. Since student laptop users have class periods of varying length, they may be less likely to take breaks than individuals with a more structured routine, making this important to include as a questionnaire item.

### 3.2.11 Repetitive or Precision Work

Exposure to high amounts of repetitive or precision work can increase the risk of developing neck or upper extremity pain. A study on Swedish student musicians found that those who practiced playing their instrument >20 hours per week were at a higher risk of developing musculoskeletal symptoms (Hagberg, Thiringer, & Brandström, 2005). This was demonstrated by a 2.4 times greater incidence of MSD's in the right hand and wrist & a 2.2 times higher incidence of MSDS in the left elbow and forearm within this population (Hagberg, et al., 2005). This finding was bolstered by research on computer users which found that high amounts of physical exposure (represented by amount of repetitive or precision work) was associated with increased risk of neck pain (Wahlström, et al., 2004). This was seen as an interaction between high job strain and high physical exposure with an excess risk of 0.75 (Wahlström, et al., 2004). The repetitive and precise nature of typing has therefore demonstrated an association with increased risk of developing neck or upper extremity pain and should be included within a questionnaire assessing risk of developing neck pain.

## 3.3 Questionnaire Analysis and Development

After review of the existing literature related to neck pain and computer use, those risk factors which remained relevant to student laptop users were identified, as they were important components to include in subsequent questionnaires for the student demographic. These risk factors include: age, gender, history of musculoskeletal pain, smoking, school strain/stress, social support at school, sedentary position, neck and upper extremity posture, relative keyboard height, use of chair armrests, head posture, hours of daily computer use, length of rest and stretch breaks and repetitive or precision work.

The following section of the literature review discusses questionnaires that have been cited in the literature related to neck and upper extremity use in relation to computers. Each questionnaire will be described and then evaluated relative to the risk factors identified in sections 3.1.1 to 3.2.11.

### 3.3.1 The Keyboard Personal Computer Style Instrument (KPeCs)

The KPeCs is a 19-item observational instrument (see Appendix A) was created to identify behaviours associated with upper extremity MSDs and keyboarding styles. The administration of this tool is carried out by a trained rater, based on observation of short video recordings. This instrument has shown good validity and reliability, with concurrent validity demonstrated for most of the items measured, an inter-rater reliability interclass correlation of ICC=0.90 ($p < .001$) and an intra-rater reliability interclass correlation of ICC=0.92 ($p < .001$) (Baker, Cook, & Redfern, 2009).

The KPeCs aims to measure three main constructs which are: static posture, dynamic posture and force and use of supports (Baker, Sussman, & Redfern, 2008). The static posture items include questions on torso, neck, shoulder and elbow angles. The dynamic posture items include questions on ulnar deviation, wrist extension, wrist displacement as well as isolation of the thumb and fifth digit. Finally, the items on force include questions on the use of back rests, supports for the wrist and forearm and the force of typing. The majority of the KPeCs focuses on the hands, wrists, fingers, and forearm, with only one question on the shoulder and neck respectively.

The KPeCs was surveyed for the inclusion of aforementioned risk factors for developing neck pain. The KPeCs does not include the following risk factors: social support at school, 'school' strain, hours of computer use and break lengths, sedentary position, the use of chair armrests, keyboard position and history of musculoskeletal pain. Although this instrument is specific to the style of keyboarding behaviour that subjects display, it does not measure where the elbow is in relation to the keyboard. As mentioned earlier, one is at risk of developing neck pain if the elbow is lower than the "J" key on the keyboard, demonstrating that relative keyboard height should be included on such an instrument (Marcus, et al., 2002).

Although the KPeCs includes important risk factors such as the degree of elbow and neck angles, it does not cover enough of the other risk factors to support the current aim of this literature review. This tool focuses on a narrow portion of physical risk factors for upper extremity MSDs. It does not include several of the risk factors identified in the literature review and therefore would not be helpful to study neck pain and laptop use. In addition, the KPeCs is an observational tool that requires the administrator to select responses on behalf of the participant based on their observations. A self administered questionnaire is needed for the purposes of this thesis, making the KpeCs unsuitable for its use.

### 3.3.2 The Student Health Related Role Functioning Scale

The Student Health Related Role Functioning Scale is a 10-item questionnaire (see Appendix B) and was designed to address the need for a tailored functional status measure specifically for the role of the student. This instrument is completed and self directed by the student. This role functioning scale has shown good internal consistency and reliability with a Cronbach's α of 0.87 (Katz, et al., 2000) . Convergent validity was found to be high with a correlation of 0.68 with the Brigham Functional Limitation Scale, 0.65 with a generic pain severity scale and 0.62 with the Brigham Symptom Severity Scale (Katz, et al., 2000).

Items consist of daily student activities such as typing a 10 page paper (double spaced), completing assignments on the computer on time, completing hand written assignments, taking notes by hand, using a computer mouse repeatedly, and carrying books around campus. This instrument is applicable to the typical student but has some inconsistencies with students taking part in laptop based education. Technology enhanced educational institutions have fostered a technological culture that include the frequent, if not constant, use of computers and laptops. For example, a student attending a laptop based university would complete the majority, if not all, assignments on their computer for electronic submission. Hand written assignments tend to be minimal within such an institution, but can vary depending on the program of study. Also, the majority of note taking would generally be done on laptop units themselves rather than by hand. In order to meet the needs of a functional status measure for student laptop users, the items “completing handwritten assignments” and “taking notes by hand” could be omitted from this instrument.

The Student Health Related Role Functioning Scale was analyzed for the inclusion of the previously stated risk factors for developing neck pain and was found to exclude the following; social support at school, ‘school strain’, sedentary position, neck and upper extremity posture, hours of computer use and break lengths, the use of chair armrests, keyboard position and history of musculoskeletal pain. Since this tool is specific to the functional status of students, it is understandable that the aforementioned risk factors were not included within this scale. The scale itself would be an excellent supplement with some small modifications, to a questionnaire addressing these risk factors and should be considered for research of upper extremity and neck MSDs within a population of student laptop users.

### 3.3.3 The College Computing and Health Survey

The College Computing and Health Survey is a tool commonly referred to in recent literature pertaining to computer use and takes approximately 30 minutes to complete. Although extensive searching was performed, this questionnaire could not be located. This questionnaire copy was not included in any of the cited articles and two of the academics cited as corresponding authors were approached via e-mail but did not respond (Hupert, et al., 2004; Katz, et al., 2000; Katz et al., 2002; Menéndez et al., 2007).

The College Computing and Health Survey instrument is said to contain items relating to demographic information, computer use duration, computer break lengths, computer type, types of applications used, and upper extremity musculoskeletal symptoms (Menéndez, et al., 2007). Items specific to computer use include: location of the most computing done, computer ownership and type of computer used, type of furniture used most while computing, average daily computer use, frequency of computer breaks, frequency of computing for more than four hours at a time without a break, and time spent using specific computer applications (Menéndez, et al., 2007). Items dedicated to upper extremity musculoskeletal symptoms include: ever experiencing upper extremity pain/discomfort during or after computer work, body location specific reports of ever feeling pain/ discomfort and currently experiencing pain/discomfort (Menéndez, et al., 2007).

Based on the information provided in the articles, the College Computing and Health Survey was analyzed for the inclusion of aforementioned risk factors for developing neck pain and was found to exclude the following: history of musculoskeletal symptoms, smoking, 'school' strain, social support at school, neck posture, upper extremity position and keyboard position.

Although the original College Computing and Health Survey allegedly has items referring to having ever experienced musculoskeletal symptoms, it only refers specifically to those symptoms associated with using a computer. This does not take into account pain perceived at different times throughout the week not during the actual time of computer use which could still have an impact on their risk of developing future neck pain. Also, as noted earlier there is an increased risk for neck pain if one's neck is in flexion at a minimum of 20˚ for greater than 70% of the time (G Ariëns, et al., 2001) . Since a copy of the actual survey itself was not available, there is no way of knowing whether this risk factor was addressed in some way, shape or form within its items referring to computer use. Unfortunately, the majority of this survey seems to be of great use to the assessment of the risk of neck pain within computer users, but its contents are largely unknown and therefore cannot be recommended for use within a student laptop user population. Further information needs to be made publicly available in order to determine if it is a practical option for research on MSDs within student populations.

## 3.4 Discussion of Findings

This review of the literature has demonstrated that there is little information on risk factors for musculoskeletal pain specifically associated with laptop use, especially in students. Although a great deal of research has taken place on the risk factors for MSDs associated with computer use in general, there is a clear gap in the literature concerning laptops and their potential to cause musculoskeletal pain. Some risk factors associated with desktop computer use are applicable to the use of laptop machines, but it is imperative to understand the differences between computer and laptop units. Laptops are designed for portability and thus have their screens attached to their accompanying keyboards while desktop computers do not. The benefits of such a system is the adjustable nature of the laptop screen itself, allowing for the adjustment of the angle at which the individual will view their screen. Unfortunately, this design does not allow for the adjustment of keyboard distance or screen height. Both of these aspects attribute to an increase in certain risk factors associated with musculoskeletal pain of the neck and upper extremities (G Ariëns, et al., 2001; Marcus, et al., 2002) .

Laptop computer use is on the rise, particularly within educational institutions, being used by 75.8% of students in a 2007 survey (Jacobs, et al., 2009). This is coupled with an increase in laptop ownership, increasing from 66% in 2006 to 88% in 2009 (Smith, et al., 2009). With such a trend it is clear that research on the risks of developing MSDs due to laptop use is imperative among this demographic. In a student population, risk factors are magnified due to the nature of their work environment. The majority of lecture hall theatres and campus study rooms are characterized by fixed furniture, without the ability to adjust either desk or chair height. This fixed nature does not allow for students of varying height or body type to adjust their workstation. In the majority of educational institutions, it is not feasible to utilize an external keyboard due to space restrictions within lecture theatres or study rooms. Unlike home or dormitory settings which have the potential for workspace modification, the institutional environment heightens the probability of exposure to certain identified risk factors such as producing an angle of neck flexion of 20˚ or more for prolonged periods of time or forcing the elbow to be in a position that is lower than the keyboard (G Ariëns, et al., 2001; Marcus, et al., 2002). Also, some institutions may opt for armless chairs to save space within lecture theatres and campus work spaces, which may increase an individual's risk of developing upper extremity and neck pain (P Côté, et al., 2009; Marcus, et al., 2002). Based on such determinants, it is recommended that questionnaires relating to laptop use in student populations include items on the length of time spent in lecture theatre settings with fixed furniture taking typed notes, length of time spent utilizing on campus study rooms as well as the length of time spent using a laptop at home or in a dormitory room. It is therefore imperative that a screening method be developed to differentiate those who are at risk of developing neck pain from individuals who are not, based on certain laptop use environments or habitual tendencies.

In this review of the current literature it was found that only a few of the risks associated with computer use also relate specifically to the use of a laptop. The risk factors identified in relation to computer use were assessed for their relevance to laptop utilization and were categorized as definite, potential or irrelevant. The remaining risk factors categorized as definite for the development of neck and upper extremity pain that also applied to laptop use in students were found to be age, gender, ethnicity, history of musculoskeletal pain, smoking, sedentary position, neck posture, upper extremity posture, keyboard position, use of chair armrests, high amounts of daily computer use, computer break length and repetitive/precision work. Other potential risk factors associated with the use of laptops were found to be school strain/stress, social support at school and head posture. Finally, job security was unlikely to affect the risk developing neck or upper extremity pain among student laptop users, and was categorized as irrelevant resulting in exclusion from further review. The risk factors categorized as definite were deemed to be essential components for any subsequent questionnaires pertaining to the risk of musculoskeletal pain and laptop use within student populations. However, measuring psychosocial factors such as school strain and social support at school would likely require a separate questionnaire that is beyond the scope of this thesis.

The aforementioned risk factors for neck and upper extremity musculoskeletal pain were found to be absent from the commonly accessible questionnaires related to computer use in general. There was no single questionnaire that related specifically to laptop use in student populations. The questionnaire related to computer use in general which appears to cover at least some of identified risk factors within student populations is the College Health and Computing Survey (Hupert, et al., 2004; Katz, et al., 2000; Katz, et al., 2002; Menéndez, et al., 2007). However the actual copy of this survey was not found in any of the sources cited in articles summarizing the results of this too and could not be obtained from the authors.

It is clear that current questionnaires do not encompass many of the risk factors for neck and upper extremity pain as they relate to laptop use which implies a disconnect within current research and outcome measures for this demographic. Although one functional status measure, the Student Health Related Role Functioning Scale, was tailored to the role of the student, it cannot be used on its own for the evaluation of potential risk of developing neck pain. This is because it does not ask about any of the risk factors identified in this review but rather focuses on functional limitation related to student activities in general, not only computer use. It is therefore recommended that a new questionnaire be developed for the assessment of the risk of developing neck and upper extremity pain among student laptop users. Items for inclusion within such an instrument should focus on the definite risk factors identified within this review, as well as items on the specifics of the educational environment, such as type of setting (i.e.: fixed furniture, space), length of time spent in fixed settings while using a laptop and length of time spent at home or in a dormitory setting while using a laptop. It is clear that the risk of developing neck and upper extremity pain has the potential to be higher among student populations and an appropriate instrument should be developed to meet their needs.

## 3.5 Chapter Summary

In summary, musculoskeletal pain has become a global public health issue characterized with high prevalence and large economic burden. While technology has advanced and service sector oriented work has increased, the use of computers and laptops has risen in turn. In order to prepare future workers, some educational institutions have focused on the daily use of technology and have implemented laptop based education. The rates of laptop use and ownership have increased substantially from 2005 to 2009 (Jacobs, et al., 2009; Smith, et al., 2009). Unfortunately, there is little information on the risks associated with laptop use in terms of detrimental musculoskeletal outcomes. Musculoskeletal disorders may, in part, be associated with laptop use which emphasizes the need for the assessment of risk factors associated with musculoskeletal pain in relation to laptop use.

After review of the literature, it was found that the following risk factors pertain to laptop use in students: age, gender, history of musculoskeletal pain, smoking, school strain/stress, social support at school, sedentary position, neck and upper extremity posture, relative keyboard height, use of chair armrests, head posture, hours of daily computer use, length of rest and stretch breaks and repetitive or precision work. However, it was found that there are very few measures for the assessment of risk factors associated specifically with laptop use for students. It is recommended that development of a questionnaire encompassing the aforementioned risk factors should be established in order to meet the demands of this demographic. Such an instrument could eventually be used as a screening method to determine if some students are more at risk than others for developing neck pain. This is the focus of manuscript I and is seen in Chapter Four.

# Chapter Four Manuscript I

## Development and Reliability of the Student Laptop Use and Neck Pain Risk Questionnaire (SLUNPRQ)

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To be Submitted for Publication

## Abstract

**Objective:** The aim of this project was to develop and study the reliability of a new questionnaire (The Student Laptop Use and Neck Pain Risk Questionnaire, SLUNPRQ) to measure risk factors for neck pain that are associated with laptop use in the student population.

**Methods:** The first draft of the questionnaire was developed based on a literature review of common risk factors associated with desktop computer use. This initial draft was refined following feedback from an expert panel of clinicians and researchers. After modification, the SLUNPRQ was administered to a class of university students (n=37, mean age=20.76). The questionnaire was re-administered seven days later. Cohen's Kappa coefficients and percent agreement were calculated for each item on the SLUNPRQ.

**Results:** Cohen's Kappa ranged from 0.36 – 1 (ranging from fair to very good) and percent agreement ranged from 67.74% to 100%. Questions with Kappa values <0.8, (fair to good range) were revised for further modification to improve reliability.

**Conclusions:** Overall, the SLUNPRQ presented with good test- retest reliability, demonstrated by the majority of Kappa scores within the 'good' to 'very good' agreement range. Questions providing "good" agreement (K= 0.61 - 0.80) or lower require further refinement to improve consistency of self reported answers. Future versions of the SLUNPRQ will have revisions made and will be re-piloted for test-retest reliability.


**Keywords:** Laptop Use, Reliability, Laptop Questionnaire, Neck Pain

## 4.1 Introduction

There has been a steady increase in the service sector industry within Canada, representing 78% of employment within Canada in 2005 (Industry Canada, 2009). With such a prevalent demand for efficient service workers, comes the natural progression toward the use of technology. In fact, as long ago as 1992 the service sector industry encompassed five of the largest purchasers of computers (Triplett & Bosworth, 2001).

With the continuing development of information technology and the move towards service sector oriented employment, there has been a consecutive increase in the incidence and prevalence of musculoskeletal disorders (MSDs), in particular neck pain (P Côté, et al., 2009). The rise in MSDs may be influenced, at least in part, by an increase in sedentary work as well as occupational and recreational computer use. Support for this is seen with a demonstrated 12-month prevalence of neck pain of 45.5% in office workers (Cagnie, et al., 2007). Recent reports have also shown that the one year prevalence of neck pain ranges from 17.7% to 63% in office workers across different countries (P Côté, et al., 2009).

The increasing demand within the service industry has led to a shift toward increasing computer based tasks and daily computer use (Cagnie, et al., 2007). In reaction to such a demand, some educational institutions have focused on technology enhanced learning and skill acquisition, even including laptop-based education to prepare students for the workplace. Laptop computer use is on the rise, particularly within educational institutions, being used by 75.8% of students in a 2007 survey, up from 52.8% in 2005 (Jacobs, et al., 2009). This is coupled with an increase in laptop ownership, increasing from 66% in 2006 to 88% in 2009 (Smith, et al., 2009). With such a prominent increase in the use of laptop computers, comes the need to assess the potential risk for the development of MSDs associated with their use.

Extensive research has been done on computer and work related MSDs which have found associations between desktop computer use and increased risk of reporting MSD symptoms. However, research on laptop computer use in this area is minimal. One study found in a population of university students that 41% of participants reported experiencing musculoskeletal pain while using a computer (Katz, et al., 2000). In a student population, risk factors are magnified due to the nature of their work environment. The majority of lecture hall theatres and campus study rooms are characterized by fixed furniture, without the ability to adjust either desk or chair height. This fixed nature does not allow for students of varying height or body type to adjust their workstation. In the majority of educational institutions, it is not feasible to utilize an external keyboard due to space restrictions within lecture theatres or study rooms. Unlike home or dormitory settings which have the potential for workspace modification, the institutional environment heightens the probability of exposure to certain identified risk factors for neck pain. These reasons make it clear that university student populations are potentially at a higher risk for developing neck and upper limb pain due to increases in the use of technology, specifically laptop computers. It is essential that the potential risks of developing MSDs in relation to laptop use are well understood and able to be measured to allow for appropriate precautions to be taken.

A self administered qualitative 14 item measure was thus developed to aid in the evaluation of the current state of student laptop use within a laptop based university. It aims to provide perspective into the environment and use patterns associated with student laptop use as well as measuring risk factors known to be associated with the development of neck and upper limb pain. This questionnaire could provide insight into behaviours that put students at a greater risk of developing future MSDs, allowing for preventative measures to be established. Here, the reliability of this qualitative tool is established for future work. The University of Ontario Institute of Technology Research Ethics Board approved this study (file # 09-131**)** and is in accordance with Tri-Council Guidelines (see Appendix C).

## 4.2 Methods

### 4.2.1 Questionnaire Development

The student laptop use survey was designed after a comprehensive review of the recent literature. Seminal work by the Bone and Joint Decade Task Force on Neck Pain and its Associated Disorders 2000-2010 on risk factors related to the development of neck pain was initially reviewed. This review conducted by these authors categorized evidence based on their methodology (i.e.: cohort studies, cross-sectional studies) and their accompanying results. Authors stated that phase I studies were those who made crude associations with possible confounding and were the least robust of the studies. Phase II studies were those who did not test etiological hypotheses and phase III studies were the most robust with pre stated hypotheses and were considered “confirmatory studies” (P Côté, et al., 2009). The level of evidence used for inclusion criteria when determining risk factors for neck pain that were relevant to laptop use were in line with the literature review conducted by the Bone and Joint Decade Task Force on Neck Pain and its Associated Disorders. For example, strong evidence was determined if studies demonstrated in this review had at least 1 phase II and one phase III study that came into agreement on a risk factor (P Côté, et al., 2009). Further detail on this methodology may be seen in The Burden and Determinants of Neck Pain in Workers by the Bone and Joint Decade Task Force on Neck Pain and its Associated Disorders (P Côté, et al., 2009). The original articles from this initial literature review were also reviewed in further detail. In addition, literature published since 2009 was also searched and reviewed as a supplement to the original Bone and Joint Decade literature review. Risk factors that were determined to have evidence for inclusion as a risk factor for neck pain but were still applicable to laptop users were found to as follows: age (Cagnie, et al., 2007), gender (Cagnie, et al., 2007; Hupert, et al., 2004; Korhonen, et al., 2003), history of musculoskeletal pain (Croft, et al., 2001; Smedley, et al., 2003), smoking (Croft, et al., 2001; Korhonen, et al., 2003), school /job-strain)/stress(G. Ariëns, et al., 2001; Niemi, et al., 1997; Wahlström, et al., 2004), social support at work at school(G. Ariëns, et al., 2001; Jensen, 2003), sedentary position(G Ariëns, et al., 2001; Menendez, et al., 2008), neck and upper extremity posture (G Ariëns, et al., 2001; Marcus, et al., 2002), relative keyboard height (Marcus, et al., 2002), use of chair armrests(Marcus, et al., 2002), head posture (Marcus, et al., 2002), hours of daily computer use (Hupert, et al., 2004; Menendez, et al., 2008), length of rest breaks (Menendez, et al., 2008) and repetitive or precision work (Hagberg, et al., 2005; Wahlström, et al., 2004). Researchers assessed these risk factors based on current evidence and applicability to the student laptop user population. Although there is evidence to suggest that smoking does increase the risk of developing neck pain (Croft, et al., 2001; Korhonen, et al., 2003), the focus of the

SLUNPRQ remained on laptop use. The measurement of extraneous factors such as smoking was not the intent of the researchers at this point in the questionnaire development process and would require in depth questions on dose as well as frequency. Smoking was therefore not included within any items in the initial design. The psychosocial risk factors of job/‘school’ strain and social support at work/school are known risk factors for neck pain as seen above and are thereby important to measure in student populations but would require a separate questionnaire developed by experts in the field which was beyond the scope of the initial development of the SLUNPRQ and were not included within any of the developed items.

In order to address those risk factors that still applied to student laptop users, items on the questionnaire were designed to include questions relating to topics of age, gender, history of musculoskeletal pain, sedentary position, neck/upper extremity/head posture, hours of daily computer use, length of rest and stretch breaks and repetitive precision work. An initial 27 item draft was developed and brought to a panel of experts within the fields of musculoskeletal disorders and qualitative measurement for further review. In specifics, this expert panel was comprised of the following: two clinical epidemiologists/academics with interests in occupational injury prevention, an occupational therapist/academic with interests in measurement related science and MSDs, a registered chiropractor/academic with interests in the determinants/burden of pain within the neck and back, a sociologist with interests in measurement science and musculoskeletal occupational injuries, and a registered chiropractor/neuroscientist with expertise in physiological changes in neck and back pain. This original draft of the SLUNPRQ may be seen in appendix D. Recommendations were made to remove items that did not have extensive evidence for inclusion, or those items that were beyond the scope of the intended aims and to remove items deemed less important in order to shorten the questionnaire. This initial copy was revised and items were removed or reworded based on the proposed recommendations. Items on laptop use patterns were specifically split into work, recreational and academic purposes to provide a more accurate representation of overall laptop use in students. Once questions were removed, the final version ready for piloting resulted in 14 items total.

### 4.2.2 The Student Laptop Use and Neck Pain Risk Questionnaire (SLUNPRQ)

The SLUNPRQ (see Appendix E) is a self administered questionnaire containing 14 items divided into two main sections. The first section is "Medical History" which contains 6 items on underlying medical conditions as well as the history of musculoskeletal pain associated with laptop use (presence/frequency/ location of pain/discomfort in the neck or upper extremity after laptop use). The second section is "Recreational, Academic and Work Related Laptop Use" which contains 8 items whereby the participant must answer each question as related to laptop use for recreational, academic or work related purposes. Items consist of questions relating to duration of use, posture, use of laptop accessories, the use/length/frequency of breaks and potential contributors to neck pain if present.

### 4.2.3 Sample

All students within a kinesiology based course were invited to take part in the piloting of this questionnaire. Participants were briefed prior to the start of the questionnaire and were told that they would be required to complete the questionnaire twice, at the initial test point and again seven days later. Participants were provided with paper copies for completion. Since we were testing reliability, but also content clarity, the questionnaires could not be anonymous as we wanted to be able to contact students to discuss unusual or unexpected responses. Such responses could mean that certain questions needed revision. As such, participants were guaranteed confidentiality of their answers and were ensured that only the researchers would have access to their data. All participants were provided with informed consent and were required to sign a consent form (see Appendix F).

Participants aged 19-24 who were students in an undergraduate health sciences class at the University of Ontario Institute of Technology, ranging from years 2-4 of their degree were recruited. Initially, all 47 participants who were present in class on day 1 completed the questionnaire. On the second trial, 39 of the original 47 participants were present in class and completed the questionnaire. After review, 2 of those questionnaires were inadequately completed due to missing information or multiple responses provided when only one was required. Researchers could not remain confident in the answers provided but unfortunately could not get in touch with those participants, resulting in a final total of 37 participants who filled out the questionnaires for the first and second administration of the SLUNPRQ.

**Table 1: Gender, Age and Program Year Distribution of Participants, n=37**

| Variable | Sample Distribution n= 37 | Percent (%) |
|---|---|---|
| Gender | | |
| Male | 15 | 40.5% |
| Female | 22 | 59.5% |
| Age (median, range) | 20.76, 19-24 | |
| Year of Study | | |
| 1 | 0 | |
| 2 | 17 | 45.95% |
| 3 | 16 | 43.24% |
| 4 | 4 | 10.81% |

### 4.2.4 Reliability Analysis

Questionnaire administration was conducted in early April of 2011 and final examinations were approaching. The researchers chose to conduct test-retest reliability over a 7 day period in order to obtain responses that reflected day to day laptop use rather than laptop use patterns associated with studying for final exams. This also ensured that the largest possible sample would be obtained since class attendance tends to diminish closer to examination weeks.

Test-retest reliability between the first and second administration of the questionnaire was calculated for each variable within each item on the SLUNPRQ using Cohen's Kappa and percent agreement. Cohen's Kappa is the measure of agreement beyond that expected by chance, a measure of "true" agreement (Sim & Wright, 2005). The formula for Cohen's Kappa may be seen below, where *Po* is the observed proportion of agreement, and *Pe* is the expected proportion of agreement.

$$K = \frac{Po - Pe}{1 - Pe}$$

Kappa coefficients of 1 represent perfect agreement beyond chance. Researchers characterized Kappa coefficients in accordance with the recent literature. Kappa values of < .20 as poor, between .21–.40 as fair, between .41–.60 as moderate, between .61–.80 as good and between .81–1.00 as very good (Altman, 1991). For the purposes of this study, items with Kappa values below 0.80 were assessed for revision in order to improve reliability in subsequent versions.

Reliability analysis was completed using Stata Software (Version 10, Stata Corp., College Station, Texas). P Values less than 0.05 were considered to be statistically significant. The 95% confidence intervals (CI) were calculated through Microsoft Excel 2007 for all Kappa coefficients. Missing responses for any of the items were coded as such and were omitted from analysis. Any discrepancies within the data set were addressed; if responses were conflicting then participant was contacted for clarification of appropriate coding. Data from inadequately completed questionnaires were omitted from analysis if the participant was unreachable.

The test-retest reliability of the SLUNPRQ was evaluated using Cohen's Kappa statistics with 95% CI, comparing the agreement of responses from the first and second questionnaire administrations for each item. Since each question had their own subset of variables, each variable was assessed individually. Kappa values were calculated for 37 variables within the 14 item questionnaire.

## 4.3 Results

A total of 37 paired questionnaires were completed and assessed for reliability. The participants were fairly evenly distributed in gender, with a slight majority being female (59.5%) and a mean age of 20.76 years. All participants were students at the University of Ontario Institute of Technology in an undergraduate Health Sciences program, ranging from years 2 to 4.

### 4.3.1 Cohen's Kappa

There were 6 variables where Kappa could not be calculated due to the unanimity of responses from both the first and second administration. The majority of Kappa values were within the good to very good range, a distribution of the calculated Kappa scores may be seen in Table 2.

**Table 2: Kappa Value Distribution for items on the SLUNPRQ**

| # of Variables | Kappa Range |
|---|---|
| 12 | 0.81-1 (Very Good) |
| 14 | 0.61-0.80 (Good) |
| 9 | 0.41-0.60 (Moderate) |
| 2 | 0.21-0.40 ( Fair) |
| 0 | <.20 (Poor) |
| 6 | Undefined |

### 4.3.2 Agreement for Individual Questions

Overall, questions within the SLUNPRQ demonstrated percent agreement ranging from 67.74% to 100%. Cohen's Kappa statistics were calculated as ranging from 0.36 (fair agreement) to 1 (perfect agreement). The following sections will discuss the agreement for each question if they yielded a Kappa statistic below 0.80. Kappa statistics and percent agreement may be found for each question in Table 3, where R is recreational laptop use, A is academic related laptop use and W is work related laptop use.

#### 4.3.2.1 Medical History Questions

The medical history section of the SLUNPRQ consisted of questions 1 and 2 with accompanying subsets (a through c). Kappa statistics ranged from 0.63 to 0.94. Questions 2b demonstrated 'good' agreement, resulting in a Kappa coefficient of 0.64. Question 2c had 5 variables for the location of pain/discomfort after laptop use, which presented with Kappa values ranging from 0.62 to 0.94 which demonstrated 'good' to 'very good' agreement.

#### 4.3.2.2 Laptop Use Questions

The laptop use section of the SLUNPRQ was comprised of questions 1 through 5 and their accompanying subsets (a through c). Overall, Kappa statistics ranged from 0.36 to 1, providing a wide range of agreement. Question 1 related to weekly laptop use and resulted in Kappa values ranging from 0.60 to 0.91 for recreational, academic and work related laptop use variables, demonstrating moderate to very good agreement for this question.

Question 2 had participants provide the appropriate posture that they used most on average for recreational, academic and work related laptop use from a designated list of illustrations. The Kappa values for this question had quite a large range from 0.36-0.84

which demonstrated fair to very good agreement. The percent agreement for variables of recreational, academic and work related laptop use ranged from 77.78% to 97.30%. This question needs further attention to address the variability seen in the Kappa coefficients and will be examined further in the discussion section of this paper.

Finally, the use and characteristics of breaks when computing on a laptop were addressed in question 5 (a through c). Question 5a on the use of breaks resulted in Kappa values ranging from 0.63 to 0.89 demonstrating good-very good agreement. Question 5b related to the length of breaks and demonstrated fair-moderate agreement with Kappa values ranging from 0.37 to 0.49 for recreational, academic and work related variables. This particular item appears to be substantially lower than the other items and requires more attention to address this variability. Question 5c addressed the number of breaks taken and demonstrated moderate to good agreement with Kappa values ranging from 0.46 to 0.67. With percent agreement ranging from 67.74% to 80% in questions 5b and 5c, there appears to be increased variability for these particular questions. Further attention is required to address potential issues with these questions and will be considered in the discussion section of this paper.

**Table 3: Cohen's Kappa Values and Percent Agreement by Questionnaire Item**

| Question | Kappa (95% CI) | Percent Agreement (%) | P Value |
|---|---|---|---|
| Medical History Section | | | |
| Q1) Do you have any underlying medical conditions (i.e.: neuropathies, multiple sclerosis, paresthesias or any other neurological disorders)? | 0, undefined | 100% | 0 |
| Q2a) After using your laptop, do you experience pain or discomfort in your neck or upper extremities? | 0.93 (0.61, 1.25) | 97.3% | 0 |

| | | | |
|---|---|---|---|
| Q2b) If you experience pain or discomfort after using a laptop, how long do these symptoms last? | 0.64 (0.38,0.89) | 77.78% | 0 |
| Q2c) If pain or discomfort is present after the use of a laptop, please indicate **ALL** of the affected areas. | | | |
| Neck | 0.83 (0.51, 1.15) | 91.89% | 0 |
| Shoulder | 0.94 (0.62, 1.27) | 97.30% | 0 |
| Elbow | 0, undefined | 100% | 0 |
| Forearm | 0.65 (0.35, 0.96) | 97.30% | 0 |
| Wrist/hand/fingers | 0.62 (0.31, 0.94) | 86.49% | 0.0001 |
| Laptop Use Section | | | |
| Q1) How many **hours per week** do you use a laptop for recreational, academic and work related purposes on average. | R= 0.63 (0.44, 0.82)<br>A= 0.60 (0.40, 0.82)<br>W= 0.91 (0.68, 1.14) | R= 72.97%<br>A= 72.97%<br>W= 94.59% | R= 0<br>A= 0<br>W= 0 |
| Q2) Which of the following postures best describes the position that you usually use while using a laptop for recreational, academic and work related purposes? | | | |
| Neck Neutral | R= 0, undefined<br>A= 0.59 (0.27, 0.90)<br>W= 0.54(0.22, 0.85) | R= 97.22%<br>A= 86.49%<br>W= 86.11% | R= 0.5<br>A= 0.0001<br>W= 0.0004 |
| Neck Flexion | R=0.72 (0.41, 1.04)<br>A=0.59 (0.27, 0.91)<br>W=0.53 (0.20, 0.86) | R= 91.67%<br>A= 81.08%<br>W= 80.56% | R= 0<br>A= 0.0002<br>W= 0.0007 |
| Slouching Forward | R= 0.48 (0.15, 0.80)<br>A= 0.77 (0.45, 0.92)<br>W= 0.62 (0.30, 0.94) | R= 77.78%<br>A= 89.19%<br>W= 91.67% | R= 0.0019<br>A= 0<br>W= 0.0001 |
| Slouching Backward | R= 0.70 (0.38, 1.03)<br>A= 0.84 (0.52, 1.16)<br>W= 0.64 (0.31, 0.96) | R= 88.89%<br>A= 94.59%<br>W= 94.44% | R= 0<br>A= 0<br>W= 0.0001 |
| Laying on Stomach | R= 0.76 (0.43, 1.09)<br>A= 0.79 (0.47, 1.10)<br>W= 0.36 (0.038, 0.68) | R= 88.89%<br>A= 97.30%<br>W= 91.67% | R= 0<br>A= 0<br>W= 0.0141 |
| Q3) Do you use an external mouse when you use a laptop for recreational, academic and/or work related purposes? | R= 0.92 (0.59, 1.25)<br>A= 1 (0.67, 1.33)<br>W= 0.89 (0.56, 1.22) | R= 97.14%<br>A= 100%<br>W= 97.14% | R= 0<br>A= 0<br>W= 0 |
| Q4) Do you use an external monitor when you use a laptop for recreational, academic and/or work | R= 0, undefined<br>A= 0, undefined<br>W= 1 (0.67, 1.33) | R= 97.22%<br>A= 100%<br>W= 100% | R= 0.5<br>A= 0<br>W=0 |

| | | | |
|---|---|---|---|
| related purposes? | | | |
| Q5a) Do you take breaks when you are computing for extended periods of time while using your laptop for recreational, academic and/or work related purposes? | R= 0.63 (0.32, 0.93)<br>A= 0, undefined<br>W= 0.89 (0.57, 1.21) | R= 91.67%<br>A= 94.59%<br>W= 94.59% | R= 0<br>A= 0.5<br>W= 0 |
| Q5b) If yes, how long are the breaks that you typically take while using a laptop for recreational, academic and work related purposes? | R= 0.45 (0.17, 0.72)<br>A= 0.37 (0.07, 0.66)<br>W= 0.49 (0.11, 0.87) | R= 67.74%<br>A= 70.59%<br>W= 70.59% | R= 0.0009<br>A= 0.0071<br>W= 0.0055 |
| Q5c) How many breaks do you typically take while using a laptop for recreational, academic and work related purposes? | R= 0.60 (0.33, 0.87)<br>A= 0.67 (0.42, 0.91)<br>W= 0.47 (0.17, 0.76) | R= 77.42%<br>A= 80.00%<br>W= 76.47% | R= 0<br>A= 0<br>W= 0.0012 |

### 4.3.3 Undefined Kappa Values

There were 6 instances where the Kappa coefficient could not be calculated. Three instances occurred where the percent agreement was 100% while the other three occurred with percent agreement ranging from 94.59% - 97.22%. Based on the Kappa formula, one can understand that the Kappa statistic is calculated using the expected proportion of agreement (Pe).

$$K = \frac{Po - Pe}{1 - Pe}$$

This is calculated by the possibility of a particular response during the first administration, multiplied by the possibility of that response during the second administration (Osen et al., 2011). Since the percent agreement was 100%, this means that on both occasions the participants chose the same answers each time. This would result in an expected proportion of agreement of 100% and Pe would therefore equal 1 resulting in a denominator of 0. Since you cannot divide by 0, Kappa cannot be calculated in this instance. This was the case for 3 questions, Question 1 under the medical history section: “Do you have any underlying medical conditions (i.e.: neuropathies, multiple sclerosis, paresthesias or any other neurological disorders)?” , the “elbow” variable within question 2c under the medical history section: “If pain or discomfort is present after the use of a laptop, please indicate all of the affected areas” and the “academic” variable for question 4 “Do you use an external monitor when you use a laptop for recreational, academic and/or work related purposes?”. These cases are considered a ceiling effect and according to authors are of no informational value to test-retest reliability (Osen, et al., 2011).

The same situation where 0 became the denominator in the Kappa formula resulting in an undefined Kappa occurred in 3 more questions, even though percent agreement ranged from 94.59%-97.22%. This may be partly due to the small sample size. In a larger sample there might have been a little more variability in the answers, allowing Kappa to be calculated. This occurred in the following questions: The “recreational” variable for the neutral neck illustration in question 2 “Which of the following postures best describes the position that you usually use while using a laptop for recreational, academic and work related purposes?”, “Do you use an external monitor when you use a laptop for recreational, academic and/or work related purposes?”, and the “academic” variable within question 5a:“Do you take breaks when you are computing for extended periods of time while using your laptop for recreational, academic and/or work related purposes?”. An example of how a high percentage (less than 100%) resulted in a Kappa value of 0 is seen in Appendix G.

## 4.4 Discussion

Based on the results, the current state of the SLUNPRQ appears to have moderate to very good test-retest reliability. This instrument produced Kappa values indicating “moderate” agreement or above for almost all items. Over half of the overall items analyzed produced Kappa values indicating “good” to “very good” agreement. As per our previously mentioned criteria, any items on the SLUNPRQ that yielded Kappa values below 0.8 were in need of further revision to increase their reliability. Therefore, Kappa values within the range of 0.61 to 0.80 were still in need of revision even though they were considered to be within the ‘good’ range. This resulted in 7 items on the SLUNPRQ that required further revision. Some variables within the Medical History section (questions 2b and 2c) yielded low Kappa values ranging from 0.62 to 0.94. The Laptop Use section of the SLUNPRQ had questions 1, 2, 5b and 5c that produced low Kappa scores. Although questions 2, 5b and 5c were substantially lower in Kappa value, ranging from “fair” to “moderate” agreement (K= 0.20 to 0.61), question 1 still yielded Kappa scores ranging from 0.60 to 0.91 which meets criteria for further revision. These particular questions will be discussed in further detail to address potential issues that may require revision in later versions of the SLUNPRQ.

### 4.4.1 Questions 2b and 2c in the Medical History Section

The question “If you experience pain or discomfort after using a laptop, how long do those symptoms last” and “If pain or discomfort is present after the use of a laptop, please indicate all of the affected areas” yielded Kappa scores ranging from 0.62 to 0.94.

#### 4.4.1.1 Length of Symptoms

Question 2b related to the length that participants were experiencing symptoms of musculoskeletal pain after using a laptop. This question yielded a Kappa score of 0.64 (0.38, 0.89) with percent agreement of 77.78%. This question could be yielding low agreement because individuals may be answering based on their most recent experience, which may include varying length of laptop use. If this is the case, pain may last longer if they were using their laptop for longer periods of time versus using their laptop for only a short period. This could result in unreliable responses for this question. In general, shaping this question as open ended and emphasizing that they estimate the length of symptoms on average may improve potential reliability of this item.

#### 4.4.1.2 Area of Symptoms

Question 2c related to the area eliciting pain or discomfort after use of a laptop. This question consisted of 5 variables within the item that yielded Kappa scores ranging from 0.62 to 0.94. The lowest Kappa values were seen in variables “wrist/ hand/fingers” and “forearm” which yielded Kappa scores of 0.62 and 0.65 respectively. Overall, it could be that individuals are finding it hard to determine where their pain originates due to unclear boundaries between the forearm and wrist/hand/fingers. It could be that a diagram is required to demonstrate boundaries for these areas so that individuals have a clear understanding of where their pain may be originating from.

### 4.4.2 Questions 1 in the Laptop Use Section

The question "How many hours per week do you use a laptop for recreational, academic and work related purposes on average" yielded Kappa scores ranging from 0.63 for recreational use, 0.60 for academic use and 0.91 for work related laptop use. These were consistent with the overall percent agreement for each variable, with 72.97% for recreational and academic laptop use and 94.59% agreement work related laptop use. The high agreement for work related laptop use could be because individuals (in most cases) have a set schedule for work and as such may have a better idea of how much time they are spending on their laptops for work purposes. In contrast, school and recreational schedules are much more flexible and as such individuals may find it harder to categorize their time spent on their laptop when their schedule is not consistent. It is important to emphasize here that we are looking for overall average computer use through the week, which may be better acquired through the use of open ended questions and subsequently overall estimates of laptop use.

### 4.4.3 Question 2 in the Laptop Use Section

The question "Which of the following postures best describes the position that you usually use while using a laptop for recreational, academic and work related purposes?" resulted in Kappa scores ranging from 0.36 to 0.84. The variables that were within the "fair" and "moderate" agreement range (>0.61) were neck neutral, neck flexion, slouching forward and laying on the stomach. These variables will be discussed.

#### 4.4.3.1 Neck Neutral

The variable “neck neutral” produced percent agreement that was relatively high for academic and work related laptop use (86.49% and 86.11% respectively), although this cannot rule out the possibility of agreement by chance. This variable resulted in moderate agreement, but the Kappa values were on the lower end of the scale. The kappa scores for the academic and work related laptop use sections were 0.59 and 0.54 respectively. Kappa could not be calculated for the recreational section due to high percent agreement (97.22%). This particular position was of interest to the researchers because it is very difficult to use a laptop without flexing the neck unless using peripherals such as a laptop riser or external monitor with the laptop. Since students are not provided with peripherals such as these when given their student issued laptop, students in theory should have been fairly certain that they are not using this posture when computing. The Kappa values for this particular variable were significantly lower than other items on the SLUNPRQ which indicates that students are unsure or more variable in choosing this as a posture. One possible explanation for this is subjects were not actually noticing the neck posture in pictures, because they were not trained to observe them. A lay audience might also find it difficult to differentiate between head and neck position, which could result in more variable responses. This could explain why the kappa values for this variable were lower than others. This could be an area for improvement on future versions of the SLUNPRQ, improvements could include providing a small explanation of the posture underneath the photo, or including a sketch with shaded areas of interest to demonstrate changes in angle.

#### 4.4.3.2 Neck Flexion

The variable "Neck Flexion" in question 2 resulted in Kappa values ranging from "moderate" to "good" agreement. The Kappa scores for recreational laptop use was significantly higher (0.72) compared to academic and work related laptop use (0.59 and 0.53 respectively). The percent agreement for academic laptop use in this position was 81.08% while work related use was 80.56%. Although this variable provided moderate agreement to good agreement, there still remains concern for the increased variability within the aforementioned variables. As mentioned earlier, it could be that students are not focusing on the position of the neck in the provided photo. Since this photo is similar to the "neck neutral" position, further explanation may be needed with this photo.

#### 4.4.3.3 Slouching Forward

The variable "Slouching Forward" in question 2 resulted in a significantly lower Kappa value for recreational laptop use (0.48) than for academic (0.77) or work related use (0.62). In addition, this question produced significantly lower percent agreement for all variables, with the lowest being within the recreational laptop use variable (77.78%) and percent agreement ranging from 89.19% for academic and 91.67% for work related laptop use. Researchers propose that this could reflect an increase in variable postures when using the laptop for recreational purposes. It could be that students are using the laptop in a multitude of positions based on the length of time that they use their laptop on any given day. For example, someone using their laptop for social networking may only require a short amount of time to complete their desired task while others who utilize their laptop for online gaming may stay on their laptop for hours. These amounts of time could reflect the postures that they are adopting but may change on any given day. Students could be interpreting their most recent postures as the "average" posture, which could change from day to day. In order to address this, an explanation of overall average posture rather than latest posture or something to that effect may be necessary for this question.

#### 4.4.3.4 Slouching Backward

For the variable "Slouch Backward", the agreement for work related (0.63) and recreational (0.70) were much lower than for academic related laptop use (0.84). The percent agreement for work was 94.44%, recreational was 88.89% and academic was 94.59%. Researchers propose that this instance is similar to the "Slouching Forward" variable, in that participants could have been choosing their most recent posture, rather than the intended average/over all posture. Again, researchers suggest placing emphasis on the overall average posture for question 2 to improve the reliability of the variables within.

#### 4.4.3.5 Laying on the Stomach

For the variable "Laying on the Stomach", the agreement for work related laptop use (0.36) compared to academic (0.79) and recreational use (0.76) was substantially lower. Overall, percent agreement was high for recreational (88.89%), academic (97.3%) and work related laptop use (91.67%). The results of the agreement for this variable are perplexing because in theory students using a laptop at work should not be laying on their stomach. The only potential explanation here could be that students were misinterpreting the word work to mean school work or something to that effect where they are not in a structured setting. We recommend that the revised questionnaire should include a clear definition of work at the beginning of this questionnaire.

### 4.4.4 Question 5a, 5b and 5c in the Laptop Use Section

The questions “How long are the breaks that you typically take while using a laptop for recreational, academic and work related purposes?” and “How many breaks do you typically take while using a laptop for recreational, academic and work related purposes?” produced the lowest Kappa values in the entire SLUNPRQ instrument. Kappa values for these questions ranged from 0.37 to 0.67.

#### 4.4.4.1 Taking Breaks

Question 5a asked whether or not the participant took breaks while using a laptop computer and yielded Kappa values below 0.80 for recreational (0.63) laptop use. Percent agreement for recreational use was 91.67%. It could be that students were unable to recall taking breaks recreational use simply because there is not a structured schedule when using their laptop recreationally. Additionally, it could be that students were thinking of their most recent recreational laptop use in which case they may or may not have taken breaks. Here, it is important to emphasize that we are looking for responses that represent on average if the student is taking breaks. Emphasizing that we are looking for taking breaks on average could improve the reliability of this question in the future.

#### 4.4.4.2 Break Length

Question 5b related to break length and resulted in overall low Kappa values for recreational (0.44), academic (0.37) and work (0.49) related laptop use, indicating that students were more variable in answering this particular question. These low Kappa scores corresponded well with the overall low percent agreement for these variables, within the recreational (67.74%), academic (70.59%) and work related laptop use (70.59%) variables. The most apparent reason that these Kappa scores were low could be because students were simply unable to recall their average break length. Another potential reason could be that some participants could have misinterpreted what a break truly is, since there was no specific definition provided within the questionnaire. An example of this was seen when one participant indicated “no” to taking breaks during the first administration but had answered “yes” for the second administration because they were unsure whether or not taking a lunch break counted as taking a break from computing on their laptop. In order to improve upon this, an explanation or examples of breaks should be provided prior to asking the series of questions on breaks to ensure that the participant is clear on what constitutes a break. It might even be important to have a separate subsection on different types of breaks, i.e.: lunch breaks, rest breaks etc.

#### 4.4.4.3 Number of Breaks

Question 5c related to the number of breaks that participants took while computing using a laptop and again resulted in significantly lower Kappa values than the rest of the SLUNPRQ. Kappa statistics revealed a value of 0.60 for recreational, 0.67 for academic and 0.47 for work related laptop use. Percent agreement further supported this variance with low values for recreational (77.42%), academic (80%) and work related laptop use (76.47%). Researchers noted that they did not provide a frame of reference for this particular question, which could have affected the reliability of this question. For example, a frame of reference such as "in x amount of hours of continuous recreational/academic/work related laptop computing how many breaks would you take on average" could improve the participant's recollection and provide a more accurate depiction of the participant's frequency of breaks. Also, within the multi-choice answers, it could be that the intervals provided were not all encompassing. This could be remedied with having this question as open ended and could have participants provide an estimate rather than choose from pre-selected variables. Continuous data would ensure that we are collecting an accurate, all encompassing depiction of break frequency.

## 4.5 Limitations

Researchers conducted test-retest reliability over 7 days, which has been stated as within the usual range of two to 14 days for test- retest reliability (Streiner & Norman, 2008). It could be that this time interval was too short and resulted in participants recalling their previous answers, which could inflate the reliability of the SLUNPRQ. Researchers could extend the testing time frame to 14 days, time permitting, on the re-administration of the revised SLUNPRQ to determine if reliability remains the same for those questions that were deemed very reliable. Also, due to the small sample size (n=37), and large amount of unanimity within the participants response, some Kappa statistics could not be calculated.

## 4.6 Summary of Intended Revisions and Additions to the SLUNPRQ

In summary, there are some revisions to be made to the SLUNPRQ in order to increase the reliability of participant responses. Firstly, the term “work” seems to have been unclear and potentially misinterpreted by participants. This term will be reworded as “job” or “employment” to emphasize employment related laptop use. It is the intention that this will eliminate any ambiguity that may have arisen from the word “work” which could have sparked responses related to “school work” for example.

Secondly, question 2c under the medical history section “If pain or discomfort is present after the use of a laptop, please indicate all of the affected areas” required further revision to improve the reliability of participant responses, particularly for the forearm and wrist/hands/fingers sections. We propose to provide a diagram with the intended anatomical features shaded and bordered off with numbers to help elucidate where each area begins and ends, potentially improving the reliability of responses in the future.

In terms of illustrative postures for question 2 “Which of the following postures best describes the position that you usually use while using a laptop for recreational, academic and work related purposes?” we propose to provide brief explanations underneath each illustration describing the posture in question. This will provide the participants with a focal point within each posture (for example the neck position) and intends to provide enough guidance to participants to respond reliability. We plan to provide emphasis on average postures, and will provide another brief explanation that postures should represent their use on average not the most recent postures. Also, either new sketch type illustrations will be reworked and embedded within the current questionnaire or shading of anatomical features such as the neck or shoulders will be incorporated to emphasize the area and angle of interest within each photo.

Question 5, overall, yielded low Kappa values and related to breaks away from the laptop computer. Question 5a “Do you take breaks when you are computing for extended periods of time while using your laptop for recreational, academic and work related purposes” yielded low reliability for recreational laptop use. We propose to emphasize that we are looking for the overall average, in which students are taking breaks or not to potentially improve the reliability of this question.

Again, the question 5b “How long are the breaks that you typically take while using a laptop for recreational, academic and work related purposes?” provided poor reliability and needs to be revised. In order to improve reliability of this item, we aim to provide examples of common types of breaks, such as lunch, stretch, coffee or tea breaks etc as a preamble to questions number 5a through 5c. We intend to emphasize that we are looking for any and all breaks that are taken away from the laptop.

Question 5c “How many breaks do you typically take while using a laptop for recreational, academic and work related purposes?” also provided poor reliability and it is our intent to provide a frame of reference for this question, i.e.: within what time frame. Since this could vary by participant, we feel that it is important for participants to have a consistent frame of reference to work from to aid in their recollection.

Finally, continuous variables (where applicable) will also be utilized to ensure that we are obtaining an all encompassing depiction of student laptop use. Categorical responses could be omitting some information because it may not necessarily apply to each and every participant.

Since this is still early in the development process of the SLUNPRQ, we propose to include some additional items within future version. The SLUNPRQ only included images of general postures thought to represent average student laptop use. In order to provide a better picture of the student laptop computing environment, further questions will be added including the type of furniture they use (i.e.: chairs with armrests vs. without) and how long students are using a laptop in certain settings such as lecture halls, campus study rooms or dormitories. We also intend to ask about the potential use of laptop risers as that was inadvertently omitted from the original version of the SLUNPRQ. It is our intent to provide the best possible picture of student laptop use within the university setting, so that we may assess the potential increased risk within this demographic.

## 4.7 Conclusion

The overall test-retest reliability of the SLUNPRQ ranges from "fair" to "very good" agreement with Cohen's Kappa statistics ranging from 0.36 (fair agreement) to 1 (perfect agreement). Questions providing "good" agreement (0.61 to 0.80) or lower require further refinement to improve consistency of self reported answers. We have provided some intended revisions and additions to the current state of the SLUNPRQ in hopes of improving reliability for those items which were not favourable. Future versions of the SLUNPRQ will again be tested for reliability and eventually content validity once the development process has reached good reliability across all items. The latest, revised version of the SLUNPRQ may be found in Appendix H.

# Chapter Five Manuscript II

## The Feasibility of Using Dual Somatosensory Evoked Potentials for the Evaluation of a 12 week Chiropractic Care Intervention for the Treatment of Neck Pain on Sensorimotor Integration

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To be Submitted for Publication

## Abstract

**Objective:** This study sought to investigate the feasibility of using dual somatosensory evoked potentials of the median and ulnar nerves in the assessment of the effect of chiropractic treatment on disordered SMI in patients with neck pain.

**Methods:** Dual somatosensory evoked potentials were elicited in 11 subjects with recurring neck pain who were free of acute neck pain at the time of data acquisition. Complete data sets were obtained from 5 out of 13 initial patients. Somatosensory evoked potentials were recorded at baseline, 6 and 12 weeks of chiropractic treatment. Somatosensory evoked potentials were recorded after stimulation of the median and ulnar nerves separately and then simultaneously (1 millisecond square wave pulse, 2.47 Hz, 1 × motor threshold). The SEP ratios were calculated from SEP amplitudes acquired through simultaneous stimulation of the median and ulnar (MU) nerves divided by the arithmetic sum of SEP amplitudes obtained from separate stimulation of the median (M) and ulnar (U) nerves for N9, N11, N13, P14-18,N20-P25, and P22-N30 peak complexes resulting in an MU/M+U ratio for each peak.

**Results:** Small sample size (n= 5) resulted from issues of within-subjects factors as well as electrical noise. Although sample size was small, preliminary trends emerged toward reduced N20 and P25 SEP peaks, with increases in the N11 and N30 SEP peaks after 12 weeks of chiropractic treatment.

**Conclusions:** This study suggests that dual somatosensory evoked potentials are a feasible technique to measure neurophysiological changes after chiropractic treatment. The reduction in the N20 and P25 peaks may be due to an increased ability to inhibit dual

peripheral input, reflecting surround inhibition. The increase in the N11 SEP peak may reflect decreased sensory filtering at spinal level which makes the increase in filtering at more central levels particularly interesting.

**Keywords:** Somatosensory Evoked Potentials, Spinal Manipulation, Chiropractic, Sensory Filtering, Sensorimotor Integration

## 5.1 Introduction

Musculoskeletal pain has become a substantial issue worldwide, and contributes greatly not only to the disability of many but to immense global economic cost as well (P Côté, et al., 2009; Denis, et al., 2008; Walker Bone, et al., 2004). Musculoskeletal disorders (MSDs) encompass a wide array of musculoskeletal tissue injuries, some of which are work related (Green, 2008). These disorders affect many areas of the body such as the neck, upper extremities or back. In particular, upper limb pain has been shown to be very common in the general population, with 36% of men and women in Britain reporting pain within the upper extremities in any given week (Walker Bone, et al., 2004). This is further supported by outcomes based on a cohort study conducted in Saskatchewan, Canada where 54% of the studied population experienced neck pain in the previous 6 months and 5% considered it disabling (P. Côté, et al., 2003). Of particular concern are those people for whom neck and upper limb pain become chronic. The annual prevalence of neck pain ranges from 27.1% in Norway to 47.8% in Quebec, while in Canada, the annual prevalence of neck pain interfering with daily activates is 14.1% within the general population of workers (P Côté, et al., 2009). Finally, MSDs have had a considerable influence on economic costs internationally. In the year 2000 alone, $500 million was spent on MSDs in Quebec, Canada while between $45- $54 billion is spent annually in the United States (Denis, et al., 2008). High prevalence coupled with enormous economic cost has evidently resulted in a widespread burden requiring much attention.

An objective measure to distinguish people with recurrent neck pain who are at risk of developing chronic neck pain would not only be of benefit to determine if patients require further treatment but to indicate whether some treatments are more favourable than others. Recent research suggests that the use of somatosensory evoked potentials in the assessment of sensorimotor integration (SMI) may be an objective measure with which to assess neck pain as it has been shown to be altered in this patient population (H Haavik-Taylor & Murphy, 2007b, 2010a). SMI is the process by which the nervous system coordinates incoming sensory (afferent) information from different parts of the body and integrates with the motor system to control movement and refers to central neural processing. The sensorimotor system continuously monitors afferent information and addresses such input by modifying the connectivity and strength of synaptic connections within the nervous system (Moller, 2001). With these continual alterations within the sensorimotor system, there is potential for long lasting maladaptive plastic changes to emerge. In fact, recent evidence suggests that such neural reorganization may occur due to altered afferent input in the form of pain (Tinazzi, Fiaschi, et al., 2000; Tinazzi, et al., 2004), as well as due to increases in peripheral afferent input as seen with repetitive muscular activity (Byl, et al., 1997; H Haavik-Taylor & Murphy, 2007a; Murphy, Haavik-Taylor, Wilson, Oliphant, et al., 2003), and in cases of reduced peripheral input such as transient or chronic deafferentation as seen in cases of carpal tunnel syndrome and radial nerve block (Murphy, Haavik-Taylor, Wilson, Knight, et al., 2003; Tinazzi, et al., 2003; Tinazzi, et al., 1998).

A key component of typical SMI is sensory filtering, which is the ability of an individual to suppress or attenuate the processing of multiple afferent peripheral inputs. It reflects “surround-like” inhibition, which in healthy individuals, allows for the contrast between stimuli to remain high by suppressing the processing of input from surrounding areas. In the visual system for example, surround inhibition works similarly to a camera focussing in on the object of interest while other objects become “fuzzy”, allowing the object of interest to be clearly perceived. In the somatosensory system, such inhibition allows for the body to perceive stimuli as separate and process them accordingly (Tinazzi, Priori, et al., 2000). This filtering process may be measured by stimulating two peripheral nerves (usually the median and ulnar nerves) of interest both separately and simultaneously to calculate the ratio between them (MU/M+U ratio, where m=median, u=ulnar and mu=median and ulnar stimulated simultaneously). Sensory filtering has been found to be altered in individuals with neck pain, after repetitive muscular activities such as typing as well as other MSDs such as Dystonia and through the use of dual somatosensory evoked potentials (H Haavik-Taylor & Murphy, 2007a, 2010a, 2010b; Tinazzi, Priori, et al., 2000).

A common treatment for neck pain is the chiropractic care. Patients with neck pain are typically found to have dysfunctional joints by chiropractors and other manual therapists. The dysfunctional joint is characterized by the presence of both reduced intersegmental range of motion and tenderness to palpation of the dysfunctional joint and they have been found to be reliable indicators (Hubka & Phelan, 1994; Jull, et al., 1994). Joint dysfunction may represent a form of altered afferent input which could lead to disordered SMI and sensory filtering, as proposed by Haavik-Taylor, Holt and Murphy (H Haavik-Taylor, et al., 2010). These authors developed a theoretical framework which proposes that altered afferent input from areas of spinal dysfunction will lead to altered afferent input to the CNS, thereby leading to altered neural processing and sensory filtering resulting in altered SMI and eventually altered motor control which then promotes pain and disability in a self perpetuating cycle.

Joint dysfunction is typically treated by chiropractors and other manual therapists, using joint manipulation, a type of physical treatment that is known to change SMI and sensory filtering in the short term, typically for at least 20 minutes after manipulation (H Haavik-Taylor & Murphy, 2007b, 2010a, 2010b). This suggests that SMI may be an objective measure to assess those with neck pain and altered SMI may be able to be addressed with targeted therapeutic interventions in some cases. The hypothetical framework provided above suggests that the treatment of neck pain and dysfunction will then lead to improved SMI and a reversal of the chronic neck and/or upper limb pain and is therefore the basis upon which we based our article. It is important to investigate whether these changes will persist over long periods of time and requires another study to determine if this is the case.

This study sought to investigate the feasibility of using dual somatosensory evoked potentials of the median and ulnar nerves in the assessment of the effect of chiropractic treatment on disordered SMI in patients with neck pain as seen by changes in the cortical and subcortical SEP peak ratios. We hypothesize that 1) individuals with neck pain will have improved SEP markers of neural processing and SMI after 12 weeks of chiropractic care as denoted by reduced MU/M+U ratios in the cortical and subcortical peaks and 2) that participants will show improvement in the Neck Disability Index and Short Form McGill Pain Questionnaire after 12 weeks of chiropractic care which mirror the improved SEP ratios.

## 5.2 Methods

### 5.2.1 Subject Recruitment and Exclusion Criteria

Subjects were recruited by using advertisement posters on the University of Ontario Institute of Technology (UOIT) and Durham College (DC) campus. Participants were required to have a history of recurring neck pain (i.e.: present during work or other daily activities) and be within the age of 18 and 50 years. Exclusion criteria for participants were any previous mechanical injury to the cervical spine (such as whiplash) as well as any previous chiropractic care within three months prior to the study's onset. Registered chiropractors at the University Health Center were responsible for assessing each patient for eligibility within the study. All subjects provided informed consent prior to participating in this study.

### 5.2.2 Sample

Sample size was selected based on similar work previously done by Haavik-Taylor & Murphy, in which small samples have provided significant results (H Haavik-Taylor & Murphy, 2007a). These authors calculated an effect size of 12, in which we adopted a sample size of thirteen to compensate for a potential drop out. Thirteen (13) subjects between the ages of 18 and 50 years with recurring neck pain were recruited for this study. Three (3) subjects could not meet the commitment requirements for treatment over the 12 week period and had to drop out. Due to previous wrist injuries in two (2) subjects, good quality SEP traces could not be obtained because of difficulty stimulating the median or ulnar nerves and they had to be excluded from the study. Finally, due to electrical noise during two (2) subject data collection sessions, the SEP patterns could not be analyzed and subsequently the data sets for these subjects could not be included within the analysis. An additional (1) subject had variable N9 SEP peaks. The N9 SEP peak is a measure of the peripheral volley entering the brachial plexus. It is an a priori condition of later SEP peaks generated in the spinal cord and brain indicating that the peripheral volley is consistent and thus this participant's data could not be included in the subsequent analysis. As such, we could not make confident conclusions that any changes in central SEP peaks were not due to peripheral instability; therefore this subject's data was not analyzed. This left a total of five (5) subjects aged 20-48 (see Table 4) with complete data across each time point (baseline, 6 weeks and 12 weeks). Participants were of both genders (1 male and 4 females) and had no history of neurologic disorders. Subjects were required to have a history of recurring neck pain but were required to be free of acute pain (i.e.: not in a neck pain episode) at the time of actual SEP recordings, as the presence of pain alone has been shown to attenuate the N20-P25 complex (Rossi, et al., 2003).

Subjects were screened by one of the registered doctors of chiropractic on campus for evidence of contraindications to cervical spine manipulation such as a history of previous fractures, high blood pressure, and metabolic, inflammatory, or neoplastic disease. Informed consent was obtained from each subject (See Appendix I). The University of Ontario Institute of Technology Research Ethics Board approved this study (file # 07-073) and is in accordance with Tri-Council Guidelines. Ethical approval may be seen in Appendix J.

**Table 4: Age distribution and Diagnosis of participants (n=5), Mean Age of 32.6**

| Subject | Age | Diagnosis |
|---|---|---|
| 1 | 48 | Muscular/Joint Dysfunction (cervical spine), Adhesive Capsulitis |
| 2 | 20 | Muscular/Joint Dysfunction, Rotator Cuff Tendonitis |
| 3 | 47 | Student Syndrome (hunched shoulders, upper thoracic tightness, forward neck) |
| 4 | 21 | Posterior Joint Syndrome (cervical Spine), Student Syndrome |
| 5 | 27 | Muscular/Joint Dysfunction (cervical spine) Myofascial Dysfunction (lumbar spine) |

### 5.2.3 Experimental Protocol

Subjects were required to attend three (3) SEP data collection sessions; baseline, 6 weeks and 12 weeks. Each data collection session was comprised of three (3) SEP trials: one trial stimulating the median nerve individually (M), one trial stimulating the ulnar nerve individually (U) and one trial stimulating the median and ulnar nerve simultaneously (MU). These trials were repeated for the baseline, 6 week and 12 week time points for each individual participant during the course of their chiropractic treatment. Each data collection session took approximately 30 minutes to complete after the participant was setup with stimulating and recording electrodes.

Prior to the onset of SEP data collection for baseline, 6 week and 12 week marks, participants were required to fill out the Neck Disability Index (NDI) and Short Form McGill Pain Questionnaire (MPQ) as a measure of improvement over time (See Appendix K and L). The NDI is a self rated measure of disability for neck pain patients. Scoring ranging from 0-4 as no disability, 5-14 as mild disability, 15-24 as moderate disability, 25-34 as severe disability and >34 as complete disability (Vernon, 2008). This instrument has been found to be valid and reliable (Vernon & Mior, 1991). The SF-MPQ is a self reported pain intensity scale with descriptors for pain, including a visual analog scale. The instrument provides a total score based on the accumulated scores throughout the instrument out of a possible score of 45. This instrument is found to be valid and reliable (Burckhardt & Bjelle, 1994; Grafton, Foster, & Wright, 2005; McDonald & Weiskopf, 2001).

### 5.2.4 SEP Stimulating Parameters

The stimulating electrodes were placed over the median and ulnar nerve at the wrist of the dominant arm with the anode proximal. Stimuli consisted of electrical square pulses of 1 ms duration delivered at a rate of 2.47 Hz, through Ag/AgCl disposable, adhesive electrodes (Kendall Medi-Trace 200, Chicopee, MA). The stimulus intensity of both the median and ulnar nerves was maintained at the subject's motor threshold. Motor threshold was characterized as the lowest intensity producing a visible muscle contraction of the Abductor Pollicis Brevis (APB) muscle for median nerve stimulation or the Abductor Digiti Minimi (ADM) muscle for ulnar nerve stimulation. The impedance of all stimulating electrodes was $< 5$ KΩ.

### 5.2.5 SEP Recording Parameters

Subjects were seated in a reclining chair within a quiet room. During SEP recording, the lights in the room were turned off and subjects were instructed to sit still, close their eyes and relax. Each SEP recording electrode (Ag/AgCl Medi-Trace 200 from

Kendall, Chicopee, MA and gold electrodes from Grass Technologies, West Warwick, RI) was placed in accordance with the International Federation of Clinical Neurophysiologists (IFCN) guidelines. Recording electrodes were placed on the ipsilateral Erb's point (over the brachial plexus) as well as over the C5 spinous process. One scalp recording electrode was placed 2 cm posterior to the contralateral central C3 site of the international 10-20 system and one other scalp recording electrode was placed 6 cm forward and 2 cm lateral to the Cz (vertex) of the 10-20 system (Rossi, et al., 2003), referred to CC' and Rossi site respectively.

Each electrode was referenced to the ipsilateral earlobe, while the C5 spinous process electrode was referenced to the anterior neck (tracheal cartilage). A ground electrode was inserted into the mouth, in between the cheek and teeth. The impedance of all recording electrodes were $<5$ KΩ.

Placement sites for the scalp recording electrodes were abraded with Nuprep abrasion gel (Weaver and Company, Aurora, CO). The remaining recording and stimulating electrode sites were abraded with 3M Red Dot Trace Prep (3M Canada, London, ON). After abrasion, all sites were wiped with alcohol swabs and left to dry prior to placing the Grass gold and Ag/AgCl disposable electrodes (Medi-Trace 200 from Kendall, Chicopee, MA). Grass gold electrodes used for the scalp recording sites were filled with Grass EC2 electrode cream for adhesion and conductivity.

### 5.2.6 Data Collection and Analysis

Electrical impulses were triggered through a Digitimer DS7A stimulator. Elicited signals were measured through the Gold and Ag/AgCl electrodes where they passed through a model 1902 Quad-System CED low noise isolated pre-amplifier and Power 1401MKII CED interface. Accompanying software (Signal, version 5) allowed us to control the trigger rate of the stimulators, average the elicited signal and graph the SEP EEG waveforms.

The EEG signal was digitised at a sample rate of 5000 samples per second. A total of 1500 sweeps were averaged by the Signal software system (version 5) and the averaged waveform was displayed as it was being collected. The waveforms elicited during recording were monitored by the researcher to ensure quality.

### 5.2.7 SEP Waveform Peak Analysis

SEP peak amplitudes were measured in accordance with IFCN guidelines (Mauguiere, et al., 1999; Nuwer, et al., 1994) from the peak of interest to the preceding or succeeding peak of opposite deflection. SEP peaks were labelled as being positive (P) or negative (N) for being downward or upward deflections respectively. This nomenclature was paired with title latency to provide a standard label for each peak of interest. The waveform peaks of interest for this study were N9, N11, N13, P14-N18, N20-P25 and P22-N30. Although these peak labels are considered standard, the latency itself may shift to an earlier or later point depending on the subject's height and/or age (Mauguiere, et al., 1999). Since latency of the elicited waveform is dependent on the distance between the stimulated site and the source of the SEP peak itself, taller individuals may display a slight delay in SEP peak latency. In these cases, the SEP peak title would remain the same regardless of latency changes.

Waveform peak amplitudes were measured manually, using the Signal software (version 5). To ensure consistency and that stimulating parameters were stable, only trials with an N9 peak (peripheral nerve volley) within ± 20% of a ratio value of 1 at weeks 6 and 12 were included in the overall data analysis. This was to ensure that the afferent volley was similar in all conditions so that any changes observed in subsequent peaks were due to central processing changes rather than flow on effects from alterations in the incoming afferent volleys. This resulted in one subject's results being omitted from the study.

In order to ensure that the appropriate peak was being chosen, there were some factors to consider. First and foremost, we ensured that the SEP waveform trace appeared to be normal. Amplitude values were measured from the averaged signal traces (1500 sweeps) for each stimulation parameter (M, U and MU). Researchers began by locating the N9 peak and recorded the latency at which this peak occurred. Generally speaking, if the N9 peak was slightly delayed, or early, then the subsequent peaks would also be delayed or early by approximately the same amount of time. As stated, each peak was measured in accordance with IFCN guidelines (Mauguiere, et al., 1999; Nuwer, et al., 1994). The N9 peak was measured to the preceding positive trough. The N11 peak was measured to the preceding positive trough and the N13 was measured to the succeeding positive trough. The N18 and N20 peaks were measured to the preceding P14 trough, while the P25 was measured to the preceding N20 peak. Finally the amplitude of the N30 peak was measured to the P22 trough.

### 5.2.8 Spinal Manipulation Intervention

Chiropractic treatment was provided at no cost to the participants for a 12 week treatment plan, which was administered at the discretion of the subject's chiropractor situated at the University's Health Center. Treatment included cervical spinal manipulation and subjects were made aware of this prior to consenting to participation in the study. As such, subjects were screened for any contraindications to cervical spine manipulation by their chiropractor prior to treatment. All chiropractic treatments were carried out by one of three doctors of chiropractic at the Campus Health Center, the treating chiropractor remained consistent for each participant. Treatments consisted of high velocity, low amplitude (HVLA) manipulation of dysfunctional joints in the cervical spine. Treatment also included soft tissue myofascial treatment to the neck and/or upper limb, depending on the patient's initial diagnosis. The treatment type and frequency was left of the judgement of the treating clinicians, as this was a pilot study to determine if chiropractic care, which included HVLA, was able to influence neural markers of SMI.

Each subject was assessed for joint dysfunction within the cervical spine prior to admittance into this study. As previously mentioned, joint dysfunction was defined as the presence of both tenderness to palpation of the relevant joint and restricted intersegmental range of motion (Hubka & Phelan, 1994; Jull, et al., 1994). If found eligible, 12 consecutive weeks of chiropractic treatment were carried out with the participant. The researcher maintained communication with each chiropractor to ensure that subjects were on track with their treatment plan. Should participants miss more than one consecutive week of care due to illness or vacation, extra time (typically 1 or 2 weeks) was provided to allow for patients to receive chiropractic care and get to the point in their initial treatment plan prior to recording SEP measures. This occurred in two instances.

### 5.2.9 Statistical Analysis

Due to the small sample size (n=5) a repeated measures ANOVA was not performed due to the large possibility of a type II error. Therefore, the averaged MU/M+U ratios were graphed for all peaks to determine if any preliminary trends within the SEP data were present. The data from each SF-MPQ and NDI administration were also averaged in Microsoft Excel 2007 to determine any trends.

## 5.3 Results

### 5.3.1 NDI and MPQ Results

The mean baseline score for the NDI was 11.8 and improved over the 6 week and 12 week chiropractic treatment period with scores of 7.8 and 7.6 respectively. This trend of improvement may be seen in a graphic representation in Figure 5.

The mean SF-MPQ baseline score was 10.2, improving with a score of 6.8 at 6 weeks and a final score of 8.6 at the 12 week mark of chiropractic treatment. As one can see in Figure 5, participants in this study reported significantly lower pain intensity compared to baseline after 6 and 12 weeks of chiropractic treatment.

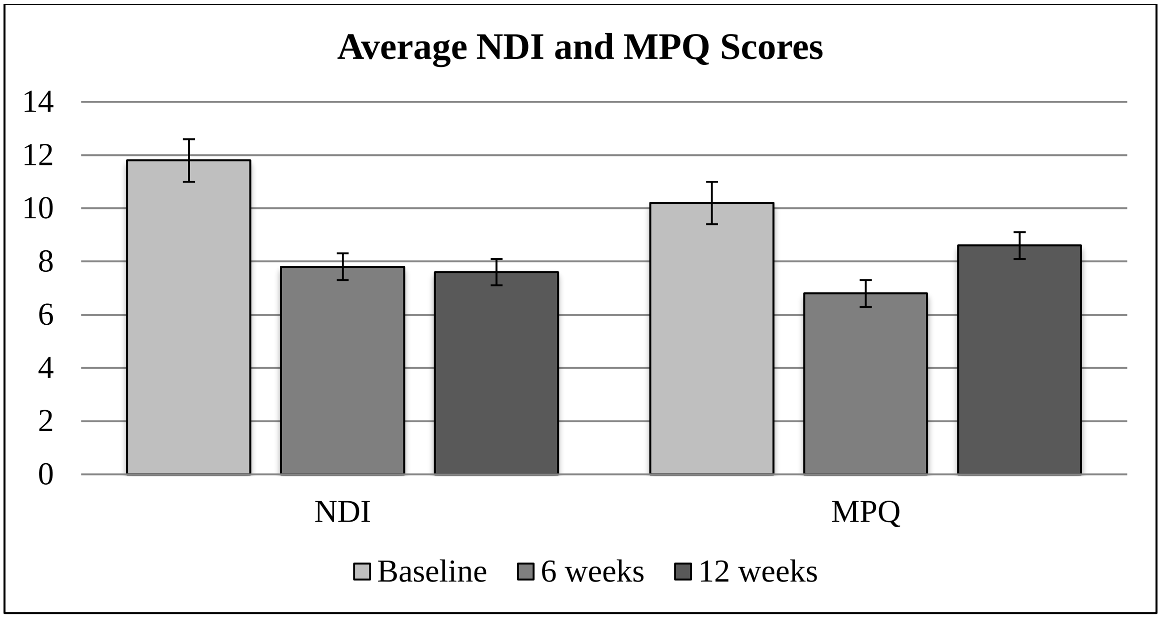



**Figure 5: Bar graph of averaged Neck Disability Index (NDI) and Short Form McGill Pain Questionnaire (SF-MPQ) scores over 12 weeks of chiropractic care.**

### 5.3.2 MU/M+U Ratio Trends

All N9 MU/M+U ratios were maintained within ± 20% of baseline values, ranging from 0.85 to 1.25. Trends appeared during the plotting of the MU/M+U ratio data (Table 5) seen in Figure 6. As one can see, there appears to be a preliminary trend of steady improvement of the MU/M+U ratio in the N20 and P25 SEP peaks. When normalized to baseline data, these peak changes represented a 22% reduction of the N20 peak and a 29% reduction of the P25 peak after 12 weeks of chiropractic care. N11 and N30 peaks appeared to trend toward an increase in the MU/M+U ratio over the 12 week period of treatment. These increases represented a 25 % increase for the N30 and a 36% increase for the N11 when normalized to baseline data. Again, there is no way of knowing if these trends are significant until more subjects are assessed, as there are only

5 subjects within this pilot study. Any trends seen here are only preliminary and need to be verified at a later date with repeated measures ANOVA.

**Table 5: Mean MU/M+U Ratio Data for baseline 6 weeks and 12 weeks post-chiropractic treatment.**

| | N9 | N11 | N13 | N18 | N20 | P25 | N30 |
|---|---|---|---|---|---|---|---|
| | **MU/M+U** | **MU/M+U** | **MU/M+U** | **MU/M+U** | **MU/M+U** | **MU/M+U** | **MU/M+U** |
| **Baseline** | 0.939011 | 0.863375 | 1.075276 | 0.70954 | 0.938445 | 1.058056 | 0.611031 |
| **6 Wks** | 0.859768 | 0.944801 | 0.83005 | 0.707836 | 0.819949 | 0.917178 | 0.6484 |
| **12 Wks** | 1.042718 | 1.171203 | 1.122559 | 0.653014 | 0.728777 | 0.748172 | 0.766358 |

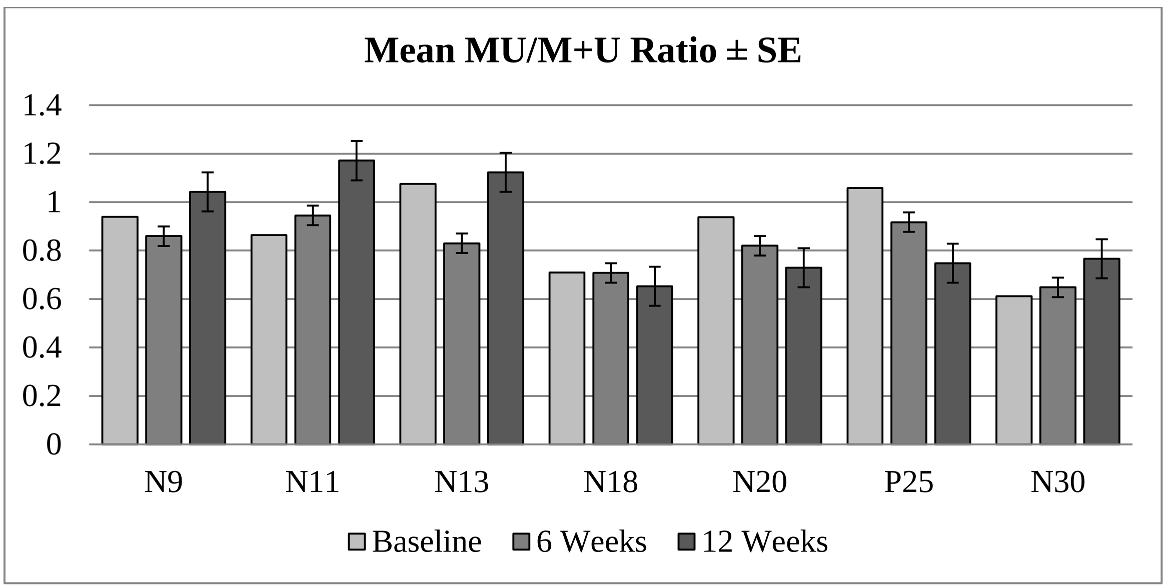



**Figure 6: Bar graph of averaged MU/M+U SEP ratios ± standard error (SE) for baseline, 6 weeks and 12 weeks of chiropractic care.**

**Table 6: Mean raw amplitude (mV) and latency (ms) data of median and ulnar nerve SEP components for baseline, 6 weeks and 12 weeks post-chiropractic treatment.**

| | **N11** | | **N13** | | **N18** | |
|---|---|---|---|---|---|---|
| | **M** | **U** | **M** | **U** | **M** | **U** |
| **Baseline** | | | | | | |
| Amplitude (mV) | 0.010614 | 0.003577 | 0.025503 | 0.017496 | 0.012431 | 0.010802 |
| Latency (ms) | 11.836 | 12.738 | 13.444 | 14.082 | 17.814 | 18.014 |
| **6 weeks** | | | | | | |
| Amplitude (mV) | 0.016858 | 0.010623 | 0.018898 | 0.019437 | 0.011191 | 0.008078 |
| Latency | 12.158 | 12.522 | 13.362 | 13.902 | 17.326 | 18.56 |
| **12 weeks** | | | | | | |
| Amplitude (mV) | 0.013417 | 0.006629 | 0.016763 | 0.01057 | 0.010701 | 0.010045 |
| Latency(ms) | 11.812 | 12.354 | 13.292 | 14.174 | 17.972 | 17.838 |

| | **N20** | | **P25** | | **N30** | |
|---|---|---|---|---|---|---|
| | **M** | **U** | **M** | **U** | **M** | **U** |
| **Baseline** | | | | | | |
| Amplitude (mV) | 0.019929 | 0.017322 | 0.015977 | 0.016497 | 0.02742 | 0.015467 |
| Latency (ms) | 19.72 | 20.25 | 24.67 | 25.122 | 31.018 | 30.79 |
| **6 weeks** | | | | | | |
| Amplitude (mV) | 0.024391 | 0.023591 | 0.0274951 | 0.02 | 0.029141 | 0.019975 |
| Latency | 19.488 | 20.404 | 24.998 | 25.212 | 30.386 | 30.576 |
| **12 weeks** | | | | | | |
| Amplitude (mV) | 0.02568 | 0.017927 | 0.026045 | 0.02009 | 0.024715 | 0.016097 |
| Latency(ms) | 20.086 | 20.274 | 25.244 | 25.95 | 30.604 | 30.178 |

## 5.4 Discussion

This was a pilot study to determine the feasibility of using dual somatosensory evoked potentials of the median and ulnar nerves to assess any treatment effects in patients with neck pain receiving chiropractic care for 12 weeks. Although there appears to be some preliminary trends toward improved MU/M+U ratios within the N20 and P25 peaks, further research needs to be conducted on a larger sample to determine if these trends are in fact consistent and significant. Although research in this area has found significant results when using a small sample size (n=13), a sample of 5 is simply too small to conclude that any changes in SEP data was significant. The initial sample size of 13 quickly diminished due to drop out rates, technical issues, and subject variability. Some of these issues could be improved upon or reduced altogether with some recommendations. Areas for improvement are noted below to improve the quality of the SEP data acquired and sample size while potential SEP trends are discussed.

### 5.4.1 Within-Subjects Variability

#### 5.4.1.1 N9 Variability

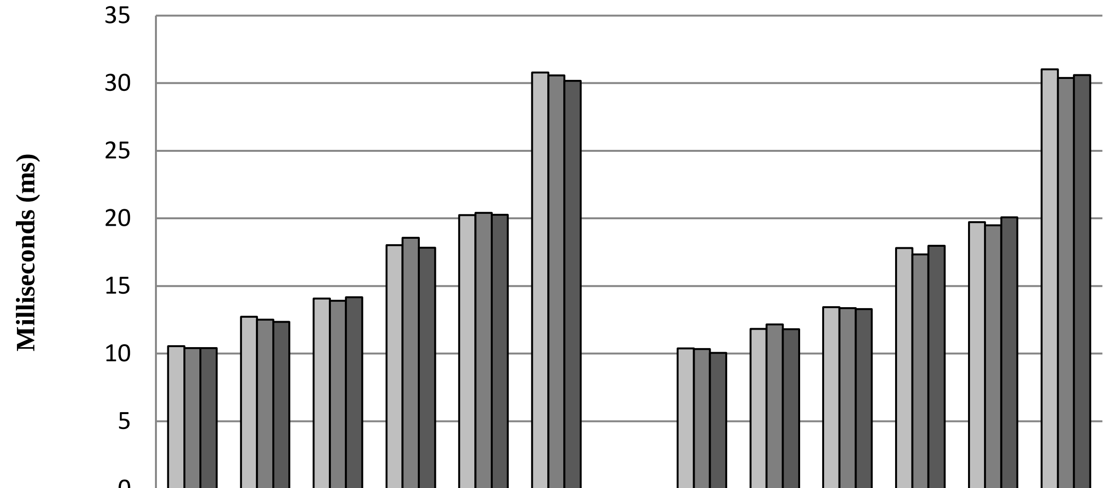
As mentioned earlier, one subject had to be omitted due to substantial N9 variability. Typically, N9 ratios should be within a close range of 1, indicating that there is no suppression of the electrical signal at the peripheral level. This is not always the case, as this may vary from subject to subject. Some participants may have scarring due to previous injuries or may have nerves that take longer/shorter routes than most which could result in skewed MU/M+U ratios for this peak. We experienced more variability within the N9 peak with the present study population and therefore broadened the exclusion criteria to be within ± 20% of baseline values for N9.

The N9 peak is a measure of stability in all SEP studies, because if stable it allows the researcher to conclude that changes in any subsequent peaks are not due to peripheral changes such as movement of the arm. In this subject's case, their variability was too great to make reliable claims regarding the data on their central peaks and had to be omitted. A few things may be done to ensure the stability of the N9 in future studies. First and foremost, the stimulated arm should be supported and maintained in a position that the subject can withstand for the allotted experiment time. Although all subject's arms and wrists were supported by a pillow during data acquisition, it may require more of a splinting technique to ensure that there is no movement whatsoever of the stimulated arm.

In some cases, the ulnar nerve would not elicit an N9 peak whatsoever. This was typically in subjects that endured previous wrist injuries. In these cases, the subsequent data could not be used for further analysis. We recommend ensuring that all potential participants are able to elicit stable N9 peaks prior to the commencement of any SEP study in the future to save both the subject and researcher's time down the road. Also, the reliability of N9 should be assessed further to determine if in fact it is a reliable measure of stability. Recommendations for reliability testing of the N9 peak in healthy subjects would be an interesting avenue to explore.

### 5.4.1.2 Ulnar Nerve Variability

One issue that arose throughout this experiment was ulnar nerve variability within the subjects who participated. The shape of the SEP waveforms were not always consistent with median nerve traces, and the latency of ulnar nerve SEP peaks were usually later than those of the median nerve. Data for the latency of median and ulnar nerve SEP peaks may be seen in Table 6. A visual illustration is provided below (Figure 7), demonstrating that ulnar nerve latency is later in most cases when compared to the latency of the median nerve. Since the afferent volley is reaching the central nervous system at different times, it could represent an inaccurate depiction of MU traces and thereby the MU/M+U ratio since there is in fact a delay between both stimuli. We recommend that in future studies, ulnar nerve conduction time is recorded and adjusted for each participant by triggering the ulnar nerve stimulator at a slightly earlier time (depending on the subject) to ensure that median and ulnar peripheral volleys are arriving at the same time to the CNS. This would allow one to truly measure the changes on sensory filtering of MU trials.




| | N9 U | N11 U | N13 U | N18 U | N20 U | N30 U | | N9 M | N11 M | N13 M | N18 M | N20 M | N30 M |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| baseline | 10.55 | 12.74 | 14.08 | 18.01 | 20.25 | 30.79 | 0 | 10.39 | 11.84 | 13.44 | 17.81 | 19.72 | 31.02 |
| 6 weeks | 10.42 | 12.52 | 13.9 | 18.56 | 20.4 | 30.58 | 0 | 10.34 | 12.16 | 13.36 | 17.33 | 19.49 | 30.39 |
| 12 weeks | 10.42 | 12.35 | 14.17 | 17.84 | 20.27 | 30.18 | 0 | 10.07 | 11.81 | 13.29 | 17.97 | 20.09 | 30.6 |

**Figure 7: Mean latency values in milliseconds for both the ulnar (U) and median (M) nerves for baseline, 6 weeks and 12 weeks.**

### 5.4.1.3 Initially Low MU/M+U ratios

Previous research by Haavik-Taylor and Murphy, the precursor to this study, was based on subjects whose initial MU/M+U ratios were over 1 prior to chiropractic treatment. This is indicative of impaired sensorimotor integration (H Haavik-Taylor & Murphy, 2010a). As one can see, initial baseline data for subjects within this study did not reach an MU/M+U ratio equalling 1, except for the N13 and P25 peaks. The N20 MU/M+U ratio was very close to 1 at .938. Ratio values may be seen in Table 5. Interestingly enough, the N20 and P25 peaks do appear to have a preliminary trend toward improvement over the course of 12 weeks of chiropractic treatment. It could be that patients with MU/M+U ratios far less than 1 are not ‘impaired’ enough to elicit any changes or improvements with treatment. This finding is in line with the similarly low NDI and SF-MPQ scores. Mean baseline data for the NDI demonstrated relatively low disability, within the 'mild' range of the scoring guide. This demonstrates that participants did not perceive themselves to be that disabled to begin with in this study. Similarly, the SF-MPQ is a scale of self perceived pain with a potential score of 45, incorporating descriptive of pain and a visual analog scale to rate pain (Melzack, 1987). Scores accumulate based on intensity of pain with this instrument. The results of the SF-MPQ for subjects in this study demonstrated mild perceived pain as values were on the low end of the potential score of 45.We recommend that prior to the start of future studies in this area, participants be screened for MU/M+U ratios close to or above 1 prior to treatment in order to assess whether or not changes occur with treatment.

It is important to note that the subjects recruited by Haavik-Taylor and Murphy were already accessing chiropractic care prior to recruitment. This would indicate that their initial complaint of neck pain was bad enough to motivate them to seek treatment of their own volition. Subjects recruited for this study were possibly motivated to participate in our study because of the free chiropractic care that they would receive. If we take into consideration the NDI and SF-MPQ scores, these subjects were considered 'mild' in their disability scores which indicates that their level of disability and pain was not very severe to begin with. It may be that subjects with NDI and SF-MPQ indicative of higher levels of disability and pain are more likely to show MU/M+U ratios above 1 and are more likely to show improvements with treatment.

### 5.4.2 Noise/Technical Issues

A major factor in any electrophysiological study is noise reduction. During data collection, researchers did their best to ensure that electrical impedance was low, with all recording and stimulating electrodes < 5KΩ by abrading skin and scalp sites well and wiping residual dead skin cells away with alcohol swabs. All lights in the room were also turned off at the time of data acquisition. Unfortunately, in this study electrical noise played a large factor in omitting a large portion of potentially usable data. Two subjects were omitted from further analysis due to the electrical noise seen on their EEG signals. Some contributing factors to this issue were the fact that the neurophysiology lab has a carpeted floor, potentially eliciting noise from static electricity. Also, construction was prominent during several data collection sessions, which could have affected the signal being collected. Another contributing factor could have been the proximity of the laboratory to the facilities department for the university. In future studies, we recommend investigating the use of other measures to decrease noise, such as grounding the subject and equipment to a common source. Researchers should also ensure that all recording and stimulating leads are not touching any metal sources within the laboratory and the equipment rack itself may need to be grounded, so that is does not act as an aerial for electrical noise.

### 5.4.3 MU/M+U Improvement Trends

The MU/M+U ratio was initially found to be elevated in patients with focal hand dystonia (FHD), which is characterized by co-contraction of antagonist muscles. Authors proposed that this increase in the MU/M+U ratio reflected a reduction in surround inhibition for these patients, which would results in excessive afferent input entering the CNS (Tinazzi, Priori, et al., 2000). This altered/excessive afferent input could result in abnormal motor outputs as seen with FHD. It is therefore evident that lower MU/M+U ratios are favourable since they would indicate an increase or restoration in surround inhibition, and allow for the filtering of excessive afferent input into the CNS. Such inhibition allows for the body to perceive stimuli as separate and process them accurately to result in appropriate motor control (Tinazzi, Priori, et al., 2000).

This study found that there appears to be a preliminary trend favouring improvement of the MU/M+U ratio for the N20 and P25 cortical peaks (see Figure 6). These findings are in line with previous research by Haavik-Taylor and Murphy who found a significant reduction in the N20 amplitude peak using median nerve SEPs acutely after spinal manipulation (H Haavik-Taylor & Murphy, 2007b). N20 reflects activity within the primary somatosensory cortex (S1) within the posterior wall of the central fissure, specifically area 3b (Allison, et al., 1989; Mauguiere, et al., 1999; Namiki, et al., 1996). P25 reflects activity within S1 specifically in Broadman’s area 1 and 2 (Mauguiere, et al., 1999; Namiki, et al., 1996). Further research is required to determine if this trend remains consistent for a larger sample size and potentially reach significance.

Interestingly enough, the N30 MU/M+U ratio, thought to reflect sensorimotor integration itself appeared to trend upward. Previous research indicates that the N30 peak amplitude from median nerve SEPs and the MU/M+U ratio from dual SEPs declines with chiropractic treatment, which would indicate a restoration of surround inhibition (H Haavik-Taylor & Murphy, 2007b, 2010a). This is in contrast to the findings seen in Figure 6. It is important to note that there were only 5 subjects within this pilot study, therefore further research needs to be conducted in order to determine if this is a continual trend with larger samples. Additionally, the N11 MU/M+U ratio from dual SEPs representing the dorsal columns within the dorsal horn gray matter seems to have trended upward, with an increase of 36% when normalized to baseline. This may reflect decreased sensory filtering at the spinal level of the medial lemniscal pathway. This finding makes the reduced MU/M+U ratio values even more interesting as it appears that the afferent information is elevated and able to be attenuated with chiropractic care.

Previous research suggests that elevated MU/+U ratios is indicative of impaired sensory filtering, as seen in dystonic patients, after repetitive muscular activity and in patients with neck pain (H Haavik-Taylor & Murphy, 2007a, 2010a, 2010b; Tinazzi, Priori, et al., 2000). Improvement of these SEP ratios has been found shortly after chiropractic treatment (approximately 20 minutes) which is the rationale behind this study (H Haavik-Taylor & Murphy, 2010a, 2010b). Should these reductions seen in the N20 and P25 ratios remain consistent with a larger sample size, this could reflect the effectiveness of chiropractic treatment in alleviating not only the symptoms of neck pain but underlying impaired neural processing associated with this musculoskeletal disorder.

## 5.5 Conclusions

In conclusion, there appears to be a preliminary trend toward the improvement of N20 and P25 MU/M+U ratios after 12 weeks of chiropractic care. Interestingly enough, the N11 which represents afferent information at the spinal level appears to be elevated which would indicate a reduction of sensory filtering at that level. Long term chiropractic care was able to attenuate initially elevated afferent information at the level of the cortex. These findings support our first hypothesis which indicated that participants would have improved markers of SMI after 12 weeks of chiropractic care. Participants also showed improved scores on the NDI and SF-MPQ which mirrored the improvements seen in the reduced MU/M+U ratios, supporting our second hypothesis. We propose that dual SEPs show promise in eventually becoming a screening tool to differentiate those with neck pain from healthy controls as they were able to show initial treatment effects in the long term. Unfortunately, we cannot conclude that changes seen in the dual SEP markers were significant as the sample size represented only 5 subjects. The research had many issues, including within-subjects factors and external electrical noise that affected the quality of the data and subsequently the total sample size. It is recommended that future studies utilizing SEPs try to eliminate or minimize electrical noise by utilizing measures such as grounding the subject and electrical equipment to a common source. We also recommend that subjects be screened prior to commencement of the study for their level of disability due to their neck pain as well as neurophysiological markers such as elevated MU/M+U ratios (close to or above 1). Ulnar nerve and N9 peak variability is also a factor to consider in future work. It was found that ulnar nerve latency was typically later than median nerve SEPs. This could require adjusting trigger rate on the ulnar nerve stimulator to ensure that both peripheral volleys are reaching the CNS at the same time when looking at MU SEPs traces. N9 variability also needs to be addressed and may require stringent splinting in order to ensure that a stable peripheral environment is met prior to collecting central processing data.

# Chapter Six Thesis Summary

Neck pain represents a widespread burden of international scale. With increases in service sector oriented employment and technology use as a whole, the potential for developing musculoskeletal disorders such as neck pain has become of great concern. Society has grown a dependence on computer related/information technology which in turn influences the risk of potentially developing neck pain. The presence of neck pain has the potential to result in time lost at work and school, as well as focus and attention while at work and school, affecting productivity, overall performance and resulting in financial loss as well as affecting quality of life.

One at risk population for neck pain is university students, particularly those who are immersed in technology based environments such as laptop based education. The nature of student life paired with current laptop technology has the potential to intensify currently known risk factors for neck pain in this population. Currently there is minimal research in the area of laptop use as it pertains to neck pain in student laptop users. It is not only imperative to determine if certain patterns of laptop use are in fact a risk factor for neck pain in students, but the development of a potential screening tool to identify students who appear to be at greater risk of developing neck pain based on their laptop use patterns may be of benefit for this demographic. In order to address this gap in the literature, experiment one encompassed developing a reliable questionnaire (The Student Laptop Use and Neck Pain Risk Questionnaire, SLUNPRQ) to assess the environment in which students at a laptop based university used their laptops. This questionnaire also aimed to address known risk factors for neck pain in this population. After reliability analysis, it was found that with some modifications the SLUNPRQ seems to be a reliable measure to provide further insight into the overall environment of laptop use within university students. With further modification, this questionnaire could highlight some areas that are increasing the risk of developing neck pain in students and could result in preventative measures to minimize this risk in the future such as the implementation of laptop risers or ergonomic work stations on campus.

Since neck pain is so prominent, it is only a natural progression to determine whether there are physiological markers which relate to neck pain which can differentiate those with recurrent pain from healthy controls and demonstrate the effect of various treatment options. Previous research has indicated that patients with neck pain demonstrate altered markers of sensorimotor integration, and that chiropractic care has the potential to improve these neural markers in this patient population, at least immediately after spinal manipulation. Experiment two aimed to determine the feasibility of using dual somatosensory evoked potentials to evaluate changes in dual SEP ratios representing sensorimotor integration after 12 weeks of chiropractic care. This would elucidate whether or not these markers were able to maintain their 'improved' state over long periods of time. Experiment two demonstrated that 12 weeks of chiropractic care has potential to improve dual SEP ratios which are representative of central sensory filtering (neural markers of sensorimotor integration) in patients with recurring neck pain. These improvements mirrored the improved Neck Disability Index and Short Form McGill Pain Questionnaire scores after the 12 weeks of care. There were some limitations with this experiment, particularly the small sample size (n=5) which was diminished from the initial group of 13 due to electrical noise and within-subjects factors that need to be addressed in future work to ensure the preservation of data quality. Due to this small sample size, initial trends need to be confirmed through further research within a larger sample size to see if they continue. Neck pain in the form of spinal dysfunction may represent a form of altered afferent input that could result in impaired sensorimotor integration and thereby sensory filtering. If these trends toward improved status of neurophysiological markers of central neural processing hold true, chiropractic care could represent a viable treatment for addressing altered neurophysiological processing as a risk factor for chronic neck pain. This could result in widespread economic savings on treatments that are less effective. Additionally, if dual SEPs are able to show treatment effects over the long term, this technique may in time be used as a screening tool to help identify those who are at risk of developing neck pain from those who are not as well as those who have neck pain from healthy individuals.

## 6.1 Future Directions

The pilot study done in experiment one will help provide a measure for university students to determine those who are at a greater risk of developing neck pain due to their laptop use habits and could eventually be used as a screening tool in future studies. Future work with the SLUNPRQ will relate to modifying questions and testing the reliability of new questions as well as the overall content and construct validity of the instrument.

The pilot data from experiment two will provide data for future work on larger samples to examine the effects of long term chiropractic treatment on neural markers of sensorimotor integration in patients with neck pain. Research in the future needs to determine if the initial trends of improved central neural processing after 12 weeks of chiropractic care persist in a larger sample. If these trends are found to be persistent, future work could include longitudinal studies to determine if dual SEPs can be used as a screening measure for neck pain by determining if: 1) elevated SEP ratios can differentiate between patients with chronic or recurrent neck pain and healthy controls, 2) elevated SEP ratios as discharge predict acute neck pain patients who go on to become chronic and 3) whether SEP ratios need to be normalized at discharge to predict long term improvement.

# Appendix A: The Keyboard Personal Computer Style Instrument

| # | Item | Question on the K-PeCS | Rating |
|---|---|---|---|
| *Items of static posture* | | | |
| 1 | Torso angle | Generally, what is the angle of the keyboard user's torso to the horizontal plane? | (1) The torso angle to the horizontal plane is greater than 105°<br>(2) The torso angle to the horizontal plane is between 90° and 105°<br>(3) The torso angle to the horizontal plane is less than 90° |
| 3 | Neck flexion angle | Generally, what is the displacement angle and position of the head? | (1) Head forward less than 10°<br>(2) Head forward between 11° and 20°<br>(3) Head forward between 21 and 30°<br>(4) Head forward greater than 30° |
| 4 | Shoulder flexion angle | Generally, what is the flexion angle of the shoulders? | (1) 0–20°<br>(2) 21–35°<br>(3) > 35° |
| 5 | Elbow flexion angle | Generally, what is the angle of the elbows? | (1) < 79°<br>(2) 80–120°<br>(3) > 120° |
| *Items of dynamic posture* | | | |
| 8 | Wrist/hand movement(displacement) | Does the keyboard user move his/her hands while typing? | (1) The keyboard user moves his/her hand occasionally to reach for keys<br>(2) The keyboard user moves his/her hand often to reach for keys<br>(3) The keyboard user moves his/her hand most of the time to reach for keys |
| 10 | Wrist ulnar angle | Does the keyboard user exceed 20° of ulnar deviation? | (1) Never exceeds 20° ulnar deviation<br>(2) Occasionally exceeds 20° ulnar deviation<br>(3) Frequently exceeds 20° ulnar deviation<br>(4) Always exceeds 20° ulnar deviation |
| 11 | Wrist extension angle | Does the keyboard user exceed 15° of wrist extension? | (1) Never exceeds 15° wrist extension<br>(2) Occasionally exceeds 15° wrist extension<br>(3) Frequently exceeds 15° wrist extension<br>(4) Always exceeds 15° wrist extension |
| 12 | Changes in pronation | Does keyboard user ever rotate his/her forearm (increase pronation or supination)? | (1) Yes, the keyboard user does rotate his/her forearm<br>(2) No, the keyboard user does not rotate his/her forearm |
| 13 | Isolated 5th digit | Does the keyboard user isolate the 5th digit? | (1) Never isolates the 5th digit<br>(2) Occasionally isolates the 5th digit<br>(3) Frequently isolates the 5th digit<br>(4) Always isolates the 5th digit |
| 14 | Isolated thumb | Does the keyboard user isolate the thumb? | (1) Never isolates the thumb<br>(2) Occasionally isolates the thumb<br>(3) Frequently isolates the thumb<br>(4) Always isolates the thumb |
| 15 | Space bar activation | What finger does the keyboard user use to strike the space bar? | (1) Right thumb<br>(2) Right index<br>(3) Other |
| 16 | No. of digits used to type | How many digits does the keyboard user use to strike the keys? | (1) 1 digit<br>(2) 2 digits<br>(3) 3 digits<br>(4) 4 digits<br>(5) 5 digits |

| # | Item | Question on the K-PeCS | Rating |
|---|---|---|---|
| 17 | MCP hyperextension | Does the keyboard user hyperextend the MCP joints? | (1) Never hyperextends the MCP joint<br>(2) Occasionally hyperextends the MCP joint<br>(3) Frequently hyperextends the MCP joint<br>(4) Always hyperextends the MCP joint |
| 18 | PIP/DIP curve | Are the keyboard user's PIP/DIP joints generally curved (>25°) or generally straight (<25°)? | (1) PIP/DIP curved<br>(2) PIP/DIP straight |
| 19 | Hypermobility | Do the DIP joints ever "collapse" when the digits strike the keys (hypermobility)? | (1) No, the DIP does not collapse (hyperextend)<br>(2) Yes, the DIP does collapse (hyperextend) |
| *Items of force or tension* | | | |
| 2 | Back rest use | Does the keyboard user rest at least 2/3 of the back against the back rest while using the computer? | (1) Yes, the keyboard user rests 2/3 of the back against the backrest all the time<br>(2) Yes, the keyboard user rests 2/3 of the back against the backrest during breaks<br>(3) No, the keyboard user does not rest 2/3 of the back against the backrest |
| 6 | Forearm support use | Does the keyboard user support his/her forearms/elbows on an arm rest or table? | (1) Yes, both forearms/elbows<br>(2) No, the right forearm/elbow is unsupported<br>(3) No, the left forearm/elbow is unsupported<br>(4) No, both forearms/elbows are unsupported |
| 7 | Wrist support use | Does the keyboard user support his/her wrist(s) on the wrist pad or table? | (1) Yes, the wrist is supported while using the keyboard<br>(2) The wrist is unsupported while using the keyboard, and supported during pauses.<br>(3) No, wrist is never supported. |
| 9 | Force | Generally, what kind of force does the keyboard user use to strike the keys? | (1) Low force<br>(2) Moderate force<br>(3) High force |

All items except 1, 2, 3, and 9 are measured on both the right and left sides; Items 17 and 18 are measured separately for digits 2–5.

From: Baker, N., Cook, J., & Redfern, M. (2009). Rater reliability and concurrent validity of the Keyboard Personal Computer Style instrument (K-PeCS). *Applied Ergonomics*, 40(1), 136-144.

# Appendix B: Student Health Related Role Functioning Scale

Student Founctional Limitations Scale

| | No difficulty | Mild difficulty | Moderate difficulty | Severe difficulty | So difficult I cannot do at all |
|---|---|---|---|---|---|
| (a) Type 10 pages (double space) on the computer | 0 | 1 | 2 | 3 | 4 |
| (b) Complete assignments on the computer (such as typed papers) on time | 0 | 1 | 2 | 3 | 4 |
| (c) Do assignments on the computer as well as you would like | 0 | 1 | 2 | 3 | 4 |
| (d) Complete handwritten assignments (such as problem sets) | 0 | 1 | 2 | 3 | 4 |
| (e) Correspond as often as you would like by email with friends, faculty and others | 0 | 1 | 2 | 3 | 4 |
| (f) Take notes in class by hand | 0 | 1 | 2 | 3 | 4 |
| (g) Take timed written examinations | 0 | 1 | 2 | 3 | 4 |
| (h) Do extracurricular activities (such as sports, musical instruments, hobbies) | 0 | 1 | 2 | 3 | 4 |
| (i) Use the mouse (or other computer pointing device) repeatedly | 0 | 1 | 2 | 3 | 4 |
| (j) Carry your books around campus | 0 | 1 | 2 | 3 | 4 |

From: Katz et al (2002) Assessment of upper extremity role functioning in students. *American Journal of Industrial Medicine, 41*(1), 19-26.

# Appendix C: Ethics Approval for SLUNPRQ Development and Piloting

UOIT
CHALLENGE INNOVATE CONNECT

RESEARCH ETHICS BOARD

**Date: July 16th, 2010**

**To: Diana Gray (PI)**

**From: Raymond Cox, REB Chair**

**File #: 09-131**

**Title: Assessing the risks associated with neck pain in student laptop users**

*The University of Ontario Institute of Technology Research Ethics Board has reviewed the above research proposal. The application in support of the above research project has been reviewed by the Research Ethics Board to ensure compliance with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS) and the UOIT Research Ethics Policy and Procedures.*

**DECISION: Approved with Note**

**COMMENTS AND CONDITIONS:**

This project has been approved for the period of **July 16th, 2010 until July 16th, 2011 and is** subject to full REB ratification at the Research Ethics Board's next scheduled meeting. The approval may be extended upon request.

**NOTE:**

*If the draft of the laptop survey (or other aspects of your study) is materially changed you are required to complete and submit a Change Request form to the REB.*

Please note that the Research Ethics Board (REB) requires that you adhere to the protocol as last reviewed and approved by the REB. The Board must approve any modifications before they can be implemented. If you wish to modify your research project, please contact REB Administration, to obtain the Change Request Form.

Adverse or unexpected events must be reported to the REB as soon as possible with an indication of how these events affect, in the view of the Principal Investigator, the safety of the participants and the continuation of the protocol.

If research participants are in the care of a health facility, a school, community organization or other institution it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and approvals of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research protocols.

Section F, Article 1.13, Review Procedures for Ongoing Research of the TCPS http://www.pre.ethics.gc.ca/english/policystatement/policystatement.cfm requires that ongoing research be monitored. A Final Report is required for all projects, with the exception of undergraduate projects, upon completion of the project. Researchers with projects lasting more than one year are required to submit a Renewal Request annually. Contact REB Administration to obtain a copy of the Renewal Request/Final Report form.

***Please quote your REB file number on all future correspondence. Thank you.***

| | |
|---|---|
| REB Chair<br><br>Dr. Raymond Cox, Faculty of Business & Information Technology<br><br>Raymond.cox@uoit.ca | Sascha Tuuha, Compliance Officer<br><br>905 721 8668 ext 3693<br><br>compliance@uoit.ca |

## Appendix D: Original SLUNPRQ Version

# Preliminary Draft of Laptop Use Survey

Date: ____________________

This questionnaire is anonymous. Once completed and submitted there is no way to retrieve your individual data. By submitting this questionnaire you are providing consent to be part of this study.

Age:____ Gender:_______ Ethnicity:____________

Handedness: ______ Program of study:_____________ Year of study in your program:_____

**Medical History**

**Q1:** Do you smoke cigarettes and/or cigars?

a) Yes
b) No

**Q2a:** In the last year, have you had any pain or discomfort in your neck or upper extremities (i.e.: i.e.: Shoulder/elbow/forearm/wrist/hand fingers)?

a) Yes
b) No

**Q2b:** If yes, please indicate ALL of the affected areas (you may circle as many choices as needed)

a) Neck
b) Shoulder
c) Elbow
d) Forearm
e) Wrist/Hand/Fingers

**Q3a:** In the past 5 years, have you experienced injury to the neck ?

a) Yes
b) No

**Q3b:** If yes, please circle the appropriate source (you may circle as many choices as needed)

a) Motor Vehicle Accident
b) Sports Related
c) Surgery
d) Overuse

**Q3c:** If your injury was due to overuse, was it due to computer use?

a) Yes
b) No

**Q3d:** If your injury was due to overuse, did it happen at:

a) Home
b) University
c) Work
d) Sport
e) Hobby

**Q4a:** In the past 5 years, have you experienced injury to your upper extremities (ie. Arm, shoulder, elbow, wrist or hands)

a) Yes
b) No

**Q4b:** If yes, please circle the appropriate source

a) Motor Vehicle Accident
b) Sports Related
c) Surgery
d) Overuse

**Q4c:** If your injury was due to overuse, was it due to computer use?

a) Yes
b) No

**Q4d:** If your injury was due to overuse, did it happen at:

a) Home
b) University
c) Work
d) Sport
e) Hobby

**Q5:** If you answered no to question ***# 4a***, have you had a history of neck and/or upper extremity pain unrelated to a known injury?

a) Yes

b) No

**Q6a:** Do you have any underlying medical conditions (i.e.: neuropathies, multiple sclerosis, parethesias or other neurological disorders)?

a) Yes
b) No

**Q6b:** If yes, please specify.

**Q7:** After using a computer, do you experience pain or discomfort in the neck or upper extremities?

a) Yes
b) No

**Q7b:** If yes, please indicate ALL of the affected areas (you may circle as many choices as needed)

a) Neck
b) Shoulder
c) Elbow
d) Forearm
e) Wrist/Hand/Fingers

**Laptop Use**

**Q1a**: Do you use a laptop on a regular basis for academic purposes?

a)Yes

b) No

**Q1b**: If yes, please estimate how many hours per week you use a laptop for these purposes.

a) 0-5 hours
b) 5-10 hours
c) 10-15 hours
d) 15-20 hours
e) 20+ hours

**Q2a:** Do you use a laptop on a regular basis for recreational purposes (i.e.: gaming)?

a) Yes

b) No

**Q2b**: If yes, please estimate how many hours per week you use a laptop for these purposes.

a) 0-5 hours
b) 5-10 hours
c) 10-15 hours
d) 15-20 hours
e) 20+ hours

**Q3a:** Do you have a job that requires you to use a laptop or computer for the majority of the work day?

a) Yes
b) No

**Q3b**: If yes, please estimate how many hours per week you use a laptop or computer at work.

a) 0-5 hours
b) 5-10 hours
c) 10-15 hours
d) 15-20 hours
e) 20+ hours

**Q4:** Please estimate in a percentage, how much of your day you spend in a sedentary (sitting) position?

a) 0%-25%
b) 25%-50%
c) 50%-75%
d) 75%-100%

**Q5:** Do you spend the majority of your time computing in a chair with armrests?

a) Yes
b) No

**Q6:** Do you use an external mouse or external monitor with your laptop?

a) Yes
b) No

**Q7:** Do you take breaks when you are computing for long periods of time?

a) Yes
b) No

**Q7b:** If yes, please estimate how often you take breaks during that length of time.

a) Every 10-15 minutes
b) 15- 59 minutes
c) 1 hour - 1 hr :59 minutes
d) 2 hours- 2 hrs: 59 minutes
e) After 3 + hours

# Appendix E: Revised SLUNPRQ for Initial Piloting

# Student Laptop Use and Neck Pain Risk Questionnaire

Name: ______________________________ Date: _____________

This questionnaire is confidential. Once completed and submitted there is no way that your individual data can be traced back to you. Please complete the consent form provided prior to filling out this questionnaire.

The purpose of this questionnaire is to measure laptop use in university students, to determine the duration and frequency of use and to determine if there is an association between a student's laptop exposure and possible presence of neck or upper limb pain. This questionnaire is split into three (3) main sections: Laptop use at school, work and for recreation. Please answer to the best of your ability.

For the purposes of this questionnaire, **laptop use refers to the active use of either the mouse, keyboard or both while operating the laptop.**

Age: ____ Gender: _______ Rt/Lft Handed ______ Program of study: __________

Year of study in your program: _____

## Medical History

**Q1a:** Do you have any underlying medical conditions (i.e.: neuropathies, multiple sclerosis, paresthesias or any other neurological disorders)?

a) Yes
b) No

**Q1b:** If yes, please specify.

_______________________________________________________________

**Q2a:** After using your laptop, do you experience pain or discomfort in your neck or upper extremities?

a) Yes
b) No

**Q2b:** If you experience pain or discomfort after using a laptop, how long do these symptoms last?

a) < 30 minutes
b) 30-60 minutes
c) 1- 6 hours
d) 6-24 hours
e) 1 day

**Q2c:** If pain or discomfort is present after the use of a laptop, please indicate **ALL** of the affected areas (you may circle as many choices as needed)

a) Neck
b) Shoulder
c) Elbow
d) Forearm
e)Wrist/Hand/Fingers

**Q2d:** If the affected areas are not listed above, please specify them here:

______________________________________________________________

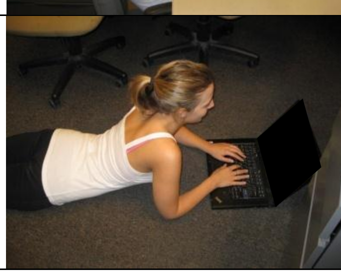
## Recreational, Academic and Work Related Laptop Use

The following questions pertain to laptop use while using the machine for recreational purposes (i.e.: gaming, watching television or movies), academic purposes (i.e.: taking notes, reading, completing course work, attending lectures) and work related activities. Please indicate your answers under each column by marking an **(X)** under the appropriate category. If these questions do not apply to you, please leave the box under that particular column blank.

**Q1**: How many **hours per week** do you use a laptop for recreational, academic and work related purposes on average.

| Time/week | Recreational | Academic | Work Related |
|---|---|---|---|
| **< 6 hours** | | | |
| **6-12 hours** | | | |
| **12-20 hours** | | | |
| **>20 hours** | | | |

**Q2:** Which of the following postures best describes the position that you usually use while using a laptop for recreational, academic and work related purposes?

| | Recreational | Academic | Work Related |
|---|---|---|---|
|  | | | |
|  | | | |
|  | | | |
|  | | | |
|  | | | |

**Q3:** Do you use an external mouse when you use a laptop for recreational, academic and/or work related purposes?

| | Recreational | Academic | Work Related |
|---|---|---|---|
| **Yes** | | | |
| **No** | | | |

**Q4:** Do you use an external monitor when you use a laptop for recreational, academic and/or work related purposes?

| | Recreational | Academic | Work Related |
|---|---|---|---|
| **Yes** | | | |
| **No** | | | |

**Q5a:** Do you take breaks when you are computing for extended periods of time while using your laptop for recreational, academic and/or work related purposes?

| | Recreational | Academic | Work Related |
|---|---|---|---|
| **Yes** | | | |
| **No** | | | |

**Q5b:** If yes, how long are the breaks that you typically take while using a laptop for recreational, academic and work related purposes?

| Time/break | Recreational | Academic | Work Related |
|---|---|---|---|
| **< 15 minutes** | | | |
| **15-45 minutes** | | | |
| **> 45 minutes** | | | |

**Q5c:** How many breaks do you typically take while using a laptop for recreational, academic and work related purposes?

| # of breaks | Recreational | Academic | Work Related |
|---|---|---|---|
| **0 breaks** | | | |
| **1-2 breaks** | | | |
| **3-4 breaks** | | | |
| **5-6 breaks** | | | |

**The focus of this questionnaire was on laptop use. What else do you think contributes to your neck pain?**

______________________________________________________________________________

______________________________________________________________________________

______________________________________________________________________________

_____________________________________________________________________________.

# Appendix F: Consent Form for SLUNPRQ Reliability Testing

RESEARCH ETHICS BOARD

**Title of Research Study:** Assessing the Incidence of Risks Associated with Neck Pain in Student Laptop Users

You are invited to participate in a research study entitled "Assessing the Incidence of Risks Associated with Neck Pain in Student Laptop Users". This study (REB File # **09-131**) has been reviewed by the University of Ontario Research Ethics Board and has been approved as of July 16th, 2010. Please read this form carefully, and feel free to ask any questions you might have. *If you have any questions about your rights as a participant in this study, please contact the Compliance Officer at 905 721 8668 ext 3693 or compliance.uoit.ca.*

**Researcher(s):**


Diana Gray, BHSc, Dr. Bernadette Murphy, DC, PhD, Dr. Pierre Côté, DC, PhD.

Faculty of Health Sciences,

University of Ontario Institute of Technology

Contact number: (905) 721-8668 Ext 2778

Email: bernadette.murphy@uoit.ca, diana.gray@uoit.ca


**Purpose and Procedure:**

The purpose of this study is to develop and pilot a questionnaire pertaining to the risk of developing neck and upper limb pain associated with laptop use in student populations. Musculoskeletal pain has become a global public health issue characterized with high prevalence and large economic burden. While technology has advanced and service sector oriented work has increased, the use of computers and laptops has risen in turn. In order to prepare future workers, some educational institutions have focused on the daily use of technology and have implemented laptop based education. Unfortunately, there is little information on the risks associated with laptop use in terms of detrimental musculoskeletal outcomes. Musculoskeletal disorders may, in part, be associated with laptop use which emphasizes the need for the assessment of risk factors associated with musculoskeletal pain specifically in relation to laptop use.

Participants will be provided with one (1) questionnaire to complete to the best of their ability. This questionnaire is: the pilot questionnaire on the risks associated with laptop use. Participants will complete this questionnaire twice within a two week period for validity purposes. The questionnaire will take approximately 20 minutes to complete, all information provided is confidential.

**Potential Benefits:**

Participants may benefit through greater awareness of their own laptop postures and patterns of use as a result of participating in this research.

As stated earlier, there are very few measures for the assessment of risk factors associated specifically with laptop use for students, this questionnaire will benefit society by providing for the needs of this demographic.

**Potential Risk or Discomforts:**

There are no known risks associated with the completion of this research project.

**Storage of Data:**

All data and consent forms will be kept in locked filing cabinets for 7 years in the UOIT neurophysiology laboratory.

**Confidentiality:**

Participant's names will be recorded on a master list, accessible only to the research team in order to match the two sets of questionnaire data. Data in research publications will be coded so that it is not traceable to individual participants. Your privacy shall be respected. No information about your identity will be shared or published without your permission, unless required by law.

**Right to Withdraw:**

Your participation is voluntary, and you can answer only those questions that you are comfortable with. The information that is shared will be held in strict confidence and discussed only with the research team. Participants are free to withdraw at any time, and such a decision will not affect the participant in any way. Participants may withdraw at any time by contacting either researcher by e-mail or phone.

**Participant Concerns and Reporting:**

This research project has been approved by the University of Ontario Institute of Technology Research Ethics Board on July 16th, 2010.

If you have any questions concerning the research study, or experience any discomfort related to the study please contact the researcher(s) at (905) 721-8668 Ext 2778 or via email at diana.gray@uoit.ca or bernadette.murphy@uoit.ca. Any questions regarding your rights as a participant, complaints or adverse events may be addressed to Research Ethics Board through the Compliance Office (905 721 8668 ext 6393).

**Debriefing and Dissemination of Results:**

You will be provided with a summary of findings at the end of the study in the form of a short report, if you so desire. Please advise us of your preferable format for communication (check one and provide details in the space provided):

☐ email_____________________________________________

☐ fax_______________________________________________

☐ written ___________________________________________

**Compensation for Participation:**

There will be no compensation to participants for involvement with this study.

**Consent to Participate:**

(a) Written Consent
Include the following statement:

1. "I have read the consent form and understand the study being described";
2. "I have had an opportunity to ask questions and my questions have been answered. I am free to ask questions about the study in the future.";
3. "I freely consent to participate in the research study, understanding that I may discontinue participation at any time without penalty. If I withdraw my data will be destroyed. A copy of this Consent Form has been given to me for my records."

_________________________________ _________________________________

(Name of Participant) (Date)

_________________________________ _________________________________

(Signature of Participant) (Signature of Researcher)

# Appendix G: Undefined Kappa Example

An example of the calculation leading to an undefined Kappa value, without 100% agreement is seen below:

Second Administration (columns); First Administration (rows)

| | No | Yes |
|---|---|---|
| No | 35 | 1 |
| Yes | 0 | 0 |

First administration = 36 No, 0 Yes. 36/36 = 1 which means that participants said no 100% of the time during the first administration.

Second administration = 35 No, 1 Yes. 35/36 = 0.972 which means that participants said no 97.2% of the time while 1/36= 0.028 meaning that participants said yes 2.8% of the time.

Since there are 35 No answers that were agreed upon, Po = 35.
In order to calculate the probability of saying no randomly, one calculates the following: 1 x 0.972 = 0.972 or 97.2%.

In order to calculate the probability of saying yes randomly, one calculates the following: 0.028 or 2.8% since there were no other 'yes' answers within the first or second administration.

Finally, one calculates the overall probability of random agreement by adding both the probability of saying yes and saying no which is equal to 0.972 + 0.028 = 1. This is the Pe value seen in the Kappa formula. Since the Kappa formula is as below with Po = 0.972 and Pe = 1:

$$K = \frac{Po - Pe}{1 - Pe}$$

$$K = \frac{0.972 - 1}{1 - 1}$$

$$K = 0$$

Therefore, the Kappa value cannot be calculated in this case because the denominator is equal to 0.

# Appendix H: Revised SLUNPRQ for Future Reliability Testing

# Student Laptop Use Survey

Name: ________________________ Date: ______________________

This questionnaire is confidential. Once completed and submitted there is no way that your individual data can be traced back to you. Please complete the consent form provided prior to filling out this questionnaire.

The purpose of this questionnaire is to measure laptop use in university students, to determine the duration and frequency of use and to determine if there is an association between a student's laptop exposure and possible presence of neck or upper limb pain. This questionnaire is split into three (3) main sections: Laptop use at school, for employment purposes and for recreation purposes. Please answer to the best of your ability.

For the purposes of this questionnaire, **laptop use refers to the active use of either the mouse, keyboard or both while operating the laptop.**

Date of Birth: ____ Gender: ____ Handedness ______ Program of study: ______________

Year of study in your program: _____

## Medical History

**Q1a:** Do you have any underlying medical conditions (i.e.: neuropathies, multiple sclerosis, paresthesias or any other neurological disorders)?

a) Yes
b) No

**Q1b:** If yes, please specify.

______________________________________________________________

**Q2a:** After using your laptop, do you experience pain or discomfort in your neck or upper extremities?

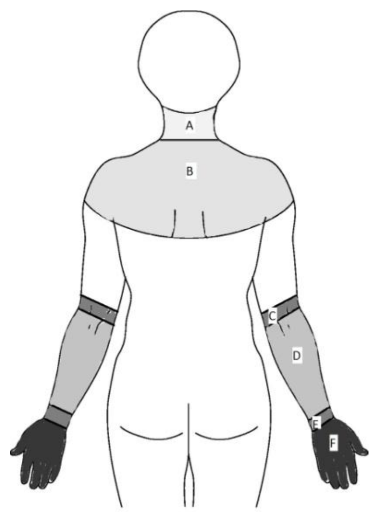
a) Yes
b) Sometimes

c) No

**Q2b:** If you experience pain or discomfort after using a laptop, how long do these symptoms last on average? Please write down your best estimate in the space provided.

______________________________________________

**Q2c:** If pain or discomfort is present after the use of a laptop, please indicate **ALL** of the affected areas (you may circle as many choices as needed)




a) Neck
b) Shoulder
c) Elbow
d) Forearm
e) Wrist/Hand/Fingers

**Q2d:** If the affected areas are not listed above, please specify them here:

______________________________________________

## Recreational, Academic and Employment Related Laptop Use

The following questions pertain to laptop use while using the machine for recreational purposes (i.e.: gaming, watching television or movies), academic purposes (i.e.: taking notes, reading, completing course work, attending lectures) and employment related activities. Please indicate your answers under each column by marking an **(X)** under the appropriate category. If these questions do not apply to you, please leave the box under that particular column blank.

**Q1**: How many **hours per week** do you use a laptop for recreational, academic and employment related purposes on average? Please provide your best estimate in the space provided.

| | |
|---|---|
| **Recreational** | |
| **Academic** | |
| **Employment Related** | |

**Q2**: On average, how long do you spend computing on your laptop in a lecture hall setting for recreational, academic or employment related purposes? Please provide your best estimate in the space provided.

| | |
|---|---|
| **Recreational** | |
| **Academic** | |
| **Employment Related** | |

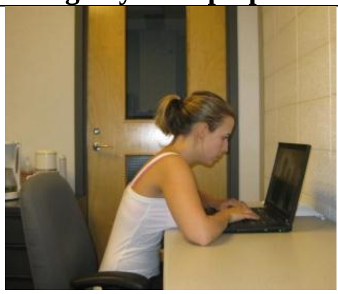
**Q3**: On average, how long do you spend computing on your laptop in a campus study room for recreational, academic and employment related purposes **on average**? Please provide your best estimate in the space provided.

| | |
|---|---|
| **Recreational** | |
| **Academic** | |
| **Employment Related** | |

**Q4**: On average, how long do you spend computing on your laptop in a dormitory setting for recreational, academic and employment related purposes **on average**? Please provide your best estimate in the space provided.

| | |
|---|---|
| **Recreational** | |
| **Academic** | |
| **Employment Related** | |

**Q5:** Which of the following postures (on the next page) best describes the position that you usually use while using a laptop for recreational, academic and work related purposes? Pay close attention to the position of your head, neck and spine in these photos and choose **one** photo that best represents your **typical** posture for each purpose listed.

| | Recreational | Academic | Employment Related |
|---|---|---|---|
|  **Neck neutral looking straight ahead at your laptop screen.** | | | |
|  **Neck flexed,facing downward looking at your laptop screen** | | | |
|  **Slouching forward, neck slightly extended** | | | |
|  | | | |

| | | | |
|---|---|---|---|
| **Slouching backward, neck in flexion** | | | |
|  **Laying on the floor or bed, neck extended** | | | |

**Q6:** Do you use an external mouse with your laptop at any time during the week? If so, please indicate how many **hours per day** you use an external mouse for recreational, academic and/or employment related purposes. Please provide your best estimate in the space provided, if you do not use an external mouse just write 0 in the box.

| | |
|---|---|
| **Recreational** | |
| **Academic** | |
| **Employment Related** | |

**Q7:** Do you use an external monitor with your laptop at any time during the week? If so, please indicate how many **hours per day** you use an external mouse for recreational, academic and/or employment related purposes. Please provide your best estimate in the space provided, if you do not use an external monitor just write 0 in the box.

| | |
|---|---|
| **Recreational** | |
| **Academic** | |
| **Employment Related** | |

**Q8:** Do you use a laptop riser with your laptop at any time during the week? If so, please indicate how many **hours per day** you use an external mouse for recreational, academic and/or employment related purposes. Please provide your best estimate in the space provided, if you do not use a laptop riser just write 0 in the box.

| | |
|---|---|
| **Recreational** | |
| **Academic** | |
| **Employment Related** | |

The following questions will relate to the use of breaks while computing on your laptop machine. Breaks include any time taken away from computing with your laptop, and may include any of the following: taking a lunch breaks while at work, a coffee/tea break, stretch/rest breaks etc.

**Q9a:** Do you take breaks while using your laptop computer? If so, how many breaks do you typically take **on average** while using a laptop for recreational, academic and employment related purposes? Please provide your best estimate in the space provided, if you do not take breaks just write 0 in the box.

| | |
|---|---|
| **Recreational** | |
| **Academic** | |
| **Employment Related** | |

**Q8b:** If you take breaks while using a laptop computer at any time during the week, please indicate how long those breaks typically are **on average** for recreational, academic and employment related purposes. Please provide your best estimate in the space provided, if you do not take breaks just write 0 in the box.

| | |
|---|---|
| **Recreational** | |
| **Academic** | |
| **Employment Related** | |

**The focus of this questionnaire was on laptop use. What else do you think contributes to your neck pain?**

______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
______________________________________________________________________________
________________________________.

# Appendix I: Consent Form for SEPs Study

Professor Bernadette Murphy

University of Ontario Institute of Technology

*Faculty of Health Sciences*

2000 Simcoe St. North

Oshawa, Ontario

CANADA  L0B 1J0

Email: Bernadette.Murphy@uoit.ca

Phone: (905) 721-8668  Fax: (905) 721-3179

**Research Information for participants**

Title: ***The neurophysiological effects of spinal manipulation- SEPs June 30, 2010*** **This study has received ethical approval from the UOIT ethics commitee (REB# 07-073)**

This is a multi-centre research study being conducted by Dr Bernadette Murphy from the Faculty of Health Sciences at the University of Ontario Institute of Technology (UOIT), in Oshawa, Ontario, Canada and Dr. Heidi Taylor from the New Zealand College of Chiropractic in Auckland, New Zealand. We are investigating how joint manipulation alters neurophysiological function in the central nervous system. In order to do this we will need to collect some information about the way your brain processes signals from your hand and forearm muscles before and after a period of chiropractic care. We will also get you to complete some questionnaires, which will provide information regarding your current functional capacity, level of neck pain (if any), and general well being.

You are invited to participate in our research and we would appreciate any assistance you can offer us. Your participation in this study is entirely voluntary (your choice) and you are free to decline taking part in this study. You may also withdraw from the study at any time without giving a reason. This will in no way affect your future chiropractic care and/or academic progress, irrespective of whether or not payment is involved. We are seeking people with no neck or arm problems as well as those who have had a history of chronic neck pain for at least three months and are aged between 18 and 50. To participate in this study you must complete an eligibility checklist in conjunction with one of the researchers, to ensure you are eligible to participant in this research.

**Measurement sessions**

If you are taking part in the chiropractic treatment component, you need to attend a baseline recording session, plus an additional three recording sessions. The second recording session would be after 6 weeks of treatment, and the third at 12 weeks after treatment. Finally there would be a follow-up session 3 months later. During each evaluation session we will collect some information about how your brain processes electrical signals from your hand and arm muscles. To do this it will be necessary to place some electrodes on your skin over your nerves at the wrist or elbow, and over your neck, shoulder and scalp. We will also collect some information about the electrical signals from your cervical neck extensor muscles. To do this it will be necessary to place some electrodes on your skin on the front and back of your neck and on your right shoulder. You may experience some mild discomfort as your skin is prepared for the electrodes by rubbing them with special abrasive tape and then wiping the area with alcohol. The electrodes over your neck, shoulder and scalp are only recording electrodes and do not pierce the skin and do not run current through your body. Only the electrodes on your arm will be stimulating electrodes. These stimulating electrodes will be used to stimulate some of your hand and/or forearm muscles by passing mild electrical current through them. This creates a mild tingling sensation on the skin over the nerve. This is not painful but may feel quite strange to you. It will also make some of your hand and/or forearm muscles twitch which is not painful either, but can also feel strange. It will also be necessary to fill in some simple questionnaires that will provide information regarding your current functional capacity, level of neck pain, and general well being. Each evaluation session will take approximately 2.5 hours and you will be given feedback about your results at each session.

**Manipulation**

If you are in the group receiving twelve weeks of care involving spinal manipulation and acupressure type massage on your neck and shoulder muscles, you will be attending either your regular chiropractor or the chiropractic centre at the UOIT Healthcare clinic, either at the Oshawa North or downtown campus site.

Your registered chiropractor will take a detailed case history and assess you to ensure that you are a suitable candidate to receive care. You will need to fill in an eligibility checklist in conjunction with your chiropractor. The treatment frequency will be individualized but may involve 2 or 3 sessions per week initially, tapering off to 1 session per week. The initial session will take 30 to 60 minutes and subsequent sessions will take 15 to 30 minutes. If for any reason, you are not an appropriate candidate for this study, we will withdraw you from the study. However, this will not impact in any way on your chiropractic care.

**Note:** if you are currently off work as a result of your condition and your leave is being paid for by your insurance company, you should check that the insurance company is happy for you to participate in this research project, before committing to the project.

**Risks and benefits**

The benefits of participating in this study is that you will learn more about your neck and arm pain and you will receive a free treatment session. You will also be aiding our understanding of these costly and disabling conditions. Only safe conventional low amplitude spinal manipulation techniques will be employed in this study. These have been used by our research group in previous studies and no participant has reported any ill effects at all. Most participants have had very positive improvements in their outcome measures. On occasion, some participants may experience soreness the day after their first treatment, but this is only transient. If any participant experiences an unexpected worsening of their condition as a result of their care they will be withdrawn from the study and encouraged to return to their medical practitioner for further advice. The surface EMG techniques have low risks such as the person getting a skin irritation from the alcohol swab or electrode gel, but these again are uncommon and not serious. The electrical stimulation is not painful but you will experience a light twitch of the muscles in your hand as the nerves at the wrist send electrical signals to make these muscles contract.

If the information you provide is reported or published it is done in a way that does not identify you as its source. All data will be kept confidential to the investigators and will be stored in a locked filing cabinet at UOIT for 7 years from the completion of the study after which it will be destroyed. You are free to withdraw from the data collection at any time up until the completion of your last data gathering session. Once you have completed the chiropractic care, your data cannot be withdrawn. Taking part in this study is voluntary and your decision to take part in this study (or not) will in no way influence your relationship with your chiropractor and/or teacher.

Thank you very much for your time and help in making this study possible. If you have any queries or wish to know more please contact Dr Bernadette Murphy, an Associate Professor at the University of Ontario Institute of Technology, Faculty of Health Sciences, 2000 Simcoe St North, Oshawa, Ontario, L1H 7K4

Phone (905) 721-8668 ext 2778 Fax (905) 721-3179 email : Bernadette.Murphy@uoit.ca

For any queries regarding this study, please contact the UOIT Research and Ethics Committee Compliance officer (compliance@uoit.ca and 905-721-8668 ext 3693).

Phone (09) 526 6789 ext 207 Fax (09) 526 6788

The data from this research will be submitted to scientific conferences and peer reviewed journals. At the completion of the study, you will be sent a summary of the research findings and any place where the data has been published. All published data will be coded so that your data is not identifiable.

**Please read the following before signing the consent form and remember to keep a copy for your own records.**

- I understand that taking part in this study is voluntary (my choice) and that I am free to withdraw from the study at any time without giving a reason and that this will in no way affect my future chiropractic care and/or academic progress, irrespective of whether or not payment is involved.

- I have read and I understand the information sheet dated June 2010 for volunteers taking part in the study designed to investigate the neurophysiological effects of spinal manipulation. I have had the opportunity to discuss this study. I am satisfied with the answers I have been given.
- I will be attending up to 5 sessions where measurements will be taken of the electrical activity in my brain following electrical stimulation of the nerves in my wrist.
- I have completed an eligibility checklist to ensure I am eligible to participant in this research.
- I understand that I can withdraw any data I supply up to the completion of my last measurement session.
- I understand that my participation in this study is confidential and that no material which could identify me will be used in any reports on this study.
- I have had time to consider whether to take part.
- I know who to contact if I have any side effects to the study.
- I know who to contact if I have any questions about the chiropractic care or the study.

I give consent for the data from this study to be used in future research as long as there is no way that I can be identified in this research. (tick one) ☐ YES ☐ NO

I would like to receive a short report about the outcomes of this study (tick one) ☐ YES ☐ NO

Signed …………………………………… Date ………......

Contact numbers of main researchers:

Dr Bernadette Murphy, Phone: + 905 721-8668 ext 2778

Dr Heidi Haavik-Taylor, Direct Dial Phone: + 64 9 526-2104 (New Zealand)

RESEARCHER TO COMPLETE

Project explained by: ________________________________________

Project role: __________________________________________

Signature: ___________________________________________

# Appendix J: Ethics Approval for SEPs Study

UOIT
CHALLENGE INNOVATE CONNECT

RESEARCH ETHICS BOARD

**Date: June 1, 2009**

**To: Bernadette Murphy (PI) and Heidi Taylor (Co-I)**

**From: Barbara Perry, REB Chair**

**File #: 07-073**

**Title: The neurophysiological effects of spinal manipulation**
*The University of Ontario Institute of Technology Research Ethics Board has reviewed the above research proposal. The application in support of the above research project has been reviewed by the Research Ethics Board to ensure compliance with the Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans (TCPS) and the UOIT Research Ethics Policy and Procedures.*

**DECISION: Continuing Review Approved**

**COMMENTS AND CONDITIONS:**

This project has been approved for the period of **June 8, 2009 to June 8, 2010** subject to full REB ratification at the Research Ethics Board's next scheduled meeting. The approval may be extended upon request.

Please note that the Research Ethics Board (REB) requires that you adhere to the protocol as last reviewed and approved by the REB. The Board must approve any modifications before they can be implemented. If you wish to modify your research project, please contact REB Administration, to obtain the Change Request Form.

Adverse or unexpected events must be reported to the REB as soon as possible with an indication of how these events affect, in the view of the Principal Investigator, the safety of the participants and the continuation of the protocol.

If research participants are in the care of a health facility, a school, community organization or other institution it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and approvals of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research protocols.

Section F, Article 1.13, Review Procedures for Ongoing Research of the TCPS http://www.pre.ethics.gc.ca/english/policystatement/policystatement.cfm requires that ongoing research be monitored. A Final Report is required for all projects, with the exception of undergraduate projects, upon completion of the project. Researchers with projects lasting more than one year are required to submit a Renewal Request annually. Contact REB Administration to obtain a copy of the Renewal Request/Final Report form.

***Please quote your REB file number on all future correspondence. Thank you.***

| | |
|---|---|
| REB Chair<br><br>Dr. Barbara Perry, Faculty of Criminology, Justice and Policy Studies<br><br>Barbara.perry@uoit.ca | Sascha Tuuha, Compliance Officer<br><br>905 721 8668 ext 3693<br><br>compliance@uoit.ca |

# Appendix K: Neck Disability Index

## The Neck Disability Index

This questionnaire has been designed to give your therapist information as to how your neck pain has affected your ability to manage in everyday life. Please answer every question by placing a mark in the **ONE** box which applies to you. We realize that 2 of the statements may describe your condition, but please mark only the **ONE** box that most closely describes your current condition.

### Neck Pain Intensity

- O I have no pain at the moment.
- O The pain is very mild at the moment.
- O The pain is moderate at the moment.
- O The pain is fairly severe at the moment.
- O The pan is very severe at the moment.
- O The pain is the worst imaginable at the moment.

### Concentration

- O I can concentrate fully when I want to with no difficulty.
- O I can concentrate fully when I want with slight difficulty.
- O I have a fair degree of difficulty in concentrating when I want to.
- O I have a lot of difficulty in concentrating when I want to.
- O I have a great, great deal of difficulty in concentrating when I want to.
- O I cannot concentrate at all.

### Personal Care (eg washing, dressing)

- O I can look after myself normally without causing extra pain.
- O I can look after myself normally but it causes extra pain.
- O It is painful to look after myself, and I am slow and careful
- O I need some help, but manage most of my personal care.
- O I need help every day in most aspects of self care.
- O I do not get dressed, I wash with difficulty, and stay in bed

### Work

- O I can do as much work as I want too.
- O I can only do my usual work, but no more.
- O I can do most of my usual work, but no more.
- O I cannot do my usual work.
- O I can hardly do any work at all.
- O I cannot do any work at all.

### Lifting

- O I can lift heavy weights without extra neck pain
- O I can lift heavy weights, but it gives extra neck pain
- O Neck pain prevents me from lifting heavy weights off the floor, but I can manage if they are conveniently positioned, for example on a table
- O Neck pain prevents me from lifting heavy weights, but I can manage light to medium weights if they are conveniently positioned
- O I can lift only very light weights
- O I cannot lift or carry anything

### Driving

- O I can drive my car without any neck pain at all.
- O I can drive my car as long as I want, with slight pain in my neck.
- O I can drive my car as long as I want, with moderate pain in my neck.
- O I cannot drive my car as long as I want, because of moderate pain in my neck.
- O I can hardly drive at all because of severe pain in my neck.
- O I cannot drive my car at all because of the pain in my neck.

### Reading

- O I can read as much as I want, with no pain in my neck.
- O I can read as much as I want, with slight pain in my neck.
- O I can read as much as I want, with moderate pain in my neck.
- O I cannot read as much as I want, because of moderate pain in my neck.
- O I can hardly read at all because of severe pain in my neck.
- O I cannot read at all because of pain in my neck.

### Sleeping

- O I have no trouble sleeping.
- O My sleep is barely disturbed (les than 1 hr, sleepless).
- O My sleep is mildly disturbed (1-2 hrs, sleepless).
- O My sleep is moderately disturbed (2-3 hrs, sleepless).
- O My sleep is greatly disturded (3-5 hrs, sleepless).
- O My sleep is completely disturbed (5-7 hrs, sleepless).

### Headaches

- O I have no headaches at all.
- O I have slight headaches which come infrequently.
- O I have moderate headaches which come infrequently.
- O I have moderate headaches which come frequently.
- O I have severe headaches which come frequently.
- O I have headaches almost all the time.

### Recreation

- O I am able to engage in all my recreational activities, with no neck pain at all.
- O I am able to engage in all my recreational activities, with some pain in my neck.
- O I am able to engage in most, but not all of my usual recreational activities, because of pain in my neck.
- O I am able to engage in few of my usual recreational activities, because of pain in my neck.
- O I can hardly engage in any recreational activities because of pain in my neck.
- O I cannot engage in any recreational activities at all because of pain in my neck.

Vernon, H. and S. Mior, *The Neck Disability Index: A Study of Reliability and Validity.* Journal of Manipulative and Physiological Therapeutics, 1991. **14**(7): p. 409-415.

From: Vernon, H., & Mior, S. (1991). The Neck Disability Index: a study of reliability and validity. *Journal of manipulative and physiological therapeutics, 14*(7), 409.

# Appendix L: Short Form McGill Pain Questionnaire

## The Short Form McGill Pain Questionnaire

Subject Information: The following form presents words that may describe the neck pain that you experience. Please tick any words that apply to your neck pain under the heading of None, Mild, Moderate, Severe.

Patients Name Date

| | None (0) | Mild (1) | Moderate (2) | Severe (3) |
|---|---|---|---|---|
| Throbbing | | | | |
| Shooting | | | | |
| Stabbing | | | | |
| Sharp | | | | |
| Cramping | | | | |
| Gnawing | | | | |
| Hot - burning | | | | |
| Aching | | | | |
| Heavy | | | | |
| Tender | | | | |
| Splitting | | | | |
| Tiring - Exhausting | | | | |
| Fearful | | | | |
| Sickening | | | | |
| Punishing - Cruel | | | | |

1. How much pain are you experiencing right now?

**No Pain** ________________________________________ **Worst Pain**

2. What is the greatest level of pain you have experienced in the last week?

**No Pain** ________________________________________ **Worst Pain**

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