MEDIAN NERVE BIAS TENSION TEST RESPONSES IN NORMAL SUBJECTS

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DECLARATION

I, Jessica Fortune declare that this research report is my own work. It is being submitted in partial fulfilment for the degree of *Master of Science in Physiotherapy* in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

Jessica Fortune

12 June 2000

DEDICATION

To my husband, Sanjay Lala, for his love, loyal support, encouragement and guidance.

To my family, for their encouragement and support.

ABSTRACT

There are numerous upper limb tension tests (ULTTs) that are used as neurodiagnostic and treatment techniques in patients who present with neck and upper limb pain. Elvey first described the ULTT1 in 1980. In 1983, Butler modified the ULTT1 to specifically stress the median (ULTT2a), radial (ULTT2b) and ulnar nerves (ULTT3). The normal sensory responses of the original ULTT1 are well documented, in addition the normal sensory responses of ULTT2b and 3 have been described. However the normal sensory responses to the ULTT2a have not been described.

The objectives of this study were:

1) to describe the normal sensory responses of ULTT2a;
2) to define the normal range of glenohumeral abduction in the final position of ULTT2a;
3) to determine the effect that joint hypermobility has on the normal range of glenohumeral abduction.

Sixty three students from the Physiotherapy Department of the University of the Witwatersrand volunteered to participate in this cross-sectional study. The selection of the students was based on criteria described by Yaxley and Juil (1991). The assessment of each student included: the collection of certain demographic characteristics; determining the presence of indicators of joint hypermobility; the recording of the normal sensory responses in various positions

of ULTT2a and the recording of the normal range of glenohumeral abduction in the final position of ULTT2a.

In a young adult population the final test position of glenohumeral abduction in ULTT2a can occur in the range 29.09 - 55.62 degrees. The mean for this range of glenohumeral abduction is 42.36 degrees. The ULTT2a appears to stress the proximal nerve roots as well as the peripheral nerve tracts in the area corresponding to the dermatomal distribution of C5, C6 and C7 and in the sensory distribution of the median nerve.

The mean range of glenohumeral abduction was less in the subjects with increased joint hypermobility than in the subjects with normal joint range (40.81 degrees compared to 45.07 degrees respectively).

This study highlights the need for more anatomical research into the composition and sequence of movements used in the modified upper limb tension tests.

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CHAPTER 1 INTRODUCTION

Physiotherapists in the clinical setting are increasingly seeing patients presenting with pain in the upper quarter. The pain may occur either as: (i) an isolated symptom in the neck, (ii) in the neck that is referred into the upper limb, (iii) in the upper back and chest, (iv) in the shoulder girdle, or (v) in the upper limb (Bogduk, 1988). It is essential that the physiotherapist is able to diagnose the origin of the pain for the physiotherapeutic management.

To ensure effective management of upper quarter pain, the physiotherapist must carry out a physical examination to identify an aetiological basis for the pain. This is important as specific aetiological causes of upper limb pain may preclude the use of certain physiotherapeutic techniques. In particular, serious visceral pathology must be excluded and referred for medical treatment. The neural tissues should be evaluated for their possible role in upper limb pain. Evaluation of the neural tissue includes the subjective report of the patient, the history and the physical examination (Elvey and Hall, 1996).

Pain experienced in the upper limb may either be local or referred pain. The local pain is an indication of pathological changes of somatic tissues immediately underlying the cutaneous area of perceived pain. Referred pain is pain in a distant region from the location of the primary source of pain (Bogduk, 1988).

Referred pain in the upper limb can originate from neural, somatic or visceral structures in the cervical spine, shoulder or thorax. Neural referred pain is caused by disorders of the spinal nerve roots, spinal nerves or peripheral nerves. This pain is referred along the course of a nerve either within a segmental or a peripheral nerve distribution (Elvey and Hall, 1996). The symptoms of neural referred pain are referred to as neurogenic symptoms. If the nerve roots are involved the symptoms are segmental and referred to as radicular pain or radiculopathy (Ellenberg et al, 1994).

Somatic referred pain is defined as pain perceived in an area adjacent to, or at a distance from the site of origin, usually within the same spinal segment (Elvey and Hall, 1996). Somatic referred pain stems directly from one of the musculoskeletal structures in the cervical spine or shoulder, i.e. the zygapophyseal or neurocentral joints; the ligaments of the posterior elements; the para-vertebral muscles; the anterior or posterior longitudinal ligaments or the intervertebral discs.

The source of visceral referred pain lies within a viscus but the pain is perceived in a part of the cutaneous tissues distant to the viscera involved. Visceral pain is poorly localised and more diffuse, often provoking strong autonomic responses, such as increased sympathetic outflow (Robertson, 1999). Visceral pain in the upper limb can be referred as a result of a myocardial infarct. This must be distinguished from other referred pain as physiotherapeutic techniques are usually contraindicated in visceral pain. Once visceral referred pain is excluded as the cause of upper limb pain, the physiotherapist must distinguish neural referred pain from somatic referred pain.

Physical tests which are used to differentiate between pain arising from (i) the neural tissue complex of the brachial plexus (and its cervical nerve roots) and (ii) the somatic structures in the upper limb are known as neural tissue provocation tests. Neural tissue provocation tests physically examine the dynamics and the associated sensitivity of the nervous system (Butler, 1994). The neural system moves in relation to the adjacent structures tested (Lundborg, 1988). If the neural tissue provocation test reproduces the patient's neurogenic symptoms, the neural structures are considered to be involved (Elvey, 1997). Neural tissue provocation tests, specifically the upper limb tension test (ULTT), are used to diagnose pain that originates in the neural structures in the cervical spine and upper limb (Elvey, 1997).

Elvey first described the neural provocation test of the upper limb (ULTT1) in 1980. Kenneally (1988) described the upper limb tension test (ULTT) as being the "analogue to the straight leg raise test" as it exerts a similar longitudinal pull on the peripheral nerve trunks and the cervical nerve roots. It is used in neuromusculoskeletal pathology both as a neurodiagnostic technique, to differentiate the source of the upper quarter pain and also as a treatment technique (Quintner, 1990; Yaxley and Jull, 1993; Sweeney and Harms, 1996). The original upper limb tension test (ULTT1) was modified by Butler to include examination of the radial nerve and ulnar nerve branches of the brachial plexus, as well as testing the median nerve (Butler and Gifford, 1989). The modified upper limb tension tests are referred to as the median nerve bias (ULTT2a), the radial nerve bias (ULTT2b) and the ulnar nerve bias (ULTT3). Kenneally (1988) described the distribution and the nature of the normal responses for ULTT1 and the radial nerve bias (ULTT2b) and the ulnar nerve bias (ULTT3) tests have been described (Yaxley and Jull, 1991).

In this project, 63 physiotherapy students were assessed and their normal sensory responses to the ULTT2a were determined. In addition the normal range of glenohumeral abduction was derived. The normal sensory responses and normal range of movement of glenohumeral abduction, have, to the best of my knowledge, not been determined for the commonly used modified median nerve bias test (ULTT2a).

OBJECTIVES

The objectives of this study were:

a) To determine the range of glenohumeral abduction when the neural tissue tracts of normal subjects were placed on tension using the modified upper limb tension test - median nerve bias (ULTT2a).
b) To define the sensory responses of normal subjects to the modified ULTT2a.
c) To determine if the subject's joint hypermobility had any effect on the extensibility of the neural structures of the upper limb, that is the range of glenohumeral abduction.

CHAPTER 2 LITERATURE REVIEW

In this chapter the anatomy and the physiological responses of the upper limb tension test (ULTT) will be discussed. The recent controversies regarding the validity of the upper limb tension test (ULTT) will also be discussed.

There are occasions when no definitive aetiology can be attributed to pain experienced in the upper limb. This has been defined by Elvey and Hall (1996), as cervicobrachial pain syndrome or disorder. Cervicobrachial pain is relatively common and recurrent episodes of this condition occur with increasing frequency with age (Elvey and Hall, 1996). In an epidemiological survey of Rochester, Minnesota, (1976 – 1990), the incidence of cervical radiculopathy was 83,2 per 100 000. This rate increased to 202.9 per 100 000 in the age group 50 – 54 years (Radhakrishnan et al, 1994). As very few population based studies have been conducted the exact incidence of cervicobrachial pain is unknown (Elvey and Hall, 1996).

The use of upper limb tension tests as diagnostic and treatment techniques may impact on the outcome of neck and upper limb pain. Earlier management of pain of neurogenic origin may decrease the time spent and reduce the cost of the treatment for the patient and the physiotherapist.

NEURAL PROVOCATION TESTS

The upper limb tension test (ULTT1) involves the application of an ordered sequence of movements to the scapula and upper limb. These movements selectively increase tension within the neural tissues and their surrounding connective tissues. The ULTT1 comprises the following steps:

1. Passive ipsilateral shoulder girdle depression
2. Glenohumeral abduction (behind the coronal plane)
3. Glenohumeral external rotation
4. Forearm supination
5. Elbow extension
6. Wrist and finger extension.

The position of the nerve relative to the moving joint axes in ULTT1, that is, shoulder depression, elbow extension and wrist extension, mainly assesses the median nerve (Quintner and Elvey, 1993). The addition of contralateral side flexion of the cervical spine and ipsilateral straight leg raise to the test position can increase the sensitivity of the neural structures to the test and confirm neural tissue involvement (Butler, 1991).

Butler modified the original ULTT1 by including movements that specifically stressed and assessed the radial nerve and ulnar nerve branches of the brachial plexus, as well as testing the median nerve (Butler and Gifford, 1989). The modified upper limb tension tests, namely the median nerve bias (ULTT2a), comprise the following steps:

1. Ipsilateral shoulder girdle depression

2. Full range elbow extension
3. Full range glenohumeral external rotation
4. Full range forearm supination
5. Full range wrist and finger extension
6. Glenohumeral abduction (Butler, 1991)

These modifications were made in response to Butler's observations of work postures in patients suffering from repetitive strain injury (RSI). Butler and Gifford (1989) postulated that the modified upper limb tension tests would be more sensitive as pathologic changes may affect nerves other than the median nerve. Depending on the patients' referred symptom pattern; they may have their symptoms reproduced with one or more of the modified upper limb tension tests, rather than with the original upper limb tension test.

Kenneally (1988) investigated the normal response to the original upper limb tension test (ULTT1). He assessed the distribution and the nature of responses among 100 normal, asymptomatic subjects. The subjects reported a deep stretch or ache sensation in the cubital fossa extending down the anterior and radial aspects of the forearm and hand. The area reported to be the most consistent normal response in the final test position of ULTT1 equated closely with the fifth, sixth and seventh cervical dermatomes. Yaxley and Jull (1991) showed that when using the modified radial nerve bias test (ULTT2b) sensory responses are different compared to the original ULTT1, which mainly stresses the median nerve. They assessed the normal sensory responses and the range of glenohumeral abduction when using the modified radial nerve bias test (ULTT2b) in 50 normal subjects. The most common sensory response was a strong painful stretch over the radial aspect of the proximal forearm. Yaxley and Jull (1991) noted that ULTT2b normal responses did not fit into a recognisable dermatomal pattern. The modified ULTT2b placed tension at different sites on the neural tissue tract, compared to the original test. Yaxley and Jull (1991) found that the available range of glenohumeral abduction for ULTT2b was 40° in the final position.

ANATOMY OF THE MEDIAN NERVE

The median nerve arises from the branches of the medial and lateral cords of the brachial plexus, derived from cervical nerve roots - C5, C6, C7, C8 and T1 (Romanes, 1981). The cords unite anterior to the third part of the axillary artery, a continuation of the subclavian artery. The nerve continues along the lateral aspect of the brachial artery and crosses superficial to the artery at the mid-humerus to lie on its medial side. In the forearm it enters between the heads of pronator teres and gives off the anterior interosseous branch. It lies on the deep aspect of the flexor digitorum superficialis muscle. In the wrist the nerve becomes superficial on the ulnar side of the flexor carpi radialis. It then passes deep to the floor of the flexor retinaculum giving off muscular branches to the thenar muscles, radial two lumbricals and cutaneous branches to the palmar aspects of the thumb, index, middle and radial half of the ring finger (Romanes, 1981).

THE DYNAMICS OF THE PERIPHERAL NERVE

Movement of a limb such as with the upper limb tension tests will result in a change in length of the nerve bed through which the peripheral nerves run. The structure of the peripheral nerves allows for straightening, then stretching and untwisting of the nerve as the nerve bed lengthens. A loose conjunctiva-like connective tissue, that allows for backward and forward sliding of the nerve surrounds the peripheral nerves (Lundborg, 1988). This allows for adaptive changes that might occur during flexion or extension at a joint. Goddard and Reid (1965) assessed the amount of movement of the sciatic nerve roots as they passed through their intervertebral foramina with straight leg raising (SLR). They dissected 30 cadavers with no known or obvious spinal deformity. The excursion of the sciatic nerve roots through their intervertebral foramina was measured using metal pins inserted in the perineurium and paper markers placed on the adjoining bone. They showed that the sciatic nerve roots moved up to 7 mm in a caudad direction in relation to the intervertebral foramina when performing the straight leg raise (SLR). In their study McLellan and Swash (1976) observed similar longitudinal excursion of the median nerve in the upper arm during movements of the upper limb and cervical spine. The longitudinal movement of the median nerve was observed while recording action potentials of single afferent nerve fibres in the median nerve of 15 subjects. They found that the maximum movement of the median nerve occurred with extension of the wrist and fingers (up to 7.5 mm towards the elbow). However, McLellan and Swash (1976) deduced the excursion of the median nerve by measuring the angulation of the tungsten needle inserted into the peripheral nerve, on movements of the arm. As the skin and subcutaneous soft tissue may have impeded the movement of the nerve, these findings are not as accurate as actual measurements of nerve movement in cadavers. The gap is the distance between two stumps of a transected peripheral nerve without further specification (Millesi, 1986). Millesi (1986) surmised that the nerve gap is influenced by joint position. In his examination of the median nerve of an adult patient, Millesi (1986) noted that the median nerve has to accommodate to a change in length of up to 20% when the nerve bed lengthens from elbow and wrist flexion to elbow and wrist extension. The surrounding tissue, such as bone and muscle may impede the normal movement of the peripheral neural tissue resulting in decreased mobility and possibly a deranged nerve.

PATHOPHYSIOLOGY OF NEURAL DYNAMICS

The nerve trunk has regional vascular bundles passing through the mobile connective tissue layer as well as an extensive microvascular system supplying the epineurium, perineurium and endoneurium (Lundborg, 1988). Total or subtotal ischaemia due to tourniquet application may result in decreased nerve function within 15 to 45 minutes. This decrease however is not related to decreased blood supply but rather due to direct compression of the nerve situated directly under the tourniquet (Lundborg 1988). Ogata and Naito (1986), using the hydrogen washout technique, determined the effect of dissection, stretching and compression on the blood flow rate of the sciatic nerve of a rabbit. They showed that short periods of ischaemia resulted in an increase in the endoneurial fluid pressure (EFP). A moderate increase in the EFP interfered with endoneurial capillary flow. A compression of 30 mmHg could result in a 3-fold increase in endoneurial fluid pressure. A pressure of 50 to 70 mmHg resulted in decreased intrafascicular blood flow and with 120 mmHg there was complete arrest in the nerve conduction (Ogata and Naito, 1986; Lundborg, 1988). In human subjects a tissue pressure level for nerve viability was consistently 30 mmHg below diastolic pressure (Lundborg, 1988). Mobilisation of the peripheral nerve may interfere with the intraneural blood supply. The effect subsides in time (Lundborg, 1988). In studies on primates, mobilisation of the ulnar nerve over 2 – 3 cm resulted in a significant decrease in the intraneural blood flow (a reduction of approximately one-third of the original blood flow was observed using the hydrogen washout technique). This recovered after three days (Lundborg, 1988).

Neural provocation tests are based on the principle that a deranged nerve is sensitive or hyperalgesic to manual stimuli applied along its length (Dalton and Jull, 1989; Quintner and Elvey, 1993). Nerve entrapment due to constriction, resulting in little or no axonal damage, causes an inflammatory reaction resulting in changes in the perineurium and endothelial cells. The perineurium becomes interrupted and endothelial cells of the microvasculature passing through the connective tissue hypertrophy (Lundborg 1988). In addition, the symptoms noted with the neural provocation tests may be as a result of chronic scar formation resulting in chronic irritation of the nerve as it passes between muscle bellies or under sharp fascial edges (Lundborg 1988). The epineurial and perineurial blood vessels are sympathetically innervated. A high sympathetic overload may impair the intraneural microcirculation resulting in vasoconstriction and should be considered as an important pathophysiologic factor in conditions associated with increased sympathetic tont s such as certain chronic pain syndromes (Lundborg 1988). The neurogenic symptoms may also present peripherally due to centrally mediated hyperalgesia (Zusman, 1992). Peripheral pathology may trigger long-lasting changes that may persist in the central nervous system long after the peripheral pathology has disappeared. The initial damage to the peripheral nerve (the C fibres and the inhibitory Aß fibres) sensitises the dorsal horn ganglion with ongoing transmission to the higher centres in the brain. This results in permanent changes in the excitability of spinal cord neurones (maladaptive plasticity) (Zusman, 1992). Relatively minor sensory stimuli such as stretching the peripheral neural system as well as non-noxious sensory inputs will result in amplified pain responses (Greening and Lynn, 1998). The central nervous system response amplifies the effect of the nerve injury (Greening and Lynn, 1998).

CONTROVERSY REGARDING THE UPPER LIMB TENSION TESTS

The precise source of neurogenic pain referred to the upper quarter is unclear as it may originate in the cervical spinal nerves, the dura, or the cords of the brachial plexus. In addition other structures in the cervical spine have been implicated in producing symptoms when using the upper limb tension tests (Wilson et al, 1994; Moses and Carman, 1996).

Moses and Carman (1996) investigated the anatomy of the lower cervical nerves and associated structures. Three human spines were dissected and histological sections of the cervical spines were viewed for the anatomical arrangement of the lower cervical nerves. Moses and Carman (1996) found that the lower cervical nerves (fifth, sixth and seventh cervical nerves) had a significant attachment to the walls of the intervertebral foramina. The nerves attached closely to the periosteum of the inferior pedicles and to the capsules of the zygapophyseal joints. The nerves were also attached to the vertebral bodies and intervertebral discs by the lateral extensions of the posterior longitudinal ligament. Moses and Carman (1996) suggested that the source of pain produced during the upper limb tension test is unlikely to be only from neuromeningeal tissue because of the extensive connections to innervated somatic structures such as the posterior longitudinal ligament. They suggested that further biomechanical investigations should be done before the effects of the upper limb tension test can be fully understood.

Wilson et al (1994) measured the strain that is produced at the subclavian artery, during contralateral and ipsilateral side flexion of the cervical spine during movement of the upper limb while performing the ULTT1 in two embalmed cadavers. The strain was defined as the stretch per unit length. This score was determined by using photographic images showing movement occurring in the brachial plexus and the subclavian artery at each step of ULTT1. This study noted that strain was produced in the lateral cord of the brachial plexus during contralateral side flexion of the cervical spine. In addition, strain was also noted in segments of the subclavian artery. Wilson et al (1994) implicated the vascular system in the symptoms reproduced by the ULTT1. However, these results must be viewed with caution as the sample size was small (n = 2) and the cadavers were embalmed and subjects used were in their 7th decade. In addition the method used to determine the strain in the subclavian artery, even though used in similar studies, has not been validated.

Most normal structures including muscle and nerve can be expected to be painful when placed on full passive stretch (Yaxley and Jull, 1991). It is important to distinguish whether pain exhibited during the upper limb tension tests is a normal response to stretching the neural tissues or whether it is pathologic. The neural structures are well innervated, and therefore pain may be produced when the neural tissues are on full stretch. In addition the nerve trunk has an extensive microvascular system (Lundborg, 1988). Ogata and Naito (1986), using the hydrogen washout technique, showed that at 15.6% of elongation, the vessels of the sciatic nerve of the rabbit were totally occluded and the nerve tissue suffered complete ischaemia. When the nerve is mobilised or stretched, the result is an acute impairment of the intraneural blood flow. With increased tension applied to the nerve the regional nutrient vessel stretches, thereby blocking blood flow (Lundborg, 1988). As axonal transport and impulse transmission relies on an adequate energy supply, the interference will result in disturbed nerve function (Lundborg, 1988). The subjects may respond to tension on the nerve by complaining of a stretching or pulling sensation, or possibly pain. Yaxley and Jull (1991) noted that it is incorrect to assume that a painful response to the upper limb tension tests is pathologic. It is therefore, important to define the range of the normal sensory responses during mobilisation of the neural tissues.

In addition, the normal range of movement of glenohumeral abduction needs to be defined. As a large variation in the range of movement in the joints of normal individuals is noted, subjects with increased joint hypermobility may present with an increased range of elbow extension and glenohumeral abduction. The author decided to determine the effect of joint hypermobility on the range of glenohumeral abduction in the ULTT2a.

THE EFFECT OF HYPERMOBILITY ON THE NEURAL PROVOCATION TESTS

Articular hypermobility is defined as a considerable degree of joint laxity in normal individuals. It is a benign condition that is not associated with underlying connective tissue disease (Beighton et al, 1988). Joint hypermobility is determined using the technique described by Carter and Wilkinson (1964) with the modification suggested by Beighton et al, (1973).

The Carter and Wilkinson (1964) scale allocates one point for each of the following indicators of joint hypermobility:

passive apposition of the thumb to the forearm;

passive hyperextension of the fingers and wrist so that the fingers lie parallel to the forearm;

hyperextension of the elbow past 10°;

hyperextension of the knee past 10°;

and excessive dorsiflexion and eversion of the foot.

The Beighton scale is most commonly used and is considered the yardstick for proposed scales (Russek, 1999). The Beighton (1973) scale allocates one point for each of the indicators of joint hypermobility. Each limb is scored individually for the first four items generating a possible score of 9. Each subject is allocated a numerical score ranging from 0 – 9 (9 being the highest hypermobile score). A score of 5 or more is used to classify the subject as hypermobile.

An increase in joint laxity referred to, as joint hypermobility is more common in females than males (Arroyo et al, 1988). Gedalia and Brewer (1993) noted that joint hypermobility diminished with age, occurring less frequently during adult life. An association between joint hypermobility and articular complaints such as degenerative joint conditions, dislocations, joint effusions and muscular pains has been reported in the literature (Arroyo et al, 1988; Gedalia and Press, 1991). This association was related to rheumatological rather than orthopaedic related conditions.

Increased movement of joints may affect the neural tracts of the peripheral nerves as they cross over the joints. Hall et al, (1995) found that position sense at the knee is decreased in patients with increased joint hypermobility. They found that subjects with increased hypermobility had an inability to determine the position of the knee joint in end-range extension compared with subjects without joint hypermobility. On review of the literature however, no clear association between joint hypermobility and increased neural tension symptoms was found. El-Shahaly and el-Sherif, (1991) noted that of 114 subjects with hypermobile joints assessed by them, 31.6%

presented with carpal tunnel syndrome and 14% presented with tarsal tunnel syndrome. In his review of joint hypermobility Russek (1999), commented that there might be an increased incidence of nerve compression disorders in people with hypermobile joints. Hudson et al, (1995) did not note this, when they compared patients with hypermobile joints and a control group that were referred to a rheumatology clinic. They reported no difference in the incidence of nerve entrapment neuropathies, in these groups.

Presently the upper limb tension tests are used as diagnostic and treatment techniques to treat pain originating from the neuromeningeal structures of the cervical spine and upper limb (Kaye and Mason, 1989; Kelley and Jull, 1998). The movements involved in the upper limb tension tests appear to stress the neural structures. However, further biomechanical and anatomical studies are needed to clarify the controversy as to the mechanism of how the upper limb tension tests identify neurogenic pain.

All the available relevant peer reviewed articles have been included in this literature review. The following chapter will describe the method used to conduct this study.

CHAPTER 3 METHODS

This chapter describes the sample of subjects and the design of the study. A detailed description of the procedures and instruments used for data collection are set out. The method used to collate and analyse the data is described. The ethical consideration relating to the study is presented.

The study was carried out in the Physiotherapy Department of the Faculty of Health Sciences, University of the Witwatersrand. Prior to the commencement of this study, ethical approval and permission was obtained from the Committee for Research on Human Subjects of the University of the Witwatersrand (ethical clearance number M980902) and the Physiotherapy Department of the University of the Witwatersrand (Appendix 1). All subjects signed an informed consent form.

The study participants were student volunteers from the second, third and fourth year physiotherapy classes. The selection of the sample was based on modified criteria described by Yaxley and Jull (1991). Male and female subjects were included in the study if they were:

- Between the ages of 18 and 35 years.
- Able to complete a questionnaire concerning their habitual physical activity

The subjects were excluded from the study if they presented with:

- A history of cervical, shoulder, elbow, wrist or hand pain and trauma that required treatment or that interrupted their normal daily activities for more than 10 days.

- A history of central or peripheral nervous system disease.
- Systemic arthritides or inflammatory diseases of the joints.
- Pregnancy.
- Pre-test screening movements that were abnormal. Movements of the cervical spine and upper limb to eliminate pathology were performed on each subject. Subjects were excluded if full range movement with overpressure of the cervical spine, that is, flexion, extension, left and right lateral flexion and left and right rotation; glenohumeral flexion, abduction, hand behind back; elbow extension; wrist flexion and extension elicited painful and/or asymmetric stretch sensations.

Each subject included in the study was assigned a number in sequential order of admission (subjects 1 – 63). This was done to ensure subject confidentiality as data was collected and recorded under the subject number.

The apparatus used and procedure followed was based on the criteria described by Yaxley and Jull (1991).

Apparatus:

- A Panamedic stature metre and an EKS scale (model 6232) were used to measure height and weight respectively.
- A standard goniometer (Biomet International standard goniometer CAT No. 576330) was used to measure the range of glenohumeral abduction and hyperextension of the little finger, knee and elbow.

- Velcro straps were used to stabilise the subject's body prior to applying the ULTT2a.
- An ALPF2 aneroid sphygmomanometer velcro cuff (No. 500-v) was used to standardise shoulder depression during the application of the ULTT2a.

Following admission to the study all subjects completed a questionnaire validated by Baecke et al (1982), concerning their level of habitual physical activity (Appendix 2). The measurement of habitual physical activity included the three dimensions of physical activity at work, sport during leisure time and other physical activity during leisure time. The questions in each dimension were allocated values and an index for each dimension was determined. The indices were combined to derive each subject's habitual physical activity score.

The height and weight of each subject was measured.

The subjects dominance was recorded and their joint hypermobility was determined using the technique described by Carter and Wilkinson (1964) with the modification suggested by Beighton et al, (1973). Each limb was scored individually for the first four items generating a possible score of 9. Each subject was allocated a numerical score ranging from 0 – 9 (9 being the highest hypermobile score). A score of 5 or more was used to classify the subject as hypermobile.

The indicators of hypermobility were assessed and points added for these movements were:

1. Passive extension of the fifth metacarpophalangeal (MCP) joint beyond 90° (1 point for each hand – a total of 2 points)
2. Passive apposition of the thumb to the flexor aspect of the forearm (1 point for each thumb – a total of 2 points)
3. Hyperextension of each elbow beyond -10° (1 point for each elbow – a total of 2 points)
4. Hyperextension of each knee beyond -10° (1 point for each knee – a total of 2 points)
5. Forward flexion of the trunk, with knees fully extended so that the palms of the hands rested flat on the floor (– 1 point)

A goniometer was used to determine the degree of hyperextension of the knees, elbows and little finger.

Before the application of the test, the following procedures were undertaken:

1. The examiner passively stretched the wrist flexcrs and extensors, once each for 10 seconds. The stretching of the wrist extensors was achieved by flexing the wrist and fingers with full elbow extension and pronation. Extending the wrist and fingers, with full elbow extension and supination of the forearm stretched the wrist flexors.

2. Goniometer reference points for glenohumeral abduction (anterior edge of the acromion process and the middle of the cubital fossa) were marked on the subjects' arm (See Figure 3.2). Goniometric measurements for the shoulder have been shown to be highly reliable when taken by the same therapist (Riddle et al, 1987).
3. The subject was positioned supine with the side to be tested close to the edge of the plinth, allowing the shoulder girdle to be depressed by the examiner's thigh.
4. To ensure that the subject felt secure and did not compensate for a change in neural tissue tension, velcro belts were secured around the hips and thorax to prevent lateral flexion of the trunk.
5. A padded 5mm metal block was positioned against the side of the head to prevent cervical lateral flexion towards the test side.
6. To maintain the cervical spine in neutral and to prevent cervical extension a velcro strap was placed from the spinous process of the second cervical vertebra and fastened across the chin.
7. During the test procedure the subjects were instructed to keep their eyes fixed on a spot on the ceiling to help eliminate cervical rotation and lateral flexion.
8. A sphygmomanometer cuff was inserted between the anterior aspect of the examiner's thigh and the subject's shoulder to ensure that the examiner could visually monitor that a constant shoulder depression was applied between the two tests. A standardised pressure increase of 40 mmHg as suggested by Edgar et al (1994), as a guide for initial shoulder depression was maintained between tests.

9. Before testing, each arm was held once in the final position of ULTT2a for 15 - 20 seconds at a time and then returned to the subject's side. The aim of this pre-stretch procedure was to familiarise the subject with the test as well as to give some preconditioning stretch to the tissues in each position.
10. The test was applied twice to each arm. The application of the test was alternated between the left and right sides starting routinely with the left side.

<u>Formal test procedure:</u>

The ULTT used in this study was the ULTT2a - an ordered combination of passive:

7. Ipsilateral shoulder girdle depression
8. Full range elbow extension
9. Full range glenohumeral external rotation
10. Full range forearm supination
11. Full range wrist and finger extension
12. Glenohumeral abduction (described by Butler 1991, ULTT2a) (See Figure 3.1)

The sensitising movement added to this sequence was contralateral cervical side flexion.

1. The shoulder girdle was depressed using a 40 mmHg increase on the sphygmomanometer cuff as a guide for the initial shoulder depression. The location and sensory responses to this movement were recorded.
2. Additional test movements as previously described were added passively until the end of range and until a firm maximal tissue resistance was achieved.

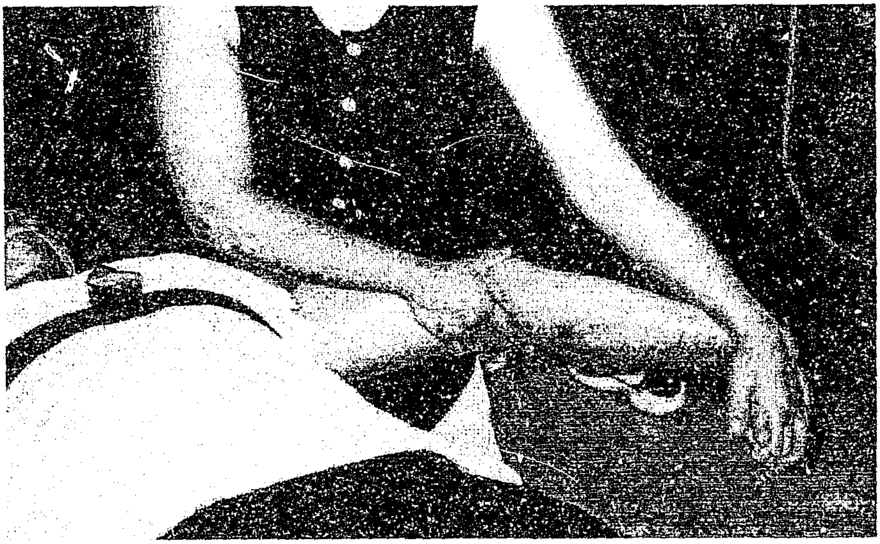

Figure 3.1: The final test position of the modified ULTT2a (median nerve bias).

3. In the final test position the assistant measured the range of glenohumeral abduction (using the marked reference points) (See Figure 3.2).
4. The subject was instructed to laterally flex the cervical spine to the opposite side ensuring no cervical rotation occurred and the effect on arm sensation was recorded. The assistant measured the range of glenohumeral abduction with the addition of the sensitising movement.
5. The subject's arm was returned to his/her side and a detailed description of the nature and area of the symptoms felt was recorded. The test was repeated on the other arm in a similar way.
6. Six subjects were randomly chosen to determine the intraobserver repeatability coefficient of the measurements.

The following data were collected from each subject:

1. The range of glenohumeral abduction available was measured on each arm using a standard goniometer:
   a) In the final test position. (See Figure 3.2)
   b) On adding the sensitising movement of cervical lateral flexion to the contralateral side in the final test position.
2. The subjects were asked to report the sensory responses felt on application of ULTT2a. The sensory responses were not defined to the subjects in order to minimise the subject's bias. The sensory responses were documented at several times during the test procedure:

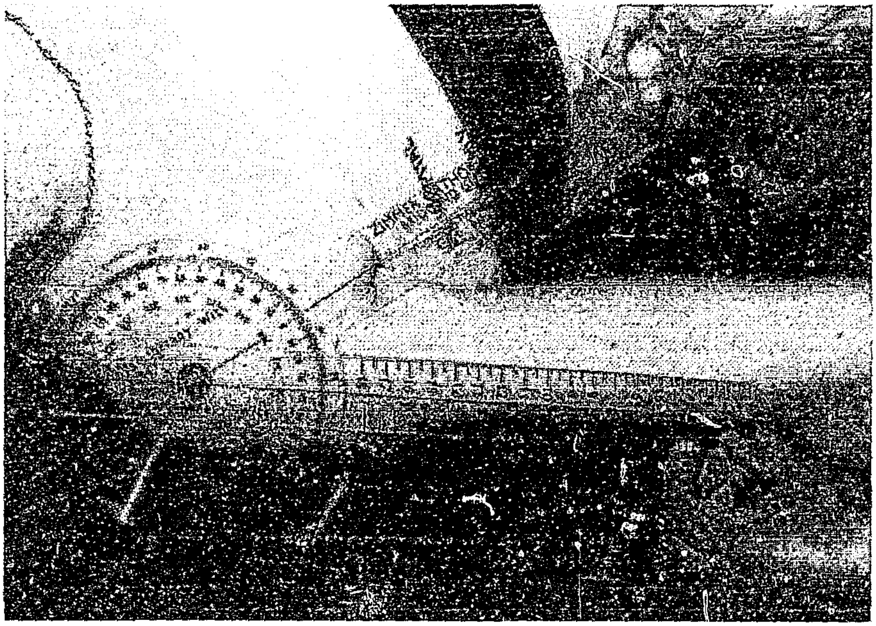

Figure 3.2 Measurement of the range of glenohumeral abduction in the final test position of the modified ULTT2a (median nerve bias).

a) Prior to performing the ULTT2a, ... sensory responses, with the glenohumeral joint in neutral and the elbow in full extension, the wrist and finger extensor and flexor muscles placed on stretch were recorded.

This allowed for differentiation between the perceived sensation of muscle stretch and the perceived sensation of a neural stretch in the final ULTT2a position.

b) In addition, the sensory responses were determined 3 times during each test procedure:

   i) with shoulder girdle depression in the initial position (this was recorded once for each side)

   ii) when the available glenohumeral abduction had been reached in the final test position

   iii) on adding the sensitising movement of cervical lateral flexion to the contralateral side in the final test position.

An assistant measured the range of abduction and recorded these sensory responses on a body chart.

STATISTICAL ANALYSES

The raw data is shown in Appendix 3. The data were analysed using descriptive statistics. Data were described using means, standard deviations and frequency distributions for categorical variables. The effect of hypermobility on the available range of glenohumeral abduction, and the comparison between the left and right arm ranges of glenohumeral abduction were made using the Student's *t*-test for parametric data. A 'p' value ≤ 0.05 was considered to be statistically significant.

An ANOVA (analysis of variance) was used to determine the relationship between gender, side tested, dominance and range of abduction.

Intraobserver reliability was tested using the method described by Bland and Altman (1986) for continuous variables. To determine the intraobserver reliability of a method of measurement, repeated measurements on a series of subjects ($n = 6$) were taken. The difference against the mean for each subject was determined. As the same method was used, the mean and standard deviation should equal zero. Ninety-five percent of the differences are expected to be less than two standard deviations (2SD) of the mean. This is the definition of the repeatability coefficient, adopted by the British Standards Institution. If it is assumed that the mean difference is zero this coefficient is very simple to estimate:

1. All the differences are squared then added up.
2. This value is divided by n (number of subjects measured).

3. The standard deviation of the differences is derived ·m the square root of the value.

4. The repeatability coefficient is less than or equal to two standard deviations (2SD)

The coefficient of repeatability measured for this sample was 12.69 degrees. A difference of 12.69 degrees is acceptable.

In the following chapter the results obtained will be presented.

CHAPTER 4 RESULTS

Seventy-five students completed the consent forms, of which 2 (3%) were excluded after the pre-test examination. The 2 subjects that were excluded presented with asymmetrical responses with overpressure of the pre-test movements. A further 10 (13%) subjects did not arrive for the pre-test examination. Sixty-three volunteers were enrolled into the study.

The demographic data of the 63 students included in the study are shown in Table 4.1. The age, weight and height are denoted as mean values with the range and standard deviation given.

Table 4.1 Distribution of Demographic Characteristics for Physiotherapy Students (n = 63)

Demographic Characteristics	Male (n = 8)	Female (n = 55)	Total Group (n = 63)
	Mean (Range); SD	Mean (Range); SD	Mean (Range); SD
Age (yrs)	22.25 (20; 26); ±1.75	20.70 (18; 26); ±1.74	20.90 (18; 26); ±1.81
Weight (kg)	76.68 (60; 101); ±14.58	60.31 (41.5; 76); ±7.97	62.39 (41.5; 101); ±10.46
Height (cm)	185.72 (73; 198); ± 9.05	167.62 (150;179); ±6.68	169.92 (150; 198); ±9.22

The mean age of the subjects was 20.90 with the age range 18 to 26 years. The distribution of males and females was unequal with 8 (13%) male subjects and 55 (87%) female subjects. The ratio of male to female subjects in this study sample is 1:7.

The physical characteristics of the 63 students included in the study are shown in Table 4.2. The habitual physical activity score is denoted as mean values with the range and standard deviation given. The number of subjects who are right or left handed and the number of hypermobile subjects are shown.

Table 4.2 Distribution of Physical Characteristics for Physiotherapy Students (n = 63).

Physical Characteristics	Male (n = 8)	Female (n = 55)	Total Group (n = 63)
	Mean (Range); SD	Mean (Range); SD	Mean (Range); SD
Habitual physical activity level	8.[illegible]4 (6.62; 10.37); ±1.22	8.50 (6.25; 12); ±1.24	8.52 (6.25; 12); ±1.23
Dominance R/L	R = 8	R = 50; L = 5	R = 58; L = 5
Joint Hypermobility H > 5	H = 2	H = 16	H = 18

R: right hand dominance

L: left hand dominance

H: the number of subjects with joint hypermobility

The mean index for the habitual physical activity level of the total group is scored at 8.52 (±1.23). Most of the subjects were right handed - 58 (92%) right handed and 5 (8%) left handed. Eighteen (29%) of the subjects were classified as having joint hypermobility.

The effects of gender and dominance on glenohumeral abduction were assessed by a one-way ANOVA and shown in Table 4.3. Even though 92% of the subjects were right handed (Table 4.2), this did not have a significant effect on the mean range of glenohumeral abduction between the left and right sides. A 'p' value of ≤ 0.05 was considered to be statistically significant.

Table 4.3 The effects of gender and dominance on the range of glenohumeral abduction determined by the one-way Anova.

Between subjects	df	Error	F	p-value
Gender	1	61	0.855	0.35
Dominance	1	60	1.382	0.78

The results of the ANOVA showed that the mean range of glenohumeral abduction in the final test position was not influenced by either the gender ($F(1,61) = 0.86$; $p < 0.35$) or the dominance ($F(1,61) = 0.8$; $p < 0.78$) of the subjects (Table 4.3). Details of the effect dominance has on the range of glenohumeral abduction is recorded in Appendix 4.

In Table 4.4 the available glenohumeral abduction in the final test position and with contralateral cervical side flexion are shown with mean values and standard deviations given. A 'p' value ≤ 0.05 was considered to be statistically significant.

Table 4.4 The mean values and standard deviations (shown in parentheses) of glenohumeral abduction (measured in degrees) of the left and right arm and total group in the final test position and with contralateral cervical side flexion.

Test position	Left Arm Mean (SD) (degrees)	Right Arm Mean (SD) (degrees)	Total Group Mean (SD) (degrees)	Student's t-test p-value
Final test position	40.97 (±7.66)	43.16 (±8.10)	42.36 (±6.77)	0.03*
Contralateral cervical side flexion	38.30 (±7.46)	39.50 (±7.08)	38.90 (±6.39)	0.17
Student's t-test p-value	0.00*	0.00*	0.00*	

* statistically significant $p \leq 0.05$

The final test position of glenohumeral abduction in ULTT2a occurred in the range 29.09 - 55.62 degrees. The mean for this range of glenohumeral abduction was 42.36 (±6.77) degrees. The range of glenohumeral abduction for each side tested was 25.95 - 55.98 degrees for the left arm and 27.28 - 59.03 degrees for the right arm. The mean range of glenohumeral abduction was 40.97 (±7.66) degrees on the left arm and 43.16 (±8.10) degrees on the right arm. This difference between side tested was statistically significant ($p = 0.03$) using the paired t-test. The difference between side tested for glenohumeral abduction in the final test position and that of glenohumeral abduction with contralateral cervical side flexion was significantly different ($p = 0.00$). Although the measurements were statistically significant, a difference of 3 degrees for the measurements of glenohumeral abduction in the final test position and 4 degrees for the measurements of glenohumeral abduction with contralateral cervical side flexion, was not clinically significant.

In Table 4.5 the effect of hypermobility on the available glenohumeral abduction in the final test position, and with contralateral neck side flexion are shown as mean values. The normal range and standard deviation are given and p-values determined by the unpaired t-test are shown. A 'p' value ≤ 0.05 was considered to be statistically significant.

Table 4.5 The effect of increased joint hypermobility on the mean and standard deviation (shown in parenthesis) of glenohumeral abduction (measured in degrees) of the left and right arm and total group in the final test position and with the sensitizing movement of contralateral cervical side flexion.

Test position	Left Arm Mean (± SD) (degrees)		Right Arm Mean (± SD) (degrees)		Total Group Mean (± SD) (degrees)		Student's t-test
	H (n = 18)	NH (n = 45)	H (n = 18)	NH (n = 45)	H (n = 18)	NH (n = 45)	p-value
Final test position	41.12 (±7.46)	40.91 (±7.82)	40.57 (±6.51)	44.22 (±8.49)	40.81 (±6.53)	45.07 (±7.25)	0.14
Contralateral cervical side flexion	39.15 (±8.61)	37.96 (±7.03)	37.81 (±6.53)	40.14 (±7.24)	38.48 (±6.76)	40.79 (±7.37)	0.39

H: increased joint hypermobility; NH: normal joint.

Increased joint hypermobility did not have a significant effect on the range of glenohumeral abduction (p = 0.14). The range of glenohumeral abduction was less in the subjects with increased joint hypermobility than in the subjects with normal joint range.

Sensory Responses

A review of the sensory responses reported by the subjects showed that there was variability in the area of sensory responses reported. Similar responses were grouped together. A muscular stretch was classified as a muscle stretch. A painful stretch, pins and needles, numbness or neural stretch were grouped as neural stretch.

Pretest position

During the pretest stretch of the flexor and extensor muscles of the wrist and fingers the sensory responses reported by the subjects are shown in Table 4.6 and 4.7.

In Table 4.6 lack of a response and location of responses (if present), as well as the type of sensation reported by the subjects, on the left and right sides, during the pretest stretch of the wrist and finger extensor muscles, are shown.

Table 4.6 Location of responses during the pretest stretch of wrist and finger extensor muscles

Location of responses	Left Arm		Right Arm	
	n	Response	n	Response
1. No response	10		7	
2. Posterior wrist	29	20 stretch 9 neural	34	25 stretch 9 neural
3. Radial aspect of forearm	10	7 stretch 3 neural	16	13 stretch 3 neural
4. Radial aspect of forearm + posterior wrist	2	stretch	3	stretch
5. Ulnar aspect of forearm	4	stretch	4	stretch
6. Ulnar aspect of forearm + posterior wrist			3	stretch
7. Other (fingers)	2	stretch	2	stretch
Total	63		63	

When the wrist and finger extensor muscles were placed on stretch, by combining the left and right arm responses, 87% of the subjects reported a sensory response. Of these subjects, 78% reported a slight stretch and 22% reported a neural stretch.

In Table 4.7 the number of responses, in addition to the description of the responses reported by the subjects, on the left and right sides, during the pretest stretch of wrist and finger flexor muscles, are shown.

Table 4.7 Location of responses during the pretest stretch of wrist and finger flexor muscles

Location of responses	Left Arm		Right Arm	
	n	Response	n	Response
1. No response	53		51	
2. Anterior aspect of wrist	7	stretch	9	stretch
3. Radial aspect of forearm	1	stretch		
4. Ulnar aspect of forearm	1	stretch	3	stretch
5. Posterior wrist	1	stretch		
Total	**63**		**63**	

When the left and right arm sensory responses were combined, 83% of the subjects reported no sensory response when the wrist and finger flexor muscles were placed on full stretch. None of the subjects reported a neural stretch.

ULTT2a POSITION

On application of shoulder girdle depression, none of the subjects reported any symptoms in the arm. The sensory responses reported by the subjects in the positions of glenohumeral external rotation and elbow extension; and wrist and finger extension are tabled in Appendix 5 and 6.

In the position of glenohumeral external rotation and elbow extension 21 (33%) subjects reported sensory responses in the left arm (with 6 reporting a sensory response in more than one area). Eighteen (28%) subjects reported sensory responses in the right arm (with 3 reporting a sensory response in more than one area). A total of 39 (62%) of the subjects reported a sensory response with glenohumeral external rotation and elbow extension. Most of the subjects reported a muscular stretch sensation (62%) rather than neural stretch sensation (38%). The most common sites of responses were in the centre of ventral aspect of forearm and wrist (33%) in the distribution of the median nerve and over various areas such as the lateral and medial aspects of the elbow, posterior wrist and anterior aspect of the shoulder (25%).

In the position of wrist and finger extension, 52 (82%) subjects reported sensory responses in the left arm (with 23 reporting a sensory response in two or more areas) and 47 (74%) subjects reported sensory response in the right arm (with 21 reporting a sensory response in two or more areas). Most of the subjects reported an equal frequency of muscular stretch sensation (50%) to neural stretch sensation (49%).

The most common site of responses was in the median nerve distribution (66%) that is the centre of the ventral aspect of the forearm spreading into the palm, second and third fingers and the radial aspect of the forearm extending into thumb and first finger. In the median nerve distribution, 54% reported a neural stretch and 46% reported muscular stretch response

In Table 4.8 the sensory responses reported by the subjects in the final test position with glenohumeral abduction are shown.

Table 4.8 Location of responses in the final test position – glenohumeral abduction

Location of responses	Left Arm (n = 63)		Right Arm (n = 63)	
	n	Response	n	Response
1. Ulnar aspect of forearm extending into the palm, third and fourth fingers	9	6 stretch 3 neural	11	6 stretch 5 neural
2. Centre of ventral aspect of forearm and wrist, spreading into the palm, second and third fingers	40	17 stretch 23 neural	37	17 stretch 20 neural
3. Radial aspect of forearm extending into the thumb and first finger	17	5 stretch 12 neural	22	8 stretch 14 neural
4. Medial aspect of elbow	9	1 stretch 8 neural	11	5 stretch 6 neural
5. Other (posterior aspect of wrist, anterior cubital fossa and anterior aspect of shoulder)	14	4 stretch 10 neural	18	11 stretch 7 neural
Total	**89**		**99**	

All the subjects reported sensory responses when glenohumeral abduction was added to the final test position. Twenty-six reported a sensory response in more than one area in the left arm, and 29 reported a sensory response in more than one area in the right arm. When the data for the left and right arms were combined, slightly more subjects reported a neural stretch sensation (57%) rather than a muscular stretch sensation (43%). The most common site of responses was in the median nerve distribution (62%), that is the centre of the ventral aspect of the forearm spreading into the palm, second, and third fingers and the radial aspect of the forearm extending into thumb and first finger (Areas 1 and 2 combined in Figure 4.1). In the median nerve distribution (Area 1 and 2 combined in Figure 4.1) 59% of the subjects reported a neural stretch and 41% reported a muscle stretch

FREQUENCY OF RESPONSES

Area 1 21% Of this 21% of subjects, 66% reported a neural stretch and 33% a muscle stretch

Area 2 41% Of this 41% of subjects, 56% reported a neural stretch and 44% a muscle stretch

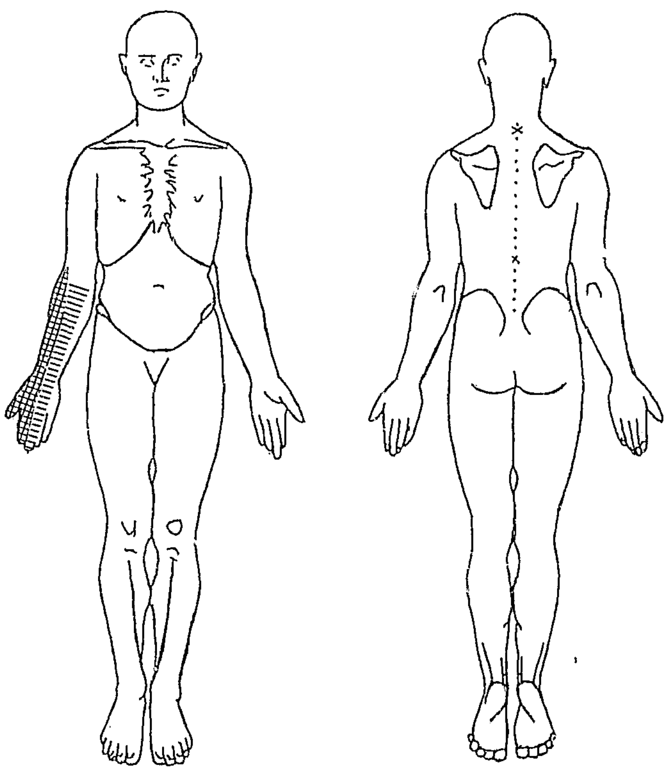

Figure 4.1 The location of sensory responses of normal subjects in the final test position of glenohumeral abduction (the left and right arm responses are combined).

In Table 4.9 the sensory responses reported by the subjects in the final test position of wrist and finger extension with glenohumeral abduction and with the sensitizing movement of contralateral neck side flexion are shown.

Table 4.9 Location of responses in the final test position – glenohumeral abduction with contralateral cervical side flexion

Location of responses	Left Arm (n = 63)		Right Arm (n = 63)	
	n	Response	n	Response
1. Ulnar aspect of forearm extending into the palm, third and fourth fingers	10	6 stretch 4 neural	11	6 stretch 5 neural
2. Centre of ventral aspect of forearm and wrist, spreading into the palm, second and third fingers	35	14 stretch 21 neural	34	13 stretch 21 neural
3. Radial aspect of forearm extending into the thumb and first finger	23	5 stretch 18 neural	19	6 stretch 13 neural
4. Medial aspect of elbow	9	3 stretch 6 neural	9	5 stretch 4 neural
5. Other				
posterior aspect of wrist	4	2 stretch 2 neural	3	3 stretch
anterior cubital fossa	17	9 stretch 8 neural	17	9 stretch 8 neural
anterior aspect of shoulder	13	4 stretch 9 neural	11	3 stretch 8 neural
Total	**111**		**104**	

All the subjects reported sensory responses in this position. Thirty-eight subjects reported a sensory response in more than one area in the left arm and 29 reported a sensory response in more than one area in the right arm. Combining the data for the left and right arms, most of the subjects reported a neural stretch (59%) rather than a muscular stretch sensation (41%). The most common site of responses was in the median nerve distribution (52%), that is the centre of the ventral aspect of the forearm spreading into the palm, second and third fingers and the radial aspect of the forearm extending into thumb and first finger (See Figure 4.2). In the median nerve distribution (Areas 1 and 2 combined in Figure 4.2) 66% of the subjects reported a neural stretch and 34% reported a muscle stretch. In the ulnar nerve distribution (Area 3 in Figure 4.2), anterior cubital fossa (Area 4 in Figure 4.2), and anterior aspect of the shoulder (Area 5 in Figure 4.2) 18%, 16% and 11% of the subjects respectively reported sensory responses.

FREQUENCY OF RESPONSES

Area 1	20%	Of this 20% of subjects, 74% reported a neural stretch and 26% muscle stretch
Area 2	32%	Of this 32% of subjects, 61% reported a neural stretch and 39% muscle stretch
Area 3	18%	
Area 4	16%	
Area 5	1%	

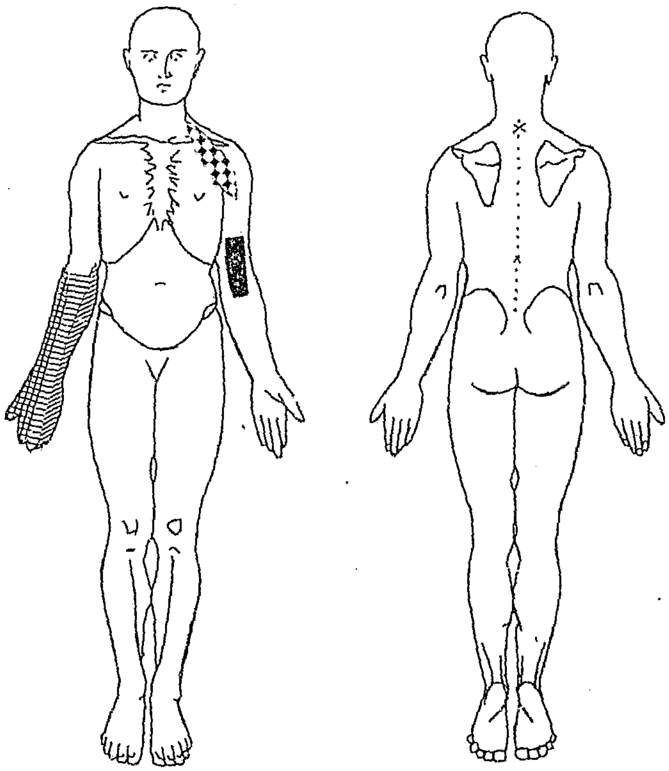

Figure 4.2 The location of sensory responses of normal subjects in the final test position of glenohumeral abduction with contralateral cervical side flexion (the left and right arm responses are combined).

CHAPTER 5 DISCUSSION

In this study the final test position of glenohumeral abduction in ULTT2a occurred in the range 29.09 - 55.62 degrees. The mean for this range of glenohumeral abduction is 42.36 (±6.77) degrees. The range of glenohumeral abduction for each side tested was 25.95 - 55.98 degrees for the left arm and 27.28 - 59.03 degrees for the right arm. The mean range of glenohumeral abduction was 40.97 (±7.66) degrees on the left arm and 43.16 (±8.10) degrees on the right arm. These results are similar to the findings of Yaxley and Jull (1991), a mean range of 42.74 degrees of glenohumeral abduction on the left and 43,48 degrees on the right, when they evaluated range of glenohumeral abduction for the radial nerve bias ULTT2b.

The unequal distribution of male to female subjects, that was due to the composition of the physiotherapy classes, did not significantly affect the range of glenohumeral abduction, nor did the hand dominance of the subjects in this study. The unequal distribution of male to female subjects (1:7) is typical of physiotherapy student classes with a predominance of female students (Scully and Cox, 1982; Warren and Pierson, 1994).

Yaxley and Jull (1991) limited their sample selection to right handed subjects with an equal distribution of male and female subjects. They found that the range of glenohumeral abduction was not affected by the gender of the subject or the side tested, i.e. left or right side. In this study a statistically significant difference between the range of glenohumeral abduction of the left and right arms was noted. However, this was not clinically significant. The hand dominance of the subjects in this study did not affect the final range of glenohumeral abduction. In the present study, however, there was only a small percentage of left hand dominant subjects. The effect of dominance on the mean limit of range of glenohumeral abduction needs further investigation.

The prevalence of joint hypermobility in normal schoolchildren was 34% (Arroyo, et al, 1988). These authors noted a trend that the frequency of joint hypermobility tends to decrease with increasing age. The frequency of joint hypermobility in this sample group (28%) was similar to the level of joint hypermobility in the South African population of a similar age group, considering that the frequency of joint hypermobility decreases with age. Joint hypermobility did not affect the range of glenohumeral abduction, as the range of glenohumeral abduction in hypermobile subjects and normal subjects was the same, or even slightly decreased in the subjects with increased joint mobility (Table 4.5). The findings in the literature (el-Shahaly and el-Sherif, 1991), suggest that increased joint hypermobility predisposes the subjects to nerve entrapment syndromes resulting in a possible decrease in range in neural mobility rather than an increased range of neural mobility. This is supported by the findings in this study (Table 4.5).

The sample of students in this study are representative of physical therapy students falling in the young adult population category. The mean age of subjects in this study, 20.70 years (± SD 1.75) is similar to that of physical therapy students in the United States of America, where the mean age group reported by Scully and Cox (1982), was 23.2 years and that reported by Warren and Pierson (1994) was 25.0 years (±SD 4.4).

The habitual physical activity index of this sample of students was scored at 8.52. The habitual physical activity indices established by Baecke et al (1982), in a Dutch population of a similar age group, 20 - 32 years, was 8.2 for males and 8.4 for females. This compares favourably to the indices reported in this sample (8.64 for males and 8.50 for females), indicating that their habitual physical activity level is typical of a young adult population.

SENSORY RESPONSES TO THE MODIFIED ULTT2a

Shoulder girdle depression

None of the subjects in this study reported a sensory response with shoulder girdle depression. Yaxley and Jull (1991) found that the shoulder girdle depression component of the radial nerve bias ULTT2b did not stress the neural structures of the upper limb sufficiently to reliably evoke symptoms. Lewis et al (1998) measured the changes in neural tension in the median nerve while performing the original ULTT1. They applied a buckle transducer to the median nerve of three cadavers and recorded the changes in tension during a series of ipsilateral and contralateral movements of the upper and lower limb. They found that no significant increase in tension occurred when the shoulder was depressed with the upper limb in a neutral position. This is a common starting position for all upper limb tension tests described. These findings suggest that shoulder girdle depression does not stress the components of the brachial plexus. This is supported by the findings in this study.

Glenohumeral external rotation and elbow extension

Most of the subjects reported feeling a muscular stretch sensation (62%) rather than a neural stretch sensation (38%). Lewis et al (1998) found that glenohumeral external rotation had no affect in increasing the tension on the median nerve. The muscular stretch sensation, felt mainly over the centre of the ventral aspect of the forearm and wrist and over various areas such as the lateral and medial aspects of the elbow, posterior wrist and anterior aspect of shoulder, possibly stretches the muscles of the arm and forearm, mainly the biceps brachii and the extensors of the wrist. The muscular stretch sensation reported in the forearm corresponds to that experienced by the subjects when the wrist and finger extensors were stretched in the pre-test position (Table 4.6). The median nerve does not appear to be specifically placed on increased tension during glenohumeral external rotation and elbow extension. This finding is supported by Lewis et al, 1998, and Reid, 1987 who reported that external rotation of the glenohumeral joint decreased the tension in all parts of the brachial plexus. Reid (1987) measured the tension produced in the brachial plexus with a buckle force transducer during the various movements of the ULLT1.

Although 38% of the subjects in this study reported a neural stretch sensation during glenohumeral external rotation and elbow extension, this was not in one distinct referral area but felt over various areas in the forearm (Appendix 3). This phenomenon may occur as a result of stretching of the muscles of the upper limb as the limb is placed in various positions of ULTT2a. The stretching of the muscles may result in a decrease in the blood supply to the peripheral nerves. The decreased blood supply may result in a decrease in the conduction of the nerves (Lundborg, 1988). Possible entrapment of the peripheral nerves as they pass through the fascial layers of the muscles of the upper limb may account for the neural sensation reported by the subjects. Streib (1992) described three cases of patients who presented with radial nerve palsy after a sudden forceful contraction and stretch of the upper limb muscles. This was as a result of the radial nerve being trapped in the lateral head of the triceps muscle.

Wrist and finger extension

The subjects reported an equal frequency of muscular and neural stretch sensation (50% reported a neural stretch and 49% reported muscular stretch response). McLellan and Swash (1976) noted that while recording action potentials in single afferent nerve fibres in the median nerve of 15 subjects, wrist and finger extension caused the greatest excursion of the median nerve. As 66% of the subjects in this study reported responses in the median nerve distribution, this indicates that the median nerve is possibly placed on longitudinal stretch during wrist and finger extension. However, of the 66% of subjects who reported a response in the median nerve distribution 54% reported a neural stretch and 46% reported muscular stretch response (Appendix 4). As the sensory responses were not predominantly of a neural nature, it appears that the somatic structures of the upper limb were also placed on stretch.

Yaxley and Jull (1991) state that the end range positions could possibly place variable amounts of stretch on articular structures, muscles and their fascia. The superficial and deep layers of muscle fascia in the cervical area and upper limb are anatomically and biomechanically independent and are not connected as are the neural tissue tracts (Yaxley and Jull, 1991). The cumulative addition of the various positions of the upper limb while performing ULTT2a places an additional stretch on the muscular structures of the forearm. However, the areas of the sensory responses with wrist and finger extension in the ULTT2a position do not correspond to those reported when the wrist and finger flexor or extensor muscles were placed on stretch in the pre test positions (Table 4.6 and 4.7).

Final test position - glenohumeral abduction

The addition of glenohumeral abduction increased the median nerve neural response with 62% of the subjects reporting a neural stretch sensation in the median nerve distribution. Kenneally et al (1988) and Butler (1991) reported increasing tension in the neural system by the sequential addition of movements with the upper limb tension test. Lewis et al, (1998) found that a trend of increasing tension was observed during the ULTT1. However, there was an unequal contribution to the increasing tension in the neural system from the individual component movements during the progression of the test with no significant increase in tension occurring in the median nerve with glenohumeral abduction (Lewis et al, 1998). In the median nerve bias ULTT2a, glenohumeral abduction is added as the final movement. In the original ULTT1, it is the second component of the test. The change in the sequential addition of the movements in the ULTT2a appears to increase the stretch in the median nerve (59% of the subjects reported a neural stretch response compared to 41% reporting a muscle stretch response). As no biomechanical or anatomical studies have been conducted to observe the tension produced in the neural tracts of the upper limb during any of the upper limb tension tests modified by Butler (Butler and Gifford, 1989), this can only be surmised from the sensory responses reported clinically.

The responses produced with the sensitising movement of contralateral neck side flexion were similar to the responses when glenohumeral abduction was added. The sensory responses extended more proximally with subjects reporting responses in the anterior cubital fossa and anterior shoulder area (Figure 4.4). The addition of the sensitising movement appears to cause tension on the neural tissue tracts proximally at the cervical nerve roots and distally in the median nerve. The increase in sensory responses is supported on the basis of increased tension in the continuous tissue tract extending from the cervical nerve roots in the neck to the peripheral nerves in the upper limb (Yaxley and Jull, 1991).

The sensory responses for the median nerve bias ULTT2a in this study have similarities and differences to those reported by Kenneally et al (1988) for the ULTT1. Kenneally et al (1988) stated that the distribution of sensations correlated well with the dermatomal distribution of the C5, C6 and C7 cervical nerve roots and found that 80% of the subjects reported a sensory response in the median nerve distribution. He noted that normal subjects should only report a mild stretch sensation across the anterior aspect of the shoulder, as the ULTT1 does not reproduce any neural sensory responses in the shoulder area. In this study 60% of the subjects reported a sensory response in the median nerve distribution in the final position, which differs from the 80% reported by Kenneally et al (1988). In addition, 16% and 11% of the subjects reported a muscular stretch response as well as a neural stretch response extending into the anterior cubital fossa and over the anterior aspect of the shoulder respectively (Figure 4.4). It appears that ULTT2a causes tension on the median nerve as it enters the cubital fossa under the cover of the bicipital aponeurosis as well as proximally at the cervical nerve roots resulting in the sensory responses noted in this study (Yaxley and Jull, 1991).

In the study completed by Yaxley and Jull (1991), none of the subjects used by them described any response over the anterior shoulder area. The radial nerve bias ULTT2b mainly stresses the distal neural tissue tracts rather than the cervical nerve roots. Yaxley and Jull, (1991), state that medial rotation of the glenohumeral joint, elbow extension, wrist and finger extension stress the ulnar nerve as well (42% of cases in their study), possibly at the elbow. They refer to an anomalous neural anatomy between the ulnar and median nerve (Guttman 1977) that could possibly explain the sensory response of the subjects in their study. From the sensory responses in the final test position it would appear that the ULTT2a stresses the ulnar nerve as well (medial cord of the brachial plexus, C8 and T1 nerve roots, with fibres of C7 picked up in the axilla) (Romanes, 1981). However, only 18% of the subjects in this study reported sensory response in the ulnar nerve distribution (Figure 4.4). Yaxley and Jull (1991) noted that the modified ULTT2b sensory responses did not fit into a recognisable dermatomal pattern. In this study, the ULTT2a sensory responses reported, appear to fit into a recognisable dermatomal pattern, namely, that of C5, C6 and C7, as well as the peripheral sensory distribution of the median nerve.

Lewis et al (1998) state that the range of movements and sensory responses of the ULTT1 cannot entirely be attributed to the increase in tension in the neural tissue tracts and the related connective tissue. The neural provocation tests differentiate the sources of the sensory responses by influencing neural tissue tracts while keeping the adjacent non-neural structures stationary. The author feels that due to the variability of the sensory responses reported in the final test position of the median nerve bias ULTT2a, the sensory response reported cannot unequivocally be derived solely from neural tissue tracts.

In chapter 6 the conclusions of this study will be discussed.

CHAPTER 6 CONCLUSION

The aims of this study were to determine the range of glenohumeral abduction and define the sensory responses when the neural tissue tracts of normal subjects were placed on tension using the modified upper limb tension test - median nerve bias (ULTT2a). In addition the effect of subject joint hypermobility on the extensibility of the neural structures of the upper limb was also determined.

The conclusions that can be drawn from this study using ULTT2a are that the range of glenohumeral abduction for ULTT2a in a young adult population is 29.09 and 55.62, with a mean of 42.36 degrees in the final test position.

The sensory responses for ULTT2a found in this study although similar to those found by Kenneally et al (1988), with neural stretch responses predominantly in the median nerve distribution, differ in that the sensory responses cannot be attributed only to tension in the neural tissue tracts. The ULTT2a appears to stress both the proximal nerve roots as well as the peripheral nerve tracts. The normal responses reported by the subjects are a neural or muscle stretch sensation in the centre of the ventral aspect of the forearm spreading into the palm, second and third fingers and the radial aspect of the forearm extending into the thumb and first finger. This area corresponds with the dermatomal distribution of C5, C6 and C7 as well as the sensory distribution of the median nerve.

Increased hypermobility of the articular joints does not increase the mean range of glenohumeral abduction, which is 40.81 degrees, and may result in decreased mobility of the peripheral neural tissue tracts. The mean limit of the range of glenohumeral abduction in normal joints (not hypermobile) is 45.07 degrees.

Previously when ULTT2a was used as neurodiagnostic technique, the sensory responses reported by the patients were compared to the contralateral limb. The normal responses of the ULTT2a described will enable therapists to differentiate normal from abnormal responses aiding with the identification and management of neural abnormalities. However, the sensory responses recorded in this study suggest that the components of shoulder girdle depression, external rotation and elbow extension of the ULTT2a do not increase tension in the median nerve. Wrist and finger extension, glenohumeral abduction and contralateral neck side flexion increase the sensory responses of the median nerve bias ULTT2a. As the upper limb tension tests are commonly used as neurodiagnostic tests, the biomechanical components of these neural provocation tests and anatomical relationships to determine the forces produced during shoulder depression and glenohumeral external rotation need to be investigated further.

Suggestions for further study

The effect of joint hypermobility on the mean range of glenohumeral abduction of the median nerve bias ULTT2a should be assessed in a larger sample group. In addition biomechanical and anatomical tests to determine the forces produced during the modified upper limb tension tests and their contribution to the mean range of glenohumeral abduction should be investigated.

In addition, the effect of hand dominance on the range of glenohumeral abduction and the sensory responses reported by the subjects need to be investigated further in a larger sample group. As there is a statistically significant difference in the mean range of glenohumeral abduction between the left and right arms, hand dominance may affect the range of glenohumeral abduction and the sensory responses reported in a larger sample size.

APPENDICES

APPENDIX 1 The ethical clearance obtained from the Committee for Research on Human Subjects of the University of the Witwatersrand (ethical clearance number M980902).

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

COMMITTEE FOR RESEARCH ON HUMAN SUBJECTS (MEDICAL)
Ref: R14/49 Fortune

CLEARANCE CERTIFICATE PROTOCOL NUMBER M980902

PROJECT Median Nerve Bias Tension Test Response In Normal Subjects

INVESTIGATORS Ms J Fortune

DEPARTMENT Physiotherapy Department, Wits Medical School

DATE CONSIDERED 980925

DECISION OF THE COMMITTEE *

Approved unconditionally

DATE 981005 CHAIRMAN.......................................(Professor P E Cleaton-Jones)

* Guidelines for written "informed consent" attached where applicable.

c c Supervisor: Ms CJ Cunningham
Dept of Physiotherapy Department, Wits Medical School

Works2\Jain0015\HumEth97 wpd\M 980902

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and ONE COPY returned to the Secretary at Room 10001, 10th Floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee.

DATE ....OCT / 1998........SIGNATURE ....

PROTOCOL NO.: M 980902

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX 2 HABITUAL PHYSICAL ACTIVITY QUESTIONNAIRE

HABITUAL PHYSICAL ACTIVITY

Date: __/__/__ File No.: __/__

I would like to determine your level of physical activity. Answer all the questions in the following list by placing a tick in the box that best represents your present level of activity.

1. What is your main occupation? ________________________________

2. At work I sit

Never	Seldom	Sometimes	Often	Always

3. At work I stand

Never	Seldom	Sometimes	Often	Always

4. At work I walk

Never	Seldom	Sometimes	Often	Always

5. At work, I lift heavy loads

Never	Seldom	Sometimes	Often	Very Often

6. After working, I am tired

Very Often	Often	Sometimes	Seldom	Never

7. At work I sweat

Very Often	Often	Sometimes	Seldom	Never

8. In comparison to others of my own age, I think my work is physically

Much heavier	Heavier	As heavy	Lighter	Much lighter

9. Do you play sport?
Yes ☐ No ☐
If yes:
- which sport do you play most frequently? ________________________________
- how many hours a week?

<1	1 - 2	2 - 3	3 - 4	>4

- How many months a year?

<1	1 - 3	4 - 6	7 - 9	>9

If you play a second sport:
- which sport is it? ________________________________
- how many hours a week?

<1	1 - 2	2 - 3	3 - 4	>4

- How many months a year?

<1	1 - 3	4 - 6	7 - 9	>9

10. In comparison to others of my own age, I think my physical activity during leisure time is

Much more	More	The same	Less	Much less

11. During leisure time I sweat

Very Often	Often	Sometimes	Seldom	Never

12. During leisure time, I play sport

Never	Seldom	Sometimes	Often	Very Often

13. During leisure time, I watch television

Never	Seldom	Sometimes	Often	Very Often

14. During leisure time I walk

Never	Seldom	Sometimes	Often	Very Often

15. During leisure time I cycle

Never	Seldom	Sometimes	Often	Very Often

16. How many minutes do you walk and/or cycle per day to and from work, school and shopping?

<5	5 - 15	15 - 30	30 - 45	>45

APPENDIX 3 Spreadsheet of original data

	1 STNO	2 SEX	3 RACE	4 AGE	5 WEIGHT	6 HEIGHT	7 PHYSACT	8 DOM	9 JTMOB	10 LABDNROM	11 RABDNROM	12 ABAV	13 LLFABROM	14 RLFABROM	15 LFABAV
1	1	F	W	20	55.0	172.0	8.0	R	2	31.5	41.5	36.5	35.5	36.5	36.0
2	2	F	W	22	68.0	172.0	10.1	R	7	39.0	36.5	37.8	35.0	32.5	33.8
3	3	F	W	20	75.0	173.5	9.3	R	2	33.5	30.5	32.0	26.0	26.5	26.3
4	4	M	B	22	78.5	177.5	10.4	R	2	52.5	68.5	60.5	45.0	59.0	52.0
5	5	F	W	22	58.5	163.0	10.6	R	1	45.5	39.5	42.5	38.5	38.5	38.5
6	6	M	W	22	85.5	188.0	7.6	R	0	28.0	28.5	28.3	21.0	20.0	20.5
7	7	F	W	26	64.0	175.0	10.0	R	5	33.0	31.5	32.3	33.5	32.0	32.8
8	8	F	W	21	62.5	175.2	9.5	R	1	51.5	45.0	48.3	40.0	35.5	37.8
9	9	F	W	20	58.5	165.5	8.5	R	3	32.5	38.5	35.5	33.5	36.0	34.8
10	10	F	W	19	58.0	159.7	7.1	R	0	44.0	51.3	47.6	43.0	47.0	45.0
11	11	F	W	21	60.0	161.0	8.1	R	2	29.5	35.0	32.3	31.5	29.5	30.5
12	12	F	W	22	64.0	159.7	7.6	R	3	32.5	56.5	44.5	37.0	48.0	42.5
13	13	M	W	20	69.5	188.4	6.6	R	0	46.0	44.0	45.0	40.5	34.0	37.3
14	14	F	W	20	59.0	162.8	8.9	L	7	33.0	28.0	30.5	30.5	28.5	29.5
15	15	F	W	21	76.0	178.0	8.9	R	5	39.0	37.5	38.3	37.5	33.5	35.5
16	16	F	W	23	61.5	164.7	10.1	R	4	48.0	46.0	47.0	44.5	40.0	42.3
17	17	F	W	21	52.5	168.5	8.1	R	4	36.0	40.0	38.0	35.5	41.0	38.3
18	18	F	W	21	68.5	167.7	6.4	R	2	41.0	39.0	40.0	40.0	44.0	42.0
19	19	F	W	23	64.0	169.0	12.0	R	9	47.0	44.5	45.8	46.5	38.0	42.3
20	20	F	W	21	65.0	174.5	10.6	R	2	43.5	48.5	46.0	31.0	47.0	39.0
21	21	F	W	20	58.5	170.0	7.6	R	2	31.3	44.5	37.9	29.0	41.0	35.0
22	22	F	W	19	57.5	173.0	6.3	R	2	39.5	41.5	40.5	38.8	35.0	36.9
23	23	F	W	21	57.0	166.5	9.1	R	1	39.0	57.5	48.3	38.5	50.5	44.5
24	24	M	B	23	62.0	176.0	8.3	R	5	49.0	43.0	46.0	38.0	37.5	37.8
25	25	F	W	20	61.0	177.0	9.0	R	0	34.0	49.5	41.8	32.8	43.8	38.3
26	26	M	W	22	101.0	195.0	9.6	R	5	40.0	46.5	43.3	40.5	47.0	43.8
27	27	F	W	20	73.0	176.0	8.3	R	2	40.0	42.0	41.0	40.0	37.5	38.8
28	28	F	B	23	48.5	151.7	9.1	R	6	28.0	33.5	30.8	30.5	32.0	31.3
29	29	F	W	21	62.0	167.5	8.6	R	5	37.5	48.5	43.0	32.0	43.8	37.9
30	30	F	W	22	55.0	159.5	9.1	R	3	34.5	42.0	38.3	30.3	36.8	33.5
31	31	F	W	22	55.0	168.5	9.5	R	5	46.8	45.0	45.9	42.8	44.5	43.6
32	32	F	W	24	61.0	169.0	11.1	R	1	56.5	55.5	56.0	55.5	44.0	49.8
33	33	F	W	18	71.0	179.5	7.4	L	2	33.0	30.0	31.5	29.5	29.5	29.5
34	34	F	W	20	63.5	167.5	9.9	R	5	33.0	34.3	33.6	34.5	31.0	32.8
35	35	F	W	19	52.0	162.0	7.6	R	2	39.5	32.8	36.1	31.0	29.5	30.3
36	36	F	W	19	73.0	176.5	6.8	R	0	33.0	42.5	37.8	40.5	43.0	41.8
37	37	F	B	23	54.5	169.5	8.9	R	4	43.5	39.5	41.5	30.0	41.0	39.5
38	38	F	W	20	73.5	166.0	8.9	R	2	38.0	43.5	40.8	36.0	46.0	41.0
39	39	F	W	19	60.0	169.0	8.3	R	5	43.0	37.0	40.0	38.0	39.5	38.8
40	40	F	W	19	66.0	166.1	9.6	R	4	43.0	38.5	40.8	41.0	36.8	38.9
41	41	F	W	20	42.0	150.0	7.3	R	5	41.5	37.5	39.5	38.5	35.0	36.8
42	42	F	W	22	68.5	173.8	8.8	R	2	44.0	41.0	42.5	[illegible]	38.5	41.0
43	43	F	W	19	41.5	152.7	7.0	R	2	27.5	40.0	33.8	32.0	43.5	37.8
44	44	F	W	20	51.0	175.7	7.5	R	7	32.5	37.5	35.0	25.5	31.5	28.5
45	45	M	W	26	67.0	173.5	8.1	R	2	38.0	64.5	51.3	40.0	44.5	42.3
46	46	F	B	21	66.0	165.6	6.9	R	1	53.0	54.0	53.5	37.5	45.0	41.3
47	47	F	W	19	43.5	159.5	6.8	R	7	45.5	48.0	46.8	48.5	51.5	50.0
48	48	F	W	22	55.5	176.8	6.6	L	0	59.0	53.0	56.0	45.0	52.5	48.8
49	49	F	W	19	62.0	167.3	8.0	R	0	40.5	44.5	42.5	42.0	46.5	44.3
50	50	F	I	21	51.0	158.7	6.9	R	4	45.8	43.0	44.4	36.5	42.0	39.3
51	51	F	W	20	58.5	172.8	7.6	R	1	49.5	51.5	50.5	42.0	39.5	40.8
52	52	F	W	20	63.5	162.2	8.8	L	4	42.5	40.5	41.5	45.0	39.5	42.3
53	53	M	W	22	90.0	198.0	8.9	R	3	39.0	50.5	44.8	35.3	31.0	33.1
54	54	F	W	23	60.0	171.0	8.5	R	2	42.5	41.5	42.0	45.0	42.0	43.5
55	55	F	W	19	57.5	165.5	8.1	R	4	40.0	47.0	43.5	36.5	40.0	38.3
56	56	F	W	19	55.0	159.5	8.8	R	5	50.0	43.5	46.8	61.5	39.0	50.3
57	57	F	W	18	64.0	167.0	8.9	R	0	40.8	41.5	41.1	32.0	42.5	37.3
58	58	F	W	26	58.0	170.2	9.6	R	5	56.0	50.0	53.0	51.0	46.5	48.8
59	59	M	W	21	60.0	189.4	9.6	R	1	38.3	30.0	34.1	31.5	37.0	34.3
60	60	F	W	20	61.0	167.5	8.0	R	1	34.0	50.5	42.3	37.0	40.5	38.8
61	61	F	W	19	76.0	174.3	9.1	L	6	46.5	47.0	46.8	40.5	37.5	39.0
62	62	F	I	21	50.0	167.5	7.3	R	4	55.5	44.5	50.0	44.5	35.0	39.8
63	63	F	W	19	61.0	165.2	8.6	R	0	51.0	41.0	46.0	60.0	52.0	56.0

APPENDIX 4 The effect of dominance on the available glenohumeral abduction in the final test position and with contralateral neck side flexion are shown (mean values, standard deviations and p-values are given).

Available glenohumeral abduction (measured in degrees) of the left and right sides in the final test position and with sensitizing movement of contralateral neck side flexion, taking dominance into consideration.

Test position	Left Arm Abduction Mean (SD) (Degrees)		Students-t Test	Right Arm Abduction Mean (SD) (Degrees)		Students-t Test
	R (n = 58)	L (n = 5)	p - value	R (n = 58)	L (n = 5)	p - value
Final test position	40.81 (±7.43)	42.81 (±10.82)	p = 0.71	43.46 (±7.88)	39.70 (±10.74)	p = 0.69
Contralateral cervical side flexion	38.32 (±7.51)	38.10 (±7.62)	p = 0.66	39.68 (±6.89)	37.50 (±9.66)	p = 0.89

R: right arm dominant

L: left arm dominant.

'p' value ≤ 0.05 was considered to be statistically significant.

APPENDIX 5 The sensory responses reported by the subjects in the position of glenohumeral external rotation and elbow extension are shown.

Location of responses during glenohumeral external rotation and elbow extension components of the ULTT2a

Location of responses	Left Arm (n = 21)		Right Arm (n = 18)	
	n	Response	n	Response
1. Anterior cubital fossa	5	3 stretch 2 neural	1	stretch
2. Ulnar aspect of forearm	4	3 stretch 1 neural	3	2 stretch 1 neural
3. Radial aspect of forearm	3	2 stretch 1 neural	4	3 stretch 1 neural
4. Centre of ventral aspect of forearm and wrist	8	5 stretch 3 neural	8	3 stretch 5 neural
5. Other (lateral and medial aspects of the elbow, posterior wrist and anterior aspect of shoulder)	7	4 stretch 3 neural	5	4 stretch 1 neural
Total	**27**		**21**	

The table is described in chapter 4, page 39.

APPENDIX 6 The sensory responses reported by the subjects with wrist and finger extension are shown.

Location of responses – wrist and finger extension

Location of responses	Left Arm (n = 52)		Right Arm (n = 47)	
	n	Response	n	Response
1. Ulnar aspect of forearm extending into the palm, third and fourth fingers	11	6 stretch 5 neural	4	4 stretch
2. Centre of ventral aspect of forearm and wrist, spreading into the palm, second and third fingers	37	17 stretch 20 neural	30	17 stretch 13 neural
3. Radial aspect of forearm extending into the thumb and first finger	12	4 stretch 8 neural	18	7 stretch 11 neural
4. Medial aspect of elbow	4	3 stretch 1 neural	4	2 stretch 2 neural
5. Other (posterior aspect of wrist, anterior cubital fossa and anterior aspect of shoulder)	14	5 stretch 9 neural	14	10 stretch 4 neural
Total	78		**70**	

The table is described in chapter 4, page 39.

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