Chapter Seven:

Study Five

Strength change of quadriceps femoris following a single manipulation of the l3/4 vertebral motion segment: a preliminary investigation.

Abstract

Objectives
The purpose of this study was to investigate if a manipulation to the L3/4 motion segment of healthy individuals would effect the strength of the homolateral quadriceps muscle tested post manipulation.

Design & Setting
Clinical cohort study performed at the Macquarie University Centre for Chiropractic Outpatient Clinic

Method
Subjects underwent a simulated manipulation in the lumbar roll position. After these procedures all subjects were required to perform under controlled conditions a unilateral isometric maximal contraction of the quadriceps femoris muscle. A force transducer was used to provide a digital measurement of the force of contraction of the quadriceps femoris.

Sample
30 randomly allocated university students aged between 18 and 34 years.

Results
The study found that in an asymptomatic student population receiving a manipulation to the L3/4 motion segment that an overall statistically significant short term increase in quadriceps femoris muscle strength was observed when compared to a control group.

Conclusion
This establishes a relationship between the short term effects of a manipulation and the modulation of muscle strength, and supports anecdotal claims. Discussion is undertaken to describe further studies that can be performed to provide information on the way in which this relationship could possibly benefit sporting populations and rehabilitation therapists.

Key Words
Chiropractic, Manipulation, Lumbar, Quadriceps, Strength,
Rehabilitation, Sport, Exercise, Training.

Introduction

Muscle weakness or muscle imbalances are characteristic of many neuromuscluloskeletal conditions. Deficits in strength may be due to many factors including aberrant neural involvement, fatigue, pain, strength weakness, or disease atrophy (Kendall et al 1993). Scientific knowledge of the effects of spinal manipulative therapy on muscle strength is absent, resulting in a restricted basis for therapy and treatment. It is known that neural integrity is vital to muscle function, yet the contribution, if any, of manipulation to muscle function has received little coverage even though some claims exists that suggests manipulation modulates neural activity (Vernon 1995).

The quadriceps femoris group receives its innervation from the spinal segments L 2,3 and 4. The nerve roots from these segments form the femoral nerve. Of these segments L3 is recognised as the main segmental supply (Moore 1985). The L3 nerve roots pass out of the central canal of the spinal column through the intervertebral foramina formed by the L3 and L4 vertebrae before joining the lumbar plexus on their respective sides (Moore 1985). I proposed that by adjusting the L3/4 motion segment, the L3 spinal segment and/or nerve roots would be affected altering quadriceps femoris function.

Skeletal muscle is made up of a series of many smaller functional motor units. These motor units in turn consist of muscle fibres which receive their innervation collectively from a single lower motor neurone emanating from the spinal cord. The strength or force of contraction of skeletal muscle depends mostly upon the number and size of the motor units recruited by a stimulus, and the frequency of action potentials to that motor unit and hence the rate at which they are activated (Schauff et al 1990).

The pattern of motor unit firing often distinguishes specific motor performance. There are two types of firing patterns. Synchronous firing occurs when motor units are recruited simultaneously and is common in power or strength events such as weight lifting and weight training. Asynchronous firing occurs when some units fire while others recover, and is common in endurance performance. Synchronous firing allows a large force to be generated quickly, predominantly through the stimulation of fast twitch fibres (Binder-Macleod & McLaughlin 1997).

Synchronous firing of the muscle fibre has the potential to increase the motor output significantly (Binder-MacLeod & McLaughlin 1997). Recent hypotheses allude to the possibility of synchronous oscillation of the corticospinal tract being able to effect greater motor output by a more efficient recruitment of motor neurones than that possible with asynchonous firing rates alone (Baker et al 1999, Hari & Salenius 1999).

However this leaves the power or strength athlete prone to fatigue. Asynchronous firing, in contrast, stimulates the slow twitch fibres which are fatigue resistant. Asynchronous firing also allows a period of recuperation further resisting fatigue (McArdle et al 1986). Synchronous but oscillating firing offers the potential to more efficiently control contraction and reduce fatigue (Conway et al 1995).

The motor neurones that supply the motor units have many synaptic inputs within the spinal cord. Most inputs are from spinal interneurones (both excitatory and inhibitory) making up the interneuronal pool, while only a few inputs are from cerebral motor centres. All of these inputs can be responsible for the activation of the motor units (Schauff et al 1990).

The recruitment of motor units occurs in a hierarchical order, from smallest to largest. Small motor units are innervated by smaller neurones which have a low threshold and are easily activated by low stimuli, whereas the larger motor neurones require greater amounts of stimulation and innervate larger motor units (Gollnick & Hodgson 1986, Gollnick et al 1974). The result is that when larger forces are required of the muscle, progressively larger motor units are recruited. An impairment to either perceive the need for increased force or to recruit motor units may result in a decreased maximal force output (Astrand & Rodahl 1977).

Recent commentary by Patterson (1993) suggests the importance of the spinal cord segmental neurology, as well as inflammation in a related area, in causing and sustaining a level of hyper excitability in the spinal cord. Consequently, this hyper activity could disrupt the normal muscle function. The description of hyper excitability used by Patterson is similar to the concept of facilitation (associated with the vertebral subluxation) that others have discussed previously (Dishman 1988, Gatterman 1995).

According to Patterson, these alterations can bring about both short term and relatively permanent changes in the neural characteristics of the cord and can also result in changes to peripheral structures.

Schmidt has reported changes that occur in the peripheral sensory receptors of the musculoskeletal system when inflammation occurs. When stimuli to these receptors occurs, such as an injury, the peripheral nerves convey the impulses to the spinal cord where they may be blocked from being sent to the brain (Schmidt 1992).

On their pathway to the spinal cord the impulses travelling through the fibres cause the release of peptides from the peripheral nerve terminals. These substances cause a cascade of events that results in sympathetic post ganglionic fibres being activated, ultimately resulting in inflammation. Once inflamed, the threshold for stimulation of the nociceptors decreases dramatically and when further stimulation to the area occurs there is an increase in the number of nociceptors activated (Schmidt 1992). This illustrates the increase in neural activity to the spinal cord, and hence in the interneuronal pool, that occurs when an injury is sustained to a joint or surrounding soft tissue.

The alterations that occur within the spinal cord manifest themselves as changes in spinal excitability independent of influences from higher centres (Patterson 1993). These processes occur at the cellular level within the neurones of the spinal cord and last varying times and have the potential to alter the functional capacity of the individual. The processes are referred to by Patterson (1993) as habituation, sensitisation, long term sensitisation and fixation.

Habituation is the progressive decrease in spinal excitability in response to a constant, repeated stimuli. Sensitisation is the opposite to habituation and occurs to a stronger stimuli and only lasts seconds to a few minutes. When sensitisation occurs repeatedly it results in a long term sensitisation which may last hours. Fixation on the other hand is a form of alteration of spinal excitability where sustained stimulation at a high intensity sees a prolonged increase of spinal activity. Levels required for fixation to occur are seen with the inflammation process, which perpetuates the increased nociceptor activity which in turn stimulates the spinal cord at a sustained high intensity (Patterson 1993). Fixation as described here is analogous to the facilitated segment described by chiropractors and treated by them using manipulative techniques (Ward 1981).

When injury occurs to the musculoskeletal system, it is hypothesised that inputs from nociceptors to the spinal cord will, in most cases, produce habituation in the spinal circuits. However once the afferent activity reaches a certain level or intensity, sensitisation occurs and the interneurone pool produces more and more output. This results in the brain, muscles and structures associated with that segment becoming activated. If inflammation occurs, the increased sensory input to the segment may allow fixation or facilitation to occur. This hyper-excitable interneuronal pool is said to cause an increase in the output to muscles, which in turn causes an increase in their tone in an attempt to splint the affected area (Patterson 1993).

Once the cycle reaches this stage, normal movements greatly increase the input to the affected spinal centres. This is because movement occurring in association with the decreased threshold of the nociceptors will cause the nociceptors in the joints and surrounding soft tissue of the injured area to be stimulated much more readily . Once this cycle of hyper excitability or facilitation is in place, it has the possibility of causing disruption to normal body function, health, and muscle function.

As an illustration of these points, Anderson (1994), in an unrelated study to Patterson (1993), reported the presence of muscular non development in an amateur bodybuilder. He proposed that on the patient's physical findings, which included CT scans, MRI, Dynamometer, and normal orthopaedic and neurological examinations, that the patient had muscular non-development in the left upper extremity. He hypothesised that the presence of a spinal dysfunction in the lower cervical spine caused the symptoms. However it is entirely possible that the subject in question presented with muscle wasting secondary to disuse and painful neglect, as the subject also presented to the practitioner with sub acromial bursitis, a painful movement based injury common to bodybuilders and weight lifters. It is possible that successful treatment of the underlying bursitis allowed the return to normal function thereby hastening the return of the normal appearance.

The patient showed marked asymmetrical muscle strength and size. Factors which may have caused this phenomenon such as improper training and hand dominance were ruled out by Anderson (1994) by having the treating doctor and highly qualified athletic trainers observing the subject training on numerous occasions. The patient responded well to manipulations and treatment of the subacromial bursitis as well as to rehabilitation of the areas involved. Response was evidenced by muscle strength and size becoming more symmetrical as measured by changes in grip strength and by visualisation.

Although only a case study, Anderson's report (1994) was significant because it demonstrated a patient with the suggested criteria for a facilitated segment as outlined by Patterson (1993). Also of importance was the successful outcome of treatment of the weak and less developed musculature by a spinal manipulative approach.

Removal of motion restrictions by causing movement between two consecutive vertebra is generally thought to have an effect by reducing stresses on the facet joint and joint capsule, spinal ligaments, intervertebral disc and surrounding musculature therefore reducing reactive proprioceptive, nociceptive, and mechanical stimuli bombardment from these structures to the associated spinal segments (Wyke 1987). This bombardment of the associated spinal segments has been implicated as an initial cause or contributing factor to the vertebral subluxation complex (Araki et al 1984, Sato & Swenson 1984, Isa et al 1985, Kurosawa et al 1987).

If spinal cord hyper-excitability is the cause of altered physiological processes, ie muscle function and strength, then reducing or removing the hyper-excitability would reduce or correct the aberrant physiological processes affecting muscle function and strength (Dubnar & Ruda 1992, McMahon et al 1993, Eide 1998). According to chiropractic literature a manipulation can reduce spinal cord hyper-excitability (Haldeman 1992, Rydevik 1992). If so, then the effects of a manipulation should be to reduce or correct the aberrant physiological processes that are occurring, which in turn would allow muscle function to normalise.

Central excitability can be triggered by noxious stimuli (McMahon et al 1993). the activation of the C fibres with strong chemical, mechanical or thermal stimuli can produce painful sensations that are enhanced during pathological states such as inflammation (Urban et al 1994). treatment can alleviate these sensations and act to improve spinal spacticity (Goulet et al 1996). Through the action of mapping the central nervous system output in those with spinal cord injury (Eide 1998), it has been shown that the actioin of the central cord is enhanced by the action of the upper motor neurones (Mayer 1997).

As muscle function and specifically strength are effected by spinal cord hyper-excitability, they are also effectors of changes to that structure. By testing muscle strength before and after a manipulative procedure said to be able to normalise a dysfunctional state, a change in muscle strength may be expected.

A study by Bonci & Ratcliff (1990), observed the strength of the biceps brachii muscle (measured bilaterally by a digital myograph). This study failed to demonstrate a statistically significant change in biceps muscle strength after a spinal manipulation of C4/5. Bonci and Ratcliff (1990) suggested that further studies were necessary before a relationship between muscle strength and manipulation could be discounted. They also raised problems which may have accounted for the results that they obtained.

Isometric strength testing existed as a possible source of problems. Strength of the muscle was only measured at one joint angle and the strength values gave no indication of a possible change in strength throughout the entire joint range of motion. To try to overcome this, the position of maximal torque for the quadriceps femoris was used in this study for isometric muscle strength testing. This position, as determined by Fischer, Pendergast and Calkins (1990), is with hip extension at 180 degrees and knee flexion at 90 degrees. It was hoped that if any change was present, whether an increase or a decrease, this position would show it.

Any change that occurred had to be solely attributable to the manipulation alone and so other factors such as muscle fatigue needed to be addressed. The problem of fatigue was overcome by having the subject perform a maximal contraction for only 5 seconds when tested and leaving 30 seconds between contractions according to an accepted protocol (Rodriquez et al 1991).

Bonci & Ratcliff (1990) tested musculature at 60 sec after the delivery of a manipulation and found no statistically significant change in strength. It is possible that any measurable change due to the manipulation could have manifested itself and resolved by the end of the 60 sec period. Such was seen in Patterson's (1993) model of sensitisation in which the effects of sensitisation lasts from 30 second to a few minutes.

This study proposed to duplicate the study by Bonci and Ratcliff (1990) by testing muscle strength at 1 minute. The present study did however choose a large predominantly fast twitch lower limb muscle rather than a smaller upper limb muscle. It was also proposed to retest at 1 minute after the manipulation to determine if any effect existed at the later time as a result of the manipulation.

Thus it was the aim overall to demonstrate a change in muscle strength of a peripheral predominantly type II muscle such as the quadriceps by manipulating the spinal vertebra (L3/4) relevant to the neuromere of supply of that muscle.

Methods And Materials

1. Subject Recruitment

Chiropractic students from the Macquarie University, Centre for Chiropractic, Sydney NSW who freely volunteered, met the inclusion criteria, and who read and signed an informed consent form were subjects for this study. This study had received approval by the Macquarie University and Tne University of Wollongong Human Ethics committees prior to experimentation.

2. Subject Sampling

15 experimental and 15 non-experimental control subjects were recruited. Both groups were matched for sex and age.

Subjects were chosen according to inclusion criteria. These criteria required subjects to have had recent lumbar X-rays (ie within last 12 months) to rule out pathology which would contraindicate a manipulation and have no history of recently (ie less than 1 month) diagnosed lumbar disc herniation, sprain, or other lumbar injury which might be aggravated by participation. The cohort chosen to act as subjects in this study were required by regulation to have spinal radiographs prior to participation in technique classes. As such all subjects received spinal radiographs in the previous 12 months. Subjects were also screened for any knee or hip injuries which may have affected their ability to perform the strength test. Subjects were over 18 years of age and also under 40 to eliminate the likelihood of degenerative joint disease complications. 30 healthy students were recruited and were randomly assigned to either the experimental or control groups by drawing a number from a sealed container.

3. Procedures

(a) WARM-UP: To prevent possible muscle strain, the same warm-up routine was performed by each subject. This involved cycling for 5 minutes on a cycle ergometer set at a light resistance (weight of the crank apparatus without any further loading of any type) and maintaining a cadence of 75 r.p.m (Golden & Dudley 1992).

(b) SUB-MAXIMAL CONDITIONING: A sub-maximal isometric contraction was performed to familiarise and pre-condition the quadriceps femoris muscle. This was performed immediately after the warm-up period.

The position of maximal torque for the quadriceps as determined by Fischer, Pendergast, and Calkins (1990) was with hip flexion at 180 degrees and knee flexion at 90 degrees. For the sub maximal and later contractions the following procedure was used.

The subject was supine (with hip and knees at the specified angles) on a padded treatment table. Straps across the shoulders and pelvis at the level of the anterior superior iliac spine (ASIS) and coracoid process on each subject and the instruction to hold onto the side of the couch prevented the subject from moving unnecessarily and possibly recruiting muscles other than the quadriceps femoris.

To further ensure testing consistency, the force transducer was positioned so that it was at the same anatomical site for each subject. The position chosen was in the groove anterior to the talotibial joint. This ensured internal consistency between subjects so that average group data could be used in any statistical analysis of the results. Strength was measured by a hand held force transducer over a contraction time of five seconds. The elbow and upper arm of the co-investigator holding the force transducer by hand was firmly braced against a solid wall. Another tester also stabilised the subject's leg from the side to prevent the leg from losing contact with the force transducer. The couch was stabilised from the other end to prevent movement of the couch.

In this equipment familiarisation and muscle pre-conditioning stage, the combined sub maximal contraction was held for 5 seconds.

(c) PRE-TEST: After a rest of 30 seconds (to ensure the muscle adequate time to recover), the first of two maximal isometric contractions were performed, and the force measured. A rest period of 30 seconds was then followed by the second contraction and measurement. The average of the two measurements was recorded as the pre-test measurement.

During each 5 second contraction, each subject was encouraged verbally to perform at their best by one of the assistants. The encouragement and motivation was performed by voice command by the same person at the same high intensity throughout the experiment for both the experimental and control group subjects.

(d) MANIPULATION: An experienced and registered chiropractor performed all the manipulations. Only one adjustive technique was employed for each group so as to further reduce the variables. Experimental subjects were placed in a basic lumbar roll (BLR) position and a BLR Anterior/Inferior thrust to the right side of the L3/4 motion segment was performed. All except four manipulations resulted in cavitations at the site of application. The manipulation chosen has been described by Byfield (1991) and Haldeman and Rubinstein (1993).

Placebo / control subjects were subjected to a simulated manipulation to the left side of the L3/4 motion segment whilst in the lumbar roll position. The sham involved a general non-specific, non-cavitating impulse into the soft tissues to help address the expectation of the subject that they were to receive a form of hands on procedure.

(e) POST TESTS: Following a period of 20 seconds after the manipulation, another series of two maximal isometric contractions were performed (30 seconds between each contraction) and the average group data recorded as the strength at 60 seconds post treatment.

Data Analysis
Means and standard deviations for the pretest, post test, and gain scores of each group were calculated. To determine whether a significant difference existed between the mean gain scores of each group, a one-way analysis of variance was utilised at a 0.05 alpha level. After obtaining a significant F value, Newman-Keuls post hoc comparisons were conducted to specify how the groups differed from each other.

Results

Calculated means and standard errors of the means for group pretest, posttest, and change scores are presented in Table 5.1. This table indicates an average reduction (2.06kg) in the post intervention performance of the isometric strength test in the control group. In contrast, an increase (3.03kg) was noted in the post intervention isometric strength test in the experimental (manipulation) group. A one-way analysis of variance of the change scores, as shown in Table 5.2, revealed a significant difference between the groups. A Newman-Keuls post hoc analysis showed that the manipulation group was significantly different to the placebo / control group.

Table 7.1. Change in means and standard errors of angle of isometric strength test value at 180° of hip extension and 90° of knee flexion for groups (in kilograms).

Group	Scores	Pretest	Posttest	Change
Manipulation	Mean	58.1	61.1	3.0
n=15	Standard Error	(5.4)	(4.4)	(1.5)
placebo / control	Mean	57.2	55.1	-2.1
n=15	Standard Error	(4.6)	(4.3)	(1.7)

Table 7.2. One way analysis of variance of change in treatment scores

Source	SS	*df*	MS	*F*
Groups	194.8	1	194.8	4.91*
Error	1110.1	28	39.6	
Total	1304.9			

* $p<0.05$

Table 7.3. One way analysis of variance of difference in pre-test groups

Source	SS	*df*	MS	*F*
Groups	6	1	6	0.02^
Error	10443	28	373	
Total	10449			

^ $p>0.05$

Discussion

The results of the experimental group demonstrated a progressive short term strength increase with repeated tests. Using the same methodology, the results of the control group demonstrates a progressive strength decrease, or fatigue with repeated tests (Table 5.3). There was an overall statistically significant change between the experimental and control groups (Table 5.4). In contrast, there was no significant difference in group means at the start of experimentation (Table 5.1). This shows that in an asymptomatic student population a manipulation to the L3/4 motion segment resulted in a change in quadriceps femoris muscle strength. An overall increase in strength of approximately 4.6 % post manipulation was recorded. There was an overall decrease of 2.0 % in muscle strength in the placebo / control group. This change could be attributed to fatigue caused by repeated maximum voluntary contractions. At 1 minute there was a 5.2% increase in muscle strength that was statistically significant ($p=0.035$). A factor to be considered in the variability in the determination of voluntary contraction. As such, any determination of percentage of mean voluntary contraction would be hazardous and ill advised (Peach et al 1998).

Although both the control and experimental groups were similarly matched, only the control group suffered from the effects of fatigue. It would be reasonable to expect that fatigue also took place in the experimental group. If this was so, then the changes in strength that occurred in the experimental group would have been even greater as they overcame the effects of fatigue. Despite these likely changes, the experimental group subjects still showed an average increase in strength. In other words, if the effects of fatigue are seen in the control group, ie a decrease in strength of 2.0 %, then the overall difference, once the effects of fatigue are removed, would be a 6.6 % improvement in strength overall in the experimental group. Thus the changes demonstrated after the manipulation could be the result of overcoming fatigue, and/or the modulation of muscle strength.

The proposed mechanisms for the observed changes in the experimental group are based on the known alterations that occur within the spinal cord that manifest themselves as changes in spinal excitability as described McMahon et al (1993), Urban et al (1994) and Patterson (1993) . These processes occur at the cellular level within the spinal cord, last for varying lengths of times, and have the potential to alter the functional capacity of the individual (Patterson 1993). This is especially true of the cellular neuropeptides involved in chemical mediation of nociceptive processing within the spinal cord (Dubner & Ruda 1992).

According to the clinical literature (Haldeman 1992, Rydevik 1992) a manipulation can reduce or correct spinal cord hyper excitability. Rydevik (1992) suggests that the manipulation restores the motion to the joint involved and relieves soft tissue tensions. It is suggested from Rydevik's work (1992) that the manipulation promotes increased movement of fluids and thus normalises tissue chemistry and respiration to the affected areas. Patterson (1993) believes these phenomena also reduce afferent activity to the hyper-excitable spinal segment, allowing it to normalise. If so, the effect of a manipulation should be to reduce the effects of long term sensitisation processes. This would allow muscle function to normalise and produce a change in muscle strength. Sensitisation is only a short term spinal hyper-excitability (lasting a few seconds to a few minutes) and only becomes relevant when discussing the more immediate effects of an manipulation.

Although the subjects used in this experiment were healthy asymptomatic students, they could still have the processes described by Patterson (1993) taking place within their spinal segments. If this was the case, a manipulation could reduce the afferent input to the hyper-excitable spinal segment in the ways described earlier. The type of process and the length of time it had been present would determine how immediate the effects of the manipulation would be. Any processes that were present in the asymptomatic student subjects would be more likely to have only been present for a short time. Therefore the effects of the manipulation on the aforementioned processes may occur more readily in such a group rather than in the long standing dysfunction that may be present in the wider population. Further study of the differences between these groups is recommended because it may show that the two groups respond differently to the same stimuli in treatment.

These results demonstrate that there is a link between spinal manipulation and the strength of a peripheral muscle supplied by the neuromere that received the manipulation. Bonci and Ratcliff (1990) may not have found a similar change at 1 minute as his sample was taken from the general population and the change may have taken longer due to the chronicity of the conditions they encountered.

Conversely, it may be said that the use of chiropractic students may have precipitated the results due to their knowledge of the chiropractic procedure. Although a limitation of the study design, I attempted to minimise this variable by choosing junior / inexperienced students utilising a sham manipulation that closely resembled the manipulative procedure, and a 'vibrant' verbal encouragement by one of the assistant researchers during the strength testing sessions.

Manipulation may have effected the segmental hyper-excitability by directly modulating the interneuronal pool. This study hypothesises that this sensitisation could change muscle strength in the following manner.

When the subject contracted the quadriceps muscles the subject produced a central stimulus from the motor cortex which descends to the required spinal levels (Barr & Kiernan 1988). If the interneuronal pool activity at that spinal level is already hyper-excitable, the central stimulus compounds with the activity already present in the interneuronal pool. The resulting hyper-stimulus that reached the motor fibres would be larger than the original central stimulus. As higher potentials activate larger motor fibres which in turn innervate larger numbers of muscle fibres, this pre-stimulation or sensitisation of the interneuronal pool via the manipulation would lead to the activation of a greater number of muscle fibres. The result would be a stronger contraction for the same central stimulus.

I hypothesise that once the sensitisation was set up, it would tend to cause hyper-excitability to rise to a peak and then level off. This process could occur with the resultant peak being reached at a time shortly after treatment. To determine if this was the mechanism behind the change, further studies could measure strength at later times. Measuring at later times would also be beneficial if the sustainability of the change is to be investigated. The use of indwelling electromyography to measure muscular activity or nerve conduction studies in addition to the gross strength changes would more clearly define any changes that were taking place. Repeat studies are required investigating the electromyographic parameters associated with muscle change. An ongoing problem of EMG analysis is that movement of the electrode creates artifacts on the electromyogram (Kraft 1990). Manipulation by definition is a high velocity thrust often positioning the patient in such a way as to render an EMG analysis ineffective or inappropriate.

In addition, there are known problems associated with the qualitative use of EMG rather than its quantitative use (Peach et al 1998). The combination of these effects makes the use of EMG particularly problematic for manipulation based studies.

When the study is replicated, and the mechanism determined, many areas of health care could be the beneficiaries. It is intuitive that a 5% change in strength would be extremely useful if strength and power athletes, as it would be, for the management of muscle weakness disorders, and rehabilitation of muscle injury.

Muscle rehabilitation may be enhanced by the use of manipulations in the following manner. A torn or injured muscle may precipitate substantial localised inflammation which according to Schmidt (1992) may lead to increased receptor activity. It also can lead to increased cellular activity within the cord (Dubner & Ruda 1992). This in turn leading to processes which alter spinal excitability resulting in muscle weakness. The use of manipulation to sensitise the cord of subjects with chronic conditions could allow a decrease in the weakness and wasting often accompanying such chronicity. Removing this common sequelae of injury could allow an accelerated passage through rehabilitation programs improving functional capacity, increasing the speed of resolution, and decreasing the concomitant cost of rehabilitation. Whilst this view remains highly speculative extrapolation, early evidence in support is emerging. Further experimentation may support or refute such a scenario.

Power and strength athletes, such as sprinters and weight lifters, could also benefit from this effect of a manipulation. As well as having a quicker recovery from muscle injury by rehabilitating in the method just described, the potential higher intensity that could be achieved in normal training could allow a more efficient and productive training session .

Further, and probably of greater interest to the athletes, the manipulation could also be utilised in enhancing performance on the day of competition. The possible increase in muscle strength via a greater state of arousal available from a manipulation could provide the athlete with a temporary increase in power and strength. Whilst it is acknowledged that a maximum contraction is seldom delivered by an increased state of arousal (Gandevia & McKenzie 1988), they are possible in selected individuals who are highly motivated and or highly aroused.

Any discussion of strength changes due to therapy or training should consider the considerable input of early changes in strength profile being largely based on neural adaptations (Hakkinen et al 1985), with later changes (after six weeks) occurring with hypertrophic changes in the muscle (Sale 1987).

Given the short term nature of the strength improvement noted in this study, the mechanism would apparently likely fall into the neural category. Gandevia & McCloskey (1978) established in early work that motor controls could be crudely interpreted at the level of the spinal cord. Jones (1995) elaborated on this theme and demonstrated that the perceived magnitude of the force was also a central phenomenon. In another study it was demonstrated that somatic sensations (as that likely to be stimulated by manual therapy) contribute to the sensation of motor output (Sanes & Shadmehr 1995), and the sense of effort (perception) is determined from central sources operating across the motor system (Somodi et al 1995). From these studies it is likely that the mechanism of strength change occurs via a neural mechanism and involves the stimulation of various somatic receptors known to be stimulated by manipulation (Korr 1975).

For those athletes that perform feats of strength or power over a short period of time (such as Olympic weight lifters, sprinters, one kilometre time trial cyclists), a temporary improvement could increase their effectiveness at competition. More research into the sustainability of change could enable the maximum beneficial effects over the greatest possible time to be controlled.

The use of manipulations to effect muscle strength in neurological weakening or wasting disorders could be beneficial for the overall management and rehabilitation of these disorders. If muscle strength can be altered it could prevent, minimise or at the very least delay wasting and encourage neural integrity through stimulation of the affected structures. It could also be effective for muscle retraining by stimulating the involved structures allowing a more responsive reaction to the same central stimulus.

The possibilities of a controllable change in muscle strength through the use of manipulations should make it clear that this relationship is an important one and has wide reaching benefits for the community. This study has demonstrated that a relationship exists, in contrast to the previous study by Bonci et al (1990).

However there were limitations in the methodology that should be recognised and remedied with further investigations. The student population could be viewed as a source of error. This error was introduced as students were more likely to know the difference between an effective manipulation and a sham manipulation. An attempt was made to overcome this by using a manipulative style with which the students were not familiar, and a practitioner and subject position that was the same in both the control and experimental groups.

As the force transducer was hand held, the force transducer may have provided a source of error in measurement as it was potentially prone to movement. Attempts were made to ensure little or no movement occurred, but further studies should utilise a mechanically braced force transducer to further reduce this error in measurement if one exists at all.

Whilst it is tenuous to compare changes in isometric strength to those measured isokinetically at different speeds, and to real life events incorporating rotary kinetics superior to any measurement device currently being used, it is a starting point worth noting. Future studies that utilise strength measurement that more closely approximate human activity are called for, as it is known that strength changes are specific to joint angle, speed and task (Wrigley & Grant 1995). On the "job" activity regimes therefore would perhaps show more distinct changes.

Although there were inconsistencies in the methodology such as those induced by the possibility of fatigue and a training effect, there was a change which occurred in the experimental group that cannot be entirely attributed to error. These inconsistencies may have affected the magnitude of the change but not the significance of the result. Addressing these variables with a larger scale trial could more rigorously assess the strength changes associated with a lumbar manipulation.

Conclusion

This study found that in an asymptomatic student population a manipulation to the L3/4 motion segment resulted in a statistically significant short term increase in quadriceps femoris muscle strength. This change could beneficially impact on rehabilitation protocols and the performance of strength athletes. I recommend that this study be followed by other more intensive and varied investigations to determine if the significance of the changes noted here are reproducible and significant in the health care and sports performance arenas.