RELIABILITY OF CERVICAL EXTENSION AND ROTATION ISOMETRIC STRENGTH TESTING IN SYMPTOMATIC SUBJECTS

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ABSTRACT

Objectives

The purposes of this study were: 1) To assess the reliability of cervical extension and rotation isometric strength testing of subjects who were experiencing neck pain at the time of testing, and 2) To determine if there is an association between cervical strength and neck pain intensity, or level of neck disability, or fear of neck movement, or cervical range of motion.

Design

A reliability study of repeated measurements of isometric cervical extension and rotation strength and a correlational study to assess the association between strength and pain, disability, fear of movement, and range of motion of the cervical spine were conducted on a sample of symptomatic subjects.

Participants

Two groups (N = 60 & N = 55) of volunteers with neck pain were recruited by advertisements located in a private chiropractic clinic and a hospital bulletin board. The group for cervical extension strength testing consisted of 25 men (age = 38 ± 14 yr; disability = 28 ± 16%; pain = 29 ± 25mm) and 35 women (age = 36 ± 12 yr; disability = 26 ± 15%; pain = 31 ± 26 mm). The other group for cervical rotation strength testing consisted of 25 men (age = 40 ± 11 yr; disability = 25 ± 13%; pain = 22 ± 20mm) and 30 women (age = 37 ± 11 yr; disability = 29 ± 13%; pain = 31 ± 24mm).

Main Outcome Measures:

Cervical extension strength was measured on an isometric extension strength testing machine (MedX™ Cervical Extension Machine). Cervical rotation strength

was measured on an isometric rotation strength testing machine (MedX™ Cervical Rotation Machine). Strength testing was carried out in 2 testing sessions (48 hours apart). Prior to each testing session all participants completed a visual analogue scale for neck pain and a neck disability questionnaire. In addition, individuals who took part in cervical rotation strength testing completed a visual analogue scale for fear of neck movement and had their cervical range of motion measured.

Results

Cervical extension strength testing (ICC = 0.949, 95% CI = 0.9477 - 0.9502) and cervical rotation strength testing (ICC = 0.965, 95% CI = 0.9645 - 0.9663) were reliable. Standard error of measurement (SEM) values for cervical extension strength and cervical rotation strength were 23% and 6%, respectively. A multiple regression analysis did not reveal any significant association between cervical strength and neck pain intensity, or level of neck disability, or fear of neck movement, or cervical range of motion.

Conclusion

The reliability of both cervical extension and rotation strength measurements in subjects who are experiencing neck pain at the time of testing was good with a clinically acceptable level of precision. There was no association between cervical strength, neck pain intensity, fear of neck movement or cervical range of motion but the sample size for a multiple regression analysis was too small.

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DEDICATION

To my spouse Cindy and to my three children: Camilia, Kristina and Jordan. Thank you for your encouragement, patience and all your love.

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Chapter 1
INTRODUCTION
1.1 Background Information

It has been speculated that disability due to neck pain can be attributed to poor cervical muscle strength. Cervical muscle testing and strengthening have been used extensively over the past two decades. Strength testing is believed to provide a measure of the level of disability related to muscle weakness. Furthermore, strength testing can be used throughout a rehabilitation program to quantify objectively any degree of improvement.

Over the years, strength testing machines have become progressively more sophisticated. These machines are designed to test muscle strength of one of the three types of muscle contraction: 1. Isometric contraction - the muscles contract against resistance without any displacement or change in the length of the muscle taking place; 2. Isotonic contraction - a muscular contraction in which the muscle exerts a constant tension against an external resistance that does not vary; 3. Isokinetic contraction - the muscles contract against a resistance and move the body part at a constant velocity through a full range of motion.

Strength testing machines have specific advantages and disadvantages, which will be discussed in greater detail in chapter three. Ideally, characteristics of a cervical strength testing machine are: that it should be safe for subjects undergoing testing; that it should allow testing through a full range of motion; that it should isolate the muscle group intended to be tested; and that it should take into consideration unintentional forces such as gravity and elasticity of the soft tissue of the neck that could influence the true measurement. Also, any strength testing machines should have a set of normative data for comparison between healthy and symptomatic individuals.

There are several requirements that a strength testing machine must have to be useful. The testing machine must be reliable; that is, the results must be reproducible with the same subject under the same conditions. There should be a certain degree of responsiveness; that is, the testing machine should be able to measure any gain or loss of strength over time. It must show a high degree of validity so that the strength measured reflects the true status for that particular subject tested.

Despite the sophistication of testing machines over the years, there is still the issue of within-subject variability, which cannot be ignored. The same subject tested repeatedly under the same condition can demonstrate different results that may be attributable to several inherent factors. For instance, it is possible that a lack of motivation, the fear of injury during strength testing, and the intensity of pain or fatigue could all affect to a certain degree the ability to produce maximal strength at the time of testing. There are no published studies on the role these factors play on the results of strength testing. Nonetheless, it can be speculated that variability within-subjects could influence strength measurements to a point at which the validity and/or the reliability of testing could be affected. Thus, it is crucial to either measure or account for any significant variables related to within-subjects variability, otherwise, the usefulness of measuring muscle strength becomes questionable.

1.2 Statement of the Problem

Test re-test reliability is an expression of the extent to which the same results are obtained on repeated applications of an assessment technique assuming no real interval change in the phenomenon under study. Test-retest reliability studies of cervical strength measurements of healthy asymptomatic subjects using isometric MedX™ testing machines have been studied previously [1-4]. However, because muscle strength testing machines are designed to assess and conduct strength conditioning among symptomatic subjects, the reliability of cervical strength testing needed to be evaluated with these types of subjects.

Therefore, for this study a sample of convenience was identified consisting of both adult male and female volunteers experiencing neck pain with or without a history of cervical trauma. The operational definition of symptomatic individuals for this study was an individual believed to have neck pain caused by soft-tissue disorder but without any recognised underlying cervical spine pathology. For safety reasons, anyone having upper extremity symptoms with or without neurological deficits at the time of testing was excluded.

Furthermore, this author believes that several factors could affect the results of cervical strength testing including: severity of neck pain; level of neck disability; fear of neck movement; and limitation of cervical range of motion.

Thus, in this study, it was felt necessary to quantify objectively these factors for each subject. It was anticipated that in the event that test-retest reliability proved to be unreliable within a symptomatic population one or more of these factors could provide a possible explanation. There are probably many other factors that most likely play an important role in test-retest reliability of cervical strength testing, such as: lack of motivation; psychosocial issues; anxiety; illness behaviour; effects of medication; and possibly on-going litigation. However, such factors are very complex and very difficult to measure clinically and were not investigated.

Chapter 2

OBJECTIVES

2.1 Purpose of the Study

The purpose of this study was to assess the reliability of cervical strength testing among a symptomatic population with neck pain. MedX™ cervical extension and cervical rotation testing machines were used to determine the reliability of repeated cervical strength measurements for both cervical extension and cervical rotation. Also, some variables including the role of neck pain intensity, the level of disability due to neck pain, the fear of neck movement and cervical range of motion were assessed to determine if there was any correlation amongst these listed variables and level of strength.

2.2 Research Questions

1) Can repeated measures using cervical isometric extension and rotation testing machines yield reliable results in subjects experiencing neck pain?
2) Does within-subject variability, as it relates to intensity of neck pain, fear of neck movement, level of disability, and restriction of cervical range of motion, have a relationship with measurements of cervical extension and rotation strength?

2.3 Hypotheses

2.3.1 Research Hypothesis 1 ($1H_1$)

Quantitative assessments of cervical static muscle torque in extension and cervical static torque in rotation using isometric testing machines (MedX™ Equipment) are reliable methods for subjects experiencing neck pain.

2.3.2 Null Hypothesis 1 ($1H_0$)

Quantitative assessments of cervical static muscle torque in extension and cervical static in rotation using isometric testing machines (MedX™ Equipment) do not yield high test-retest correlation coefficients ($r \geq 0.80$) in subjects experiencing neck pain.

2.3.3 Research Hypothesis 2 ($2H_1$)

Neck pain intensity, level of neck disability, fear of neck movement and reduced cervical range of motion, together or independently, have a negative relationship to the values of cervical strength measurements using isometric testing machines (MedX™ Equipment).

2.3.4 Null Hypothesis 2 ($2H_0$)

Neck pain intensity, level of neck disability, fear of neck movement and reduced cervical range of motion, do not have a relationship ($r \geq 0.80$) to cervical strength measurements using isometric testing machines (MedX™ Equipment).

2.4 Aims of the Study

In conjunction with studying the test-retest reliability of cervical strength testing in a symptomatic population, this study also assessed the relationship between maximum voluntary cervical strength produced from subjects having neck pain and their reported level of intensity of pain, fear of neck movement, level of disability and measured cervical range of motion.

2.5 Assumptions

1) All subjects are highly motivated to participate in the study and are prepared to perform isometric cervical strength testing to the best of their physical ability.
2) The cohort population consists of volunteers having chronic neck pain.
3) The cohort population represents a range of severity of neck pain and disability. However, subjects volunteering for this study could reflect a self-selection bias so that the subjects are not representative of the general population suffering neck pain. It is possible that compared to the general

population the subjects who volunteered for this study had less severe neck pain, or worse neck pain. In any event it is uncertain how the cohort population compares to the general population, limiting our ability to generalize the results of this study.

2.6 Limitations

1) Subjects who had sustained a neck injury from a motor vehicle accident less than 8 weeks at the time of testing were excluded or asked to return after 8 weeks from the time of the accident.

2) There was no known objective measure to determine a subject's motivation to produce maximal effort during testing, so none was used.

2.7 Delimitations

1) The sample size was limited to 115 subjects (n=60 for cervical extension and n=55 for cervical rotation testing). This sample size although sufficient for a reliability study was insufficient for the purpose of a multiple regression analysis.

2) The age of the subjects ranged from 18 to 62 years.

3) No subjects with acute neck pain took part in this study.

4) At least 8 weeks had elapsed since the injury in those subjects who gave a history of a neck injury.

5) Only cervical extension and rotation strength were studied and not cervical flexion or lateral flexion strength.

2.8 Definitions

1) ***Angle selector:*** locks movement arm into any position of cervical extension or rotation.

2) ***Cervical extension***: backward movement of the cervical spine on a sagittal plane through a vertical axis.

3) ***Cervical rotation:*** *side to side movement of the cervical spine on a transverse plane through a range of motion.*

4) ***Concentric contraction:*** moving a resistance while muscle shortening occurs.

5) ***Correlation coefficient:*** describes the relationship between two or more variables. It can range from +1.0 to -1.0, and it is often used to express the reliability of test-retest measurements.

6) ***Dynamic fatigue:*** when a repetitive muscular effort can no longer be sustained at a certain output.

7) ***Eccentric contraction:*** moving a body part against a resistance while muscle lengthening occurs due to greater external resistance than the internal muscular tension produced.

8) ***Head mass counterweight:*** counterbalances the mass of the head to eliminate measurement errors due to gravity.

9) ***Isoinertial (isodynamic) contraction:*** muscular contraction against a constant external resistance, which results in a torque generated causing acceleration.

10) ***Isokinetic contraction:*** Derived from the Greek *isos*, equal, and *kinetos*, moving. In theory, a muscular contraction performed at a constant angular limb velocity through a full range of motion. Thus, a dynamic exercise in which the speed of motion remains constant.

11) ***Isometric contraction:*** muscular force produced without any displacement or change in the external length of the muscle takes place. Tension but no motion.

12) ***Isometric fatigue:*** is defined as the point at which a muscular contraction can no longer be maintained at a certain level.

13) ***Isotonic contraction:*** Derived from the Greek *isos*, equal, and *tonus*, tension. In theory, a muscular contraction in which the muscle exerts a constant tension against an external resistance that does not vary. Thus, the internal force of the muscle does not vary.

14) ***Learning effect:*** the process of becoming familiar with a manoeuvre as a

result of performing that particular activity.

15) ***Movement arm:*** lever arm of machine, which rotates on a machine axis. It is connected to a strain gauge for measurement of force output.

16) ***Net muscular torque:*** the total torque produced by muscular contraction minus the stored energy torque and head mass torque.

17) ***Precision:*** the degree to which the differences between repeated measurements fall within an acceptable error of tolerance.

18) ***Potentiometer:*** a device, which indicates the position of the angle selector throughout the patient's range of movement.

19) ***Range of motion:*** the degree to which a body part is able to rotate about its joint(s) axis.

20) ***Reliability:*** repeatability of test measurements.

21) ***Stored energy torque:*** Energy produced due to elastic recoil phenomenon of soft tissue.

22) ***Strain-gauge:*** an electro-mechanical device used to convert tension to an electronic signal that can, in turn, be used to quantify strength. It measures changes in electrical resistances (ohms).

23) ***Tensiometer:*** a device that measures the tensile strength of a muscle resulting in a torque output.

24) ***Torque:*** is the product of a force times the perpendicular distance from its line of action to the axis of motion [$\tau = F(\perp d)$].

25) ***Torso restraint:*** stabilizes upper body during testing and training.

Chapter 3

REVIEW OF RELATED LITERATURE

3.1 Prevalence of Neck Pain in the General Population

Prevalence of neck pain in the general population is defined as the proportion of people who are suffering from neck pain at a specific point in time. The prevalence of neck pain can vary according to the time frame chosen in the survey. Also, differences in methodological procedures to study the prevalence of any condition play an important role in the responses. The assessment of prevalence of neck pain is directly related to what kinds of questions are used in the surveys or interviews; consequently, owing to several methodological factors, there are significant variations in the reported prevalence rate of neck pain. This is further compounded by the absence of an unequivocal definition for neck pain.

Because prevalence is directly related to the period of time it covers in the survey, it must be expressed accordingly. For instance, point prevalence refers to the proportion of people who have neck pain at a specific point in time. This point in time usually refers to the time the survey was conducted, but it can refer to a specific point in calendar time or to a fixed point in the course of events that varies in real time from person to person [5]. Period prevalence relates to the proportion of individuals who suffered from neck pain over a specific period of time. Therefore, period prevalence is a compound measure and is constructed from prevalence at a point in time, plus new cases and recurrences during a succeeding time period [6]. The longer the period chosen to evaluate period prevalence, the larger will be the proportion of individuals reporting neck pain. Thus, lifetime prevalence usually represents the larger proportion of individuals since it includes people who have experienced neck pain in their life span.

Several studies, especially in the Scandinavian countries, have looked at the prevalence of neck pain in the general population. To assess the prevalence of neck pain in Sweden, a postal survey of the general population was conducted, involving 1009 randomly chosen individuals, between the ages of 18 and 84 years [7]. This study revealed a period prevalence rate of 2.3% of the respondents being affected by some degree of neck pain over the previous 6 months, 4.6% having neck pain for less than 1 month and 19.3% having chronic neck pain (over 6 months). Another similar study involving 10000 randomized Norwegians showed that 34.4% had neck pain within the last year and a total of 13.8% reported neck pain that lasted for more than 6 months [8]. One recent Finnish study on the prevalence of neck pain showed a lower order of magnitude for chronic neck pain between 9.5% and 13.5%, for both men and women, respectively [9]. This population-based questionnaire study, also included a comprehensive health examination comprising an interview and a clinical examination among 8000 adults over the age of 30. In addition, this study assessed lifetime prevalence of neck pain at 71%, and period prevalence (neck pain during the month preceding the examination) at 41.1%.

Looking at neck or shoulder pain in a Norwegian study, Hasvold and Johnsen found that 15.4% and 24.9% of the males and females, respectively, between the ages of 20 and 56 years reported suffering weekly from neck or shoulder pain [10]. The authors reported a significant increase in neck or shoulder pain with age. Similarly, Takala and his co-workers [11] found a lower prevalence of neck pain under the age of 50 (13% versus 22%). In a study from Sweden, of the 2537 persons examined, 18% had neck-shoulder pain at the time of the study. The frequency of neck and shoulder problems was found to increase with age and occupational physical exertion [12]. Another study confirmed the contribution of various working conditions (extension of the neck, strenuous muscular activity) and of some psychological features, especially anxiety, to the development of neck pain [13]. In this particular study, the authors reported a prevalence rate of 10.2% of neck pain in a working population of 990 male and female workers.

The wide discrepancy in the prevalence rate among the Norwegian, Finnish, and Swedish populations is likely attributable to the differences in survey methods (questionnaires versus interviews format). Another confounder in studying the prevalence of neck pain could arise from seasonal variation of neck symptoms. For example, a Finnish study conducted among 351 bank tellers between the age of 20 and 50 years, showed a change in the frequency of neck and shoulder symptoms in 40.5% of the subjects during the follow-up period from autumn to spring. They reported a decrease in the frequency of symptoms from autumn and winter to spring [14]. Furthermore, older age was a significant predictor of a high frequency of symptoms.

In summary, point prevalence rate of neck pain in the general population has been reported, varying from 4.6% to 18% [7,12], while period prevalence rate has been recorded from 2.3% to 41.4% [7-9,11] (see table 3.1). Prevalence of chronic neck pain varies from 11.5% to 21.2% [8-10] which seems to be constantly slightly higher in the female population by 4% to 10%. Life-time prevalence rate of neck pain has been reported by Mäkelä et al. to be as high as 71% [9]. As suggested by several studies [10-12,14], the prevalence of neck pain seems to be influenced by the age of the sample studied.

Table 3.1 Summary of studies on prevalence of neck pain in the general population.

PREVALENCE:	Point	Period	Chronic neck pain	Lifetime
Norway (1994) *Bovim et al.*	N/A	34.4%	13.5% (F=17%, M= 10%)	N/A
Norway (1993) *Hasvold et al.*	N/A	N/A	21.2% (F=24.9%, M=15.4%)	N/A
Finland (1991) *Mäkelä et al.*	N/A	41.4%	11.5% (F=13.5%, M=9.5%)	71%
Finland (1991) *Takala et al.*	N/A	13% (<50 yrs) 22% (>50 yrs)	N/A	N/A
Sweden (1989) *Brattberg et al.*	4.6%	2.3%	N/A	N/A
Sweden (1980) *Westerling et al.*	18%	N/A	N/A	N/A

3.2 Cost of Neck Pain

Over the past decade, medical complaints arising from neck trauma sustained in motor vehicle accidents have been on the rise. The results of a study on the incidence of soft tissue injuries of the cervical spine after road traffic accidents suggest a progressive increase since 1982 [15]. Furthermore, in 1995, the Québec Task Force on Whiplash-Associated Disorders pointed out an increasingly worrisome problem in the Western World, leading to serious consequences at a social and economical level, as well as to the enormous medical cost of neck injuries [16]. They emphasized that whiplash is essentially a benign condition with the vast majority of patients recovering, but it is the refractory minority that accounts for an inordinate proportion of the costs.

In 1993, the Insurance Corporation of British Columbia spent $409.7 millions on 37400 soft-tissue injuries to the cervical spine (averaging $10955/claim), representing 72% of all injury claims from motor vehicle accidents [17]. Similarly, in Saskatchewan an average of $9857 per neck injury from motor vehicle accident was spent between January 1992 and July 1992, totalling 26.2 millions for 2658 claims [18]. Neck injuries from work-related accidents cost the Saskatchewan Workmen's Compensation Board $3.9 millions in 1992 (averaging $4524/claim) [19].

3.3 Exercises as Treatment of Neck Pain

Traditionally the treatment for soft tissue injury to the neck had been rest and immobilisation with a cervical collar. This approach has been shown to be ineffective, and to prolong the disability. As stated in the Québec Task Force of Whiplash Associated Disorders, it is recommended to use rest and a cervical collar for only a very short period of time (less than 3-4 days) [16]. To prevent prolonged disability, physical activity, especially the normal activity of daily living, is further recommended by the Québec Task Force.

Pennie et al. conducted a prospective trial of the management of 135 adult patients who had sustained soft-tissue injuries of the neck in motor vehicle accidents. Random allocation was made on the basis of the casualty number to either standard treatment or treatment by physiotherapy. The standard treatment was two weeks rest in either a soft collar or a moulded one of thermoplastic polyethylene foam. Physiotherapy consisted of intermittent halter traction using 5.4 kg for 10 minutes twice a week combined with some advice on neck care, sleeping posture and instruction on simple neck and shoulder exercises. The authors concluded that there was no benefit from early traction and physiotherapy but that rest in a cervical collar gave the best pain relief [20].

McKinney assessed the long-term effect of early mobilization exercises in patients with acute sprains of the neck after road accidents. It was concluded that advising patients to mobilize in the early phase reduces the number of patients still experiencing symptoms two years later; in addition, mobilization was superior to manipulative physiotherapy. Also, prolonged wearing of a cervical collar was associated with persistence of symptoms [21].

Specific neck strengthening exercises are used commonly, and although they are believed to have some benefits on neck pain and disability, there are, however, very few studies on the matter [2,22-25].. Most of the literature shows strengthening the neck musculature to be helpful principally in reducing the risk of cervical injuries in sports [26,27]. Nonetheless, this author is not aware of any published randomized control trial on neck strengthening exercise and its benefits.

3.4 Cervical Strength Testing

Historically, the fundamental issues of reliability and validity of strength testing have been largely ignored [28]. Only a few studies have assessed the reliability and validity of trunk strength testing [29-35]. There has been minimal published scientific studies on the evaluation of the reliability and validity of neck muscle strength testing [1-4,36-39].

Neck strength measuring devices vary from simple manual muscle testing to highly sophisticated computerized equipment. Manual muscle testing is inexpensive and very convenient in a clinical setting; however, its reliability is greatly affected by the subjective interpretations of the assessors and bias [40]. For instance, in 1978, Nicholas and his co-workers published a study of the factors influencing manual muscle testing in physical therapy. According to their study, the factor that most influenced the tester's perception of strength deficits was the duration of the tester's effort multiplied by the average applied force during each test [41]. On the other hand, instrumented methods for cervical muscle strength testing are believed to be more reliable and valid, although generally very expensive.

Typically, the instrumented methods utilise a strain gauge dynamometer or potentiometer to measure changes in applied forces. Different machines are designed to test muscle strength, either dynamically (isokinetic testing) or statically (isometric testing). Both forms of testing have their inherent advantages and disadvantages.

3.4.1 Methods of Muscular Strength Testing

Three types of muscular contraction are distinguished: concentric contraction, where muscle shortening occurs; isometric contraction, where there is no change in muscle length; and eccentric contraction, where muscle lengthening occurs. Consequently, there are several methods used for testing muscle strength, although no single test method is the best or the most valid. Typically, muscular strength is measured either isometrically, isotonically, isokinetically or isoinertially; thus, testing equipment has varied from simple tensiometers to sophisticated computerized measurement devices [42].

Isometric testing techniques include manual muscle testing, spring and strain gauges, and dynamometers. The advantage of isometric testing is believed to be its low cost, depending on the sophistication of the instrumentation used for testing. It is usually a simple form of the testing, and data are relatively easy to interpret. The most controversial issue in connection with isometric testing is the unknown relationship to dynamic function. For instance, lifting in real life is a dynamic activity [42]. Safety for the subject tested and risk of injury is minimal under isometric testing in comparison to other methods of muscular strength testing. Chaffin has claimed that isometric testing of the trunk is absolutely safe [43]. In the prospective Boeing study, there were 3 injuries reported in 495 pre-employment placement isometric trunk tests [44]. As a result, some authors recommend isometric force application to the point of discomfort rather than to the point of maximum effort, because they believe it is safer and more relevant to setting work-level limitations [45].

Isotonic strength measurement techniques include the use of free weights in a controlled movement system or the use of a constrained system that allows unequal effort. Most isotonic assessments are concentric muscular contraction. Since the word, "isotonic," means "constant internal force," a pure isotonic exercise requires changing the resistance throughout the range of motion in proportion to changes in moment arm, referred to as a variable resistance exercise. Reliability of testing is a problem, and isotonic resistance testing is often an unfamiliar task to the patient. Safety and risk of injury remain considerable [42].

In order to develop a more realistic testing procedure, isokinetic and isoinertial techniques have been introduced. Isokinetic assessment requires the subject to move a body part against a resistance set at a constant controlled speed. The isokinetic dynamometer controls the rate of movement of the crank-arm to some preselected angular velocity regardless of the force exerted by the contracting muscles [46]. These dynamometers have been shown to produce relatively reliable data when testing simple, uniaxial joints, such as the knee, as well as when testing the spine in flexion and extension [47]. The advantage of all isokinetic testing devices is that they test throughout the range of motion and at different speeds, and the results are computer generated. Several authors have suggested that isokinetic testing is generally well tolerated [48-50] since it is relatively difficult for subjects to overexert, and effort can be abandoned at any time. Although, isokinetic testing may be considered safe; during the initial onset of testing there is an excessive amount of torque that is produced by the muscles being tested, which could result in muscle strain injury. Other disadvantages include cost, constraints in motion pattern and the unfamiliar task of moving a limb at a pre-selected speed [42].

3.5 Musculature of the Cervical Spine

Tables 3.5.1. and 3.5.2. summarize the muscles of the cervical spine responsible for movement of the neck. Description of specific neck muscles with regard to their origins and insertions is found in the appendices under the section: Postvertebral Muscles of the Neck, pages 89 to 94.

Table 3.5.1 Muscles Responsible for Movements of the Head on the Neck.

Movement	Muscles
Flexion	Longus capitis Rectus capitis anterior Sternocleidomastoid (anterior fibres)
Extension	Semispinalis capitis Splenius capitis Rectus capitis posterior major Rectus capitis posterior minor Obliquus capitis superior Longissimus capitis Trapezius Sternocleidomastoid (posterior fibres)
Rotation & Lateral Flexion	Strenocleidomastoid Obliquus capitis inferior Obliquus capitis superior Rectus capitis lateralis Longissimus capitis Splenius capitis

The above listed muscles are responsible for moving the head on the neck in different planes of motion. Muscles are listed by order of significance in their role for these particular movements [51,52].

Table 3.5.2 Muscles Responsible for Movements of the Neck.

Movement	Muscles
Flexion	Sternocleidomastoid Longus colli Longus capitis
Extension	Splenius capitis Splenius cervicis Semispinalis capitis Semispinalis cervicis Iliocostalis cervicis Longissimus capitis Longissimus cervicis Trapezius Interspinales
Rotation & Lateral Flexion	Strenocleidomastoid Scalene group Splenius capitis Splenius cervicis Longissimus capitis Longissimus cervicis Levator scapulae Longus colli Iliocostalis cervicis Multifidus Intertransversarii

The above listed muscles are responsible for moving the neck in different planes of motion. Muscles are listed by order of significance in their role for these particular movements [51,52].

3.6 Important Issues Related to Strength Testing

There are many important issues that must be acknowledged when assessing strength. Some of these issues relate to technical problems encountered during testing, such as: calibration, patient stabilization, axis placement, moment arm, muscle torque, gravity, damping effect when using isokinetic machines, limited range of motion and use of reciprocal contractions. Also, there is the subject variability that must be taken into consideration, such as within subject variability, motivation, fatigue, normalization for body weight and height, gender, race, level of fitness, learning effect, warm-up effect, pain intensity, fear of movement and perceived level of disability. Furthermore, the reliability and validity of a strength testing measuring device cannot be assumed without proper scientific investigations. Ideally, such a device should be safe, time- and cost-effective, simple to perform, reliable and accurate in assessing risk of future injury [45,53].

It is beyond the scope of this study to discuss every issue related to strength testing; however, a few important issues are discussed in more detail in the following sections.

3.6.1 Maximum Isometric Muscle Torque

The maximum isometric strength that a muscle group is able to produce can be measured indirectly by having the subject make a maximum effort against a fixed resistance. When force is recorded, it is multiplied by the perpendicular distance between the joint axis and the point of attachment of the force transducer to measure the torque [$\tau = F\ (\perp d)$] [46]. The torque in relation with the angle of the joint can be plotted to obtain the strength curve for that particular muscle group. The torque varies significantly throughout the range of motion, recognizing that a strength curve is dependent on the angle of insertion and the joint angles at every given point in the range of motion [54]. Consequently, different muscle groups produce different isometric strength curves. For instance, the pronators-supinators, hip flexors, and hip abductors-adductors have a linear decrease in strength, while the elbow flexor muscles and the quadriceps femoris muscle have peak forces in mid-range of motion [46].

Leggett et al. showed that isometric cervical extension strength decreases from a position of flexion to extension [36]. This specific pattern for the cervical strength curve was attributed to the input of force from the cervical muscles, which varied in different positions, and because of changes in position altering the leverage of the joint system. This finding correlates well with the fact that typically muscles show greater strength when they contract from their elongated position (cervical flexion) than when they contract from their shortened (cervical extension) position [46]. Similar results were demonstrated by Trinkle who constructed isometric cervical rotation curves for males and females, which were both descending from a fully elongated position to a fully contracted position of cervical rotation [4]. The characteristic patterns of cervical extension and rotation strength curves could also be attributed to muscle recruitment and possibly muscle fatigue.

3.6.2 Individual Variability

Individuals vary a great deal at different times of the day, so that any single measurement of strength might be quite unrepresentative. Therefore, variability is a function of true within-subject and between-subject variation and random error [55]. Consequently, several important factors play an important role in the outcome measurements of muscle strength testing. For instance, if the subject is uncooperative, is a symptom amplifier, or is trying to deceive for purposes of secondary gain, then such factors would definitely affect muscle testing [42]. The results may vary with the encouragement given to the subject and may depend on whether the subject wishes to impress or disappoint the observer [56]. Many other factors such as pain intensity, fear of injury, motivation and level of self-perceived disability may play important roles in the outcome of muscle strength testing. Consequently, an accurate measure of muscular strength depends on subject participation [42].

Some other very important issues to consider are: a) the role of "learning effect" that has been clearly documented in isometric testing [57]. Learning effect and warming up effect should be minimized, by using the second test session as baseline measures [58]; b) because patient symptomatology can vary considerably throughout the day, it is strongly recommended that patients be assessed at approximately the same time of day on two occasions separated by a time interval sufficiently short that we can assume the underlying process is unlikely to have changed [59]; c) inter-observer variability, as well as intra-observer variability, may be reduced by level of experience and formal training of the observer [55].

Nonetheless, there are also other aspects related to consistency during strength testing that need to be monitored closely: 1)each subject should be wearing appropriate non-restrictive clothing; 2) the observer must utilise consistent anatomic land marks; 3) the observer must understand the technical aspects of the instruments; 4) the observer must collect and record data consistently; and 5) any verbal encouragement should be standardised. For instance, the interaction between assessor and subject should be such that the former treats each subject the same way and provides neither unnecessary encouragement nor discouragement [55].

3.6.3 Pain Intensity

Pain may be defined as an unpleasant sensory and emotional experience associated with actual and potential tissue damage, or described in terms of such damage [60]. This definition is qualified by several cautions including: 1) Pain is always subjective, and the meaning of the word is learnt by personal experiences; 2) It is always unpleasant, i.e. an emotional experience; 3) Pain may be perceived in the absence of any pathophysiological cause; 4) From the subjective report, the experience of pain from psychological causes cannot be differentiated from that due to tissue damage [60].

The current trend is to measure perceived pain quantitatively and qualitatively using questionnaires, and to observe pain-related behaviours [61]. The questionnaire approach uses either a single pain question or a battery of pain questions (i.e.: McGill Pain Questionnaire), responses being scaled often on a visual analogue scale or Likert scales (point scale), or similar alternative [61].

Pain rating scales remain the most frequently used tools in pain research [62], possibly because of their simplicity and ease of administration [63]. There is controversy in the literature as to which scale is the most reliable and valid. In a comparative study of 4-point Likert, horizontal and vertical visual analogue scales and 11-box numerical pain rating scales, Downie et al. showed good to excellent levels of correlation between the scales [64], while another similar study only demonstrated moderate levels of correlation between the scales studied in their capacity to measure change in pain [65]. In an extensive comparative study of six pain rating scales (10 cm VAS, 101-point numerical scale, 11-point box scales, 6-point behavioural rating scale, 4-point verbal rating scale and 5-point verbal rating scale), Jensen et al. concluded that the six methods of testing pain gave similar "correct completion rates" (92%-97%), and had similar predictive validity [66].

3.6.4 Fear of Neck Movement

The literature suggests that fear-avoidance beliefs about physical activity and work might form specific cognition intervening between low back pain and disability. A recent study involving 210 patients showed that fear-avoidance beliefs about work accounted for 23% of the variance of disability in activities of daily living and 26% of the variance of work loss [67]. If fear-avoidance beliefs are strongly related to loss of work due to low back pain, they may have a similar effect on neck pain.

3.6.5 Self-Perceived Level of Disability

Subjective report on self-perceived level of disability is another useful tool to help quantify how patients perceive their disability. A commonly used tool in the assessment of self-perceived level of neck disability is known as the Neck Disability Index Questionnaire (NDI) developed and tested by Vernon and Mior [68]. This modified Oswestry Low Back Pain Index questionnaire had been constructed producing a 10-item scale. Face validity was ensured through peer-review and patient feedback sessions. Test re-test reliability was conducted on 52 "whiplash"-injured subjects and showed a total index alpha of 0.80, with all items having individual alpha scores above 0.75. Concurrent validity was assessed using a smaller subset of 10 subjects. Each subject completed a course of conservative care; the percentage of change on NDI scores before and after treatment was then compared to visual analogue scale scores of percent of perceived improvement in activity levels. There was also a comparison of the NDI scores of 30 subjects with scores attained on the McGill Pain Questionnaire (gold standard). The method of assessing concurrent validity showed a moderately high correlation from 0.60 to 0.70. The results of the study demonstrated that the NDI achieved good reliability and internal consistency.

Nevertheless, one should not make the assumption that a high degree of self-perceived disability implies poor functional capacity. A study by Mayer et al. evaluated the degree of physical deconditioning of spinal surgery patients. They assessed pain intensity and level of disability and found them both to be poor measures of functional capacity three months post-operatively [50].

3.6.6 Motivation

It has been claimed that inconsistencies in performance indicate lack of effort [69]. Lack of repeatability can also be a sign of poor effort rather than indicative of a valid deficit, since effort is difficult to measure [42]. Although it has been suggested that it is difficult to repeat submaximal performances, a recent study on the test-retest reliability of lumbar isometric strength testing of 89 patients with chronic low back pain showed moderate to high reproducibility of submaximal effort [31]. However, if the task is unduly complex or time consuming, the observer and subject may fatigue and reliability of the resulting data may decline accordingly [55].

3.6.7 Cervical Range of Motion

Performance of active neck movements provides an overall assessment of the neck function by estimating the ability of the soft tissues of the neck to reach their extremes of length [70]. In the absence of diseases resulting in myofascial hypertonicity, neuro-pathology or joint pathology found with arthritic diseases, there are other factors for limiting active cervical range of motion. Therefore, it can be speculated that limited cervical range of motion can be due to scar tissue formation as a result of soft tissue healing, or to the severity of neck pain with active movement, or possibly due to some fear of causing further neck injury with movement, or even due to lack of motivation. All of these limiting factors may play an important role in the assessment of reliability of cervical strength testing. Therefore, it is essential to reliably assess the active cervical range of motion in symptomatic subjects and to analyse statistically if limited motion plays an important role in the measurement of strength.

Several studies [71-74] have looked at the intra- and inter-tested reliability of cervical range of motion measurements by using the Cervical Range of Motion (CROM) device. The CROM measures accurately and quickly the range of sagittal, coronal and horizontal movements that can be performed by the head and neck. That is to say, active neck movements in 6 planes: flexion, extension, left and right lateral flexion, and left and right rotation. Few reliability studies are available on other instruments such as the universal goniometer [75], arthrodial protractor, electrogoniometers [76], bubble goniometers [77], radiographs [78,79], hydrogoniometers [80], and computerized tomography [81].

Capuano-Pucci and his co-workers showed good intra- and inter-tester reliability of the CROM when measuring cervical range of motion in all 6 planes [71]. Another study by Youdas and his co-workers examined the intra-tester and inter-tester reliability of active cervical range of motion obtained with a CROM instrument on 337 healthy subjects whose ages spanned 9 decades [73]. The CROM instrument demonstrated good intra-tester and inter-tester reliability with intra-class correlation coefficients generally greater than 0.80. Because these studies involved healthy volunteers it raises the issue of the CROM's reliability with symptomatic subjects.

Love et al. looked at the inter- and intra-examiner reliability of cervical passive range of motion in flexion and extension using the CROM. They found good intra- and inter-examiner reliability (ICC 95% CI = 0.96 to 0.99) [74]. Also, Rheault and his co-workers investigated the inter-tester reliability of the CROM on symptomatic subjects (15 female and 7 male). Moderate to high intra-class correlation coefficients (ICC = 0.76 to 0.98) were found between testers. Furthermore, the mean differences (0.5° to 3.6°) between testers were also consistently low for all six measurements (flexion, extension, left and right rotation and left and right lateral flexion) [72].

The validity of the Cervical Range of Motion (CROM) instrument was assessed for internal consistency by comparing its results to a 10-item cervical pain questionnaire. The results of the study showed a strong correlation between decreased range of motion and severity of pain [82].

A study of high school football players showed no correlation between the size of the athlete's neck and cervical range of motion [83].

In conclusion, previous studies have concluded a high degree of reliability for the CROM device when it is used on healthy and symptomatic subjects [71-74].

3.6.8 Normalization

In treatment, the patient is his own control; therefore, a normal database is not absolutely required, although it is helpful to know the normal range to provide a treatment goal [42]. In spite of increasing interest in techniques and devices for quantifying muscular strength, relatively little research has been done to determine optimal normalizing factors for strength [84]. Ideally, normative data for all isometric machines for assessing cervical rotation and extension strength would allow for sex, body weight, and age.

3.8.9 Age

In both genders, muscle strength is gained from birth through adolescence, peaking between the ages of 20 and 30 years, and gradually declining with advancing age [46]. There is some evidence for a weak relationship between isokinetic knee strength performance and age [85-89].

3.6.10 Gender

Men as a group are stronger than women, but when normalized to body weight, women may be as strong as men [42]. Therefore, the greater strength in males appears to be related primarily to the greater muscle mass they develop after puberty [46].

3.6.11 Body Weight and Height

Several variables relating to height and weight have been studied to determine optimal normalization. Mayer et al. looked at actual body weight (BW), ideal weight (IW) and adjusted weight (AW) and their relationship to isolated trunk strength and showed that actual body weight was the best normalizing factor for isokinetic trunk flexor/extensor strength and lumbar lifting [84].

3.7 Reliability of Strength Testing

Reliability is a measure of repeatability of experimental outcomes [90]. In other words, reliability is an expression of the extent to which the same results are yielded from repeated applications of an assessment technique, assuming no true interval change in the phenomenon under study [55]. The usual approach to assessing test re-test reliability is to administer the test on two occasions, separated by a time interval sufficiently short so that we can assume the underlying process (biological variability) is unlikely to have changed [59].

The reliability of an assessment technique can be improved, by attempting to minimize several sources of variability. The most important areas of concern are patient variability, observer variability, and operational influences [55].

The smaller the variability in the measurement process, the greater its reliability and vice versa [55]. Variability may be attributed to either the subject variability (V_t) or random error (V_e). Subject variability can be due either to between subject variability or to within subject variability. Subject variability is discussed further in the next section. On the other hand, random error refers either to the observer error or to the variability in the performance of a mechanical device. With regard to observer error, it is generally recognized that the variability between different observers (inter-observer variability) exceeds that of a single observer making repeated assessments on the same patient (intra-observer variability) [55].

As repeated measures rarely yield exactly the same result, it follows that some degree of inconsistency is the rule. The result of a calculation, which delineates an index of agreement is termed a reliability coefficient. This coefficient is an estimate of the percentage of the total variance that can be described as true variance. The total variability can be considered as being composed of true variation, i.e. natural variation between or within subjects (V_t) and error variation (V_e) (i.e. random error). Thus, the reliability of an assessment technique (R_b) is a ratio of the true variation to the total variation, i.e. $R_b=V_t/(V_t+V_e)$. When $V_e=0$, $R_b=1$, thus, the instrument is perfectly reliable. However, when $V_t=0$ (i.e. there is no variation amongst the subjects) or when $V_t>0$, $R_b=0$, thus, the instrument is totally unreliable [55].

3.7.1 Reliability Studies on Cervical Strength Testing.

Vernon and his co-workers looked at the reliability and validity of the modified sphygmomanometer-type dynamometer in 40 healthy male subjects and 24 symptomatic whiplash patients. They found the instrument to be highly reliable for the evaluation of isometric muscle strength in the neck in normal and symptomatic subjects (intra-class coefficients ranging from 0.79 - 0.97 for normal subjects and ranging between 0.95 - 0.99 for symptomatic subjects) [39].

Leggett et al. published an abstract of their study on quantitative assessment of cervical extension strength through full range of motion. The purpose of their study was to develop normative data depicting the cervical extension strength curve, and to determine the reliability of strength measurements for the isometric MedX™ cervical extension machine. The study included 52 healthy volunteers (29.9 (mean) ± 12.5 (SD) years), mostly males (38 males vs 14 females). Repeated testing was performed over 2 different trials. The elapsed time between each trial was not reported. Their results showed isometric strength measurements on isolated cervical extension muscles at multiple joint angles are highly reliable [36].

Later, Leggett and his co-workers evaluated the reliability and variability of repeated measurements of isometric cervical extension strength among 73 healthy volunteers and determined the effect of 10 weeks of dynamic variable resistance cervical extension training on isometric cervical extension strength. Their results showed high correlation coefficient (Pearson product-moment correlation coefficient, $r = 0.90$ to 0.96) between test 2 and test 3. Test variability between test 2 and test 3 was low (standard error of the estimate of individual scores about the line of regression, SEE = 7.4% to 10.2% of mean) through various angles throughout the full range of motion [2].

Shank evaluated the reliability and variability of repeated measurements of isometric cervical extension strength through various angles throughout the full range of motion. Fifty-three healthy men (age = 29 ± 12 yrs) and 20 healthy women (28 ± 12 yrs) underwent cervical isometric strength testing in 4 separate trials. The results of the study showed that normal isometric cervical extension strength curves were linear, descending from flexion to extension. Also, data indicated that repeated measures of isometric cervical extension strength were highly reliable ($r = 0.90$ to 0.96) [3].

Foster and his co-workers studied the quantitative assessment of isometric cervical rotation net muscular torque. The purpose of their study was to quantify net muscular torque by accounting for stored energy, and to compare the strength curves for net muscular torque and total torque. They also assessed test re-test reliability in two separate trials. Correlation coefficient for test re-test reliability ranged from 0.86 – 0.98 and single test variability was 5 – 9% [1].

Trinkle conducted a study on quantitative assessment of full range-of-motion isometric cervical rotation strength. The purpose of the study was to establish the reliability and variability of the MedX™ cervical rotation strength testing machine to establish the isometric strength curve of the cervical rotators through a full range-of-motion. Sixty-four healthy males (age = 29 ± 11 yrs) and 26 healthy females (age = 28 ± yrs) were tested on four separate days. Test re-test reliability was analysed using Pearson product moment correlation coefficient for between-day tests and showed high level of reliability ($r = 0.85$ to 0.98) [4].

The weaknesses of the above-mentioned studies are numerous. First of all, cervical isometric strength testing was assessed with asymptomatic subjects. It could be argued that strength testing is more relevant with symptomatic subjects rather than healthy subjects; consequently these studies are not providing useful information on test re-test reliability with the targeted population. Second, some authors used visual feedback during testing via a computer monitor to help the subject in their accuracy at reproducing the same results during repeated measurements. This procedure is believed to increase the reliability of the results but undoubtedly introduces an important bias for assessing test re-test reliability. A study by Graves and James showed that maximal isometric force measured during strength testing is better obtained using concurrent visual feedback [91]. Therefore, any visual feedback or verbal feedback from the assessor could significantly affect the reliability positively. Third, improper statistical analyses were done for the majority of these studies. Pearson product-moment (*r*) tends to overestimate reliability [90]. When *r* is small, low reliability can be inferred, but when *r* is large, there is no assurance of good reliability. The relevant statistic for assessment of test re-test is the two-way ANOVA intra-class correlation coefficient (ICC). In addition to reliability, one must determine to what degree the differences between individual scores fall within an acceptable error of tolerance (precision). Test variability was assessed to determine the precision by computing the standard error of estimate (SEE). A major concern with SEE is that it is actually a measure of the error in prediction and can underestimate the actual differences between trials. A better alternative method of assessing the variability (precision) of our estimated limit of agreement is to use standard errors and confidence intervals to see how precise is our estimate of variability within our sample population [92].

In summary, almost all reported studies of test-retest reliability of cervical isometric strength testing have been based on healthy asymptomatic subjects [1-4,36]. All of these studies showed good test re-test reliability in healthy subjects, but they inappropriately concluded good validity of the instrumentation without using any descriminant statistic to confirm this finding. The topic of validity of a test is discussed in greater detail in the section to follow.

3.8 Validity of Strength Testing

Validity can be defined as the degree to which the results of a measurement correspond to the true state of the phenomenon being measured [93]. Although a technique may be reliable, its validity is not guaranteed [94].

There are four principal types of validity: face, content, construct, and criterion. In general, face and content validity are assessed using judgmental techniques, while construct (convergent or discriminant) and criterion (concurrent or predictive) validity employ statistical methods examining a level of association which has been specified *a priori* [94]. It is beyond the scope of this paper to discuss these four different types of validity; however, a brief overview of discriminant construct validity testing, as it applies to strength testing in a symptomatic population, is discussed below.

A valid instrument should be able to discriminate between normal subjects and subjects with neck pain. Therefore, the validity of any test depends in its sensitivity, its specificity and its predictive values (discriminant construct validity).

Sensitivity (true-positive results) is defined as the frequency with which persons who have the condition test positive (i.e., the probability of the test correctly identifying a subject with neck pain). Meanwhile, specificity (true-negative results) is defined as the frequency with which persons who do not have the disease test negative (i.e., the probability of correctly identifying pain free subjects) [95]. Predictive value, on the other hand, measures whether or not an individual actually has the condition investigated [5]. The determinants of predictive value are the sensitivity and specificity of the test and the prevalence of the condition being investigated [96].

To date there have been no published research studies assessing the validity of cervical isometric strength testing using proper discriminant statistics. A low back pain study by Burdorf and his co-workers used discriminant statistics and found very little difference in isoinertial performance between normal subjects with no history of low back pain and subjects with a history of low back pain. Their analysis gave limited results with both a false-positive and false-negative rate of more than 30% [97]. It was unclear in their study whether the subjects with a history of low back pain had pain at the time of the study, - a factor which would influence the validity of the study. Furthermore, the validity of muscle strength testing is influenced by several factors. Pain and effort are believed to limit significantly the validity of the data recorded [42].

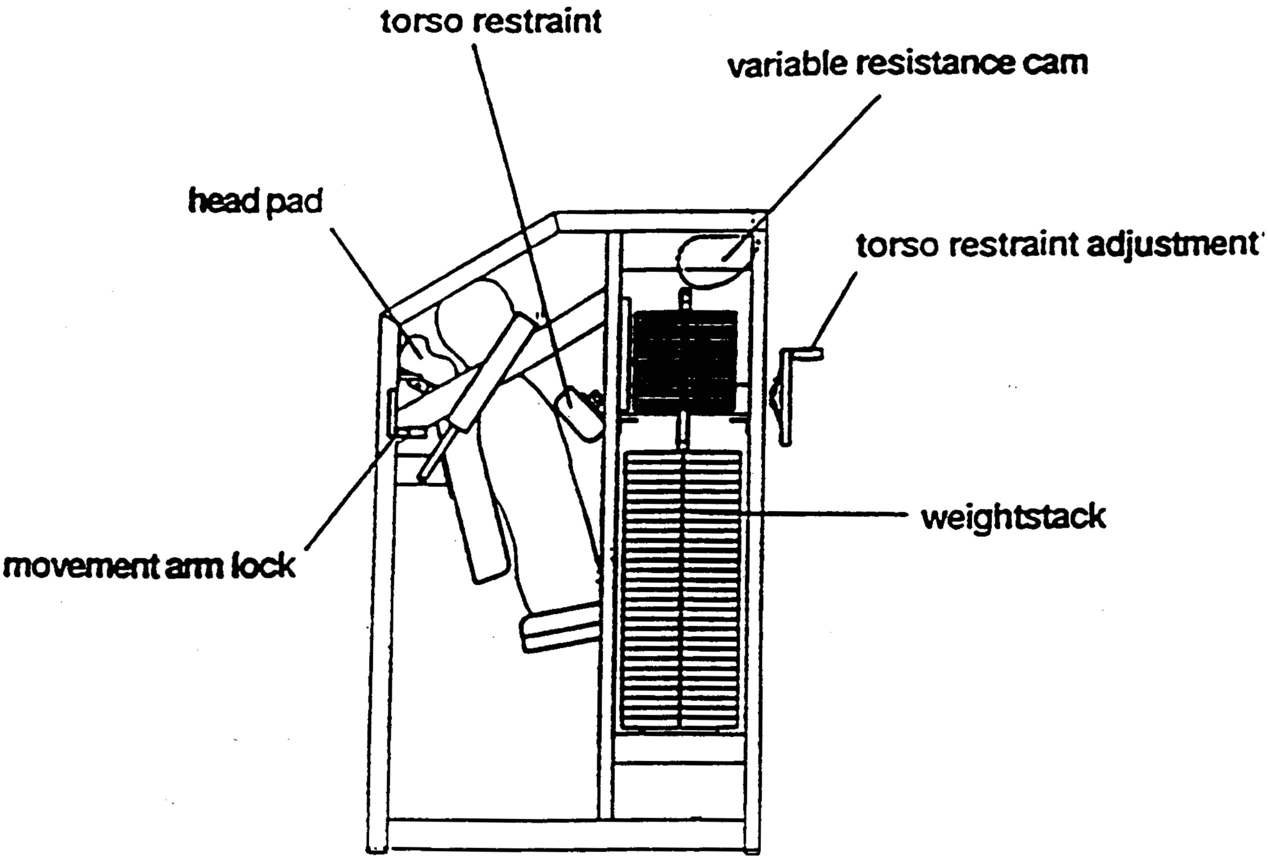
Chapter 4

Materials and Methods

4.1 MedX™ Cervical Extension Strength Machine.

The isometric MedX™ cervical extension strength machine is manufactured by MedX™ Corporation of Ocala, Florida. This equipment is designed to perform cervical isometric extension strength testing through a full range of motion (Figure 4.1.1). The testing machine has some particular features necessary for reliable and precise cervical extension strength testing. It is believed to provide isolation of the cervical extensor muscles by using an upper body restraint system. Further studies using electro-myography would be necessary to verify if significant extensor muscle group isolation is achieved without other muscle recruitment. The MedX™ machine provides counter weighting of the mass of the head and neck to minimize positive and negative effect of gravitational force. Also, it is believed to eliminate stored energy (the initial resting force recorded by the tensiometer due to a soft tissue recoil phenomenon when under tensile force) providing a net muscular force (true strength)[98]. The machine is fully adjustable for subjects with different physical characteristics (body size and height).

FIGURE 4.1.1 MedX™ Cervical Extension Machine – Side Views.



4.2 MedX™ Cervical Rotation Strength Machine

The isometric MedX™ cervical rotation strength machine is also manufactured by MedX™ Corporation of Ocala, Florida (Figures 4.2.1 and 4.2.2). This machine has features similar to the cervical extension strength equipment. It provides a restraint system for the upper body to help with muscle group isolation. It is fully adjustable to adapt for different physiques. Testing is performed through full range of motion.

FIGURE 4.2.1 MedX™ Cervical Rotation Machine – Front View.

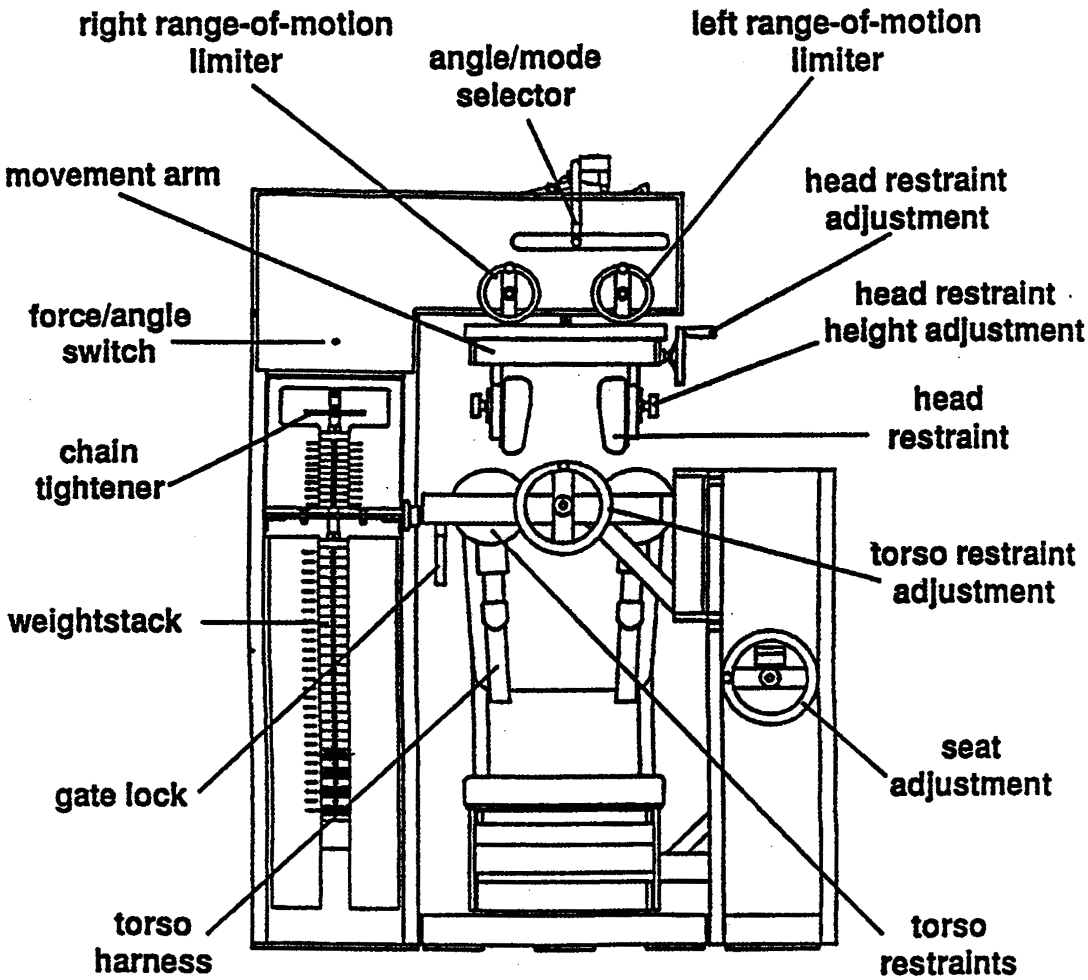
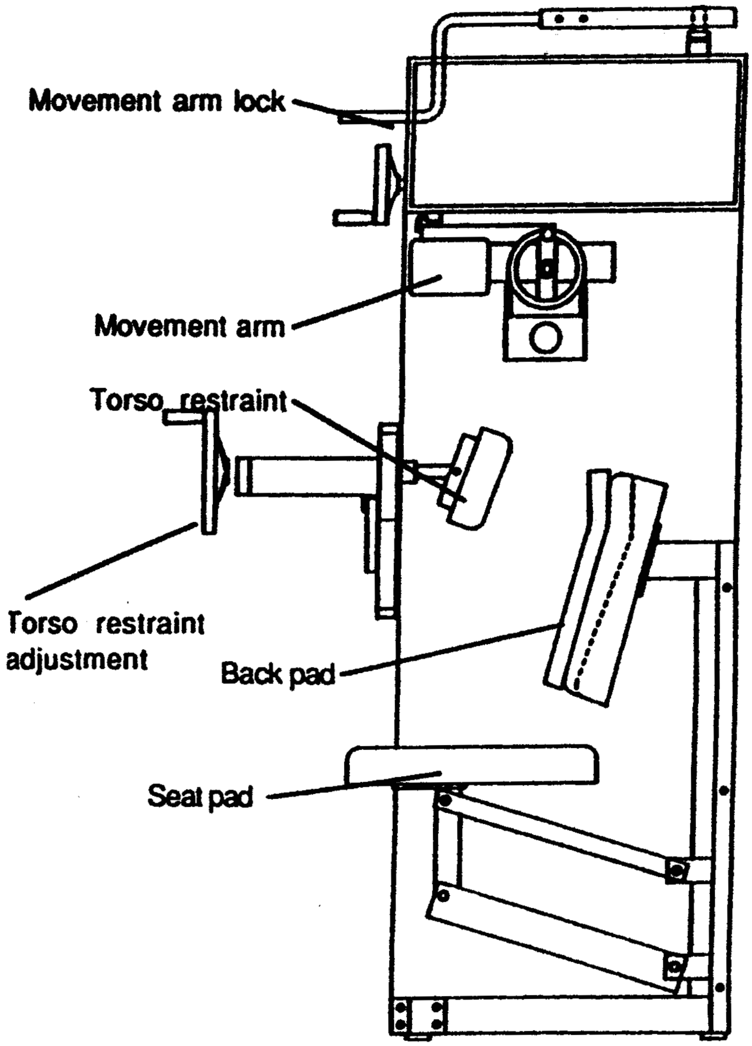


FIGURE 4.2.2 MedX™ Cervical Rotation Machine – Side View.



4.3 Research Design

This research incorporated a descriptive study of the distribution of age, height, weight, neck pain intensity, cervical extension strength, cervical rotation strength, cervical range of motion and level of self-perceived neck disability in a cohort population of males and females. It included a correlational study assessing the association of several pre-selected variables such as severity of neck pain, degree of neck disability, fear of neck movement, and cervical range of motion, cervical extension and rotation strength. In addition, it included a test-retest reliability study of cervical extension and rotation strength measurements on symptomatic subjects.

4.3 Selection of Subjects

4.3.1 Inclusion Criteria

Symptomatic subjects (sample of convenience) were adult age male and female volunteers experiencing idiopathic neck pain for more than 4 weeks. Subjects were recruited by advertisements posted in a local private chiropractic clinic and a hospital bulletin board.

4.4.2. Exclusion Criteria

Subjects were excluded if they had: a) pain radiating down the arms, with or without neurological deficits; b) previously diagnosed spinal disorders, such as spinal tumour, spinal infection, and/or inflammatory arthritis; c) a history of spinal fracture; d) previous cervical spine surgery; e) structural spinal deformity, such as a cervical spondylolisthesis, Scheuermann's disease, or cervico-thoracic scoliosis. Subjects with respiratory disorders such as bronchitis, chest cold, emphysema or thorax deformities (i.e.: barrel chest, Pectus Excavatum and Pectus Carinatum) were also excluded due to the nature of the testing, which required patient stabilization by means of a chest restraint system on each of the MedX™ machines.

For safety purposes, those individuals with a history of heart disease, hypertension, open heart surgery, or a pacemaker were excluded. Individuals with medical conditions such as cerebrovascular disease, neurological disease with or without a history of seizures, diabetes, osteoporosis, severe asthma, or a history of long-term use of corticosteroids were excluded. Pregnant women were also excluded.

4.5 Research Protocol

The study consisted of two parts. The first part determined the test-retest reliability of cervical extension strength. The second part of the study assessed the test-retest reliability of cervical rotation strength and the relationship between cervical rotation strength and neck pain intensity, level of neck disability, fear of neck injury and cervical range of motion.

Prior to enrolment every subject signed a consent form (Figure 4.5.1). In part one of the study, subjects were asked to complete a brief screening health questionnaire specifically designed for this study (Figure 4.5.2), a 100 mm VAS for pain (Figure 4.5.3) and a neck disability index questionnaire (Figure 4.5.4). In part two of the study, all subjects completed the above mentioned questionnaires with the addition of a 100 mm visual analogue scale for fear (Figure 4.5.5). In cervical rotation range of motion was measured for all subjects who underwent cervical rotation strength testing.

A standard protocol developed by the University of Florida was followed for both extension and rotation strength testing [99]. Once the subject was sitting in the cervical extension machine, the seat was adjusted so that the subject's thyroid cartilage was in alignment with the axis of rotation of the movement arm. Proper alignment prevented sliding from occurring between the head and the resistance pad. Subjects were secured by a specially designed restraint system, which included a shoulder harness, seat belt, and torso restraint. The shoulder harness prevented any movement of the torso.

Figure 4.5.1 CONSENT FORM

Title of study: Test-retest Reliability of Cervical Isometric Strength Testing.
Researchers: Dr. Joe Lemire & Dr. Ken Yong-Hing

The *Centre for Neuromusculoskeletal Health* at the Royal University Hospital has established a research unit to study motor vehicle injuries in Saskatchewan. These injuries are a big problem in Saskatchewan because, although some people heal quickly, others suffer considerable pain, disability, family and social disruption, and economic hardship.

You are invited to participate in a research project, which is designed to measure muscular neck strength. If you decide to participate in our study, you will be required to complete a health screening questionnaire, a neck disability questionnaire and a visual analogue scale to assess your level of neck pain. Also, you will be asked on two separate days to perform several maximal voluntary contractions to assess your neck strength. On the first testing day these tests will take approximately 30 minutes and the second day 10 minutes.

The risk of injuries from maximal static muscular neck contraction is quite low. It is, however, possible to experience some neck discomfort or pain for 24 hours after each test.

You are under no obligation to participate in this study, and your participation will not affect any claims that you may have with the Saskatchewan Government Insurance (SGI). Furthermore, anyone who agrees to be in this study can withdraw at any time. Your participation will remain confidential at all time and SGI will not have access to your test results, unless you consent for the release of your test results to SGI. The results of your test might be subpoenaed and only in those cases where required by law would the test results be released to any third party.

At the end of your involvement with our study, we will provide you with a written report of the results of your tests.

If, during the course of this study, you have questions or concerns about your participation, please feel free to call or write to the Centre for *Neuromusculoskeletal Health*, Royal University Hospital, Saskatoon, Saskatchewan, S7N-0W8. Telephone: Office: 966-8198, lab:966-7631.

If you consent to being in this study, please print and sign your name below and have someone witness your signature.

I ____________________ understand the content of the consent which has been explained to me and I agree to take part in this study.

____________________________/________________________ ________________
(signed) (print) (Date)

____________________________/________________________ ________________
(Witness) (print) (Date)

FIGURE 4.5.2 Screening Health Questionnaire.

Name:______________________ Date: ___d/___m/___y
D.O.B. ___d/___m/___y Weight:____lbs Height:____in

Yes	No	
☐	☐	Are you suffering from neck pain at the <u>present</u>?
☐	☐	Have you experienced neck pain in the <u>past 12 months</u>?
☐	☐	Do you have pain radiating down your arms at the <u>present</u>?
☐	☐	Have you ever sustained a neck injury in the past (ie: whiplash)? If yes, when? ___________
		HISTORY
☐	☐	Have you been on corticosteroid medication (ie: Prednisone)? If yes, for how long? ________
☐	☐	Have you ever had a spinal surgery?
☐	☐	Have you ever had a spinal tumor?
☐	☐	Have you ever had a spinal infection?
☐	☐	Have you ever had a spinal fracture?
☐	☐	Have you ever had a stroke?
☐	☐	Have you ever had a heart attack?
☐	☐	Have you ever had a heart surgery?
☐	☐	Are you aware of any spinal deformities that you may have? (ie: scoliosis) If yes, explain ________________
		PRESENT
☐	☐	Do you have a heart condition or high blood pressure?
☐	☐	Do you have osteoporosis?
☐	☐	Do you suffer from any kind of inflammatory arthritis?
☐	☐	Do you suffer from any respiratory disorders (emphysema or asthma)?
☐	☐	Do you suffer from seizures?
☐	☐	Do you suffer from diabetes?
☐	☐	Are you pregnant? If yes, how many months? ________

Figure 4.5.3 Visual Analogue Scale for Pain.

Complete below <u>if you have experienced Neck Pain within the past 12 months</u>.

On the line below, mark one point between "No Pain" and "Pain As Bad As it Could be" to indicate how severe your neck pain is <u>now</u>.

No Pain ____ Pain as Bad as it Could Be

On the line below, mark one point between "No Pain" and "Pain As Bad As it Could be" to indicate how severe your neck pain is <u>usually</u>.

No Pain ____ Pain as Bad as it Could Be

FIGURE 4.5.4 Neck Disability Questionnaire.

Section 1 - Pain Intensity
- ☐ I have no pain at the moment.
- ☐ The pain is very mild at the moment.
- ☐ The pain is moderate at the moment.
- ☐ The pain is fairly severe at the moment.
- ☐ The pain is very severe at the moment.
- ☐ The pain is the worst imaginable at the moment.

Section 2 - Personal Care (Washing, Dressing, etc.)
- ☐ I can look after myself normally without causing extra pain.
- ☐ I can look after myself normally but it causes extra pain.
- ☐ It is painful to look after myself and I am slow and careful.
- ☐ I need some help but manage most of my personal care.
- ☐ I need help every day in most aspects of self care.
- ☐ I do not get dressed, I wash with difficulty and stay in bed.

Section 3 - Lifting
- ☐ I can lift heavy weights without extra neck pain.
- ☐ I can lift heavy weights but it gives extra neck pain.
- ☐ Neck pain prevents me from lifting heavy weights off the floor.
- ☐ Neck pain prevents me from lifting heavy weights.
- ☐ I can lift very light weights.
- ☐ I cannot lift or carry anything at all.

Section 4 - Reading
- ☐ I can read as much as I want, with no pain in my neck.
- ☐ I can read as much as I want, with slight pain in my neck.
- ☐ I can read as much as I want, with moderate pain in my neck.
- ☐ I cannot read as much as I want, because of moderate pain .
- ☐ I can hardly read at all because of severe pain my neck.
- ☐ I cannot read at all because of the pain in my neck.

Section 5 - Headaches
- ☐ I have no headaches at all.
- ☐ I have slight headaches which come infrequently.
- ☐ I have moderate headaches which come infrequently.
- ☐ I have moderate headaches which come frequently.
- ☐ I have severe headaches which come frequently.
- ☐ I have headaches almost all the time.

Section 6 - Concentration
- ☐ I can concentrate fully when I want to with no difficulty.
- ☐ I can concentrate fully when I want to with slight difficulty.
- ☐ I have a fair degree of difficulty in concentrating when I want to.
- ☐ I have a lot of difficulty in concentrating when I want to.
- ☐ I have a great deal of difficulty in concentrating when I want to.
- ☐ I cannot concentrate at all.

Section 7 - Work
- ☐ I can do as much work as I want to.
- ☐ I can only do my usual work, but no more.
- ☐ I can do most of my usual work, but no more.
- ☐ I cannot do my usual work.
- ☐ I can hardly do any work at all.
- ☐ I cannot do any work at all.

Section 8 - Driving
- ☐ I can drive my car without any neck pain at all.
- ☐ I can drive my car as long as I want, with slight pain in my neck.
- ☐ I can drive my car as long as I want, with moderate pain in my neck.
- ☐ I cannot drive my car as long as I want, because of moderate pain.
- ☐ I can hardly drive at all because of severe pain in my neck.
- ☐ I cannot drive my car at all because of the pain in my neck.

Section 9 - Sleeping
- ☐ I have no trouble sleeping.
- ☐ My sleep is barely disturbed (less than 1 hr. sleepless).
- ☐ My sleep is mildly disturbed (1-2 hrs. sleepless).
- ☐ My sleep is moderately disturbed (2-3 hrs. sleepless).
- ☐ My sleep is greatly disturbed (3-5 hrs. sleepless).
- ☐ My sleep is completely disturbed (5-7 hrs. sleepless).

Section 10 - Recreation
- ☐ I am able to engage in all my recreation activities, with no neck pain at all.
- ☐ I am able to engage in all my recreation activities, with some pain.
- ☐ I am able to engage in most, but not all, of my usual recreational activities.
- ☐ I am able to engage in a few of my usual recreational activities.
- ☐ I can hardly engage in any recreational activities because of pain.
- ☐ I cannot engage in any recreational activities at all because of pain.

modified from Fairbank et al, Physiotherapy 1960

Figure 4.5.5 Visual Analogue Scale of Fear.

Complete below:

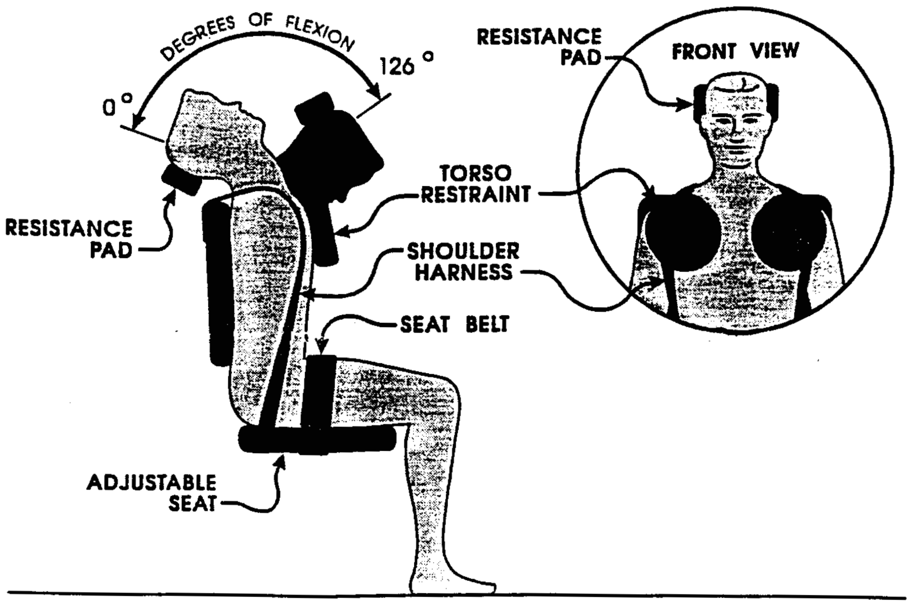
How much fear do you feel about moving your neck at the moment. **Please mark one point between "None" and "The Highest Imaginable level" on the line below.** **None ____ Highest Imaginable level**

How much fear do you feel about moving your neck <u>usually</u>. **Please mark one point between "None" and "The Highest Imaginable level" on the line below.** **None ____ Highest Imaginable level**

The torso restraint consisted of two pads, mounted on an adjustable crank that was placed against the chest just below the clavicles. The combination of these restraining forces stabilized the torso, allowing no lateral, vertical, or rotational movement. Standardized positioning of the arms was achieved by instructing the subjects to rest their hands on their laps. The mass of the head was counterbalanced to eliminate the influence of gravity on the net torque measured. Body position and counterbalance adjustment were recorded and used for all subsequent testing.

Prior to testing, subjects warmed-up by performing a trial at 50% of their maximal effort. This warm-up period provided subjects an opportunity to familiarize themself with the testing procedure (minimizing learning effect) and at the same time warmed up the extensor muscle group to be tested (minimizing risk for injury). After a 5 minute rest period the subject proceeded to testing with maximal voluntary effort. To initiate testing, the subject was locked into different positions of cervical flexion. Depending on the amount of range of motion for that particular individual, the tested interval ranged from a maximum of 126° of cervical flexion to 0° of cervical extension. This range of motion relates to the lever arm's range of motion on the MedX™ cervical extension testing machine (Figure 4.5.6). Each subject was tested within his or her own physiological cervical range of motion. As a safety precaution strength testing was not performed at the very end range of motion but at 6° less than full range in flexion and extension.

Figure 4.5.6. MedX™ Cervical Range of Motion.



Each subject was instructed to slowly and continuously push backwards with his or her head against the resistance pad for a 2 to 3 seconds and then relax slowly over a 2 to 3 second period. A few seconds rest interval was provided between each isometric contraction while the next angle of measurement was set. Contrary to the suggested protocol by MedX™ no concurrent visual feedback was provided during testing, which was felt to bias repeated measurements. Subjects were verbally encouraged to give a maximum effort. To ensure torso stabilization, the torso restraint was tested and tightened if any torso movement was observed during testing.

In order to assess test-retest reliability of cervical isometric strength testing, the procedure was repeated 48 hours later. If the interval between test and retest was shorter, then the test process itself, or a memory effect, may influence the values obtained at the retest. This effect is called reactivity and may result in augmented (or possibly diminished) levels of correlation. In contrast, if the interval was long between the initial test and the retest, then true change may occur in the interim, and the technique would appear less reliable than is the case [55].

The testing protocol for cervical rotation was basically the same as for the cervical extension protocol. Maximal effort was produced by the subject rotating the head through the full cervical range of motion.

4.6 Outcome Measures

For part one and part two of this study, each subject completed a visual analogue scale for pain to quantify the intensity of his or her neck pain. Each subject also completed a neck disability questionnaire to assess self-perceived level of disability caused by the neck pain. These outcomes measures were completed on day 1 and day 2 of testing (i.e.: 48 hours apart). For part two of the study, all subjects completed a visual analogue scale for fear; a coping questionnaire and cervical range of rotation was recorded prior to each testing session.

4.6.1 Visual Analogue Scale for Pain Intensity

A 100mm VAS Pain scale is a simple and useful method for measuring the severity of neck pain at the time of testing. This scale was used prior to each testing session. Also, it required the subject to rate his or her pain felt on the day of testing as well as to rate the usual intensity of pain.

4.6.2 Visual Analogue Scale for Fear of Neck Movement.

In order to determine if fear of neck movement played an important role in cervical strength, a visual analogue scale for fear was designed and utilized.

Fear of neck injury or movement was assessed, using two 100-mm visual analogue scales, one for fear at the time of testing and one for fear of neck movement usually. The questions asked were: "How much fear do you feel about moving your neck at the moment" and "How much fear do you feel about moving your neck usually." The visual analogue scale was designed for the purpose of assessing fear of neck movement. The selection of the most appropriate wording for the visual analogue scale for fear of neck movement was presented and discussed among the research staff within the orthopaedic department. It was felt that the question should be directed to fear of neck movement, rather than to fear of neck injury, in order to minimize the patients' worries just prior to neck strength testing.

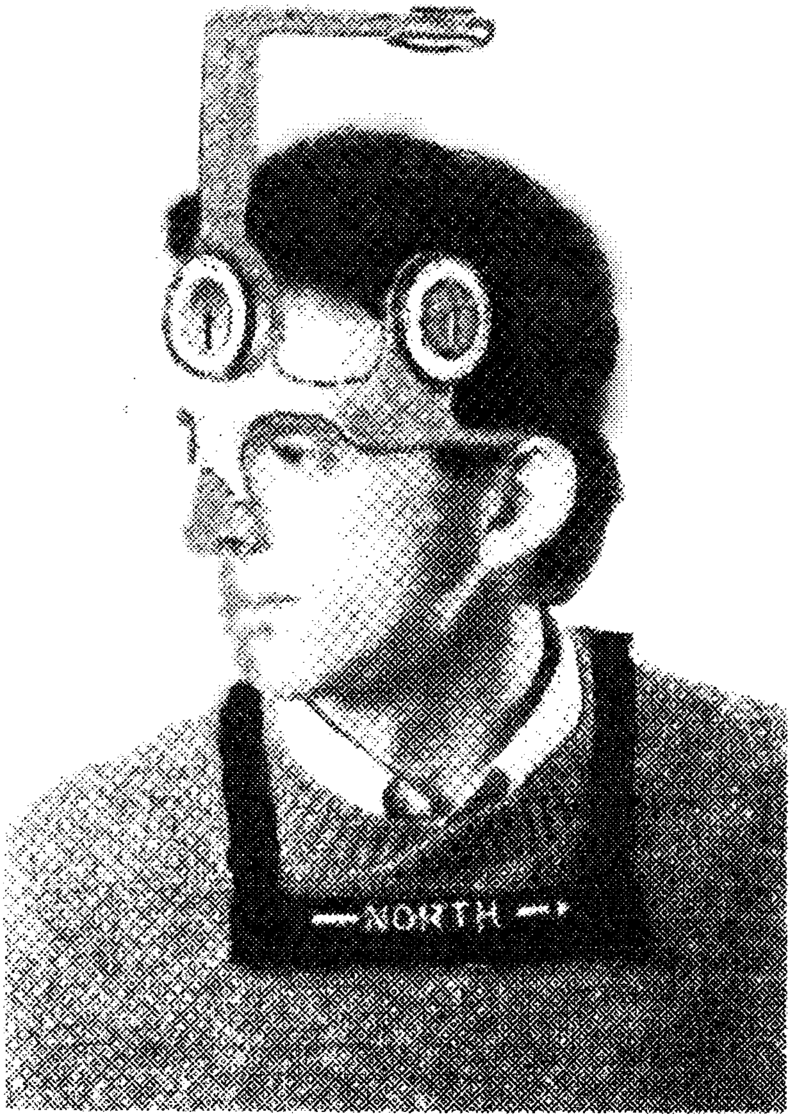
4.6.3 Neck Disability Index Questionnaire

The neck disability index questionnaire is a 10-item scaled questionnaire with regard to activities of daily living. It has been shown to be a reliable and valid instrument for assessing self-perceived level of disability [68].

4.6.4 Cervical Range of Motion Measurements

The Cervical Range of Motion instrument (CROM), a product of Performance Attainment Associates [100] (Figure 4.6.4.1) was used to assess left and right rotation prior to rotation strength testing. The CROM instrument was chosen for a number of reasons, namely: ease of application, efficiency, adjustability, readability, standardization of landmarks and positioning, standardization of protocol, good reported reliability and reasonable cost.

FIGURE 4.6.4.1 Cervical Range of Motion Instrument.



According to the CROM procedure manual, it is important to determine which direction is north in order to obtain an accurate measurement. This information allows the rotation meter with its magnetic arrow to respond quickly to the shoulder-mounted magnetic yoke. However, our testing lab was situated close (20 feet) to the Magnetic Resonance Imaging (MRI) laboratory, and this proximity caused the magnetic arrow to be deviated from true north. Under these circumstances it was felt more appropriate and more reliable to re-direct the shoulder-mounted magnetic yoke toward the MRI as it was felt to be a stronger magnetic field than true north. Rotation movements were measured and performed as instructed in the standardized protocol provided in the CROM procedure manual (appendices, page 88).

Chapter 5

STATISTICAL ANALYSES

5.1 Data Analyses

The strength data collected for both men and women were pooled together for the reliability analysis using intra-class correlation coefficients. Also, a linear regression and a multiple regression analyses were used to assess the predictability of the mean from average torque measurements for age, height, weight, pain intensity, range of motion, level of disability, and fear of neck movement. R^2 values, which give percentage of the between-subject variability in the strength being predicted, provided measures of predictability.

Precision of the reliability was assessed by determining if the predicted values were on the regression line while actual values of the mean of the two trial measurements for approximately 95% of the subjects was within 2 standard errors of the line. This was accomplished by using the inter-trial correlation between trials 2 and 3. Consequently, the standard error of the measurement (SEM) values were calculated to determine the precision using pooled standard deviation of trials 2 and 3 for all measurements.

5.2 Reliability Analysis

The intra-class correlation coefficient (ICC) is the statistic of choice for the reliability of examiners for continuous data [101]. Intra-class correlation coefficient values are readily interpretable, ranging from 1.00 (highest) to 0.00 (lowest) [102]. In general, and assuming that the retest interval selected is appropriate, higher R values, particularly those of $R \geqslant 0.80$, can be regarded as acceptable [55].

There are two important limitations of intra-class correlation coefficient analysis. First, ICC requires variation between subjects to be a meaningful index of reliability [90]. A normal distribution of the population studied is therefore essential. Second, the intra-class correlation coefficient value gives no indication of the magnitude of the disagreement within subjects. The average disagreement depends as much on the magnitude of the outcome measures as it does on the precision of those measures [90]. For instance, it is possible to get two different sets of data with the same ICC, but a ten-fold difference in disagreement. The statistical analysis of choice for assessing the precision of the measurement is discussed in greater detail in the next section.

There are numerous versions of the intra-class correlation coefficient that can give quite different results when applied to the same data. Each version is appropriate for specific situations defined by the experimental design and the conceptual intent of the study [103]. Thus, it is imperative to apply the most appropriate form for assessing reliability. For instance, one can assess the intra-observer reliability coefficient to measure variation, which occurs within an observer, or to assess the variation that occurs between observers (inter-observer reliability). Another approach is called test-retest reliability, as it implies that no observer bias is involved in the data collected. Such data input include health questionnaires or testing with instrumentation where the observer is believed to have no influence on the data recorded.

Accordingly, test-retest reliability is the intended purpose of this study, where subject variability is directly related to the reliability testing of the instrumentation. The most appropriate form of ICC refers to the Model C described by Müller and Büttner which is based on a two-way ANOVA analysis. This model allows differentiation between bias (systematic errors) and random error. This Model C for intra-class correlation originates from psychometric theory and was constructed for test-retest analysis of psychometric tests (partially to control for learning effects) [104].

Because the interaction between the observer and the target (muscular strength) can be assumed to be absent, intraclass correlation coefficient (Model

C) can be defined as [102]:

$$ICC = (BMS - EMS) / BMS$$

where BMS is the "mean square between subject" and EMS is the mean square between residual. Intra-class correlation coefficients were calculated via computer generated statistical analysis (SPSS® software package for microcomputer data management and analysis).

5.3 Sample Size Estimate for Reliability Studies

The method used for sample size calculation depends on the design of the study and the nature of the data. In conducting a reliability study, we are attempting to estimate the reliability coefficient with as much accuracy as possible; that is, we want to be certain that the true reliability coefficient is reasonably close to the estimate ($r \geqslant .80$) we have determined [59].

For comparison of means, α (Type I error), ß (Type II error), delta, and standard deviation (σ) are the key factors. The values for Type I and Type II errors are set by convention and the values for Z_α and Z_β derived from standard tables found in many textbooks of statistics. Delta is the minimum clinically important difference in which the investigator is interested. Delta reflects the precision of the experiment and it is usually determined from a pilot study, clinical experience, or the literature, a relevant baseline value which is then multiplied by an appropriate percentage (e.g. 20% difference) to give an absolute value for a "clinically important difference". The standard deviation is derived from either a pilot study or the literature. The value of the standard deviation is a function of inherent variability in the population from which it is derived [55].

Also, the confidence interval (CI) is a useful tool to determine the range of values that we are confident (but not certain) contains the parameter being estimated [105]. The relation between sample size (N) and confidence interval (CI) is:

$$N = (Z_{\alpha/2}/CI)^2 + 3$$

Where $Z_{\alpha/2}$ = 1.96 for 95 per cent confidence interval and 2.54 for a 99 per cent confidence interval [59].

If a measure is modestly reliable, the sample size requirements for its use will be higher than for an equivalent but more reliable technique. For instance, if an arbitrary minimum clinically important difference of within patient variability of 20% for cervical strength is selected, the Type I error set at $0.05_{2\text{-tails}}$ (Z_α=1.96) and Type II error at 0.10 (Z_β=1.28), sample size requirements for comparing two independent means can be calculated. As a result, the sample size requirements diminish as reliability is enhanced and both measurement error and SD decline [55].

5.4 Precision of Reliability

It has been reported that muscular strength testing has a normal physiological variation for both females and males of 11.6 and 9.3%, respectively [106]. Consequently, it essential to determine if the results of muscular strength testing of their population studied fell within a reasonable estimate. In the MedX™ protocol for reliability study a 20% within subject variability has been judged acceptable. The rationale for this decision is not explained, however, because of the arbitrariness of setting acceptable subject variability, for the purpose of this study, a 20% within subject variability was deemed acceptable. Therefore, a precision less than 20% would be accepted as good precision and any percentage above 20 as relatively poor precision.

Since the reliability coefficient involves 2 quantities, namely, the error of variance and the variance between subjects, it can be expressed in terms of the error of measurement. Thus, the standard error of the measurement (SEM) is particularly well suited for the interpretation of precision and is arguably more useful to the clinician than reliability coefficients when interpreting strength measurement [37]. SEM is defined in terms of the standard deviation (σ) and the reliability (R) as:

$$SEM = \sigma \sqrt{(1 - R)} \qquad \text{where } \sigma = \text{pooled standard deviation of trials 2 \& 3.}$$

5.5 Regression Analysis

A correlation does not imply causation. For example the height of an individual does not cause that individual's weight, although the two are highly correlated. Therefore, regression analysis looks at the strength of the relationship between the variables (dependent and independent). This analysis is done by assessing any deviation of the Best Fitted Line to the horizontal line of the 2 means. Thus, the square of the correlation coefficient (r^2) is called the coefficient of determination, and it equals the proportion of the total variance in Y that can be associated with the variance X. Thus, r^2 is the percentage of a variance (i.e. strength) that can be associated with the variance in the other variable (i.e. pain).

When there are 2 or more independent variables used in the analysis it is called a multiple regression analysis. As a result, the square of the multiple correlation can be interpreted directly as the proportion of the variance in the dependent variable ratings accounted for by the independent variables. Thus, coefficients indicate the degree of relationship between performance and each independent variable after the effects of all other variables have been accounted for. There are a number of esoteric criteria used to determine the order in which variables are introduced in the multiple regression analysis. Basically, the computer enters them in order of decreasing ability to account for additional variance. This process is referred to as a Stepwise Regression Analysis, where the variables are introduced one at a time into the regression equation, and the change in the multiple correlation is determined.

However, a variable may not be a useful predictor of the dependent variable for 2 reasons:

1. it has a low correlation with the dependent variable,

2. it has a reasonable correlation with the dependent variable but is highly correlated with another independent variable that has higher correlation with the dependent variable and enters the equation first.

Chapter 6

RESULTS

6.1 Statistical Analysis

6.1.1 Reliability Analysis

The basic notion of a normal population distribution is crucial when conducting a reliability analysis to allow for within group comparison and extrapolation to the general population. In this study, there were two different cohort populations studied, one for cervical extension strength and one for cervical rotation strength. Both groups consisted of both female and male volunteers experiencing neck pain. Both groups represented a normally distributed population sample with regards to age, weight, height, pain intensity, level of disability, cervical strength, and cervical range of motion. Table 6.1.1.1 shows the characteristics of the population that participated in the cervical extension strength measurements, including the means, standard deviations and ranges for age, level of neck disability and neck pain intensity. Similarly, Table 6.1.1.2 shows the same characteristics for the cervical strength rotation population, as well as three additional variables; fear of injury and cervical range of motion for left (ROM-Lt) and right rotation (ROM-Rt). Each graph demonstrating the distribution of each of these variables for both females and males for the two groups studied are shown in the appendices, pages 104 to 111. These graphs show a normal distribution for all the variables.

Table 6.1.1.1 Cervical Extension Population Distribution.

Study Population – Cervical Extension N = 60 (M = 25 & F = 35)				
	Gender	Mean	Standard Deviation	Range
Age	F	36 yrs	12	18-62
	M	38 yrs	14	21-65
Disability	F	26%	15	2-62
	M	28%	16	2-56
Pain	F	31 mm	26	2-82
	M	29 mm	25	2-78

Table 6.1.1.2 Cervical Rotation Population Distribution.

Study Population – Cervical Rotation N = 55 (M = 25 & F = 30)				
	Gender	Mean	Standard Deviation	Range
Age	F	37 yrs	11	22-60
	M	40 yrs	11	20-66
Disability	F	29%	13	5-61
	M	25%	13	7-54
Pain	F	31 mm	24	1-78
	M	22 mm	20	1-68
Fear	F	18 mm	22	1-77
	M	12 mm	17	0-57
ROM – Rt	F	63°	7	48-80
	M	61°	11	38-78
ROM – Lt	F	65°	9	48-80
	M	62°	9	48-75

Test-retest reliability was assessed using repeated measures analysis of variance (ANOVA) and intra-class correlation coefficients (ICC, model C) for random effects. The group of individuals tested during cervical isometric extension strength testing consisted of 60 symptomatic subjects experiencing neck pain (female=35, male=25). The total number of strength measurements performed on the second trial was 377. The data collected during cervical extension strength testing for trials 2 and 3 was pooled for the reliability analysis. The correlation coefficient was 0.9490 with a 95% confidence interval of 0.9502 and 0.9477 ($P < 0.0005$). Similarly, the data for cervical isometric rotation strength testing was obtained from assessing 30 females and 25 males (different subjects from those in cervical extension testing). The pooled data consisted of 301 strength measurements during the second trial. The statistical analysis revealed a correlation coefficient of 0.9654 with a 95% confidence interval of 0.9663 and 0.9645 ($P < 0.0000$). Statistical analysis for the reliability can be found in the appendices pages 95-98.

6.1.2 Precision of Reliability

Precision of the reliability was assessed using inter-trial correlations between trials 2 and 3 to calculate the standard error of measurement (SEM) for both cervical extension and cervical rotation measurements. The standard of error of measurement was 23.48% for cervical extension strength measurements and 6.4% for cervical rotation strength measurements.

6.1.3 Linear Regression Analysis

Several variables, including weight, height, age, pain intensity, fear of neck movement, level of disability, pain intensity and period of disability were analysed to determine if any significant correlation existed with cervical strength.

Both male extension and rotation strength data revealed a negative correlation between level of disability and cervical strength with correlation coefficients of $R=-0.592$ ($P=0.001$) and $R=-0.598$ ($P=0.001$), respectively. Despite being statistically significant the coefficients for a correlation between cervical strength and neck disability are in the moderate range. Table 6.1.3.1 and Table 6.1.3.2 summarise all the correlation coefficients for the male population.

Table 6.1.3.3 and Table 6.1.3.4 depict correlation coefficients that are not statistically significant for the female population during cervical extension strength measurements. Female rotation strength data revealed a moderate correlation between left rotation strength and left rotation range of motion, R=0.539 (P=0.001).

Table 6.1.3.1 Male Cervical Extension Correlation Coefficients

Male - CERVICAL EXTENSION STRENGTH	
WEIGHT	R = 0.375*
HEIGHT	R = 0.081
AGE	R = 0.184
DISABILITY	R = –0.592**
PAIN INTENSITY	R = –0.134

(* = P < 0.05 and ** = P < 0.01)

Table 6.1.3.2 Male Cervical Rotation Correlation Coefficients

Male - CERVICAL ROTATION STRENGTH	
WEIGHT	R = 0.407*
HEIGHT	R = 0.447*
AGE	R = 0.324
DISABILITY	R = –0.598**
PAIN INTENSITY	R = –0.466*
PERIOD SINCE MVA	R = 0.270
FEAR OF NECK MOTION	R = –0.446*
LEFT – ROM	R = 0.440*
RIGHT – ROM	R = 0.404*

(* = P < 0.05 and ** = P < 0.01)

Table 6.1.3.3 Female Cervical Extension Correlation Coefficients.

Female - CERVICAL EXTENSION STRENGTH	
WEIGHT	R = 0.401**
HEIGHT	R = 0.141
AGE	R = 0.141
DISABILITY	R = –0.192
PAIN INTENSITY	R = –0.292*

(* = P < 0.05 and ** = P < 0.01)

Table 6.1.3.4 Female Cervical Rotation Correlation Coefficients.

Female - CERVICAL ROTATION STRENGTH	
WEIGHT	R = 0.272
HEIGHT	R = 0.144
AGE	R = –0.189
DISABILITY	R = –0.363*
PAIN INTENSITY	R = –0.229
PERIOD SINCE MVA	R = –0.101
FEAR OF NECK MOTION	R = –0.201
LEFT – ROM	R = 0.539**
RIGHT – ROM	R = 0.259

(* = P < 0.05 and ** = P < 0.01)

6.1.4 Stepwise Multiple Regression Analysis

Cervical extension strength and rotation strength data was analysed through a multiple regression analysis. Cervical extension strength data for both male and female consisted of age, height, weight, pain intensity, level of disability and isometric extension strength measurements. In the male population correlation coefficients (Pearson *r*) were not significant, except for a negative association between cervical extension strength and level of disability, $r = -0.592$ (P=0.001) (Table 6.1.4.1). The female population correlation coefficients were also not significant for the most part, with the exception of a moderate association between the intensity of pain and the level of disability, $r = 0.545$ (P=0.001) (Table 6.1.4.2).

Table 6.1.4.1 Stepwise Multiple Regression Analysis

Male Cervical Extension Strength

	N = 25	STRENGTH
Pearson Correlation	AGE	0.184
	HEIGHT	0.081
	DISABILITY	- 0.592**
	PAIN	- 0.134
	WEIGHT	0.375*

(* = P < 0.05 and ** = P < 0.01)

Table 6.1.4.2 Stepwise Multiple Regression Analysis

Female Cervical Extension Strength

	N = 33	STRENGTH
Pearson Correlation	AGE	0.141
	HEIGHT	0.175
	DISABILITY	- 0.157
	PAIN	- 0.272
	WEIGHT	0.394*

(* = P < 0.05 and ** = P < 0.01)

Similarly, data collected from both male and female cervical rotation strength were analysed for age, height, weight, pain intensity, level of disability, rotation strength, but also for fear of neck movement and cervical range of motion. Tables 6.1.4.3 and 6.1.4.4 summarise the associations between all these different variables. For the female population, the results did not show any significant associations amongst the variable analysed except as expected for left rotation strength and right rotation strength, $r = 0.935$ ($P<0.000$). The average rotation strength which consists of both left and right rotation strength showed a high degree of association (left; $r = 0.943$, $P<0.000$ and right; $r = 0.983$, $P<0.000$).

The male population revealed an association between the level of disability and pain intensity, $r = 0.766$ ($P<0.000$). Other positive but moderate associations are height and range of motion (left; $r = 0.651$, $P<0.000$ and right; $r = 0.514$, $P=0.005$) and level of disability associated with fear of neck movement ($r = 0.554$, $P=0.002$). Some negative associations but moderate exist between left rotation strength and level of disability ($r = -0.547$, $P=0.003$), age and pain intensity ($r = -0.531$, $P=0.004$), and finally, height and level of disability ($r = -0.544$, $P=0.003$).

Table 6.1.4.3 Correlation Coefficients for all Variables

Male Cervical Left Rotation Strength

	N = 24	Left – STRENGTH
Pearson Correlation	AGE	0.372*
	HEIGHT	0.383*
	DISABILITY	- 0.547**
	PAIN	- 0.463*
	WEIGHT	0.408*
	FEAR	- 0.449*
	LEFT – ROM	0.440*

(* = P < 0.05 and ** = P < 0.01)

Table 6.1.4.4 Correlation Coefficients for all Variables

Male Cervical Right Rotation Strength

	N = 24	Left – STRENGTH
Pearson Correlation	AGE	0.343
	HEIGHT	0.354*
	DISABILITY	- 0.525**
	PAIN	- 0.430*
	WEIGHT	0.331
	FEAR	- 0.361*
	RIGHT – ROM	0.404*

(* = P < 0.05 and ** = P < 0.01)

Table 6.1.4.5 Correlation Coefficients for all Variables

Female Cervical Left Rotation Strength

	N = 28	Left – STRENGTH
Pearson Correlation	AGE	- 0.221
	HEIGHT	0.141
	DISABILITY	- 0.336*
	PAIN	- 0.220
	WEIGHT	0.330*
	FEAR	- 0.147
	LEFT – ROM	0.536**

(* = P < 0.05 and ** = P < 0.01)

Table 6.1.4.6 Correlation Coefficients for all Variables

Female Cervical Right Rotation Strength

	N = 28	Right – STRENGTH
Pearson Correlation	AGE	- 0.177
	HEIGHT	0.099
	DISABILITY	- 0.366*
	PAIN	- 0.300
	WEIGHT	0.241
	FEAR	- 0.197
	RIGHT – ROM	0.250

(* = P < 0.05 and ** = P < 0.01)

Chapter 7

DISCUSSION

7.1 Results

Cervical strength testing has become a common practice amongst practitioners, despite the lack of current evidence as to its reliability. This study investigated two research hypotheses concerning the reliability of cervical isometric strength testing in subjects with mechanical neck pain and the relationship of several variables with maximal voluntary effort.

Hypothesis 1: Reliability of cervical strength testing. Test re-test reliability results of both cervical extension strength and cervical rotation strength testing were high; that is ICC = 0.95 (95% CI 0.9502-0.9477, $P < 0.0005$) and ICC = 0.97 (95% CI 0.9663-0.9645, $P < 0.0000$) for extension and rotation, respectively.

The precision of the reliability for cervical strength testing was set at 20% *a priori* as an acceptable within subject variability. The SEM was 23.48% for the cervical extension and 6.4% for cervical rotation strength measurements. The difference in the precision between the two types of cervical strength testing could be attributable to the wider range of torque produced during extension testing. For instance, extension torque varied from 9 to 506 NM while the rotation torque range was 4 to 233 NM.

Nevertheless, from these results, it would appear that both cervical extension and rotation strength testing are reliable amongst symptomatic subjects experiencing idiopathic neck pain. However, in this study cervical rotation strength measurements provided a more precise measurement with a variability of only 6.4%, well within the acceptable subject variability of 20%, while cervical extension strength testing variability was 23.48%, slightly above the acceptable 20%.

Hypothesis 2: Individual variabilities and maximal voluntary strength. It is reasonable to expect that optimal cervical strength is influenced by several factors such as neck pain intensity, level of disability, fear of neck movement and reduced cervical range of motion. Possibly other factors such as physical characteristics for a particular gender such as age, height and body weight could also influence cervical strength. The results from the female population suggest no relationship between the variables mentioned above and cervical strength testing in symptomatic subjects, with the exception of a significant correlation between the intensity of pain and the level of disability ($R=0.545$, $P=0.001$). Nonetheless, this correlation is only in the moderate range. This finding was also true for the male population, but with a higher correlation ($R=0.766$, $P<0.000$). Other significant correlations for the male population were height and cervical rotation range of motion (left; $R=0.651$, $P<0.000$ and right; $R=0.514$, $P=0.005$) and level of disability associated with fear of neck movement ($R=0.554$, $P=0.002$). Some moderate negative correlations exist between left rotation strength and level of disability ($R=-0.547$, $P=0.003$), age and pain intensity ($R=-0.531$, $P=0.004$). Height and level of disability appeared to have a negative effect on each other ($R=-0.544$, $P=0.003$). It is unclear on how taller individuals would report less disability than shorter people but the correlation coefficient was only in the moderate range.

7.2 Main Findings in Relation to the Literature

Reliability studies. The reliability coefficients are consistent with other studies. Leggett and his co-workers evaluated the reliability and variability of repeated measurements of isometric cervical extension strength in a asymptomatic population using MedX Equipment [2]. Although their reliability analysis was done using a Pearson product-moment correlation coefficient which has a tendency to overestimate reliability, the correlation coefficients ranged from 0.90 to 0.96, compared to the current study's result of an ICC=0.95 (95% CI, 0.9502-0.9477, $P < 0.0005$) for a symptomatic population. Similarly, Foster and his co-workers assessed the test-retest reliability of isometric cervical rotation strength on asymptomatic volunteers using MedX™ Equipment [1]. Their results showed a

Pearson product-moment correlation coefficients ranging between 0.86 to 0.98 which is in keeping with this study's reliability analysis of an ICC=0.97 (95% CI, 0.9663-0.9645, $P < 0.0000$). An important difference between the previous reliability studies and the current study is the selection of symptomatic subjects.

With regards to the precision of the reliability findings, both the Leggett and Foster's studies used the standard error of estimate (SEE) which is actually a measure of error in prediction and can underestimate the actual differences between trials. A better alternative is to calculate the standard error of measurement (SEM). Thus, Leggett et al. demonstrated a SEE of 7.4 to 10.2% compared to a SEM=23% for the precision of reliability for cervical extension strength testing. On the other hand, Foster et al. reported a SEE= 5 to 9% for cervical rotation testing comparable to a SEM=6%.

Therefore, test-retest reliability of both cervical extension and rotation isometric strength testing is very reliable; however, the results of cervical extension strength testing appear slightly over the 20% acceptable limit of variability during testing.

Nevertheless, since this 20% of within subject variability had been chosen arbitrarily, and since our analysis of 23% for within the cohort studied represents a small difference, it is not likely to warrant a change in current clinical practice. Therefore, both cervical extension and rotation isometric strength testing can be used reliably to assess symptomatic individuals.

Factors that can affect cervical strength. Several studies have indicated the difficulties in assessing muscular strength reliably and accurately: these difficulties are due to several different factors, which affect within subject variability. Factors such as fear of neck movement, pain intensity, lack of motivation, level of disability, reduced range of motion, psychological factors, age, and gender, to name a few, all play an important role in the reliability of strength testing. Unfortunately, these inherent factors are very difficult to control for or even to measure objectively.

In this study, some measurable variables, including neck pain intensity, fear of neck movement, level of self-perceived disability and cervical range of motion were assessed throughout testing to determine if any of these factors played a significant role in the assessment of cervical strength. Our regression analysis revealed a moderate association between the intensity of pain and the level of disability ($r = 0.545$, $P=0.001$) for the female population and a relatively stronger association for the male population ($r = 0.766$, $P<0.000$). This difference between the female and male population cannot be explained, but owing to the small sample size in both groups, it is difficult to make any firm conclusion. Nevertheless, it is reasonable that greater degrees of neck pain may cause or result in greater disability. No other studies were found for comparison.

7.3 Strengths of Study

Subjects. Contrary to other studies on cervical isometric strength testing, in this study the sample population consisted of symptomatic subjects experiencing mechanical neck pain. In most cases the onset of symptoms was attributed to a motor vehicle accident.

Normal distribution. The male and female population studied represented a wide range of variety in terms of pain intensity, level of disability, fear of neck movement, cervical range of motion and age. Therefore, the findings of this study can be generalized to a population experiencing chronic mechanical neck pain.

Appropriate statistical analysis. Test-retest reliability was calculated using intra-class correlation coefficient, which takes into account random error. The reliability of a test on its own has very little clinical merit unless it is accompanied by the precision of the results. Test-retest reliability was determined to be excellent for both cervical extension and rotation strength; however, the precision was poor for extension measurements.

Factors influencing strength. It was attempted to determine if some specific factors would play an important role in strength measurement. Except for pain intensity and neck disability, there were no significant correlations amongst the variables assessed and cervical strength.

7.4 Weakness of Study

Chronic subjects. The sample size consisted mainly of chronic neck pain subjects suffering from mechanical neck pain. A wider spectrum of neck conditions (i.e.: arthritis, post-surgical, and cervical disc lesions) was not included in this study. Also, subjects experiencing symptoms in their upper extremities were not included.

Small sample size. The sample size for both extension and rotation cohort study was insufficient for assessing the true effects of different variables on strength, such as level of pain intensity, fear of injury, level of disability, and cervical range of movement.

Location of neck pain. The fact that there was no attempt to determine if the location of the neck pain was either on the left or right side, could have influenced the overall reliability of cervical strength testing. Without knowledge of the side of neck pain it is not feasible to determine the degree of reliability of cervical strength testing for each side. In this current study the test-retest reliability results were good, which did not seem to be influenced by the location of neck pain.

Volunteer bias. All subjects were volunteers, so the individuals who did not want to take part in this study may represent a group of people very different from our cohort study. This factor could have altered our findings.

Environmental factor. Cervical range of motion was assessed in proximity to a Magnetic Resonance Imaging facility. As a result, the testing protocol had to be modified and adapted in consequence. This factor could have affected the reliability of cervical range of motion measurements.

Maximal effort. There were no objective measurements to determine if maximal effort was achieved during each trial. The use of a surface electro-myogram could have provided more indication of the degree of effort.

Chapter 8

CONCLUSION

The results of this study strongly indicate that cervical isometric strength testing for both rotation and extension can be used reliably in a clinical setting to assess cervical muscle strength with patients suffering from neck pain.

The precision of the reliability was acceptable for the cervical rotation strength testing but somewhat poor for the cervical extension strength testing, exceeding the acceptable 20 percent within subject variability. The lack of precision for cervical extension isometric strength may be attributable to the much higher level of strength exerted by the cervical extensors resulting in a greater range of variability of the measured strength.

This study did not assess the validity of cervical isometric strength testing. While an individual with neck pain may show reliable test results during cervical strength testing, these test results should not be interpreted as the individual's true cervical strength because there are no means of knowing if the individual produced his best effort during testing. As a result, there is a danger in categorizing someone either weak or normal based on cervical strength testing alone when there are many variables that could influence the test results. These variables include the intensity of pain, the fear of further injury, the level of self-perceived disability, the degree of motivation and overall attitude of the subject being tested, psychosocial issues, the degree of anxiety, the interaction of illness behaviour, the effects of medication, and the influence of on-going litigation.

In this study, a few variables were selected and measured. The severity of neck pain, fear of neck movement, level of disability and cervical range of motion showed no association with cervical isometric strength. However, a study with a larger sample that the current study is required to re-study the variables pain, fear, disability, and range of motion, all of which may play an important role in strength measurement.

CHAPTER 9

SUMMARY

9.1 Summary of Results and Discussion

The results of this study showed excellent test-retest reliability of both cervical extension and rotation isometric strength testing in a symptomatic population with mechanical neck pain. Precision of the reliability was adequate for cervical rotation strength measurements, though poor for extension measurements. This study demonstrated an association between pain intensity and level of self-perceived disability, especially for males and to a lesser degree for females.

9.2 Recommendations for Further Study

This study revealed a high degree of test-retest reliability amongst subjects experiencing chronic mechanical neck pain; however, it did not assess the validity and responsiveness of cervical strength testing. Although, cervical strength testing may be very reliable, it is very important to determine if the result of any single test reflects the true status of that particular individual in terms of muscular strength. Further studies are needed to evaluate the validity of cervical isometric strength testing.

Also, another study with a larger sample size should further assess the role of the different variables mentioned earlier and their relationships to muscular strength measurements. Further studies are needed to develop a regression model analysis to model strength.

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APPENDICES

APPENDICES

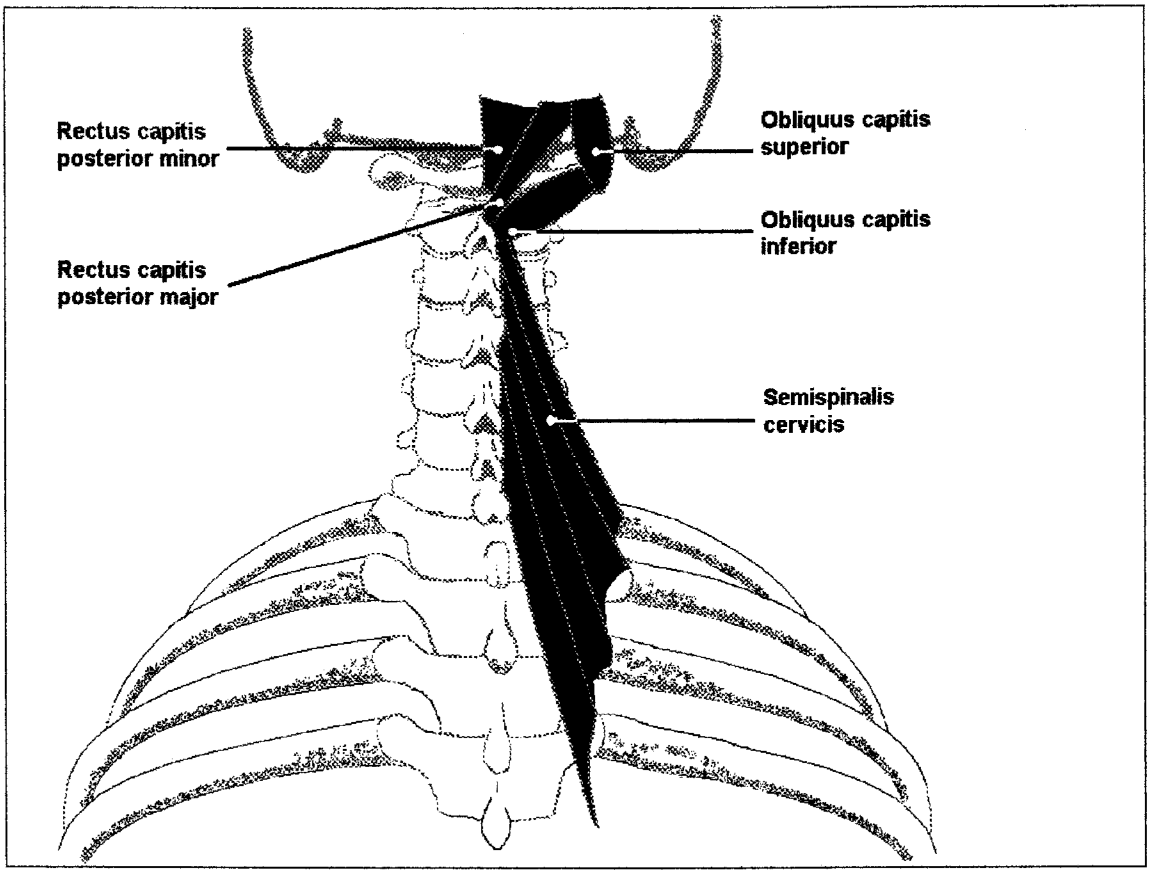
A) Protocol on Cervical Rotation Measurements.

The magnetic yoke is placed on the subject's shoulders with the arrow pointing north (in our case toward the MRI). Subject is instructed to sit erect in a straight-back chair with the sacrum against the back of the chair, the thoracic spine away from the back of the chair, arms hanging at sides and feet flat on the floor. The lateral flexion and sagittal plane meters must read zero for the rotation meter to be level; if necessary, assist the subject into the correct position. As the subject faces straight ahead, grasp the rotation meter between your thumb and index finger and turn the meter until one of the pointers is at zero.

Instruct the subject to focus on a horizontal line on the wall so the head is not tipped during rotation. Have the subject turn the head as far to the left as possible, and to ensure that no shoulder rotation occurs, lightly stabilize the right shoulder with your hand. (note; if the head and shoulders are rotated together the pointer will not move because the magnetic yoke positioned on the shoulders eliminates shoulder substitution.) While you lightly stabilize the left shoulder, instruct the subject to turn the head as far as possible to the right.

B) Postvertebral Muscles of the Neck

Deep Layer (Suboccipital Group):



Rectus capitis posterior major
Arises from the spinous process of the axis. Inserts into the occipital bone deep to the obliquus capitis superior and semispinalis capitis, below the inferior nuchal line. Extends and rotates the head on the neck towards the same side.

Rectus capitis posterior minor
Arises from the posterior tubercle of the atlas. Inserts into the occipital bone medial and deep to the insertion of the rectus capitis posterior major. Extends the head on the neck.

Obliquus capitis inferior
Originates from the spinous process of the axis and passes upward, laterally and forward. Inserts into the posterior aspect of the transverse process of the atlas. Rotates the head on the neck toward the same side.

Obliquus capitis superior
Arises from the transverse process of the atlas at the site of insertion of the inferior oblique muscle, and passes backward, upward, and somewhat medially. Inserts into the occipital bone between the superior and inferior nuchal lines, lateral to the semispinalis. Extends the head on the neck.

Semispinalis cervicis
Arises from the transverse processes of the upper thoracic and the articular processes of the lower cervical vertebrae. Inserts into the spinous porcesses of the cervical vertebrae. Extends the cervical spine.

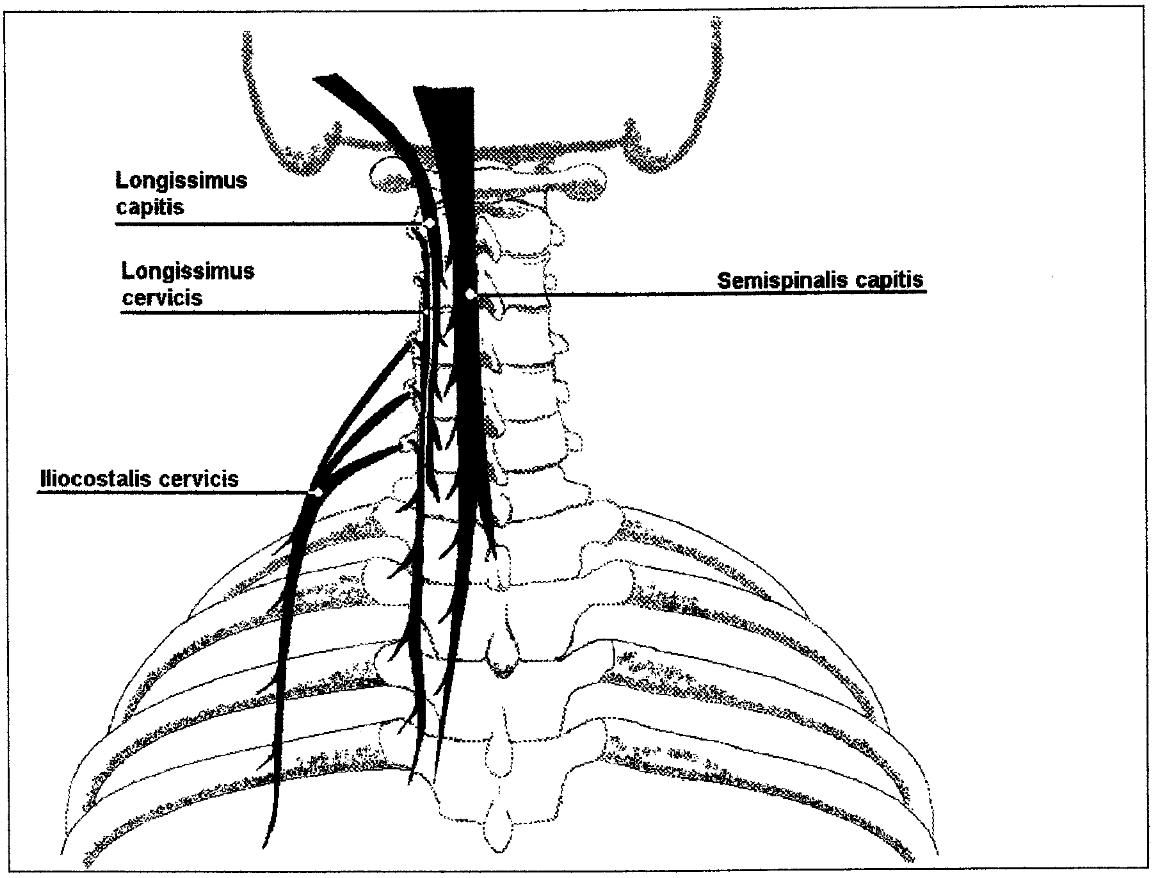
Deepest Layer:
Interspinales
They are short and insignificant bands extending from one spinous process to the next, lying on either side of the interspinous ligament. They are best developed in the cervical and lumbar regions. Probably act as extensile ligaments.

Intertransverasii
Small muscles extending between the transverse processes in the cervical and lumbar regions. In the cervical portion of the column they lie both anterior and posterior to the emerging ventral rami of the spinal nerves. Probably act as extensile ligaments.

Multifidus
Lies in the furrow between the spinous processes of all the vertebrae and their transverse processes, from the dorsal surface of the sacrum to the axis. Extends, laterally flexes and rotates the cervical spine, however, its main function is to stabilize the vertebral column.

Rotatores
Represent the deepest layer of the multifidus muscles and usually poorly developed in the cervical spine. They arise from the transverse process of one vertebra. Insert into the lamina of the vertebra directly above it. Rotary movements of the vertebral column but mostly they play a role as extensile ligaments.

Intermediate Layer:
Ilicostalis cervicis
Originates from the upper six ribs. Inserts into the posterior tubercles of the transverse process of the lower cervical vertebrae. Plays a minor role in extension, lateral flexion and rotation of the cervical spine on the same side.



Longissimus cervicis
Originates from the transverse processes of the upper six thoracic vertebrae, medial to the insertions of the longissimus thoracic. Inserts into the posterior tubercles of the transverse processes of all cervical vertebrae except the first and the seventh. It lies deep to the iliocostalis cervicis. Plays a small role in extension, lateral flexion and rotation of the cervical spine on the same side.

Longissimus capitis
Originates from the transverse processes of the upper thoracic vertebrae, in common with longissimus cervicis, and also from the articular processes of the lower four cervical vertebrae. Inserts into the posterior aspect of the mastoid process, deep to splenius capitis. Extends and laterally flexes the skull on the neck, and rotates the face to the same side.

Superficial Layer:
Spinalis capitis
It is the most medial part of the semispinalis capitis which may be attached to some of the lower cervical spinous processes. Contributes to extension of the head on the neck.

Splenius capitis
Arises from the lower part of the ligamentum nuchae, and from the spinous process of the seventh cervical and the upper three or four thoracic vertebrae. Inserts into the posterior aspect of the mastoid process and the lateral part of the superior nuchal line, deep to the attachement of the sternocleido mastoid. Acting together they extend the head and neck; when one acts individually, it extends the head and neck, laterally flexes the neck, and turns the face to the same side.

Splenius cervicis
Arises in common with the splenius capitis, but rather lower down, from the spinous processes of the third to the sixth thoracic vertebrae. Inserts into the posterior tubercles of the transverse processes of the upper three or four cervical vertebrae. Acting together they help extend the neck; when one acts individually, it laterally flexes and slightly rotates the cervical portion of the vertebral column to the same side.

Semispinalis capitis
Originates from the tips of the transverse processes of the upper six thoracic and the articular processes of the lower four cervical vertebrae. Inserts into the medial impression between the superior and inferior nuchal lines of the occipital bone. The most powerful extensor of the head on the neck, and is a strong postural muscle preventing flexion at the atlanto-occipital joint.

Most Superficial Layer:
Trapezius
Originates from the medial third of the superior nuchal line of the occipital bone, the external occipital protuberance, the ligamentum nuchae, the spinous processes of the seventh cervical and all the thoracic vertebrae, and the intervening supraspinous ligaments. Inserts into the posterior border of the lateral third of the clavicle, the medial border of the acromion, the upper border of the crest of the spine of the scapula, and the tubercle on this crest. Although it originates from the ligamentum nuchae in the cervical spine, the main function of the upper fibres is to pull the shoulder girdle up towards the skull (shoulder shrug) rather than directly acting on the neck.

Levator scapulae
Arises from the posterior tubercles of the transverse processes of the first three or four cervical vertebrae posterior to scalenus medius. Inserts on the medial margin of the scapula between the superior angle and the spine. Elevates the scapula and helps to retract it. Thus, it has very little function on the cervical spine,unless when the scapula is stabilized it helps to laterally flex the neck on the same side.

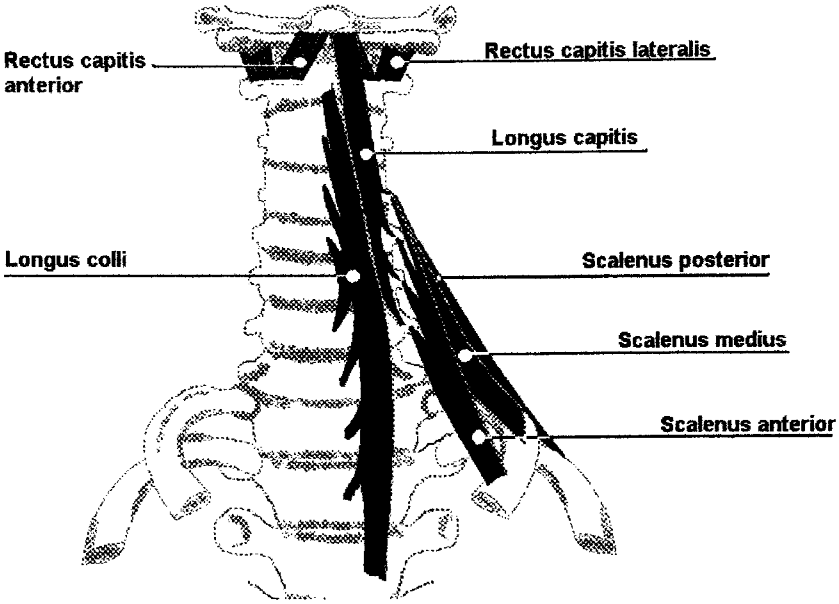
Lateral Muscles of Neck:
Sternocleidomastoid
It has two heads of origin (sternal and clavicular). The sternal head arises from the anterior surface of the manubrium sterni, and the broad clavicular head from the upper surface of the clavicle in its medial third. The clavicular head originates from the superior medial one third of the clavicle and passes deep to the sternal head. The clavicular head passes deep to the sternal head, and the united muscle is inserted into the outer surface of the mastoid process and into the lateral third of the superior nuchal line of the occipital bone. Tilts the head towards the same side and rotates it turning the face to the opposite side and upwards. The anterior fibres flex the head on the neck at the atlanto-occipital joint. The posterior fibres may extend the atlanto-occipital joint.

Scalenus anterior
Arises from the anterior tubercles of the transverse processes of the third to the sixth cervical vertebrae. Inserts into the scalene tubercle on the first rib. Helps to produce lateral flexion of the neck.

Scalenus medius
Arises from the posterior tubercles of the transverse processes of all the cervical vertebrae. Inserts into a rough impression on the first rib behind the groove for the subclavian artery. Helps to produce lateral flexion of the neck. Helps to produce lateral flexion of the neck.

Scalenus posterior
Arises behind the scalenus medius from the posterior tubercles of the fourth, fifth, and sixth cervical transverse processes. Inserts into the outer side of the second rib posterior to the origin of serratus anterior. Helps to produce lateral flexion of the neck.

Prevertebral Neck Muscles:
Longus colli
Arises from the anterior tubercle of the atlas and from the fronts of the bodies of the upper cervical vertebrae, as well as the transverse processes of the fifth and sixth cervical vertebrae. Inserts on the fronts of the bodies of the upper thoracic and lower cervical vertebrae, as well as the transverse processes of the third, fourth and fifth cervical vertebrae. Bends the neck forward and may help to produce lateral flexion.



Longus capitis

Arises from the basilar part of the occipital bone. Inserts on the transverse processes of the middle three or four cervical vertebrae. Flexes the head and the upper part of the cervical spine against resistance.

Rectus capitis anterior

Originates from the basilar part of the occipital bone between the longus capitis and the occipital condyle. Inserts on the anterior surface of the lateral mass of atlas. Flexes the head on the neck and stabilizes the atlanto-occipital joint during movements.

Rectus capitis lateralis

Arises from the inferior surface of the jugular process of the occipital bone. Inserts on the transverse process of the atlas. Bends the head to the same side and stabilizes the atlanto-occipital joint.

C) RELIABILITY ANALYSIS – CERVICAL EXTENSION STRENGTH

Analysis of Variance (Repeated Mesures)

Source of Variation	Sum of Sq.	DF	Mean Square	F	Prob.
Between People	7738589.8090	376	20581.3559		
Within People	407732.5000	377	1081.5186		
Between Measures	12835.9695	1	12835.9695	12.2217	0.0005
Residual	394896.5305	376	1050.2567		
Total	8146322.3090	753	10818.4891		
Grand Mean 211.5159					

Reliability Coefficients 2 items

Alpha coefficient = 0.9490 Standardized item alpha = .9515

Intra-Class Coefficient (model C)
ICC = BMS - EMS / BMS = 20581.3559 - 1050.2567 / 20581.3559 =
ICC = 0.9490

95% Confidence Interval:
FO = 20581.3559 / 1050.2567 = 19.5965
FL = 19.5965 / 0.975 (constant) = 20.0990 (376,376)
FU = 19.5965 x 0.975 (constant) = 19.1066 (376, 376)

$$1 - 1/20.10 < ICC < 1 - 1/19.11$$
$$1 - 0.0498 < ICC < 1 - 0.0523$$
$$0.9502 < ICC < 0.9477$$

Effect Size = SSb / SStotal = 7738589.8090 / 8146322.3090 = 0.950

ICC = 0.9490 95% CI (0.9502, 0.9477)

Standard Error of Measurement (SEM)

$$SEM = \sigma \sqrt{(1 - R)} \qquad (R = 0.9490)$$

σ = pooled deviation of trial #2 & #3

$$\sigma = \sqrt{(SD\#2 + SD\#3)^2 / 2} \qquad SD\#2 = 98.6030 \qquad SD\#3 = 109.1286$$

$$\sigma = \sqrt{(98.6030)^2 + (109.1286)^2 / 2}$$
$$\sigma = \sqrt{9722.55 + 11909.05 / 2}$$
$$\sigma = \sqrt{10815.8} = 103.999$$

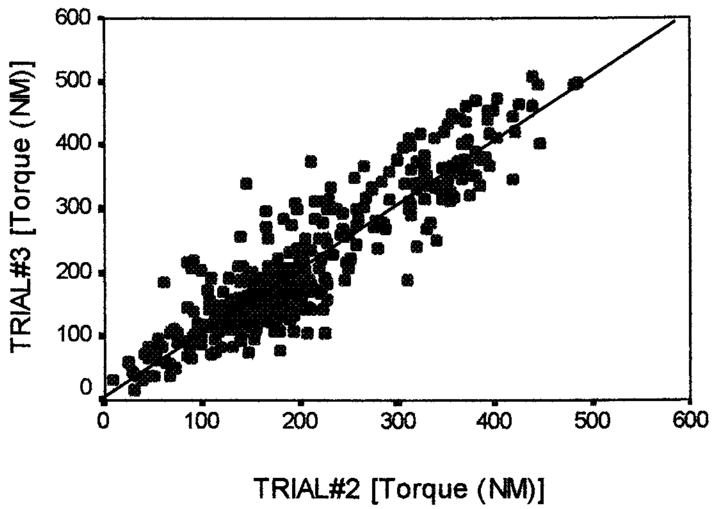
$SEM = 103.999 \sqrt{(1 - 0.9490)} =$ **23.48% (Precision of Cervical Extension Strength Measurements)**

D) SCATTER DIAGRAM & STATISTICAL FREQUENCIES

Test-Retest Reliability (Scatter Diagram)

Cervical Extension Strength Measurements

Trial #2 vs Trial #3



Statistics

	N Valid	N Missing	Mean	Mean Std. Error	Median	Std. Deviation
TRIAL#2	377	0	207.3899	5.0783	184.0000	98.6030
TRIAL#3	377	0	215.6419	5.6204	181.0000	109.1286

	Variance	Range	Minimum	Maximum
TRIAL#2	9722.5523	476.00	9.00	485.00
TRIAL#3	11909.0603	491.00	15.00	506.00

Wt = Weight in pounds
Ht = Height in inches
MVA = Number of months since motor vehicle accident
ND2 = Results of 2nd Neck Disability Questionnaire
P1 = Results of 1st Visual Analogue Scale for Pain "at the moment"
P1U = Results of 1st Visual Analogue Scale for Pain "usually"
P2 = Results of 2nd Visual Analogue Scale for Pain "at the moment"
P2U = Results of 2nd Visual Analogue Scale for Pain "usually"
St = Average Cervical Extension Strength

E) CERVICAL EXTENSION STRENGTH DATA

	Age	Sex	Wt	Ht	MVA	ND1	ND2	P1	P1U	P2	P2U	St
1	47	F	206	59	--	62	60	72	62	74	76	186
2	38	F	125	65	2	9	12	1	2	5	2	200
3	33	F	130	65	33	48	46	18	58	34	31	161
4	45	F	160	64	126	18	26	25	43	35	50	149
5	31	F	215	68	72	20	20	3	30	3	32	200
6	46	F	150	67	--	20	0	3	5	1	35	154
7	32	F	138	64	9	12	10	32	47	29	30	197
8	49	F	161	63	15	40	40	3	95	52	89	159
9	47	F	157	63	7	26	26	28	37	37	31	179
10	34	F	150	67	22	10	14	52	64	60	50	104
11	35	F	135	67	17	44	38	49	53	23	52	180
12	29	F	198	65	36	30	26	22	25	50	28	151
13	58	F	180	63	420	4	4	22	11	12	23	169
14	42	F	100	62	36	30	24	51	55	70	56	151
15	22	F	125	64	11	38	38	80	54	37	60	68
16	56	F	131	62	--	6	6	2	36	0	71	191
17	36	F	135	66	2	16	18	18	48	35	19	156
18	49	F	165	62	26	30	38	82	61	23	50	168
19	47	F	162	66	24	24	20	11	53	29	49	125
20	61	F	170	65	14	16	18	11	35	25	45	116
21	20	F	155	66	25	38	44	54	23	92	23	146
22	49	F	128	62	8	40	40	49	57	48	66	48
23	40	F	164	63	276	46	38	47	77	30	88	122
24	18	F	95	63	12	12	12	29	44	13	42	77
25	26	F	141	66	45	30	32	32	61	81	43	125
26	22	F	187	72	12	34	34	69	56	55	67	200
27	?	F	164	62	12	0	2	2	17	1	14	180
28	28	F	155	63	12	40	40	60	53	70	53	130
29	21	F	163	65	4	28	28	48	34	62	31	163
30	24	F	125	66	8	14	16	2	43	3	60	160
31	18	F	115	66	4	30	20	60	43	24	42	101
32	32	F	140	68	--	0	4	0	0	10	0	178
33	41	F	150	66	--	30	30	8	80	8	81	130
34	31	F	145	67	18	28	24	1	25	2	14	152
35	29	F	138	67	3	46	?	37	45	?	?	?
36	62	M	220	70	--	26	12	24	53	17	51	320
37	40	M	250	71	--	14	16	0	38	2	44	395
38	25	M	185	73	7	48	52	15	25	48	23	230
39	29	M	188	71	18	34	38	30	40	39	38	297
40	26	M	155	68	14	44	32	42	38	29	21	264
41	27	M	220	72	18	26	18	38	46	21	30	360
42	24	M	230	70	36	56	56	54	68	73	67	326
43	28	M	185	73	21	50	52	8	80	4	79	195
44	41	M	185	69	192	6	6	2	35	3	45	361
45	34	M	170	66	12	56	74	68	76	89	69	99
46	52	M	212	69	33	48	56	2	62	72	54	234
47	36	M	225	71	24	40	38	7	28	16	5	357
48	58	M	209	70	--	28	26	76	59	66	55	260
49	39	M	230	68	28	16	22	16	17	20	17	236
50	26	M	165	69	9	8	10	4	14	6	17	324
51	36	M	170	65	11	16	18	22	31	43	21	331
52	56	M	170	70	--	2	4	0	2	4	2	331
53	22	M	155	70	12	36	36	24	24	6	23	161
54	22	M	155	70	10	28	30	24	35	36	37	262
55	21	M	218	73	6	16	12	71	58	32	63	388
56	64	M	200	65	10	34	46	49	65	67	56	384
57	57	M	208	72	--	18	10	75	76	14	74	285
58	39	M	187	66	2	14	10	56	49	31	53	348
59	46	M	168	72	--	12	8	1	7	0	2	390
60	55	M	165	70	168	30	?	28	37	?	?	256

F) RELIABILITY ANALYSIS – CERVICAL ROTATION STRENGTH

Analysis of Variance (Repeated Measures)

Source of Variation	Sum of Sq.	DF	Mean Square	F	Prob.
Between People	687013.3654	300	2290.0446		
Within People	28793.0000	301	95.6578		
Between Measures	5029.2359	1	5029.2359	63.4904	0.0000
Residual	23763.7641	300	79.2125		
Total	715806.3654	601	1191.0256		
Grand Mean 54.7708					

Reliability Coefficients 2 items

Alpha coefficient = 0.9654 Standardized item alpha = 0.9658

Intra-Class Coefficient (model C)
ICC = BMS - EMS / BMS = 2290.0446 - 79.2125 / 2290.0446 = 0.9654
ICC = 0.9654

95% Confience Interval:
FO = 2290.0446 / 79.2125 = 28.9101
FL = 28.9101 / 0.975 (constant) = 29.6514 (300,300)
FU = 28.9101 x 0.975 (constant) = 28.1873 (300,300)

$$1 - 1/29.65 < ICC < 1 - 1/28.19 =$$
$$1 - 0.0337 < ICC < 1 - 0.0355 =$$
$$0.9663 < ICC < 0.9645$$

Effect Size = SSb / SStotal = 687013.3654 / 715806.3654 = 0.960

ICC = 0.9654 95% CI (0.9663, 0.9645)

Standard Error of Measurement (SEM)

$$SEM = \sigma \sqrt{(1 - R)} \qquad (R = 0.9654)$$

σ = pooled deviation of trial #2 & #3

$$\sigma = \sqrt{(SD\#2 + SD\#3)^2 / 2}$$

SD Trial #2 = 33.6931 SD Trial #3 = 35.1288

$$\sigma = \sqrt{(33.6931)^2 + (35.1288)^2 / 2}$$
$$\sigma = \sqrt{1135.225 + 1234.0326 / 2}$$
$$\sigma = \sqrt{1184.6288} = 34.4184$$

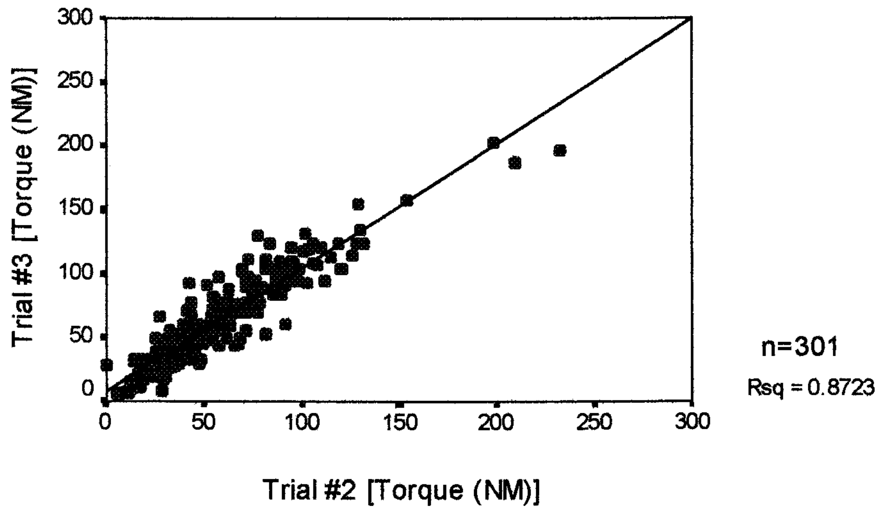
SEM = 34.4184 $\sqrt{(1 - 0.9654)}$ = **6.4% (Precision of Cervical Rotation Strength Measurements)**

G) SCATTER DIAGRAMS OF LEFT AND RIGHT CERVICAL ROTATION

Test-Retest Reliability (Scatter Diagram)

Left Cervical Rotation Strength Measurements

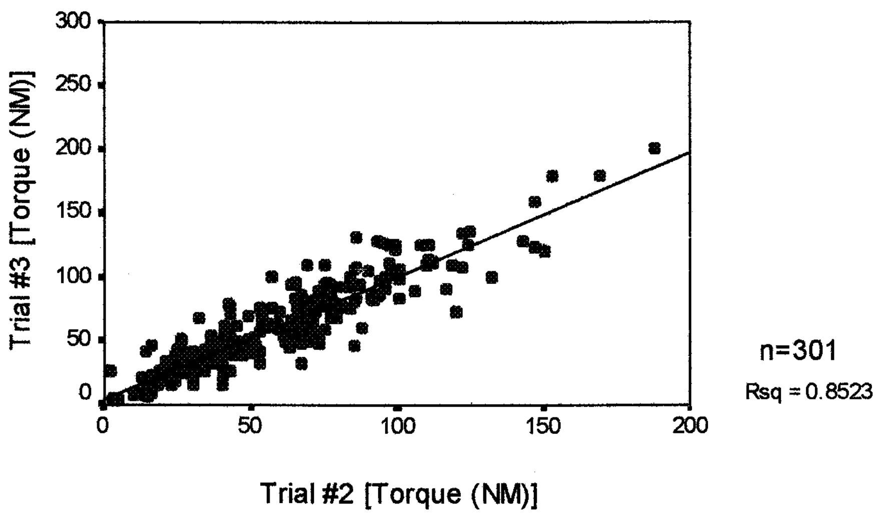
Trial #2 vs Trial #3



Test-Retest Reliability (Scatter Diagram)

Right Cervical Rotation Strength Measurements

Trial #2 vs Trial #3



H) CERVICAL ROTATION STRENGTH DATA

Nd1 = Results of 1st Neck Disability Questionnaire
Nd2 = Results of 2nd Neck Disability Questionnaire
P1 = Results of 1st Visual Analogue Scale for Pain "at the moment"
P2 = Results of 2nd Visual Analogue Scale for Pain "at the moment"
F1 = Results of 1st Visual Analogue Scale for Fear "at the moment"
F2 = Results of 2nd Visual Analogue Scale for Fear "at the moment"
Rr1 = Right rotation on day 1
Rr2 = Right rotation of day 2
Lr1 = Left rotation of day 1
Lr2 = Left rotation of day 2
Mva = Number of months since motor vehicle accident
F1u = Results of 1st Visual Analogue Scale for Fear "usually"

	Nd1	Nd2	P1	P2	F1	F2	Rr1	Rr2	Lr1	Lr2	mva	F1u
1	2	56	37	52	40	6	60	58	60	60	12	37
2	50	50	44	43	19	25	50	48	50	54	10	25
3	30	42	5	11	2	6	58	62	58	54	12	4
4	12	12	13	4	7	4	60	50	62	68	--	20
5	48	48	62	60	17	60	48	50	55	60	30	78
6	24	14	38	17	19	4	60	56	60	70	3	8
7	18	16	15	4	2	2	70	74	54	74	8	8
8	28	18	20	2	0	0	74	80	64	68	4	0
9	42	34	68	46	2	2	56	50	54	54	2	2
10	30	26	0	7	30	15	68	68	72	72	5	29
11	44	42	76	35	75	54	?	?	?	?	33	75
12	20	10	6	3	0	0	64	64	64	64	2	0
13	28	30	47	30	0	0	60	60	60	60	58	0
14	26	?	13	?	33	?	70	64	70	70	19	34
15	60	52	74	63	51	66	60	48	48	50	2	51
16	54	62	57	66	58	62	48	46	48	40	18	57
17	30	18	21	20	30	17	70	76	78	80	12	21
18	32	26	3	5	0	0	60	60	68	62	33	20
19	28	22	63	23	33	15	60	54	70	64	4	35
20	18	14	19	9	1	1	80	84	80	80	--	4
21	14	10	10	9	3	4	52	58	70	74	4	11
22	18	?	7	?	3	?	50	?	60	?	78	3
23	22	22	25	22	0	0	64	68	60	68	13	0
24	52	50	17	8	21	5	50	60	50	58	22	12
25	14	18	10	22	0	1	68	68	62	64	204	0
26	40	40	65	83	70	66	64	62	68	60	8	51
27	16	18	16	12	4	10	62	72	70	74	--	15

28	36	40	15	15	11	34	38	30	40	40	6	35
29	10	12	0	15	0	1	72	78	68	68	12	0
30	44	38	44	63	58	35	70	78	70	80	5	51
31	26	24	50	32	4	9	60	70	58	60	20	6
32	22	20	40	4	0	0	70	68	70	68	--	0
33	22	16	26	23	23	25	60	70	80	90	--	21
34	36	28	63	46	2	19	62	58	68	64	--	2
35	12	16	0	1	1	0	60	64	60	68	12	5
36	24	18	1	0	20	15	56	60	52	62	72	20
37	14	8	14	2	1	6	78	72	70	72	--	7
38	20	20	9	20	1	1	72	72	72	70	--	1
39	4	4	0	0	0	0	70	78	72	78	--	0
40	20	20	15	13	0	0	64	70	60	64	--	0
41	18	14	5	10	0	0	66	72	70	82	--	0
42	38	38	20	27	0	0	68	50	50	50	48	14
43	28	24	31	24	4	3	68	60	74	68	96	3
44	12	6	4	2	35	26	66	66	70	76	--	34
45	22	22	17	25	24	17	48	52	48	52	--	23
46	22	18	66	46	43	39	60	60	60	68	--	40
47	6	2	2	0	0	0	70	72	74	78	--	0
48	26	18	44	34	1	0	68	74	72	74	--	1
49	16	10	18	14	6	1	70	54	60	52	--	6
50	20	22	8	14	1	1	50	60	50	60	--	22
51	12	12	10	0	3	0	72	66	72	72	200	3
52	22	?	24	?	20	?	40	42	50	52	48	20
53	40	28	37	37	8	34	68	66	72	80	48	8
54	24	28	55	67	26	48	62	62	68	54	--	20
55	28	?	17	?	3	?	62	?	54	?	--	23

F2u = Results of 2nd Visual Analogue Scale for Fear "usually"
P1u = Results of 1st Visual Analogue Scale for Pain "usually"
P2u = Results of 2nd Visual Analogue Scale for Pain "usually"
Ars = Average right strength for day 1 and day 2
Als = Average left strength for day 1 and day 2
Rs1 = Average right strength for day 1
Rst = Average right strength for day 2
Ls1 = Average left strength for day 1
Lst = Average left strength for day 2
Wt = Weight in pounds

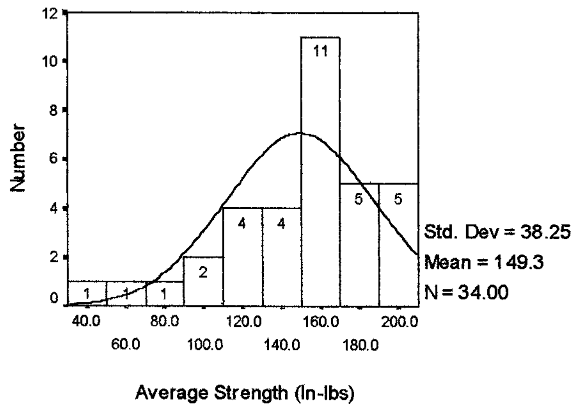
	F2u	P1u	P2u	Ars	Als	Rs1	Rs2	Ls1	Ls2	Age	Sex	Wt
1	18	45	35	9	12	12	7	11	12	60	F	117
2	27	36	41	34	34	32	36	39	28	39	M	180
3	12	37	22	75	75	73	76	64	86	65	M	210
4	10	42	38	29	29	24	39	24	35	40	F	?
5	79	99	100	4	6	4	4	6	6	21	F	145
6	8	30	13	18	19	15	21	17	20	30	F	162
7	2	16	10	69	66	65	72	62	70	37	M	166
8	0	18	38	37	36	37	37	33	40	27	F	134
9	2	51	66	48	42	34	62	30	54	25	M	160
10	18	4	4	21	22	21	20	19	23	32	F	185
11	64	46	50	29	30	35	24	30	30	35	F	145
12	0	6	3	138	144	131	145	142	146	55	M	190
13	0	32	44	38	37	29	35	32	41	35	F	180
14	?	48	?	44	42	42	41	36	47	39	F	125
15	66	55	64	20	19	19	25	25	12	30	F	200
16	48	61	53	34	16	26	40	16	16	34	M	170
17	22	25	22	52	50	59	45	56	43	35	F	175
18	1	41	23	24	24	26	22	25	22	44	F	181
19	39	45	37	25	34	25	25	31	36	27	F	175
20	2	24	9	65	53	63	68	42	55	25	F	160
21	7	11	10	66	53	64	67	51	55	41	F	225
22	?	7	?	?	?	41	?	44	?	37	M	165
23	0	56	44	31	36	27	34	34	38	48	F	185
24	13	47	24	67	61	68	66	50	71	43	F	185
25	0	10	16	90	83	92	87	82	84	41	M	145
26	50	62	60	48	40	45	50	41	38	46	F	220
27	26	34	29	95	105	103	87	103	107	41	M	205
28	29	43	50	62	67	73	50	80	53	53	M	180
29	0	0	0	57	49	55	58	47	51	37	F	175
30	34	77	47	66	45	63	69	46	43	19	M	145
31	8	51	55	34	33	31	38	34	32	23	F	140
32	0	45	74	40	34	38	42	31	36	25	F	135
33	23	24	19	50	48	49	51	46	49	50	F	190
34	5	50	48	68	57	65	70	48	66	27	F	170
35	6	3	7	70	70	61	78	56	83	37	M	200
36	14	20	11	31	24	29	33	23	25	36	F	190
37	6	19	13	71	65	75	66	70	60	39	M	145
38	1	13	7	93	80	88	98	74	85	31	M	190
39	0	0	0	54	48	59	49	45	51	22	F	145
40	1	28	28	30	25	29	30	22	27	54	F	152
41	0	29	18	37	30	35	39	29	30	52	F	125

42	28	17	25	10	10	12	7	11	8	57	F	170
43	3	34	18	37	37	39	35	38	36	29	F	135
44	24	66	1	69	74	65	72	67	80	50	M	172
45	18	22	21	88	66	86	90	67	65	61	M	210
46	37	64	63	33	18	22	34	13	31	53	F	145
47	0	0	1	81	88	64	98	82	93	38	M	220
48	0	19	10	83	81	81	85	77	85	37	M	165
49	17	17	14	97	100	98	96	99	100	42	M	250
50	18	37	31	70	69	55	84	54	83	31	M	150
51	0	20	1	103	90	110	97	92	88	36	M	175
52	?	33	?	91	82	78	103	75	89	47	M	200
53	11	32	15	77	85	80	74	81	88	34	M	205
54	50	50	49	83	80	78	88	77	82	23	M	180
55	?	53	?	?	?	?	?	?	?	45	M	190

I) FEMALE POPULATION DISTRIBUTION

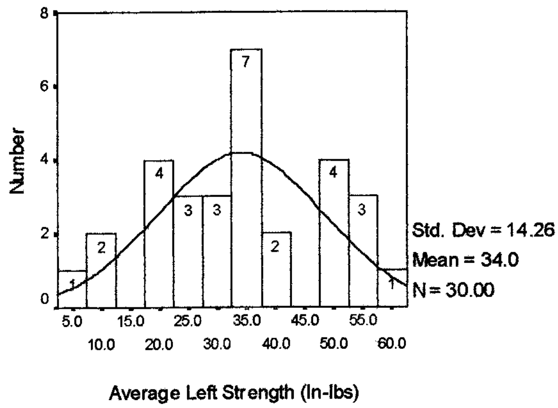
Cervical Extension

Female Average Strength Distribution



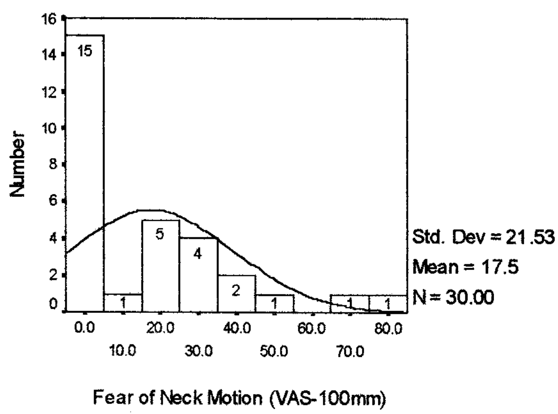
Cervical Rotation

Female Average Left Strength Distribution



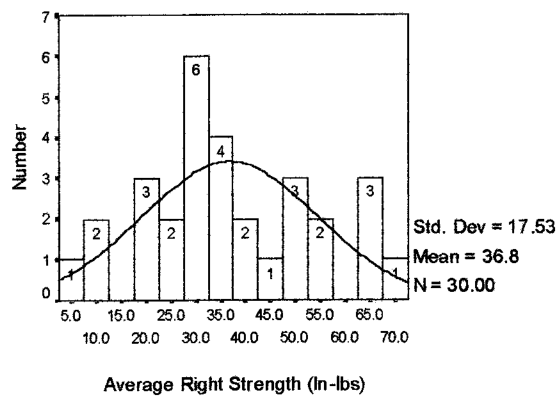
Cervical Rotation

Female Fear of Neck Motion Distribution



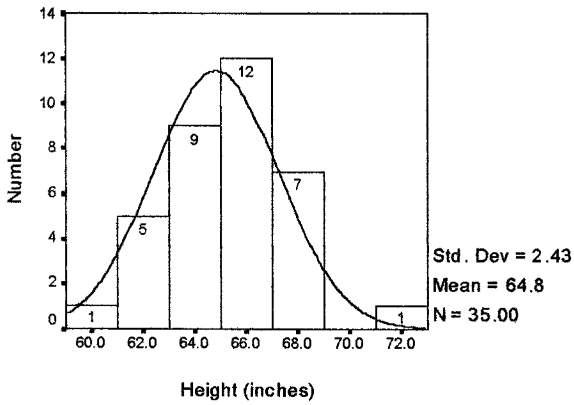
Cervical Rotation

Female Average Right Strength Distribution



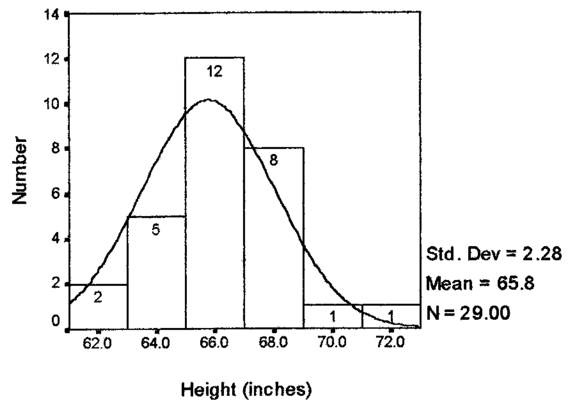
Cervical Extension

Female Height Distribution



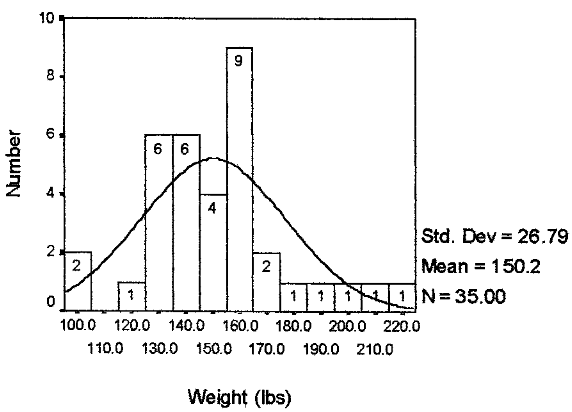
Cervical Rotation

Female Height Distribution



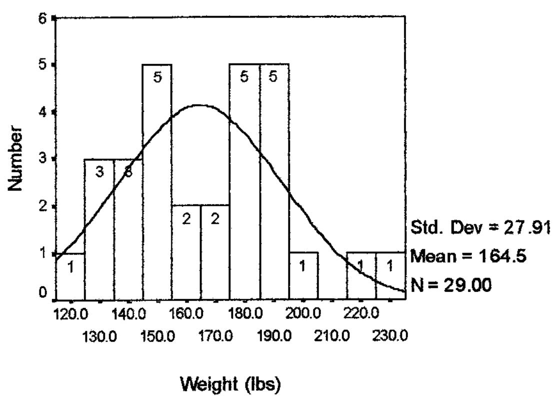
Cervical Extension

Female Weight Distribution



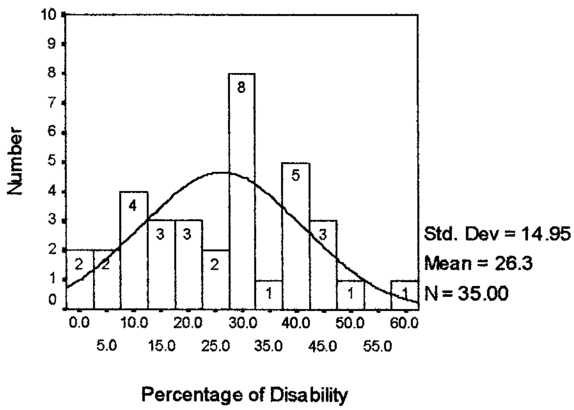
Cervical Rotation

Female Weight Distribution



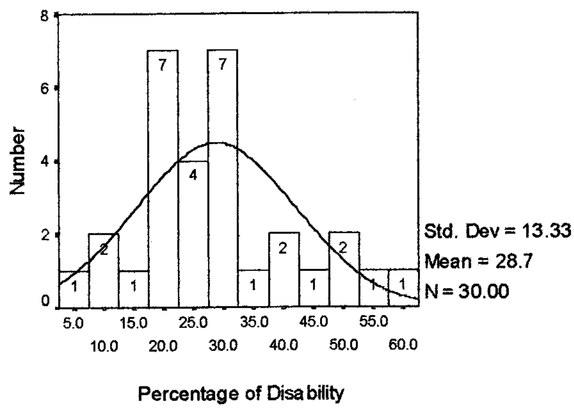
Cervical Extension

Female Disability Distribution



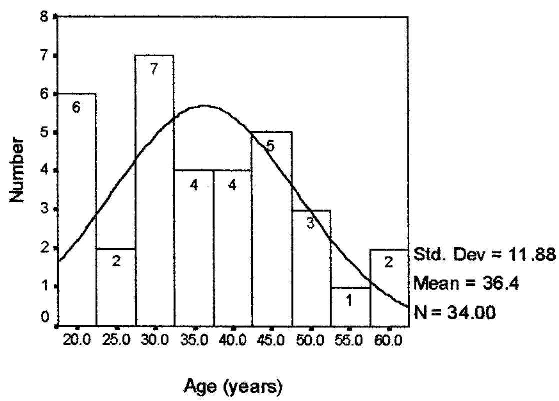
Cervical Rotation

Female Disability Distribution



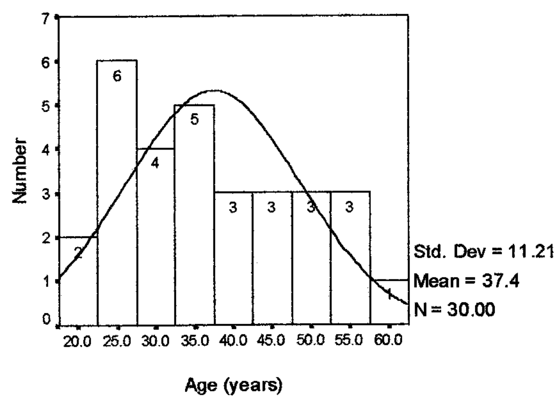
Cervical Extension

Female Age Distribution



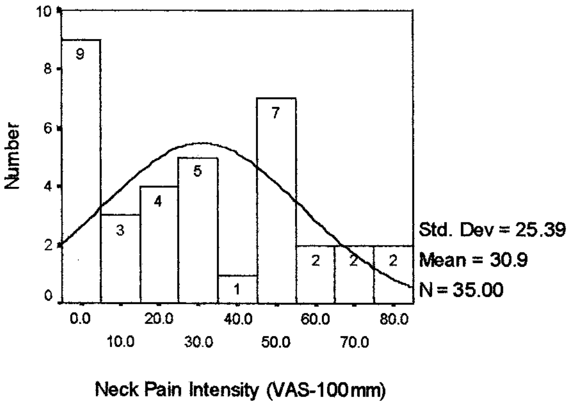
Cervical Rotation

Female Age Distribution



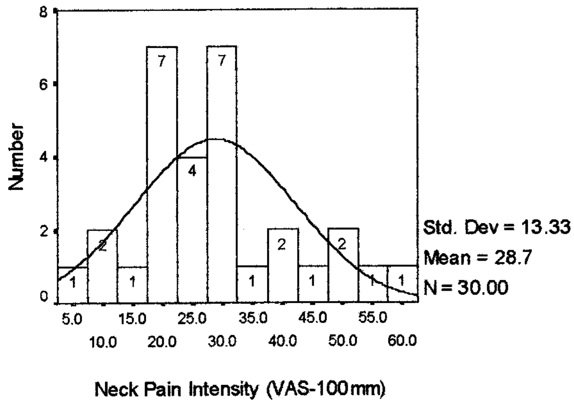
Cervical Extension

Female Neck Pain Intensity Distribution



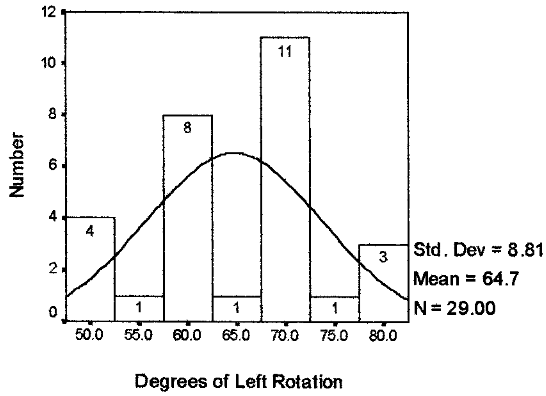
Cervical Rotation

Female Neck Pain Intensity Distribution



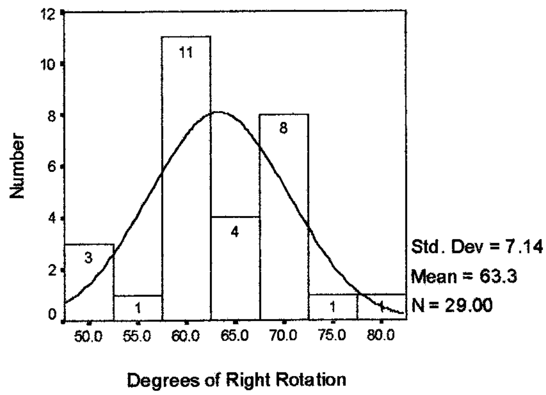
Cervical Rotation

Female Left ROM Distribution



Cervical Rotation

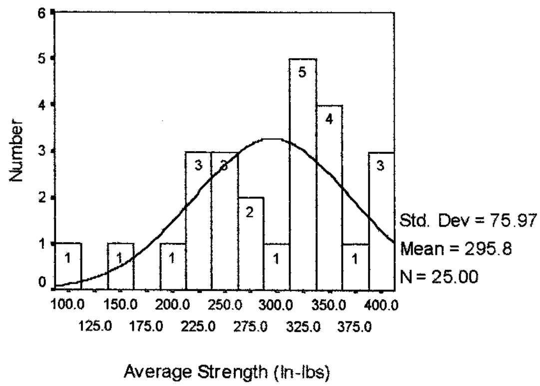
Female Right ROM Distribution



J) MALE POPULATION DISTRIBUTION

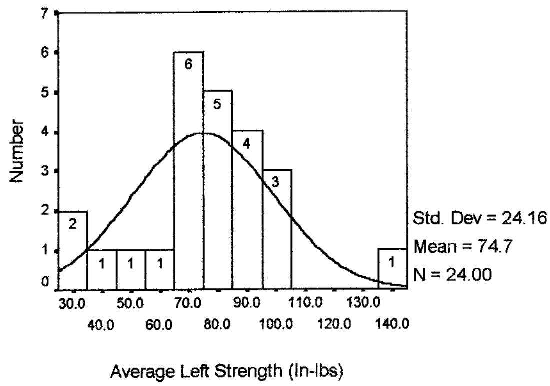
Cervical Extension

Male Average Strength Distribution



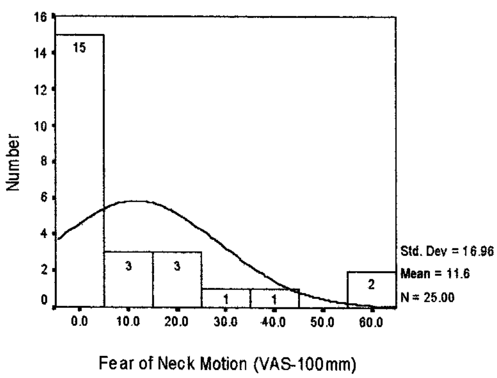
Cervical Rotation

Male Average Left Strength Distribution



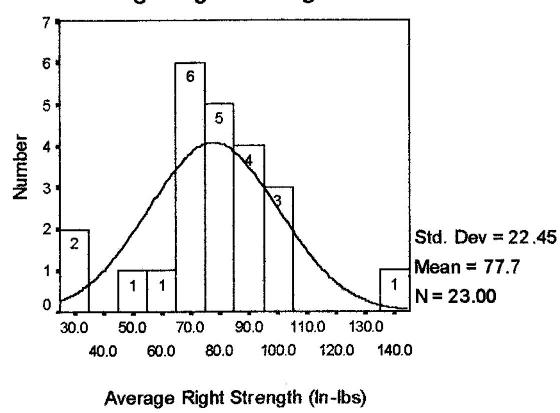
Cervical Rotation

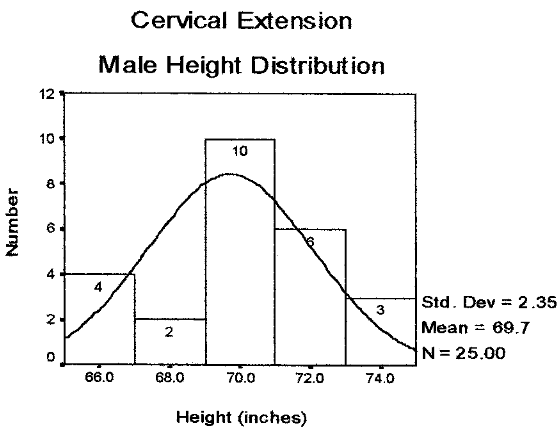
Male Fear of Neck Motion Distribution

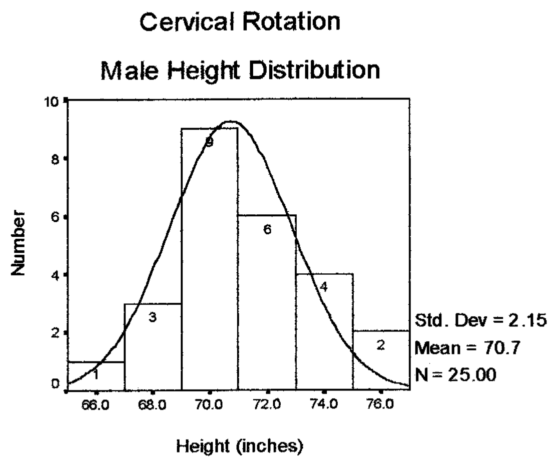


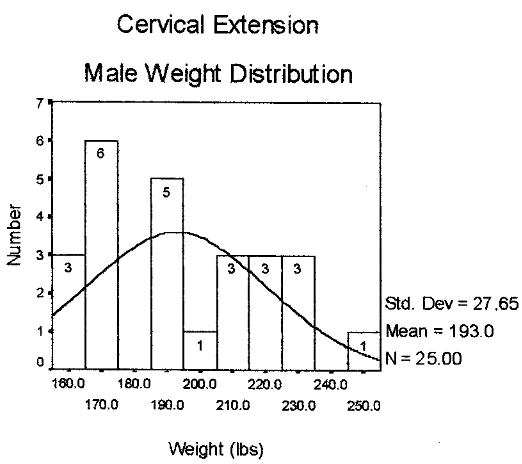
Cervical Rotation

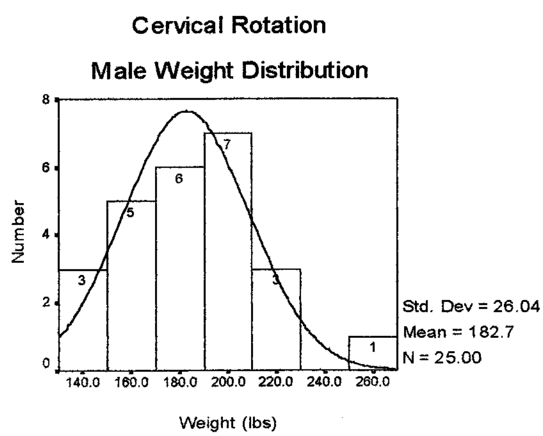
Male Average Right Strength Distribution




Cervical Extension
Male Height Distribution
Number
Height (inches)
Std. Dev = 2.35
Mean = 69.7
N = 25.00
66.0
68.0
70.0
72.0
74.0

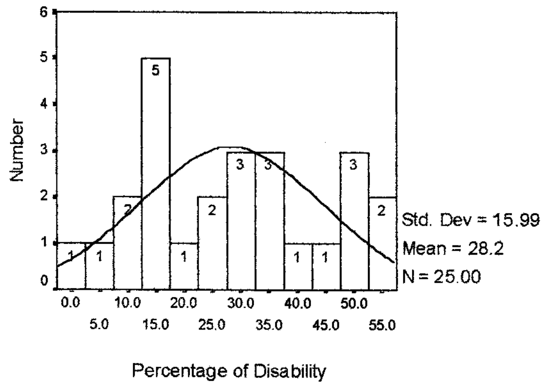

Cervical Rotation
Male Height Distribution
Number
Height (inches)
Std. Dev = 2.15
Mean = 70.7
N = 25.00
66.0
68.0
70.0
72.0
74.0
76.0


Cervical Extension
Male Weight Distribution
Number
Weight (lbs)
Std. Dev = 27.65
Mean = 193.0
N = 25.00
160.0
180.0
200.0
220.0
240.0
170.0
190.0
210.0
230.0
250.0


Cervical Rotation
Male Weight Distribution
Number
Weight (lbs)
Std. Dev = 26.04
Mean = 182.7
N = 25.00
140.0
160.0
180.0
200.0
220.0
240.0
260.0

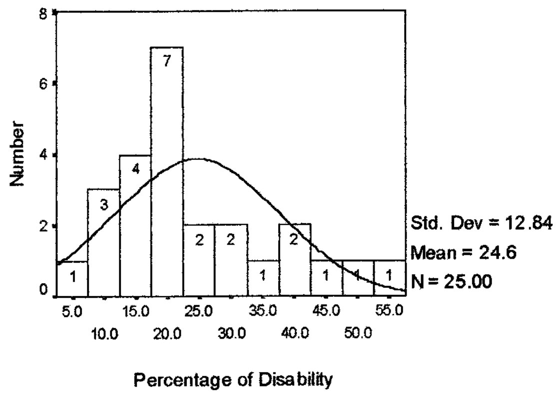
Cervical Extension

Male Disability Distribution



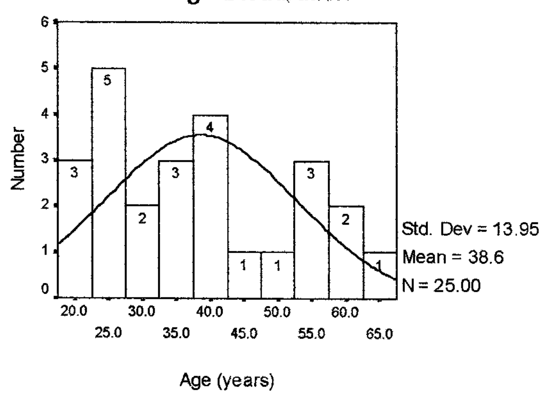
Cervical Rotation

Male Disability Distribution



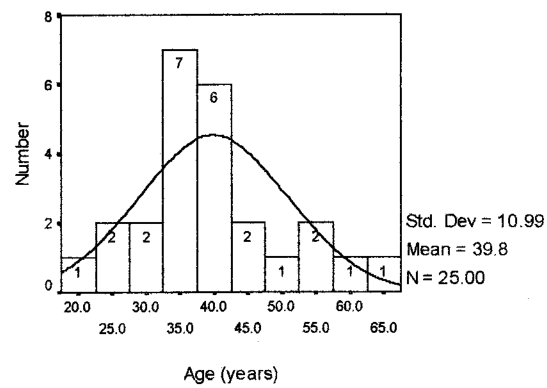
Cervical Extension

Male Age Distribution



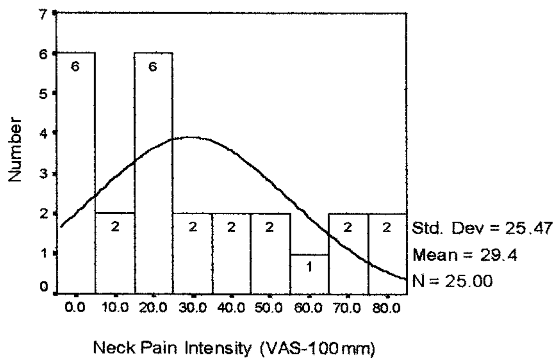
Cervical Rotation

Male Age Distribution



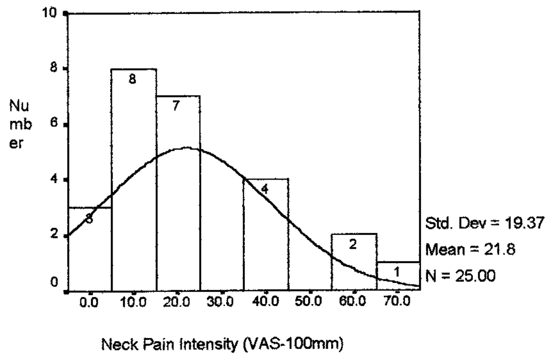
Cervical Extension

Male Neck Pain Intensity Distribution



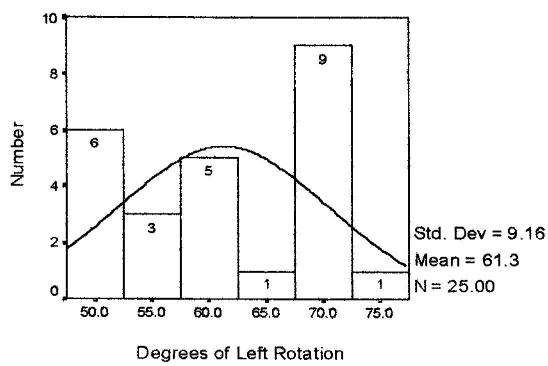
Cervical Rotation

Male Neck Pain Intensity Distribution



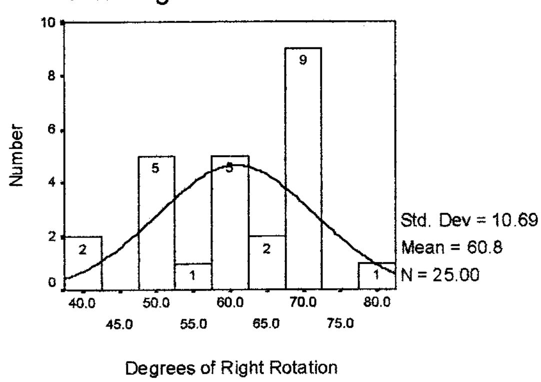
Cervical Rotation

Male Left ROM Distribution



Cervical Rotation

Male Right ROM Distribution



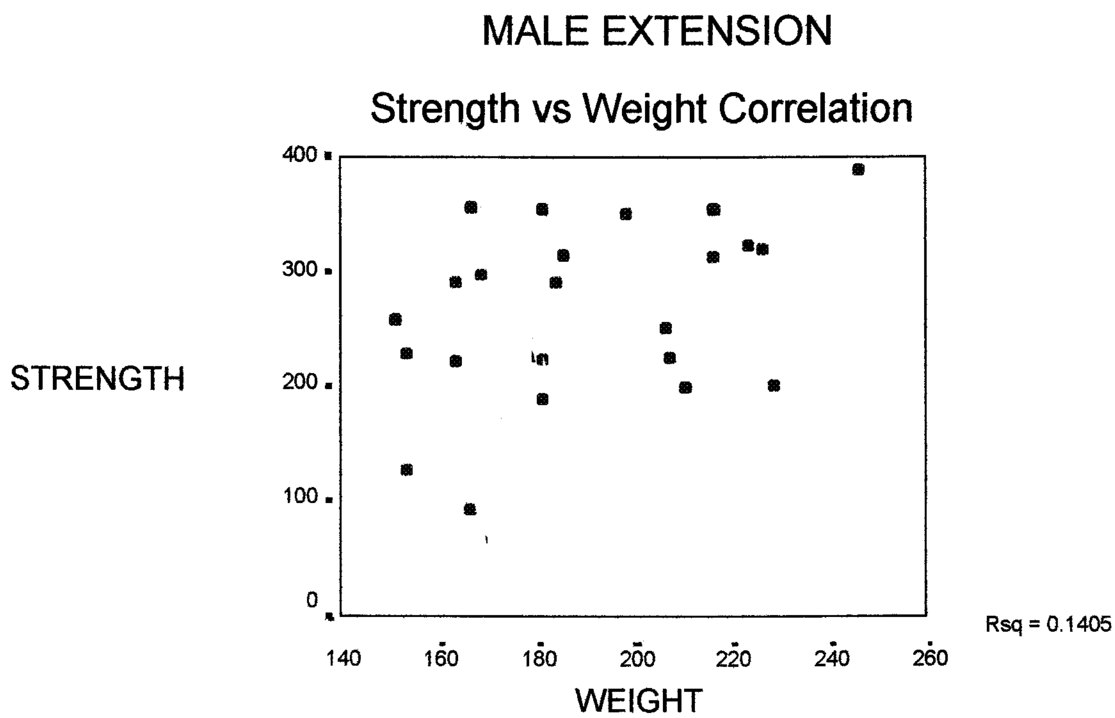
K) LINEAR REGRESSION ANALYSIS:
1) Male Cervical Extension Strength vs Weight

Descriptive Statistics

	Mean	Std. Deviation	N
STRENGTH	295.7600	75.9749	25
WEIGHT	193.0000	27.6511	25

Correlations

		STRENGTH	WEIGHT
Pearson Correlation	STRENGTH	1.000	.375
	WEIGHT	.375	1.000
Sig. (1-tailed)	STRENGTH	.	.032
	WEIGHT	.032	.
N	STRENGTH	25	25
	WEIGHT	25	25



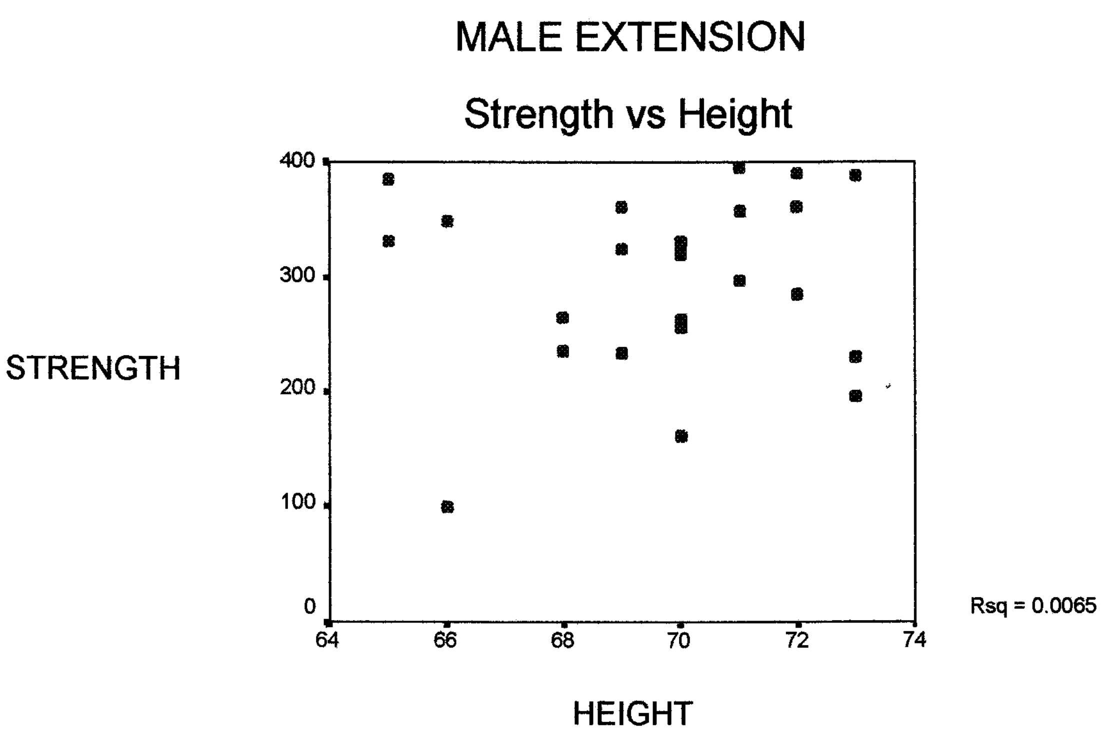
2) Male Cervical Extension Strength vs Height

Descriptive Statistics

	Mean	Std. Deviation	N
STRENGTH	295.7600	75.9749	25
HEIGHT	69.7200	2.3544	25

Correlations

		STRENGTH	HEIGHT
Pearson Correlation	STRENGTH	1.000	.081
	HEIGHT	.081	1.000
Sig. (1-tailed)	STRENGTH	.	.351
	HEIGHT	.351	.
N	STRENGTH	25	25
	HEIGHT	25	25



3) Male Cervical Extension Strength vs Age

Descriptive Statistics

	Mean	Std. Deviation	N
STRENGTH	295.7600	75.9749	25
AGE	38.6000	13.9523	25

Correlations

		STRENGTH	AGE
Pearson Correlation	STRENGTH	1.000	.184
	AGE	.184	1.000
Sig. (1-tailed)	STRENGTH	.	.190
	AGE	.190	.
N	STRENGTH	25	25
	AGE	25	25

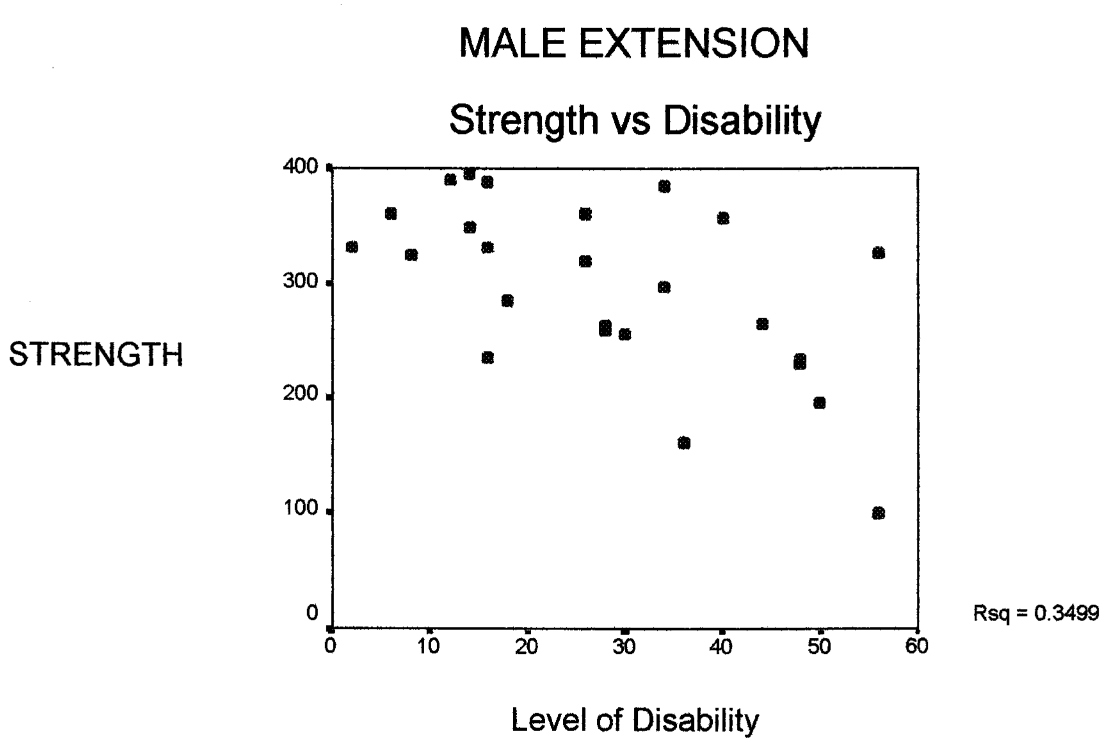
4) Male Cervical Extension Strength vs Disability

Descriptive Statistics

	Mean	Std. Deviation	N
STRENGTH	295.7600	75.9749	25
ND1	28.2400	15.9929	25

Correlations

		STRENGTH	ND1
Pearson Correlation	STRENGTH	1.000	-.592
	ND1	-.592	1.000
Sig. (1-tailed)	STRENGTH	.	.001
	ND1	.001	.
N	STRENGTH	25	25
	ND1	25	25



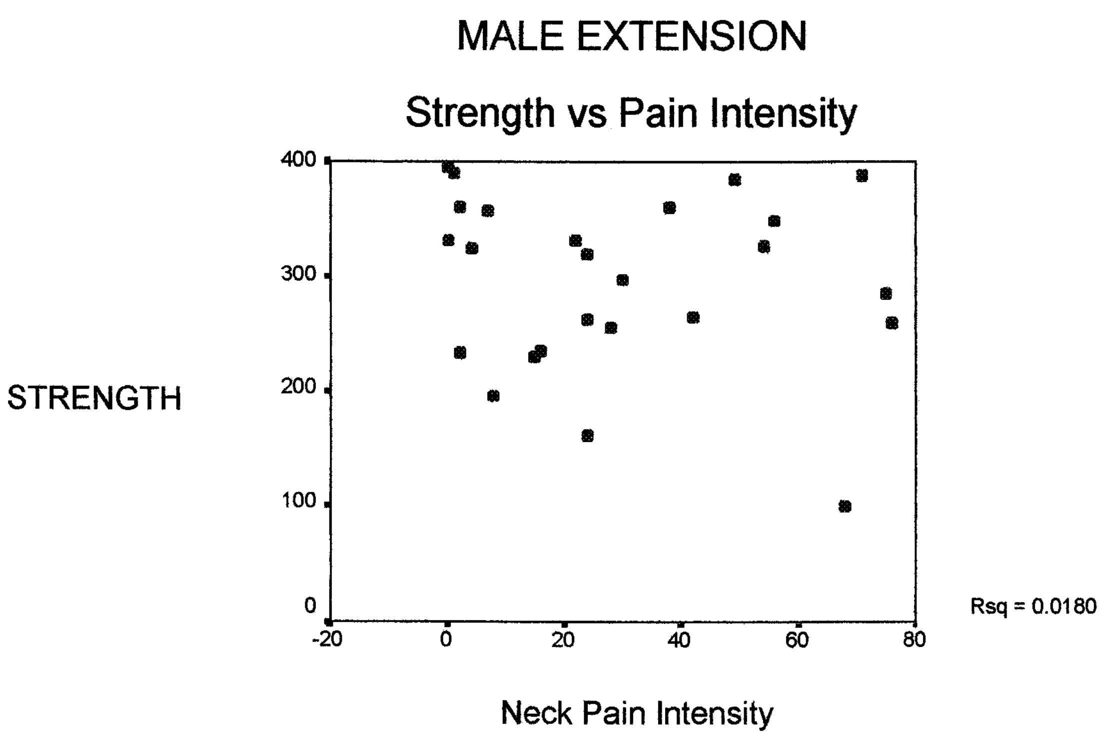
5) Male Cervical Extension Strength vs Pain Intensity

Descriptive Statistics

	Mean	Std. Deviation	N
STRENGTH	295.7600	75.9749	25
PAIN1	29.4400	25.4740	25

Correlations

		STRENGTH	PAIN1
Pearson Correlation	STRENGTH	1.000	-.134
	PAIN1	-.134	1.000
Sig. (1-tailed)	STRENGTH	.	.261
	PAIN1	.261	.
N	STRENGTH	25	25
	PAIN1	25	25



6) Male Cervical Rotation Strength vs Age

Descriptive Statistics

	Mean	Std. Deviation	N
ASTRALL	74.7083	24.1602	24
AGE	39.6250	11.1738	24

Correlations

		ASTRALL	AGE
Pearson Correlation	ASTRALL	1.000	.324
	AGE	.324	1.000
Sig. (1-tailed)	ASTRALL	.	.061
	AGE	.061	.
N	ASTRALL	24	24
	AGE	24	24

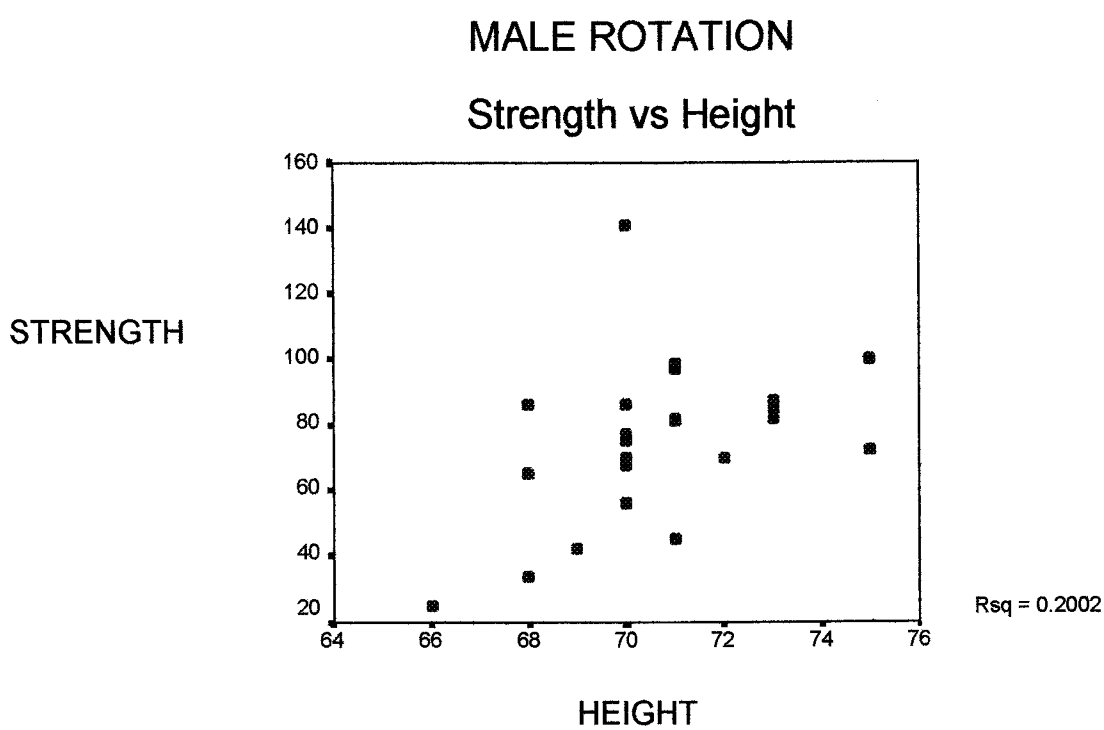
7) Male Cervical Rotation Strength vs Height

Descriptive Statistics

	Mean	Std. Deviation	N
ASTRALL	74.7083	24.1602	24
HEIGHT	70.6250	2.1430	24

Correlations

		ASTRALL	HEIGHT
Pearson Correlation	ASTRALL	1.000	.447
	HEIGHT	.447	1.000
Sig. (1-tailed)	ASTRALL	.	.014
	HEIGHT	.014	.
N	ASTRALL	24	24
	HEIGHT	24	24



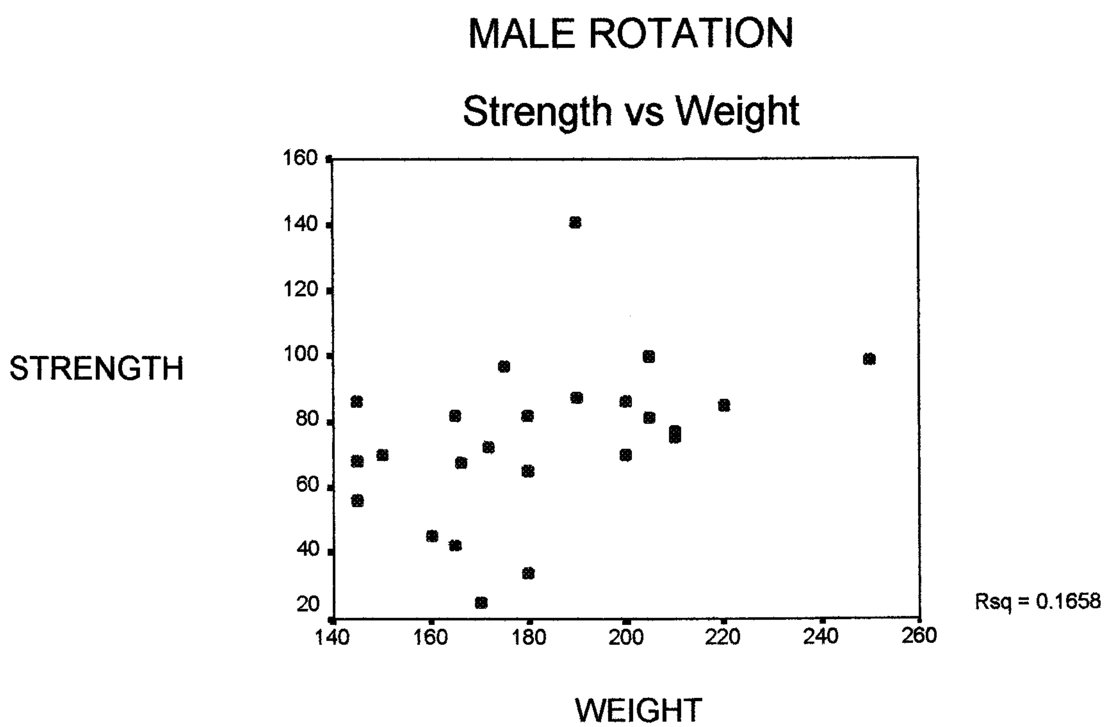
8) Male Cervical Rotation Strength vs Weight

Descriptive Statistics

	Mean	Std. Deviation	N
ASTRALL	74.7083	24.1602	24
WEIGHT	182.4167	26.5558	24

Correlations

		ASTRALL	WEIGHT
Pearson Correlation	ASTRALL	1.000	.407
	WEIGHT	.407	1.000
Sig. (1-tailed)	ASTRALL	.	.024
	WEIGHT	.024	.
N	ASTRALL	24	24
	WEIGHT	24	24



9) Male Cervical Rotation Strength vs Period since MVA

Descriptive Statistics

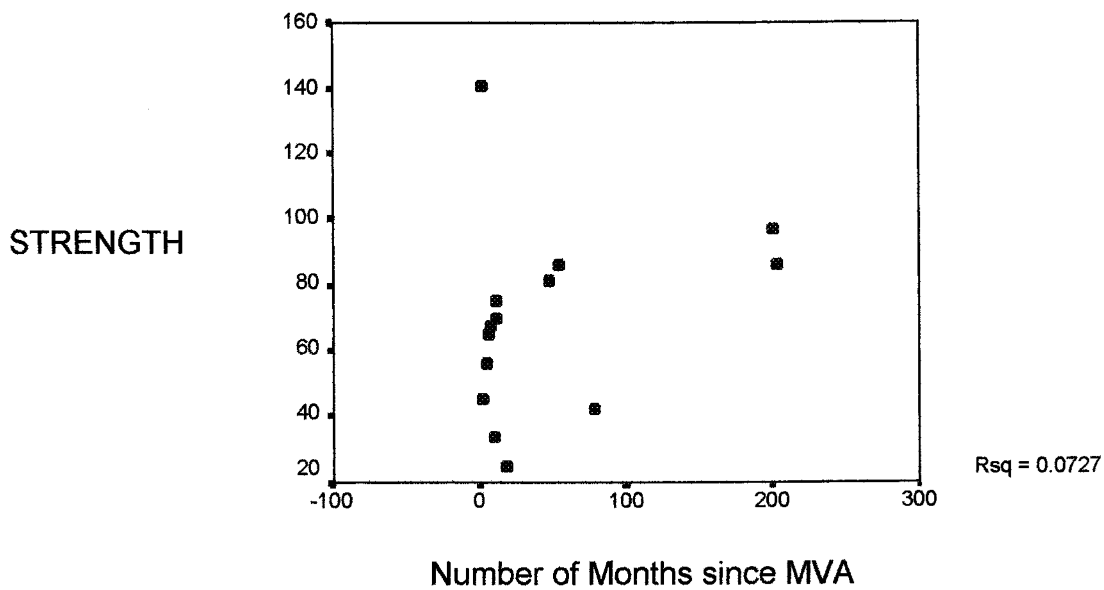
	Mean	Std. Deviation	N
ASTRALL	69.3571	29.5501	14
MVA	47.0714	69.4733	14

Correlations

		ASTRALL	MVA
Pearson Correlation	ASTRALL	1.000	.270
	MVA	.270	1.000
Sig. (1-tailed)	ASTRALL	.	.176
	MVA	.176	.
N	ASTRALL	14	14
	MVA	14	14

MALE ROTATION

Strength vs Period since MVA



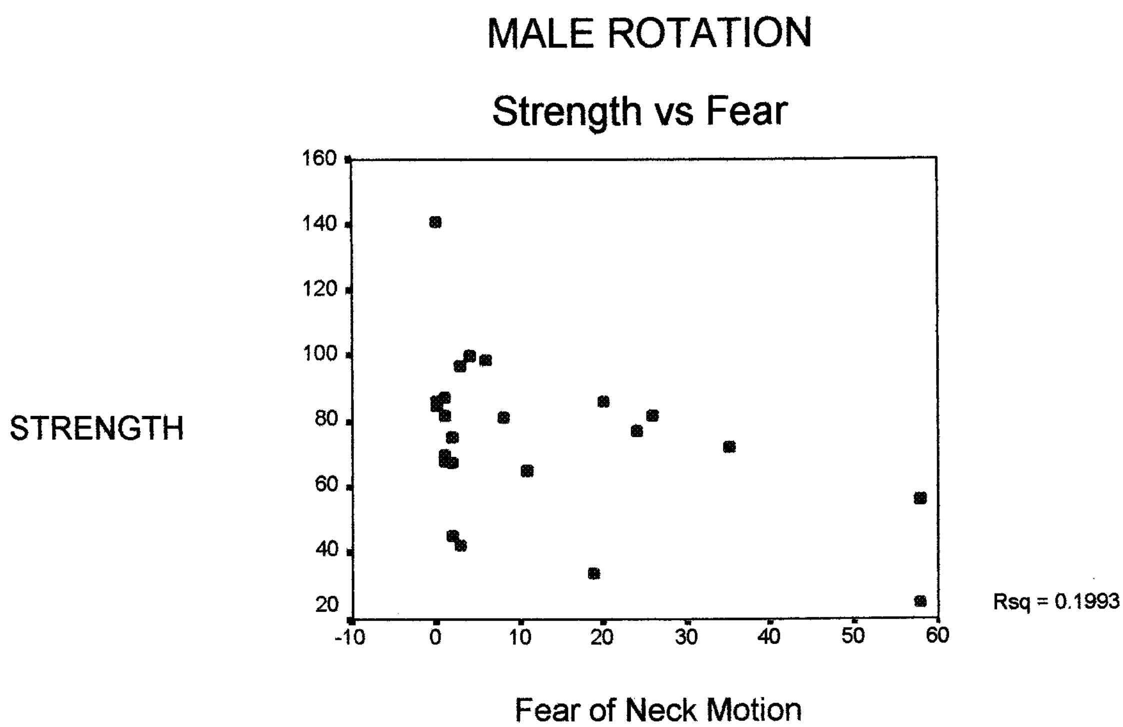
10) Male Cervical Rotation Strength vs Fear of Neck Motion

Descriptive Statistics

	Mean	Std. Deviation	N
ASTRALL	74.7083	24.1602	24
VASF1	11.9167	17.2322	24

Correlations

		ASTRALL	VASF1
Pearson Correlation	ASTRALL	1.000	-.446
	VASF1	-.446	1.000
Sig. (1-tailed)	ASTRALL	.	.014
	VASF1	.014	.
N	ASTRALL	24	24
	VASF1	24	24



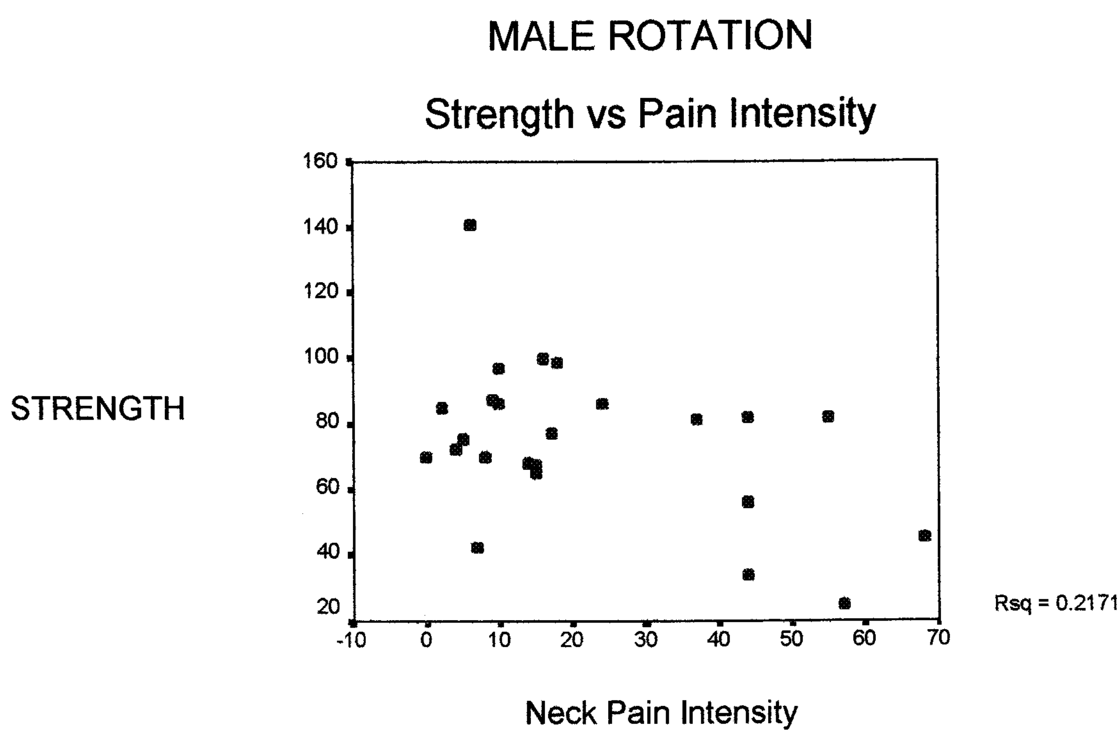
11) Male Cervical Rotation Strength vs Pain Intensity

Descriptive Statistics

	Mean	Std. Deviation	N
ASTRALL	74.7083	24.1602	24
VASP1	22.0417	19.7605	24

Correlations

		ASTRALL	VASP1
Pearson Correlation	ASTRALL	1.000	-.466
	VASP1	-.466	1.000
Sig. (1-tailed)	ASTRALL	.	.011
	VASP1	.011	.
N	ASTRALL	24	24
	VASP1	24	24



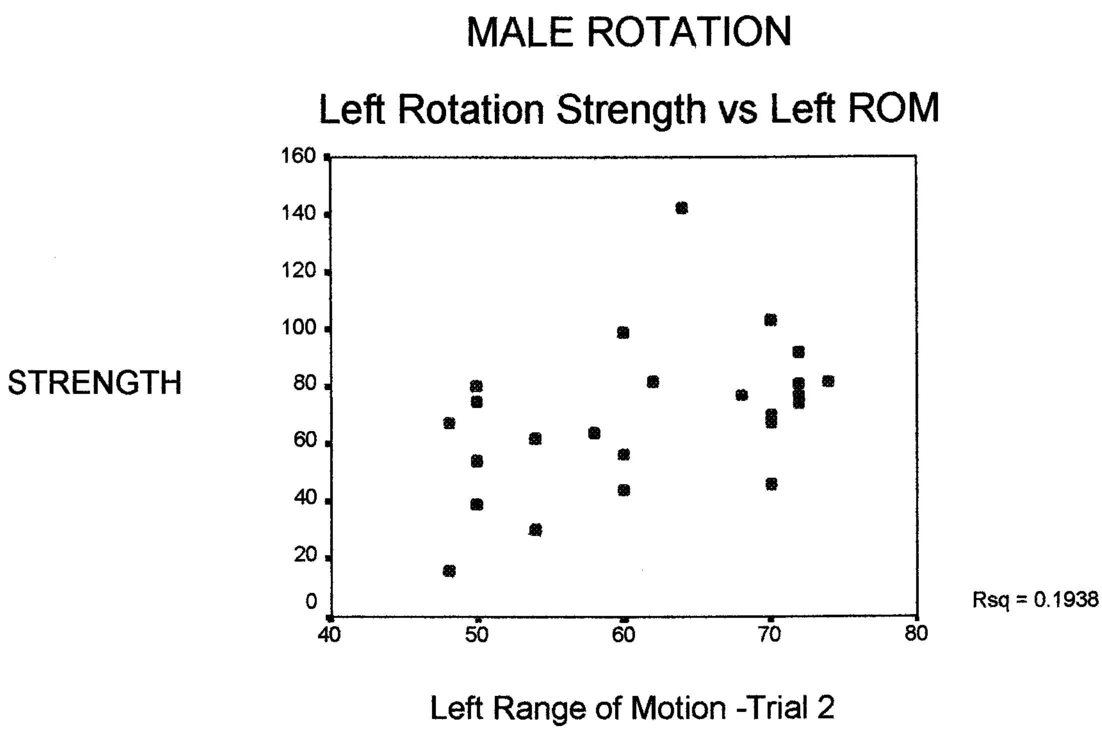
12) Male Cervical Left Rotation Strength vs Left ROM

Descriptive Statistics

	Mean	Std. Deviation	N
LSTR1	69.9583	25.9975	24
LROT1	61.5833	9.2309	24

Correlations

		LSTR1	LROT1
Pearson Correlation	LSTR1	1.000	.440
	LROT1	.440	1.000
Sig. (1-tailed)	LSTR1	.	.016
	LROT1	.016	.
N	LSTR1	24	24
	LROT1	24	24



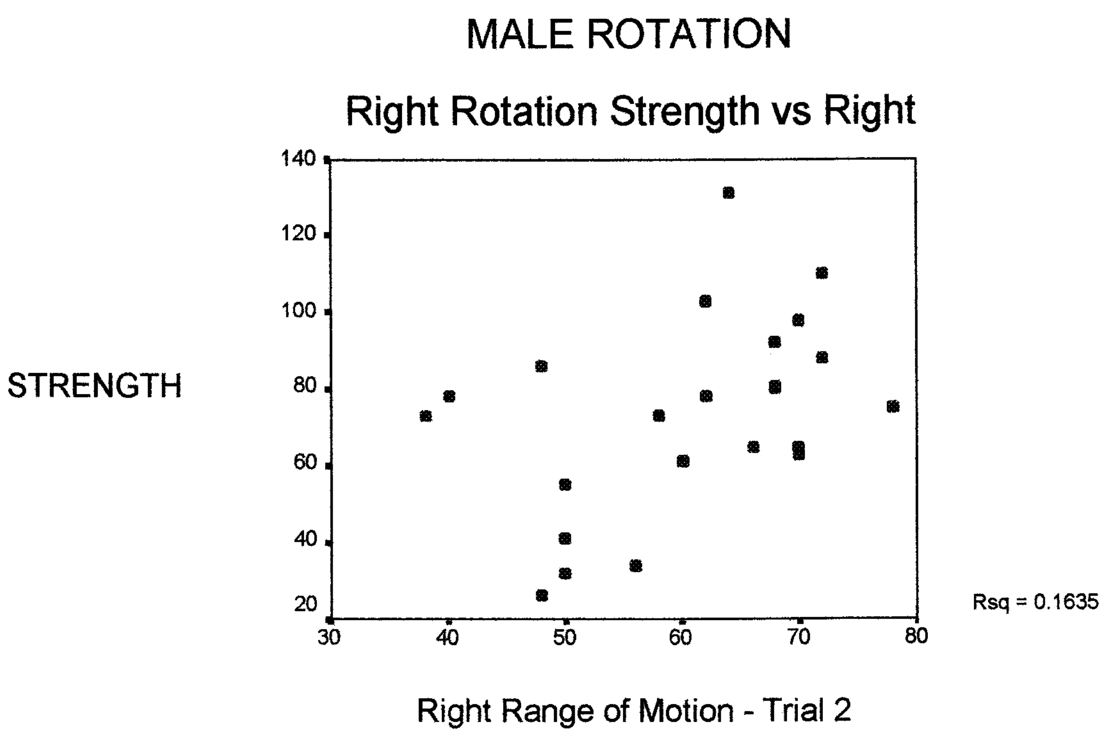
13) Male Cervical Right Rotation Strength vs Right ROM

Descriptive Statistics

	Mean	Std. Deviation	N
RSTR1	73.0000	25.0148	24
RROT1	60.7500	10.9197	24

Correlations

		RSTR1	RROT1
Pearson Correlation	RSTR1	1.000	.404
	RROT1	.404	1.000
Sig. (1-tailed)	RSTR1	.	.025
	RROT1	.025	.
N	RSTR1	24	24
	RROT1	24	24



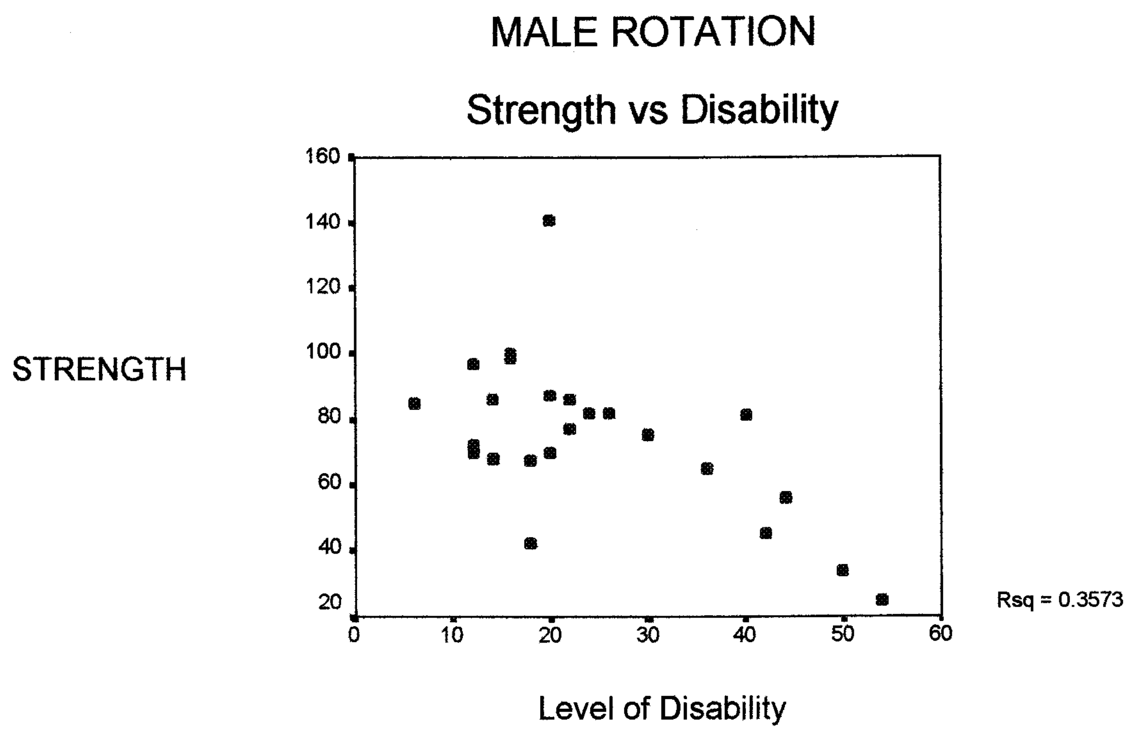
14) Male Cervical Rotation Strength vs Disability

Descriptive Statistics

	Mean	Std. Deviation	N
ASTRALL	74.7083	24.1602	24
NDI1	24.5000	13.0983	24

Correlations

		ASTRALL	NDI1
Pearson Correlation	ASTRALL	1.000	-.598
	NDI1	-.598	1.000
Sig. (1-tailed)	ASTRALL	.	.001
	NDI1	.001	.
N	ASTRALL	24	24
	NDI1	24	24



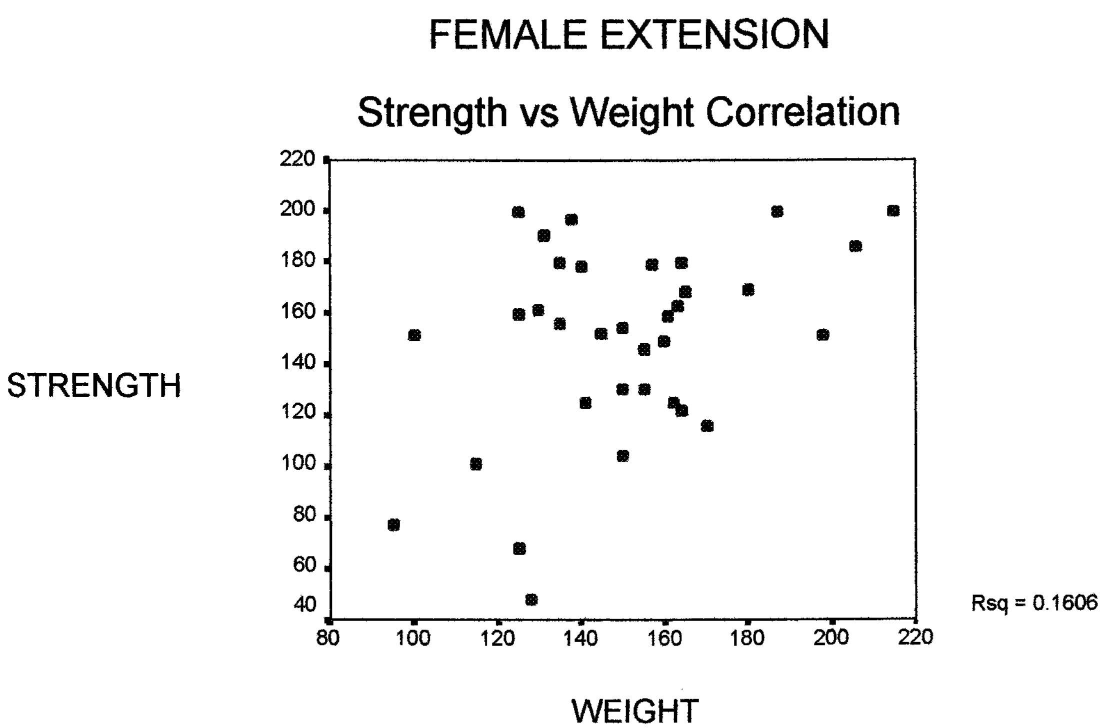
15) Female Cervical Extension Strength vs Weight

Descriptive Statistics

	Mean	Std. Deviation	N
STRENGTH	149.2941	38.2532	34
WEIGHT	150.5882	27.1037	34

Correlations

		STRENGTH	WEIGHT
Pearson Correlation	STRENGTH	1.000	.401
	WEIGHT	.401	1.000
Sig. (1-tailed)	STRENGTH	.	.009
	WEIGHT	.009	.
N	STRENGTH	34	34
	WEIGHT	34	34



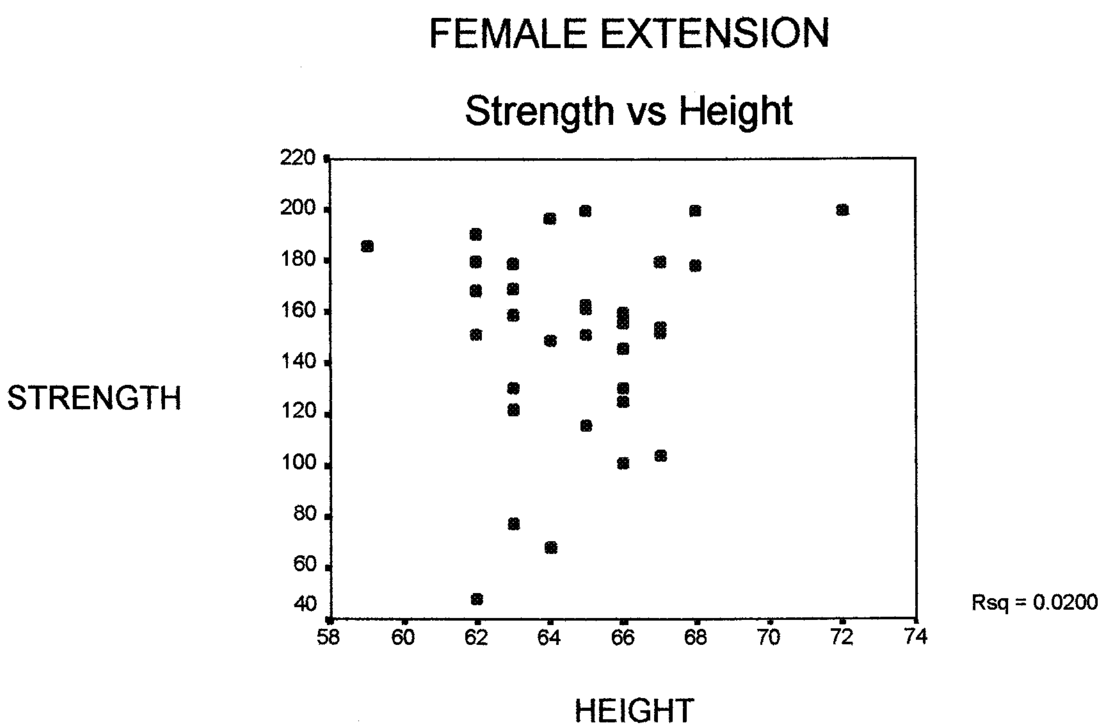
16) Female Cervical Extension Strength vs Height

Descriptive Statistics

	Mean	Std. Deviation	N
STRENGTH	149.2941	38.2532	34
HEIGHT	64.7647	2.4378	34

Correlations

		STRENGTH	HEIGHT
Pearson Correlation	STRENGTH	1.000	.141
	HEIGHT	.141	1.000
Sig. (1-tailed)	STRENGTH	.	.212
	HEIGHT	.212	.
N	STRENGTH	34	34
	HEIGHT	34	34



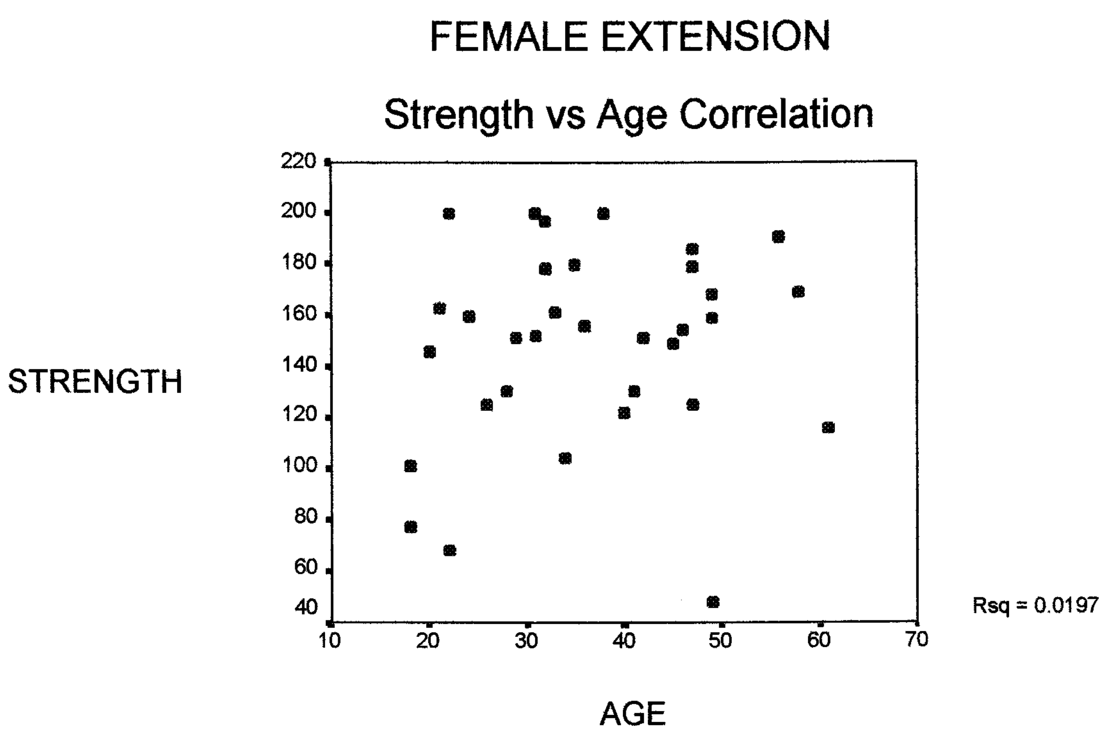
17) Female Cervical Extension Strength vs Age

Descriptive Statistics

	Mean	Std. Deviation	N
STRENGTH	148.3636	38.4536	33
AGE	36.5758	11.9949	33

Correlations

		STRENGTH	AGE
Pearson Correlation	STRENGTH	1.000	.141
	AGE	.141	1.000
Sig. (1-tailed)	STRENGTH	.	.218
	AGE	.218	.
N	STRENGTH	33	33
	AGE	33	33



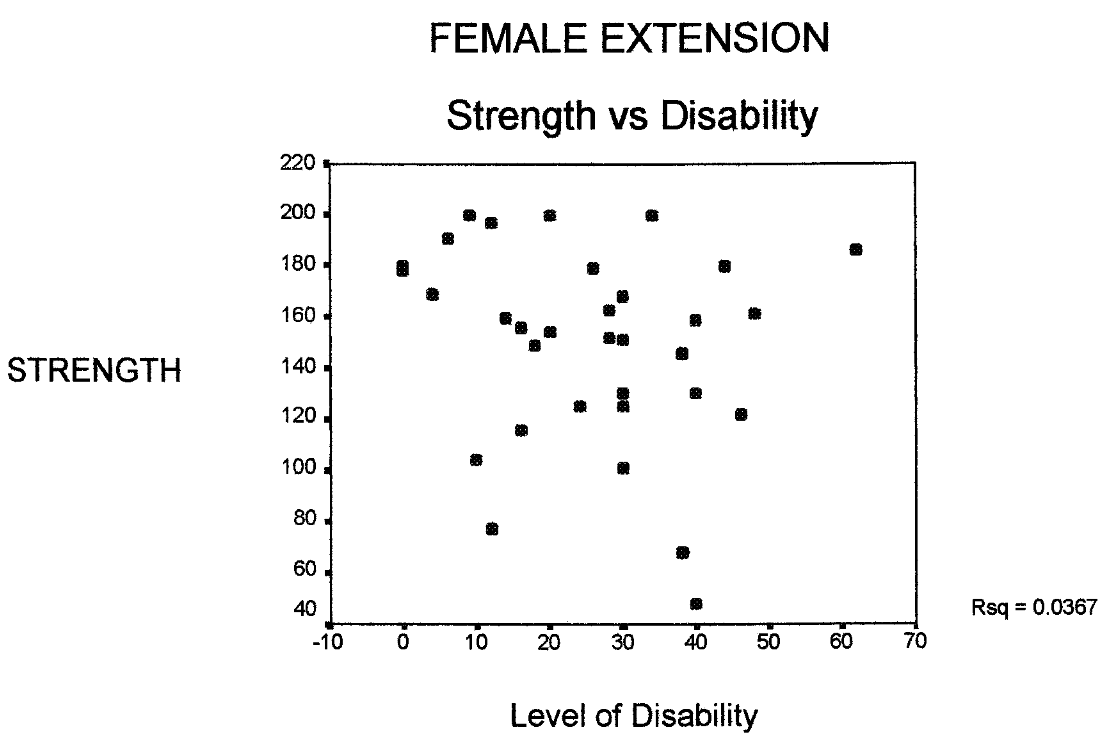
18) Female Cervical Extension Strength vs Disability

Descriptive Statistics

	Mean	Std. Deviation	N
STRENGTH	149.2941	38.2532	34
ND1	25.6765	14.7725	34

Correlations

		STRENGTH	ND1
Pearson Correlation	STRENGTH	1.000	-.192
	ND1	-.192	1.000
Sig. (1-tailed)	STRENGTH	.	.139
	ND1	.139	.
N	STRENGTH	34	34
	ND1	34	34



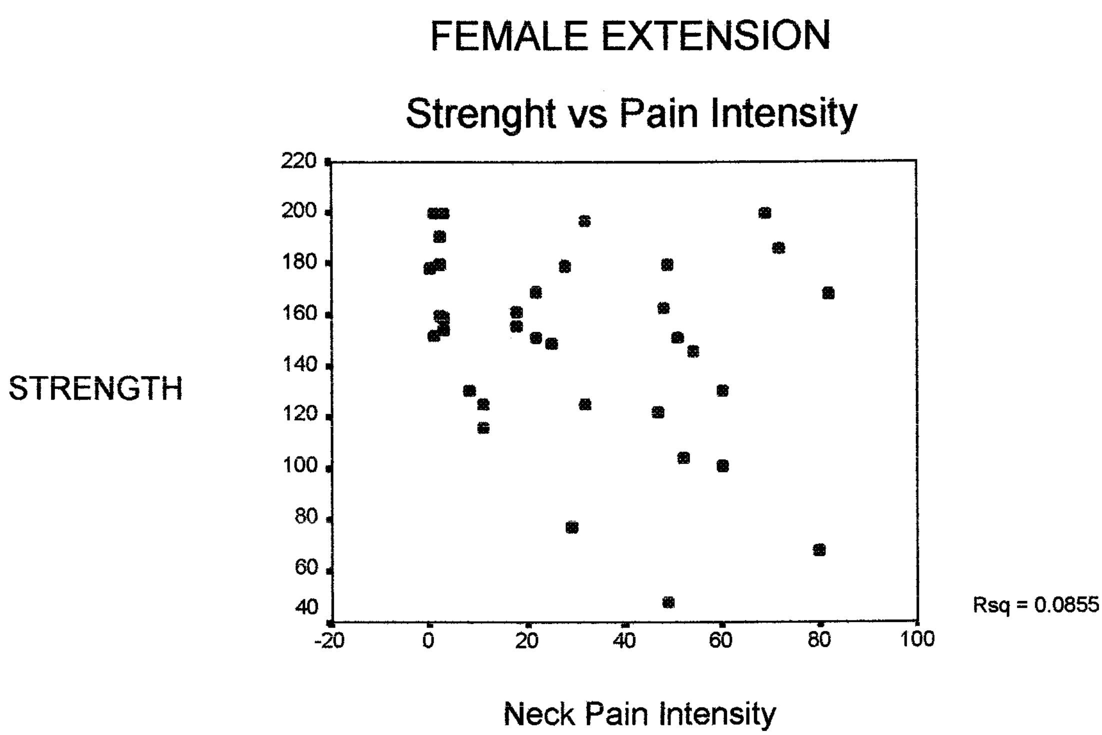
19) Female Cervical Extension Strength vs Pain Intensity

Descriptive Statistics

	Mean	Std. Deviation	N
STRENGTH	149.2941	38.2532	34
PAIN1	30.7647	25.7530	34

Correlations

		STRENGTH	PAIN1
Pearson Correlation	STRENGTH	1.000	-.292
	PAIN1	-.292	1.000
Sig. (1-tailed)	STRENGTH	.	.047
	PAIN1	.047	.
N	STRENGTH	34	34
	PAIN1	34	34



20) Female Cervical Rotation Strength vs Age

Descriptive Statistics

	Mean	Std. Deviation	N
ASTRALL	35.4500	15.7898	30
AGE	37.4333	11.2086	30

Correlations

		ASTRALL	AGE
Pearson Correlation	ASTRALL	1.000	-.189
	AGE	-.189	1.000
Sig. (1-tailed)	ASTRALL	.	.158
	AGE	.158	.
N	ASTRALL	30	30
	AGE	30	30

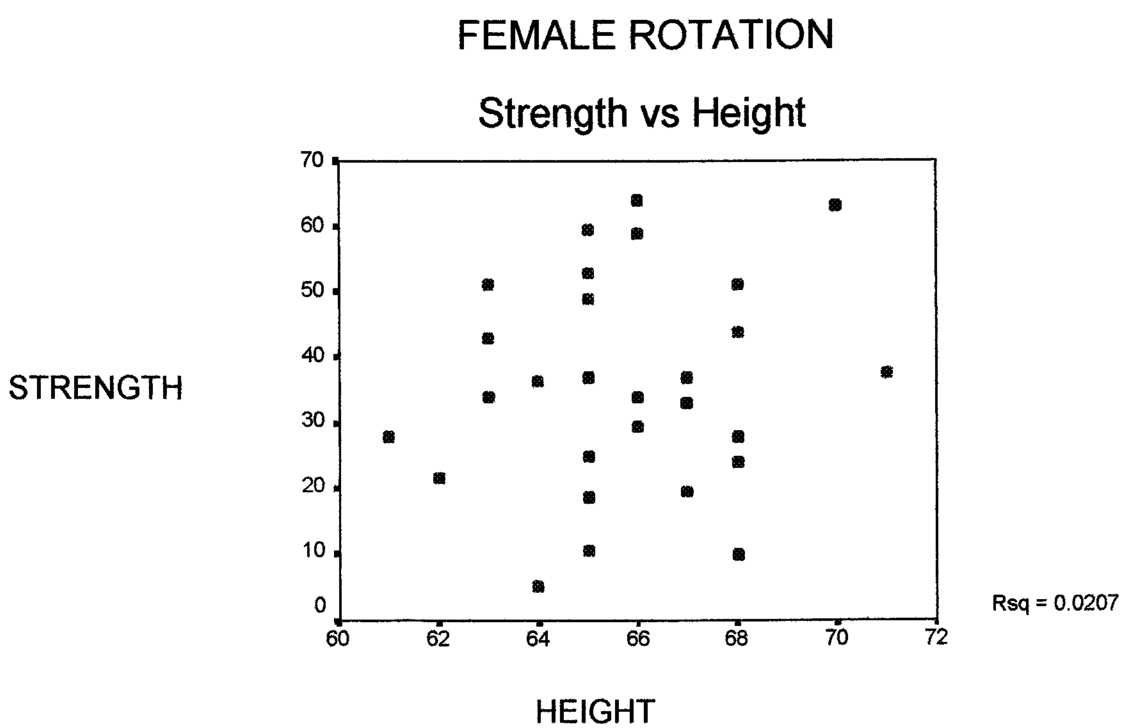
21) Female Cervical Rotation Strength vs Height

Descriptive Statistics

	Mean	Std. Deviation	N
ASTRALL	35.6724	16.0213	29
HEIGHT	65.7586	2.2781	29

Correlations

		ASTRALL	HEIGHT
Pearson Correlation	ASTRALL	1.000	.144
	HEIGHT	.144	1.000
Sig. (1-tailed)	ASTRALL	.	.228
	HEIGHT	.228	.
N	ASTRALL	29	29
	HEIGHT	29	29



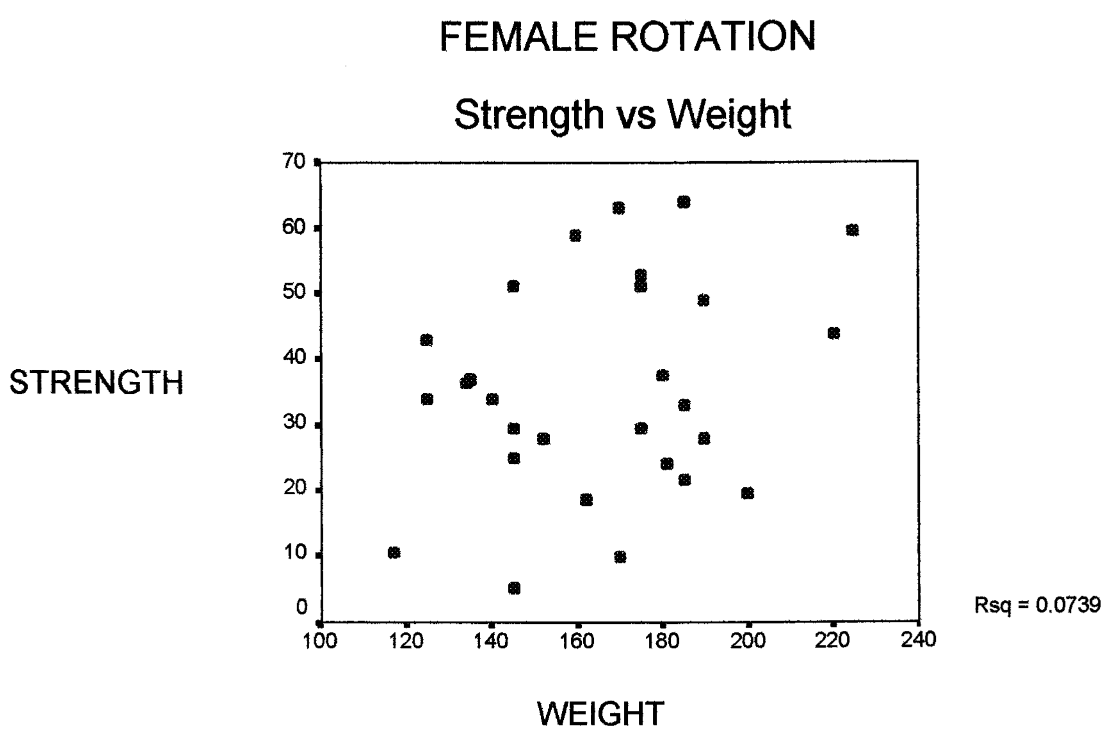
22) Female Cervical Rotation Strength vs Weight

Descriptive Statistics

	Mean	Std. Deviation	N
ASTRALL	35.6724	16.0213	29
WEIGHT	164.5172	27.9139	29

Correlations

		ASTRALL	WEIGHT
Pearson Correlation	ASTRALL	1.000	.272
	WEIGHT	.272	1.000
Sig. (1-tailed)	ASTRALL	.	.077
	WEIGHT	.077	.
N	ASTRALL	29	29
	WEIGHT	29	29



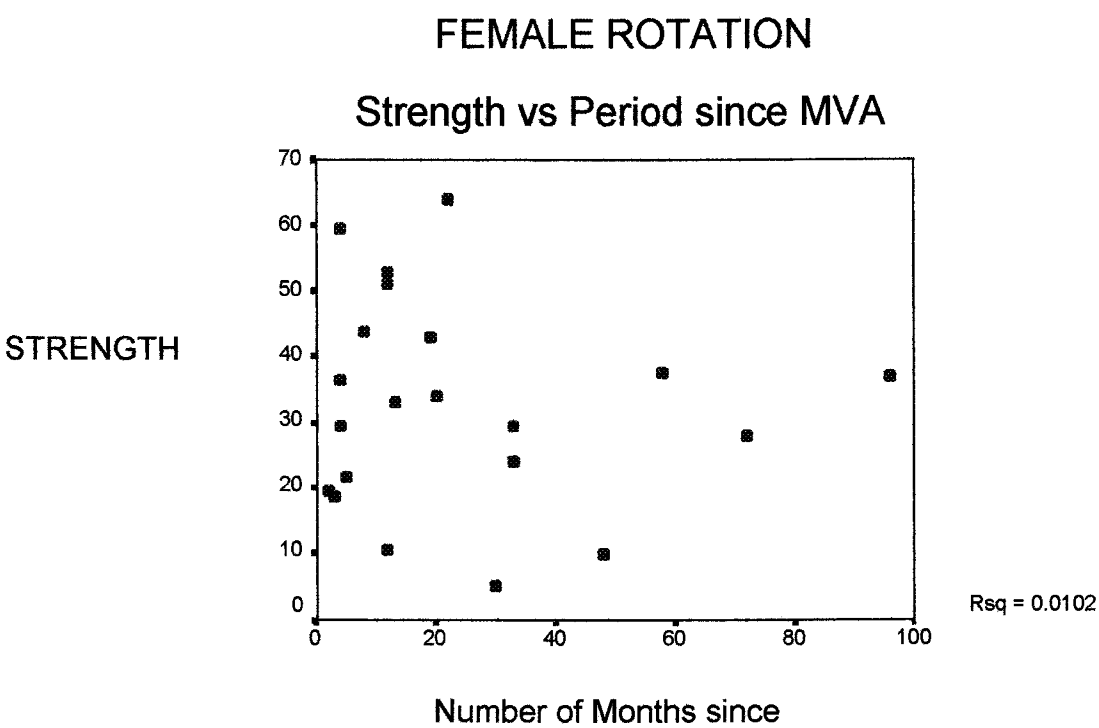
23) Female Cervical Rotation Strength vs Period since MVA

Descriptive Statistics

	Mean	Std. Deviation	N
ASTRALL	32.7857	16.0176	21
MVA	24.2857	25.2550	21

Correlations

		ASTRALL	MVA
Pearson Correlation	ASTRALL	1.000	-.101
	MVA	-.101	1.000
Sig. (1-tailed)	ASTRALL	.	.331
	MVA	.331	.
N	ASTRALL	21	21
	MVA	21	21



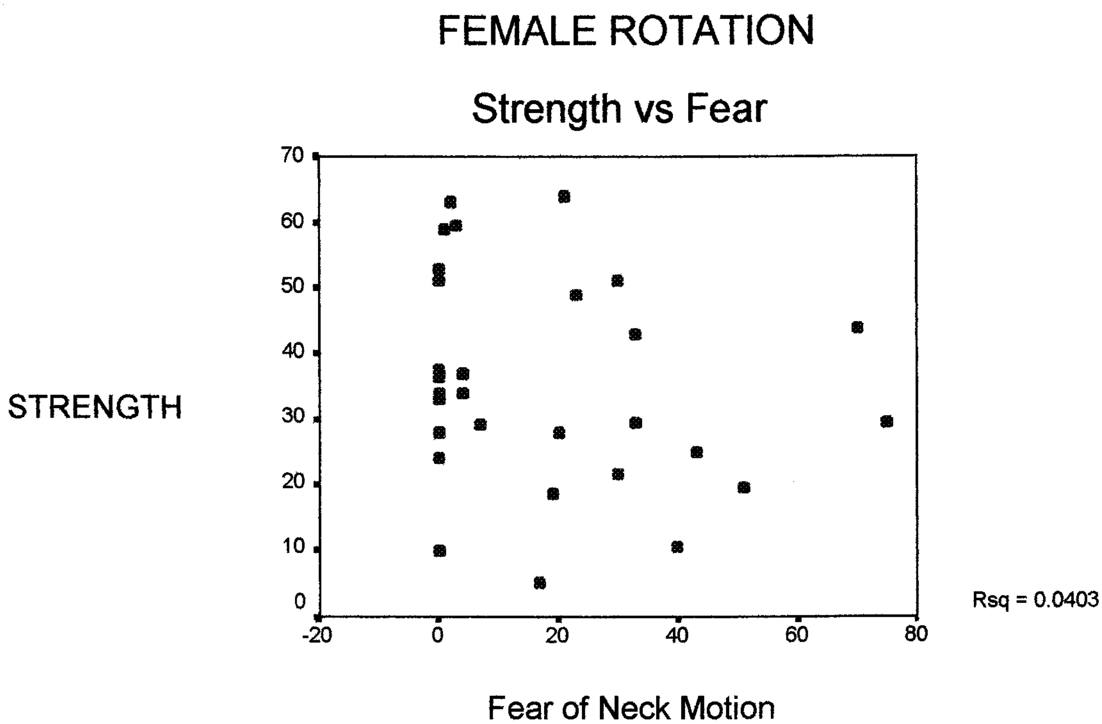
24) Female Cervical Rotation Strength vs Fear of Neck Motion

Descriptive Statistics

	Mean	Std. Deviation	N
ASTRALL	35.4500	15.7898	30
VASF1	17.5333	21.5322	30

Correlations

		ASTRALL	VASF1
Pearson Correlation	ASTRALL	1.000	-.201
	VASF1	-.201	1.000
Sig. (1-tailed)	ASTRALL	.	.144
	VASF1	.144	.
N	ASTRALL	30	30
	VASF1	30	30



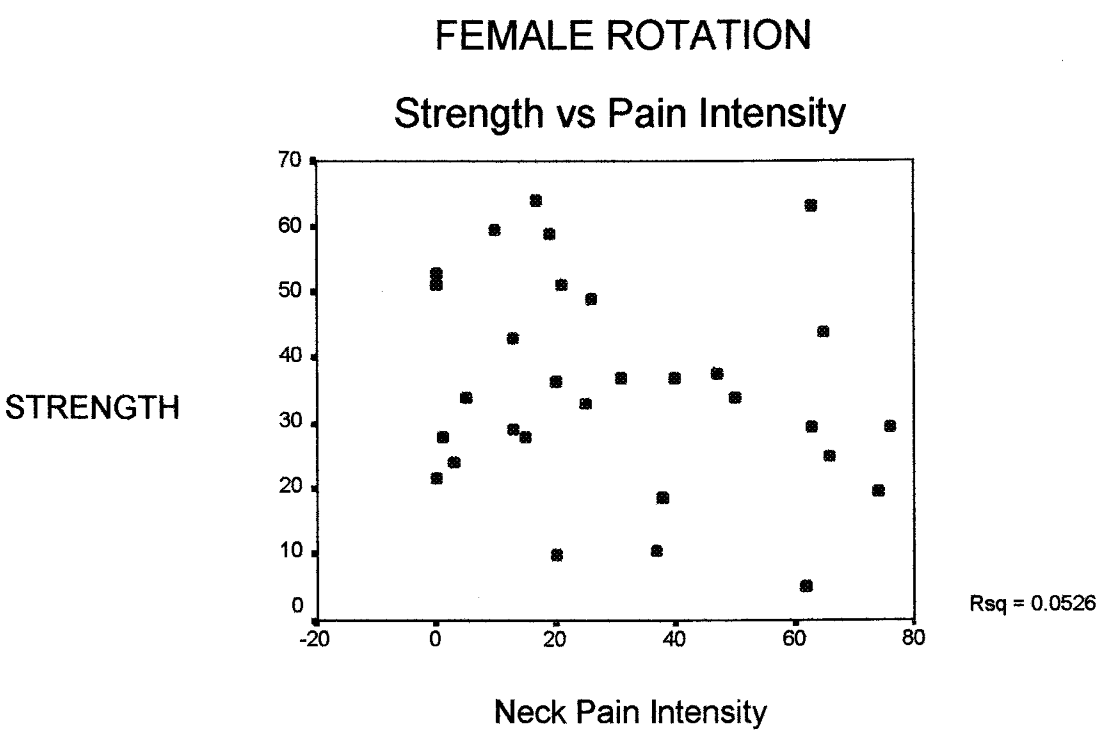
25) Female Cervical Rotation Strength vs Pain Intensity

Descriptive Statistics

	Mean	Std. Deviation	N
ASTRALL	35.4500	15.7898	30
VASP1	30.6667	24.4771	30

Correlations

		ASTRALL	VASP1
Pearson Correlation	ASTRALL	1.000	-.229
	VASP1	-.229	1.000
Sig. (1-tailed)	ASTRALL	.	.111
	VASP1	.111	.
N	ASTRALL	30	30
	VASP1	30	30



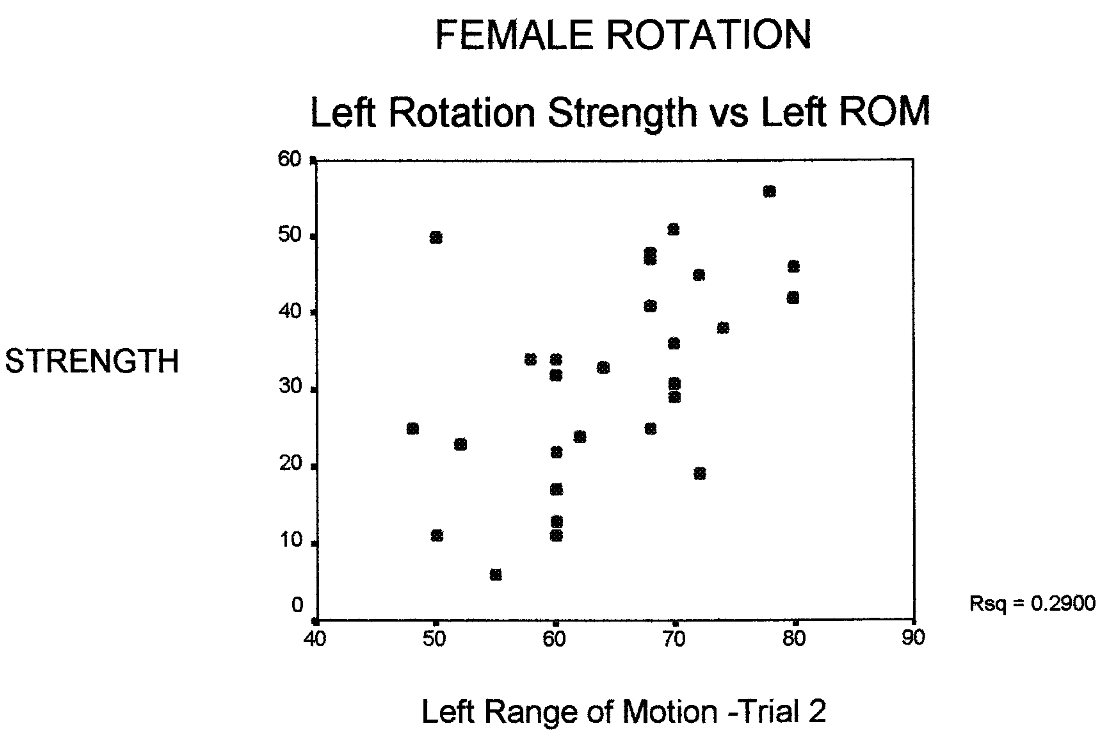
26) Female Cervical Left Rotation Strength vs Left ROM

Descriptive Statistics

	Mean	Std. Deviation	N
LSTR1	31.7241	13.3815	29
LROT1	64.7241	8.8111	29

Correlations

		LSTR1	LROT1
Pearson Correlation	LSTR1	1.000	.539
	LROT1	.539	1.000
Sig. (1-tailed)	LSTR1	.	.001
	LROT1	.001	.
N	LSTR1	29	29
	LROT1	29	29



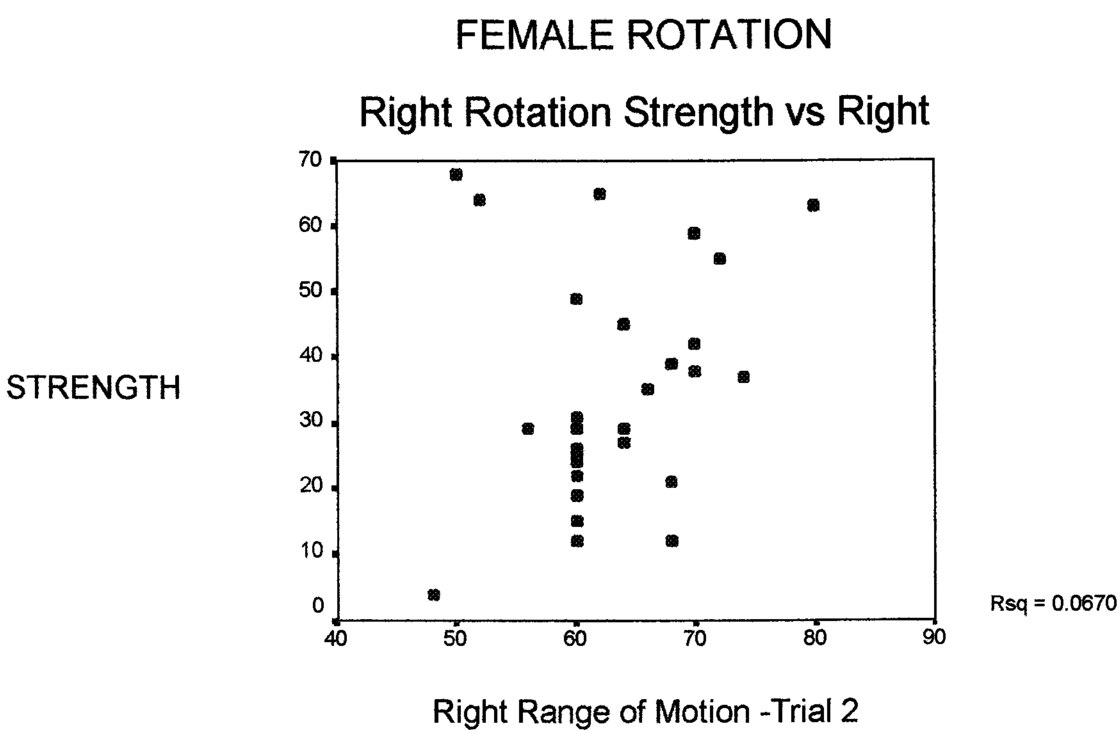
27) Female Cervical Right Rotation Strength vs Right ROM

Descriptive Statistics

	Mean	Std. Deviation	N
RSTR1	35.9655	17.9712	29
RROT1	63.3103	7.1369	29

Correlations

		RSTR1	RROT1
Pearson Correlation	RSTR1	1.000	.259
	RROT1	.259	1.000
Sig. (1-tailed)	RSTR1	.	.088
	RROT1	.088	.
N	RSTR1	29	29
	RROT1	29	29



28) Female Cervical Rotation Strength vs Disability

Descriptive Statistics

	Mean	Std. Deviation	N
ASTRALL	35.4500	15.7898	30
NDI1	28.7333	13.3337	30

Correlations

		ASTRALL	NDI1
Pearson Correlation	ASTRALL	1.000	-.363
	NDI1	-.363	1.000
Sig. (1-tailed)	ASTRALL	.	.024
	NDI1	.024	.
N	ASTRALL	30	30
	NDI1	30	30