CHAPTER 2

LITERATURE REVIEW

Chapter Overview

This chapter commences with historical background and definition of facet syndrome. Anatomy, biomechanics and function of lumbar facet joint is described in brief. Chapter continues with literature on outcomes used in study and their reliability, such as Sorensen’s Test, Modified Schober's test, Modified Oswestry Disability Questionnaire and Pressure pain threshold. Chapter ends with literature on therapeutic ultrasound, Maitland spinal mobilization, Mulligan’s sustained natural apophyseal glides, back endurance exercises.

2.1 Historical background of facet pain

Facet joints, have long been recognized as a potential source of low back pain. In 1911, Goldthwaite first noted that the peculiarities of the facet joints could be a significant source of back pain and instability. Sixteen years later, after anatomical dissections of 75 cadavers, Putti suggested that local inflammation and degenerative changes in lumbar facet joints could result in sciatica from irritation of nerve roots. In 1933, Ghormley coined the term “facet syndrome,” which he defined as lumbosacral pain, with or without sciatica that was likely to occur after a sudden rotatory strain. The 1940s saw a rise in the interest of facet joints as a source of pain generation when Badgley suggested that up to 80% of cases of LBP and sciatica are due to referred pain from lumbar facet joint pathology, rather than direct nerve root compression. Hirsch et al. published the first article whereby the injection of facet joints reproduced patients’ low back pain.

Later on facet syndrome was broadly defined by Gatterman, as pain or dysfunction arising mainly from the facet joints and their close soft tissues.

2.2 Anatomical and biomechanical overview of lumbar facet joint

The lumbar facet joints are paired, true synovial type of joints that encompass the posterolateral articulation between vertebral levels. Each joint comprises a larger, posteriorly, and medially facing concave superior articular process from the inferior vertebral level of the joint and a reciprocally anteriorly and laterally facing inferior
articul ar process from the superior vertebral level. Lumbar facet joint contain hyaline cartilage, synovial membrane, fibrous capsule, and a joint space. The presence of menisci (meniscoids) in the lumbar facet joint has been highlighted in many publications which may be responsible for locking of facet joints and low back pain. The capsule of facet joints serves to limit rotation and resist a backward sliding motion during extension. The joint capsule is thick posteriorly, supported by fibers arising from the multifidus muscle and anteriorly, the capsule is replaced by the ligamentum flavum.

The orientation of the facet joint in a transverse plane varies from the upper level of the lumbar spine to the lower one. The lumbar facets are generally sagittally oriented. The joint plane of L3-L5 facets are oriented away from that plane (mean range, 40-56°). The oblique orientation of the facets offers resistance to intervertebral shear forces, compressive forces, and intervertebral torsion. Sagittal orientation of the facet joint allows greater range of flexion and limits axial rotation in the lumbar region.

From a biomechanical point of view, the facet joint play an important role in load transmission; they provide a posterior load-bearing helper, stabilizing the motion segment in flexion and extension, and they are also involved in the mechanism of rotational kinematics by restricting the axial rotation. In normal conditions, between 3 and 25% of segmental load are conveyed over the facet joint; this percentage rises up to 47% in degenerative facets.

In an upright position there are continuous forward shear forces applied to the facet joint between the 5th lumbar vertebra and sacrum because of lumbar lordosis. The tendency toward the increasing cartilaginous area of the facets in the lower lumbar segment seems to be a normal consequence of Wolf’s law.
Fig 1: Lateral view (A) and axial view of a (B) vertebra showing the anatomy of the facet joints, articulations, and orientation relative to its angle with each of the axial plane (β) and of the sagittal plane (α).

2.3 Pain originating from the lumbar facet Joint

Each lumbar facet joint is innervated by the medial branches of the primary dorsal rami from that level and the level above. The facet joint L4-L5 are innervated by both the L4 and the L3 medial branches. The L5 dorsal ramus runs in the groove between the superior articular process of S1 and the sacral ala. The medial branch of L5 divides from the dorsal ramus of L5 at the inferior aspect of the facet joint L5-S1. A communicating branch from the S1 posterior ramus may travel from the superior edge of the posterior S1 foramen up to the inferior margin of the facet joint L5-S1.

Fig 2: Facet joint and its innervation
The capsule of the facet joint is richly innervated with nociceptive and autonomic nerve fibers. Mechanoreceptors have been confirmed in rabbit facet joint capsules and substance P innervation has been isolated in degenerative facet joint subchondral bone.

The synovium may contain nociceptors, although these synovial nerves may serve only to regulate blood flow. Facet joint have been mentioned in the medical literature as a source of low back and lower extremity pain since 1911.

Marks also studied patterns of pain induced from lumbar facet joints, from the posterior primary rami of L5 and from the medial articular branches of the posterior primary rami from T11 to L4, he reported that the pain radiating to the buttocks or trochanteric region occurred mostly from the L4 and L5 levels, while groin pain was produced from L2 to L5, concluding that the nerves supplying the facet joints gave rise to distal referral of pain significantly more commonly than the joints themselves.

Clinically, pain that originates from lumbar facet joint is defined as “lumbar facet joint syndrome.” The diagnosis is made clinically and by excluding other origins of LBP. The typical symptoms and signs are localized “pseudoradicular” lumbar pain that may radiate unilaterally or bilaterally to the buttock, the hip, the groins, and the thighs, typically ending above the knee without neurological deficits. Patients usually report increased complaints in the morning and during periods of inactivity. Pain increases with stress, exercise, lumbar spine extension, rotary motions, and when standing or sitting. Lying supine or prone lead to pain relief.

Fig 3: Pain referral pattern of lumbar facet pain adapted from McCall et al
2.4 Injury mechanism in lumbar facet joint

As with any other synovial joint, degeneration, inflammation and injury can lead to pain upon joint movement, leading to limitation of ROM secondary to pain. It eventually leads to overall physical deconditioning and irritation of the facet joint innervation in itself, leading to secondary muscle spasm. In patients with sagitally oriented facet joints, recurrent rotational strains result in myriad changes to the discs and paired facet joints, including loss of disc height, osteophyte formation, and degenerative hypertrophy of the facets.\textsuperscript{141} It has been assumed that degeneration of the disc would lead to associated facet joint degeneration and the subsequent low back pain. These assumptions were based on the pathogenesis of degenerative cascade in the context of a three joint complex that involves the articulation between two vertebrae consisting of the intravertebral disc and adjacent facet joints, as changes within each member of this joint complex will result in changes in others in the lumbar spine.\textsuperscript{142-143}

2.5 Validation of the lumbar facet joint as a source of low back pain

In order for a body structure to be accepted as a source of pain it must satisfy certain criteria. These criteria, or “postulates”, which were developed by Bogduk\textsuperscript{144} are comparable to Koch’s original postulates for bacterial disease, and assist in determining whether a structure is capable of causing pain. Each of the four criteria presented in table can be applied to the lumbar facet joint to determine whether it is biologically plausible that this structure may be a source of pain, and therefore that patients with pain arising from the lumbar facet joint represent a valid subgroup of low back pain.

Table 2 : Bogduk’s postulates for determining whether a structure is capable of causing pain

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<th>Sr. No</th>
<th>Postulates</th>
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<td>1.</td>
<td>The hypothesized causal structure must be innervated</td>
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<td>2.</td>
<td>The structure must be capable of causing pain that is seen clinically</td>
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<tr>
<td>3.</td>
<td>The structure must be susceptible to disease or injury that is known to be pain provoking</td>
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<td>4.</td>
<td>The structure must be identified as a source of pain in patients using diagnostic techniques of known validity and reliability</td>
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The first postulate states that for a structure to be a source of pain, it must be innervated. The lumbar facet joint fulfils this first postulate as it is innervated by the medial branches of the lumbar dorsal rami of spinal nerves. Each medial branch supplies the lumbar facet joint above and below its course and thus each joint is considered to receive dual innervation. In addition it has been demonstrated that the capsule of the lumbar facet joint is richly innervated with encapsulated and free nerve endings likely to transmit nociceptive information. The presence of the nociceptive neuropeptide substance P nerve fibres in both the subchondral bone of degenerative lumbar facet joint and intra-articular inclusions suggests that these structures may also be a source of pain.

The second postulate states that to be a potential source of pain, a structure must be capable of producing pain in people without pathology that is consistent with the types of pain seen clinically. The lumbar facet joint fulfils this postulate. Pain has been produced in the lumbar facet joint of volunteers without pathology by injecting hypertonic saline solution into the joint resulting in pain patterns consistent with those seen clinically.

The third postulate states that the structure must be susceptible to disease or injury that is known to be pain provoking. The lumbar facet joints are synovial joints, consisting of hyaline cartilage lining the articular facets, a synovial membrane attaching to the borders of the articular cartilage, and a joint space surrounded by a fibrous joint capsule. They are therefore at risk of the common pathologies that affect all synovial joints and fulfil the third postulate. These conditions may be broadly classified into severe “red flag” pathology, inflammatory arthropathies, conditions relating to mechanical dysfunction, and osteoarthritis.

The fourth postulate states that a structure must be identified as a source of pain in patients using diagnostic techniques of known validity and reliability. Two techniques commonly used to diagnose pain arising from the lumbar facet joint include intraarticular injections and medial branch blocks. Many authors have mentioned about these techniques in diagnosis of facet pain, however their validity and reliability as a diagnostic technique is controversial given the high rate of false positives when single blocks are used.
2.6 Back muscle endurance

The first test for evaluating the isometric endurance of trunk extensor muscles was described by Hansen in 1964. In 1984, following a study by Biering-Sorensen, this test became known as the “Sorensen test” and gained considerable popularity as a tool reported to predict low back pain within the next year in males. The test includes measuring the amount of time (in sec) a participant can hold the unsupported upper body in a horizontal prone position with the lower body fixed to the table. This test has been used in many studies, either in its original version or as variations.

Since 1984, the Sorensen test has been used in several studies, either in its original or in adapted versions: the differences concerned the arm position, number of straps, criteria for stopping the test, etc.\textsuperscript{148}; the test has also been performed on a roman chair in a few studies\textsuperscript{149}, sometimes with 45 degrees of hip flexion.\textsuperscript{150} These numerous methodological variations can affect muscle activity considerably and result in considerable discrepancies in study findings. The Sorensen test has sometimes been considered as a definite tool for assessing the back muscles.\textsuperscript{151}

Some authors call it a “strength test”, it rather assesses muscle static endurance.\textsuperscript{152} Although the reproducibility of the Sorensen test has been evaluated in several studies, most of these suffered from methodological weakness.\textsuperscript{148} In general, investigations reported a moderate or high intra-session, intersession and inter-tester reproducibility\textsuperscript{149}, except in case a Roman chair was used.\textsuperscript{150} Although the reproducibility is satisfactory in patients with LBP\textsuperscript{149,151} it was suggested to repeat the test twice (with a 15-minute rest in between) to avoid a learning effect which has been found in some patients.\textsuperscript{148} Most studies have reported a good discriminative validity of the Sorensen test reflected by a holding-time being significantly lower in patients with LBP compared to healthy subjects.\textsuperscript{149,152} The safety of the test has also been investigated. A small number of subjects reported back pain during the test,\textsuperscript{153} sometimes resulting in the interruption of the test\textsuperscript{151}; however, no persistent adverse effects have been reported following the test and it could even be applied in elderly people.\textsuperscript{151}

Christophe Demoulin et al\textsuperscript{154} in their a critical appraisal of the literature concluded that the Sorensen test can be a important tool of reference for evaluating muscle performance in patients with low back pain, most notably before and after
rehabilitation programs. The reliability and discriminative validity of the Biering-Sorensen tests was determined in low back pain patients.\textsuperscript{151} Sixty three subjects (23 experiencing nonspecific low back pain, 20 who had had an episode, and 20 who were asymptomatic) performed the Biering-Sorensen test twice, 15 minutes apart. Test-retest reliability was assessed by calculating intra-class correlation coefficients (ICC 1,1), 95\% confidence intervals (CI), and standard errors of the measurement (SEM) for the total group and for the subgroups. Study concluded that Biering-Sorensen test provides reliable measures of position-holding time and can discriminate between subjects with and without nonspecific low back pain.

The literature review which describes and evaluates the use of isometric back extension endurance tests was conducted using relevant articles in english were retrieved through a search of MEDLINE and the Index to Chiropractic Literature. The principal criterion for inclusion of study was as follows: any study that discussed or tested an isometric type of back endurance extension test. Thirty-seven of the early studies were included in this review. The authors determined that the Sorensen is probably the most clinically useful of all tests; it is easy to perform, requires no special equipment, and enjoys the most support from the literature. As per the article the Sorensen method enjoys abundant positive support in the literature; this test seems to be a valid, reliable, and useful outcome measure for tracking changes in isometric extension endurance capacity in the clinical setting.\textsuperscript{155}

The validity and reproducibility of the Sorensen test in chronic low back pain (CLBP) was studied. This study showed a validity and satisfactory reliability of the Sorensen test to assess endurance of trunk extensor muscles. It also described that test is easy to perform and inexpensive tool to assess the muscular performance of low back pain patient. Few authors looked at training effect and perceived fear with regards to the Sorensen test versus static and dynamic trunk extension and flexion. Authors concluded that the Sorensen test was a decent and reliable test, as no training or emotional effect on the subjects was found.\textsuperscript{156}

\subsection*{2.7 Modified Schobers test}

Modified Schober test is one of the renowned method for measuring lumbar range of motion because of its simplicity, its high co-relation with flexion measurements of lumbar spine obtained through radiograph. Along with these potentials, it gives
precise measurements, can be used universally and materials used are reasonable and easily available. This method is reliable, valid and convenient for both therapist and patient as it does not need any fixation and landmarks are easy to palpate. Unlike the radiographic technique which has health risks related to repeated exposure to x-ray radiation, it does not harm the patient.\textsuperscript{157,158}

Macrae and Wright Modified the original Schober method by marking a point 5 cm below and 10 cm superior to the lumbosacral junction. The rationale for this modification was an observation that on forward flexion, both the lumbosacral and 10-cm superior skin marks tended to move superiorly relative to the spinous processes and the skin was more firmly tethered at the point 5 cm lower on the sacrum. In addition, they suggested that the effect of inaccurate identification of the lumbosacral junction was condensed by adding the landmark 5 cm under the lumbosacral function.\textsuperscript{159} Moll and Wright suggested that the modified Schober method might also be useful for assessing lumbar extension by measuring the attraction of the skin marks as they approach each other during backward bending.\textsuperscript{160} Several authors have reported the reliability of lumbar measurements obtained by the Modified Schober Method.\textsuperscript{161,162}

The psychometric properties of the Modified Schober test (MST) was estimated in low back pain patients.\textsuperscript{163} This study compared range of motion measurements of lumbar flexion in low back pain (LBP) patients using the MST with measurements calculated on X-rays as the gold standard, and compared the measurements taken by two independent examiners. In this study they found the MST showed moderate validity but excellent reliability and minimum metrically detectable change. The reliability of lumbar flexion and extension range-of motion measurements gained with the modified-Schober’s and the double inclinometer methods on subjects with low back pain.\textsuperscript{164} Fifteen patients (8 women, 7 men), aged 25 to 53 years (X=35.7, SD=99), with chronic low back pain were measured by three physical therapists with 3 to 12 years (01=8.3, SD=4.7) of clinical experience. Authors found that modified Schober method appeared to be a reliable method for measuring lumbar flexion and extension for patients with low back pain, whereas the double inclinometer technique needs improvement.
2.8 Pressure pain threshold

Assessing pressure pain threshold (PPT) is a method of quantifying sensitivity of deeply placed structures to mechanical pain.\textsuperscript{165} PPT has a good to excellent relative reliability in many anatomical locations such as neck\textsuperscript{166}, knee, temporalis and masseter muscles\textsuperscript{167} and the low back region.\textsuperscript{168}

Pressure algometers are designed to measure deep pressure pain thresholds or tenderness resistance. Pressure Pain Threshold (PPT) is one of these tests and it is defined as the least force applied which induces pain. When a particular site of the body is pressed with a rubber disk having an area of 1 cm\textsuperscript{2}, the device displays the pressure.

Pressure algometers are advantageous for quantifying the pressure pain thresholds of bones and muscles. This quantification concept was raised by Libmann in 1934, and normal pressure pain thresholds in skeletal muscles of the body have been measured since the 1980s. Subsequently, pressure algometers have been extensively used in clinical practice. The dolorimeter, that used scales to measure applied pressures was the first algometer device established. Since then, pressure algometry using this instrument has been extensively employed to assess myofascial pain syndrome and numerous musculoskeletal diseases.\textsuperscript{169} This measure has proven to be commonly useful in evaluating muscles and articular tenderness symptoms, which are associated to painful musculoskeletal conditions, as well as for diagnosis of such conditions and for management strategies efficacy analysis.\textsuperscript{170,171} The use of an algometer (pressure device that induces mechanical stimuli) is to standardize the amount of pressure applied, similar to that when performing muscle palpation. It can increase reliability for the assessment of deep pain sensitivity.\textsuperscript{172}

The reliability of pressure pain threshold according to raters or measurement frequencies is relatively high. According to studies published high intra-class coefficients ranging from 0.9 to 0.95 have been reported, implying very high reliability. Errors resulting from measurement devices used were not significant.\textsuperscript{173}

A research study was conducted to compare pressure pain threshold (PPT) values between patients with chronic nonspecific low back pain (CLBP) and healthy individuals. Secondary aim was to correlate PPT values of the structures investigated with demographic and clinical data from patients with CLBP. 40 patients were
included in the study: 20 with a clinical diagnosis of CLBP and 20 healthy individuals. Results of this study showed that individuals with CLBP have lower PPT values than healthy individuals in almost all examined structures.  

An observational study was conducted to assess the usefulness of a pressure algometer to measure pressure pain threshold (PPT) for diagnosis of myofascial pain syndrome (MPS) in the upper extremity and trunk muscles. A group of 221 desk workers complaining of upper body pain contributed in this study. Five physiatrists made the diagnosis of MPS using physical examination and PPT measurements. PPT measurements were determined for several muscles in the back and upper extremities. This study concluded that pressure algometry shows high intra-rater reliability for PPT measurements. Authors also suggested that PPT is a useful parameter for assessing a treatment's effect, but not for use in diagnosis or even as a screening method.

In another study conducted on twenty-nine adult vine-workers with threefold objectives of evaluating the intra-session absolute and relative reliability as well as minimal detectable change (MDC) values of PPT within 14 locations covering the low back region of vine-workers. Other objective of study was to determine the number of trial required to ensure reliable PPT assessments and to assess the effect of modifier factors such as gender, age, body mass index (BMI) and pain intensity on PPT reliability. The study resulted in PPTs assessed over the low back region of vine-workers have excellent relative and absolute reliability. Reliable PPT assessments can be equally achieved when using the mean of three PPT measurement or with the first measurement. PPT were lesser for women and in existence of pain. Authors of this study suggested that the assessment of PPT over the low back region of vine-workers can be used to measure the effects of interventions.

A literature review was conducted with purpose to review the effects of Non-thrust mobilizations as measured by pressure pain threshold. A search was conducted in relevant databases and 135 article abstracts related to manual therapy. After full text examination, 7 articles met the inclusion criteria and 2 were added from a hand search. Findings of the review were, majority of the studies in this systematic review whose participants were symptomatic, had significantly increased pressure pain threshold (PPT) values after mobilization as MODQ compared to control groups.
2.9 Modified Oswestry disability questionnaire (MODQ)

Self-reported measurements of disability have been used as an outcome measure for people with low back pain (LBP). Numerous disability scales have been established for people with LBP, and their importance as measures of treatment outcome in clinical trials has been highlighted.\textsuperscript{178}

The Oswestry low back pain questionnaire (OSW) used by clinicians and researchers to quantify disability for low back pain. This validated questionnaire was first published by Jeremy Fairbank et al. in Physiotherapy.\textsuperscript{179} The current version was published in the journal of spine in 2000. Individual items included in the OSW were selected based on the experience of the scale's developers and were pilot tested in a sample of 25 patients.\textsuperscript{179} The questionnaire consists of 10 items addressing different aspects of function. Each item is scored from 0 to 5, with higher values representing greater disability. The total score is multiplied by 2 and expressed as a percentage. The OSW was modified by Hudson-Cook et al,\textsuperscript{180} who replaced the sex life section with a question related to fluctuations in pain intensity. Hudson-Cook et al reported levels of test-retest reliability and internal consistency for the modified version similar to those of the original OSW. The measurement properties of this scale have been studied extensively, and a recent report of the International Forum for Primary Care Research in Low Back Pain contended that this scale is acceptable for measuring disability related to LBP.\textsuperscript{180}

The modified Oswestry disability index is currently considered by many as the gold standard for measuring degree of disability and estimating quality of life in a person with low back pain.

A study was conducted with the purposes to examine the validity of a global rating of change as a reflection of meaningful change in patient status and to compare the measurement properties of a modified Oswestry low back pain disability questionnaire and the Quebec Back Pain Disability.\textsuperscript{67} patients with work-related acute low back pain referred for physiotherapy were included in the study. The two scales were administered at baseline and after 4 weeks of physiotherapy. The Physical Impairment Index which was a measure of physical impairment due to low back pain, was measured initially and after 2\textsuperscript{nd} and 4\textsuperscript{th} week. A global rating of change survey questionnaire was completed by each subject after 4 weeks. The test-retest reliability
over a 4-week period was higher for the MODQ than for the Quebec Back Pain Disability. The modified OSW was more receptive than the Quebec Back Pain Disability as assessed by Guyatt's Responsiveness Index and in correlations between change scores and the global rating of change.  

An observational study was conducted to examine 5 commonly used questionnaires for assessing disability in people with low back pain. The modified Oswestry Disability Questionnaire, the Quebec Back Pain Disability Scale, the Roland-Morris Disability Questionnaire, the Waddell Disability Index, and the physical health scales of the Medical Outcomes Study 36-Item Short-Form Health Survey (SF-36) were compared in patients undergoing physical therapy for low back pain. The study concluded that Measurements obtained with the modified oswestry disability questionnaire, the SF-36 Physical functioning scale, and the Quebec back pain disability scale were the most reliable and had sufficient width scale to reliably detect improvement or worsening in most subjects.

2.10 Therapeutic Ultrasound in spinal pain

Therapeutic ultrasound (US) is amongst the frequently used physical modalities in clinical practice for treatment of soft tissue injuries. There is a dearth of evidence for the clinical use of therapeutic US in patients with LBP. Therapeutic US is delivered in two modes: 1) Continuous mode in which the delivery of US is non-stop throughout the treatment period; 2) Pulsed mode in which the delivery of US is intermittently interrupted.

Therapeutic effects of US are classified as thermal and non-thermal. Ultrasonic energy causes soft tissue molecules to vibrate from exposure to the acoustic wave. This increased molecular motion generates frictional heat and consequently increases tissue temperature. This increased temperature, named thermal effects, is thought to cause changes in nerve conduction velocity, increase in enzymatic activity, changes in contractile activity of skeletal muscles, increase in collagen tissue extensibility, increase in local blood flow, increase in pain threshold, and reducing muscle spasm.

Acoustic waves, normally present minute gas pockets in the tissue develop into microscopic bubbles or cavities. With therapeutic US, stable acoustic cavitation results, whereby the microbubbles pulsate without collapsing. This pulsation leads to
microstreaming of fluid around the pulsating bubbles. When it occurs around cells, this process, referred to as non-thermal effects, is reported to alter cell membrane activity, vascular wall permeability, and facilitate soft tissue healing. Traditionally, continuous US is used for its thermal effects. Pulsing the US is thought to minimize its thermal effects. In fact, it is not possible to truly isolate the thermal and non-thermal effects as both effects occur with US application.

An experimental study evaluated the effectiveness of continuous ultrasound in addition to exercise therapy in patients with chronic LBP. A total of 46 patients, between the ages 18 and 65 years old who have had LBP for more than three months were recruited from university hospitals. Participants were randomized to receive continuous ultrasound plus exercise therapy or placebo ultrasound plus exercise therapy. These groups were treated for 10 sessions during a period of 4 weeks. Primary outcome measures were functional disability and pain intensity. Lumbar flexion and extension range of motion, as well as changes in electromyography muscle fatigue parameters, were measured as secondary outcomes of study. All outcome measures were measured at baseline, after completion of the treatment sessions, and after one month. The results of this trial helped to provide some evidence regarding the use of continuous ultrasound in chronic LBP patients.

A randomized control trial on forty two low back pain patients was conducted to evaluate the effects of therapeutic ultrasound on pain, disability, walking performance, quality of life (QOL) and depression. Patients in experimental group received therapeutic ultrasound, exercise, and hot packs, while patients in control group were treated with sham ultrasound, exercise, and hot packs. All treatments (ultrasound, sham ultrasound, hot packs, and exercise) were performed 5 days a week for 3 weeks. Authors found that therapeutic ultrasound was effective on pain, some particular parameters of QOL, functional performance, and depression in patients with CLBP. An experimental study was conducted to determine the effect of continuous ultrasound to pain caused by degenerative diseases of the musculoskeletal system in the intensity and duration of ultrasound treatment. The other objective of study was to determine the correlation between the degrees of pain reduction with: location of pain, age, gender and body mass index (BMI). This study included 68 patients with chronic pain localized in the region of the spine or major joints of the extremities, depending on the localization of the degenerative changes. Patients were allocated into two
groups. The first group received ten applications of continuous ultrasound with frequency of 1 MHz, intensity 0.4 W/cm² for 8 minutes, and the other group with 10 applications of ultrasound with frequency of 1 MHz, intensity 0.8 W/cm² for 4 minutes. Results of the study indicated a significant reduction of pain in degenerative musculoskeletal system after continuous treatment with ultrasound.\textsuperscript{188}

### 2.11 Mulligan’s Mobilization Technique

The Mulligan concept is now an integral component of many manual physiotherapists’ clinical practice. Brian Mulligan founded the techniques of this model in New Zealand in the year 1970s. Mulligan’s techniques include NAGS, SNAGS and MWMs.\textsuperscript{69} Passive oscillatory mobilizations called ‘NAGs’ (natural apophyseal glides) and sustained mobilizations with active movement ‘SNAGs’ (sustained natural apophyseal glides) are the mainstay of this concept’s spinal treatment.\textsuperscript{189} NAGS are natural apophyseal accessory glides applied to the cervical spine with the patient is passive during treatment. SNAGS are sustained natural apophyseal glides whereby the patient attempts to actively move a painful or stiff joint through its range of motion whilst the therapist overlays an accessory glide parallel with the treatment plane. The Mulligan’s concept has its foundation built on Kaltenborn's principles of restoring the accessory component of physiological joint movement. MWMs are mobilizations with movement and are applied to the peripheral joints. The underlying principle to MWMs is derived from Kaltenborn who argued that joint surfaces are not fully congruent, physiological movements are a combination of rotation and glide, and glide is essential to pain free movement.\textsuperscript{190} In treating the spine Maitland will follow the planes of the intervertebral body joints whilst Mulligan’s techniques follow the plane of the zygapophyseal joints. Exelby claims that the zygapophyseal joints guide the spine and so improving their glide by applying NAGs and SNAGs which improves the range of spinal movement.\textsuperscript{191} Applying treatment on the plane of the intervertebral body joints results in compression on the zygapophyseal joints and will not promote glide. SNAGs are most efficacious when symptoms are triggered by a movement and are not multilevel.\textsuperscript{75}

SNAG techniques are used in the treatment of spinal musculoskeletal conditions with as many as 41% of British therapists’ who treat low back pain reporting their use.\textsuperscript{192}
Success following a MWM treatment of a clinically diagnosed locked lumbar facet joint syndrome was the first article to document effect of SNAGs in lumbar facet syndrome. In this case study 46-year-old female presented to physiotherapy 3 days after experiencing a sharp pain in the lower lumbar region whilst returning from a flexed position after performing arm curls with a barbell in a flexed lumbar spine position. Physical examination shown a flexed lower lumbar spine and lordotic (extended) upper lumbar spine with all active movements limited to a quarter range because of pain. Treatment included a SNAG consisting of a central sustained glide of the L4 spinous process while the patient first performed repeated flexion followed by repeated extension in lying. The findings of case showed dramatic reduction in symptoms after the sessions of MWM technique. A scientific paper was presented by Exelby on application of Mulligan’s technique for spinal pathologies in which he explained the clinical examples to illustrate the concept’s application to the spine, how it has evolved and been integrated into constantly changing physiotherapy practice. Furthermore, he also suggested that lumbar SNAGs are usually preferred in the case of low back pain.

Treatment of acute locked thoracic facet joints was reported in literature with a modified SNAG. The case involved a 20-year-old male university student who presented with acute left-sided thoracic pain adjacent to the T8/9 inter-vertebral joint following an incident the previous night when his friend had picked him up and shaken him in a bear hug maneuver. Initial examination revealed that he had a constant dull ache over the left thoracic spine and was locked in a position of forward and right side flexion such that he needed to support himself on his right hand. Any attempt to extend, flex to the left or rotate produced severe pain. Pain and resistance to displacement was elicited on palpation of the left T8/9 facet joint. The initial treatment involved a central SNAGs applied in a cephalad direction on the spinous process of T8 while supporting the patient’s trunk and assisting him to move into an upright posture. This procedure, performed pain-free, was repeated another three times until the patient was able to sit upright independently with only a mild ache. Tape was applied to provide further support. On the second visit the patient reported a 95% improvement and had maintained an upright posture. Examination of range of movement revealed only a slight restriction in lateral flexion to the left and slight tenderness over the left T8/9 area. The biomechanical explanation for the clinical
presentation was that of a locked T8/9 facet joint in which there was compromise of a meniscoid structure. It was postulated that the SNAGs could be likened to a longitudinal distraction, which may have been sufficient to release the trapped meniscoid, allowing it to re-enter the joint space.  

Immediate effects of flexion mobilizations with movement techniques (MWMs) on spinal range of motion was investigated in 26 subjects with Low back pain. Subjects were treated with MWM intervention and a placebo intervention in a randomized order. Lumbar spinal flexion, extension and pain during flexion were recorded immediately before and after each intervention using double inclinometer and VAS. The MWM technique produced statistically significant, but small, instant increase in spinal mobility but no pain reduction when compared with placebo.

A survey was conducted to investigate the current use of mobilizations with movement (MWM) for LBP management in Britain. A postal survey of a random sample of 3295 working physiotherapists in Britain was conducted. A response rate of 72.1% (n=2357) was obtained. Of these, 48.2% (n=1136) reported treating LBP, of whom 41.1% (n=467) reported using MWMs in LBP management. Therefore, the sample applicable for analysis involved of these 467 therapists treating LBP and using MWM technique. Over half of the respondents used MWMs on at least a weekly basis, with 61.9% using MWMs primarily for mechanical LBP. The most frequently reported changes seen instantly after the application of MWMs were increases in range of movement (ROM) (54.4%) and pain relief (27.5%). On average, two spinal levels were mobilized using 2-3 sets of 4-5 repetitions. The lower lumbar levels were treated more often. Most therapists indicated using a combination of other treatment approaches together with MWMs when treating LBP patients. In conclusion, this study is the first to describe the current practice of MWMs by physiotherapists in Britain, and the results of this study are helpful to design a clinical trial exploring the effects of MWMs for LBP. Combined effect of SNAGs and exercises as compared to SNAGs alone in cases of nonspecific neck pain was studied using an experimental design. The SNAGs manual physical therapy technique along with isometric exercises was applied on 51 patients in group A and SNAGs manual physical therapy techniques was applied alone on 51 patients in group B. The duration of intervention was 6 weeks, at 4 times per week. Authors concluded that patients with non-specific neck pain treated with SNAGs manual physical therapy techniques...
along with isometric exercises was more effective in reduction of pain and enhancement of function, as compared to those patients treated with SNAGs manual physical therapy techniques alone.\textsuperscript{195}

Role of Mulligan’s SNAGs technique was studied in a 44 year old case of cervical pain. In the morning the patient had woken with pain, stiffness and loss of ROM. The treatment undertaken involved grade 3 down slope mobilization on the left side at C5-C6 and C6-C7 in supine lying. This technique was then progressed by placing the subject in upright position and SNAGs were performed at C6. Immediately following the treatment, the patient reported a considerable decrease in pain and less difficulty in movement and decreased stiffness.\textsuperscript{196} In a double blinded study; authors studied the effects of the Mulligan’s sustained natural apophyseal glides (SNAG) mobilization in the lumbar flexion range on 49 subjects which were randomly divided into two groups. One group received SNAGs mobilization and another sham mobilization at the level of L3 & L4 spinal levels with active flexion in sitting were performed. They concluded that SNAG mobilization did not demonstrate significant differences in flexion ROM when compared to sham mobilization.\textsuperscript{197}

A randomized control trial was conducted to compare the effects of McKenzie extension exercise program (EEP) versus Mulligan’s SNAGs technique patients suffering with chronic mechanical low back pain (CMLBP). A total of 37 patients were examined out as per inclusion criteria and randomly allocated into two groups. Twenty patients in group A were treated with Mulligan’s SNAGs and 17 patients in group B with McKenzie EEP for four weeks at two session per week and single session per day. Authors concluded that Mulligan’s SNAGs are more effective in the improvement of lumbar ROM as compared with Mechanize EEP in the management of CMLBP.\textsuperscript{198}

Two-armed randomized placebo-controlled trial was conducted with purpose to compare the immediate- and short-term effects of lumbar Mulligan’s sustained natural apophyseal glides (SNAGs) on patients with nonspecific low back pain with respect to 2 new kinematic algorithms (KA) for range of motion and speed as well as pain, functional disability, and kinesiophobia. Subjects were divided in real-SNAG group (n = 16) or a sham-SNAG group (n = 16). This study provided preliminary evidence
that lumbar SNAGs have immediate- and short-term efficacy in the treatment of a targeted group of patients with nonspecific LBP.

2.12 Maitland spinal mobilization:

The Maitland concept of manual physiotherapy, emphasizes a specific way of thinking, continuous evaluation and assessment and the art of manipulative physiotherapy and a total commitment to the patient. Maitland’s techniques involve the application of passive and accessory oscillatory movements to spinal and vertebral joints to treat pain and stiffness of a mechanical nature. The technique goal to reestablish motions of spin, glide and roll between joint surfaces and are graded according to their amplitude. Grade I is a small amplitude movement performed below the range of resistance and is suitable for treating highly irritable conditions. Use of Grade I enables the slack in collagen to be taken up when connective tissue is not under load and can relieve pain by working on neural structures. A Grade II mobilization is wider in amplitude but still below resistance. Use of Grade I and II are appropriate when palpation elicits pain before restriction of movement. Grade III and IV are used when resistance to movement is encountered before pain. A Grade III is a large amplitude movement performed within resistance and generally used to improve range of motion. Grade IV is a small amplitude movement performed within resistance used for chronic aches of low irritability. Grade V is a high velocity thrust used in manipulation. Maitland also recommends stretching techniques to deal with muscle spasm.

An experimental study was conducted to check whether posteroanterior (PA) mobilization is more effective in relieving low back pain (LBP) when the treatment is delivered to the level identified by the therapist as responsible for the LBP. 120 subjects suffering from LBP received central posteroanterior mobilization as per Maitland’s grades. Authors found that PA mobilization treatment is a useful approach to relieve pain in patients suffering LBP where lumbar flexion is the worst movement.

Short-term effects of joint mobilizations on acute mechanical low back dysfunction in collegiate athletes was studied by Sean Hanrahan et al. Objective of the study was to examine the short-term effects of grade 1 and 2 posteroanterior joint mobilizations at the lumbar spine on subject pain and muscle force after an episode of acute,
mechanical low back pain. At the end of 24 hours it was found that Grade 1 and 2 joint mobilizations reduced subjects’ pain and increased force production in the short-term stages of mechanical low back pain.\textsuperscript{204} A double blind randomized control trial was conducted to investigate the effect of posterior-to-anterior spinal mobilization and prone press-ups in non-specific low back pain. One group received Maitland’s PA glide while other group was assigned with prone press up exercises. Authors concluded that PA mobilization proved to be superior in reducing pain and increasing lumbar extension resulting in improved functional outcome.\textsuperscript{205}

Maitland’s lumbar posteroanterior mobilizations was performed at different rates to investigate the effect on pressure pain threshold and the extent of the hypoalgesia. A repeated measures, single blind, randomised-trial was conducted on 30 asymptomatic subjects. PPTs were measured at 4 sites in the upper and lower quadrants, before and after the application of lumbar posteroanterior mobilizations. The results of their study demonstrated an immediate and significant improvement in PPT measures ($P = 0.000$) irrespective of the rate or site tested.\textsuperscript{206} A study was conducted to investigate the importance of amplitude as part of the treatment dose and to explore the extent of any pain reliving effects seen following Maitland mobilization at different frequency of oscillations mobilizations. Procedure included large amplitude of oscillations, small amplitude of oscillations quasi-static. Each condition involved a 3x1 minute central PA mobilization at a frequency of 1.5 Hz on the lumbar spine. Results demonstrated a significant increase in PPT following lumbar mobilization ($p = 0.013$) at all measured sites. This study also suggested that in asymptomatic subjects a systemic hypoalgesic response is caused by lumbar mobilization regardless of amplitude.\textsuperscript{207}

Posterior chain’s flexibility, low back’s mobility, trunk extensor’s endurance and low back extensors’ muscle strength was analyzed after one treatment session using the Maitland method on youth with low back pain. On PA mobilization application, there was significant improvements in muscular strength (immediate post-treatment and past seven days) and muscular endurance (immediate post-treatment). Authors concluded that the lumbar PA mobilization was effective for increasing muscular strength and endurance, with stabilization of the level of pain, flexibility and mobility.\textsuperscript{208}
2.13 Back muscle endurance exercise

Muscular endurance is the ability of an isolated muscle group to perform repeated contractions over a period of time, assuming the intensity of the activity is moderate.\textsuperscript{209} It is one of the basic elements of muscular performance that has great relevance to activities of daily living, lifting and bending being examples of activities in which the ability of the trunk extensors to resist fatigue may be of particular importance, especially in an industrial setting.\textsuperscript{150} Muscles have been identified as a potential source of low back pain (LBP)\textsuperscript{100} as their failure to protect passive structures from excessive loads may result in damage to these pain sensitive structures and produce pain.\textsuperscript{210} Poor endurance of the trunk muscles may induce strain on the passive structures of the lumbar spine and eventually result in LBP.\textsuperscript{98} Muscle endurance has been found to be lower in people with LBP than those not suffering from it.\textsuperscript{94} Enhancing the endurance of trunk muscles may help to reduce LBP; hence, trunk muscle endurance training has been recommended as a means of increasing fatigue threshold and improving performance and subsequently reducing disability.\textsuperscript{94}

The effect of a trunk extensor endurance exercise protocol (TEEP) on trunk extensor muscle endurance (TEME) of 42 seemingly healthy students was assessed using a two-group pre-test–post-test quasi-experimental design.\textsuperscript{211} Subjects in the experimental group exercised once daily four times a week for 6 weeks while those in the control group did not exercise. The trunk extensor endurance of all subjects was assessed at weeks 0, 3 and 6 of the study using a modified Sorensen test. The study concluded that the TEEP used in this study was effective for increasing the isometric endurance of trunk muscles.

An experimental study was designed to check whether endurance and pain due to nonspecific sub-acute low back pain are improved by the endurance training of trunk extensors.\textsuperscript{212} This study compared the efficacy of trunk extensors endurance training and general exercise to decrease pain, improve endurance and to decrease functional disability in patients of nonspecific sub-acute low back pain and researchers concluded that both trunk extensors endurance training and general mobility stretching and strengthening exercises are equally effective in reducing pain, increasing endurance and decreasing disability in patients with nonspecific sub-acute low back pain. A study on efficiency of musculoskeletal physiotherapy on chronic low back disorder on 302 patients, aged 18–65 years, with chronic low back disorder,
treated with manual therapy \((n = 121)\) with a maximum number of 10 interventions, a 10-week spinal stabilization rehabilitation programme \((n = 121)\) with 1-h classes, or a minimal intervention control group \((n = 60)\) receiving an educational booklet.\(^{213}\) Authors concluded that as a component of musculoskeletal physiotherapy, the spinal stabilization programme is more effective than manually applied therapy or an education booklet in treating chronic low back disorder over time. Both manual therapy and the spinal stabilization programme are significantly effective in pain reduction in comparison to an active control.

A study on Long-term effects of specific stabilizing exercises for first-episode low back pain done by Kladny et al.\(^{214}\) where they studied 99 patients, aged 18–55 years with chronic LBP. The patients were randomized to one intervention group \((n = 50)\) receiving specific spinal stabilization exercises, or one control group \((n = 49)\) receiving general strengthening exercises of abdominal and back muscles, and manual therapy according to Maitland or McKenzie. At the end of 3 months follow up Outpatient rehabilitation improved functional capacity and pain in both groups. Advantages could be seen in the intervention group concerning functional status. And authors concluded that the specific stabilization exercise approach appears to be effective in conservative treatment programs of LBP and lumbar disc disease.

The effectiveness of trunk extensor endurance training was evaluated in reducing pain and decreasing disability in subjects with sub-acute low back pain (i.e., onset of back pain within 7 days to 7 weeks). Subjects in the experimental group attended endurance exercise sessions 3 times per week for 6 weeks. Subjects in the control group did not do exercises. Both groups were given back care advice and hot packs for 15 minutes, 3 to 5 times per week. Reassessments for outcomes were carried out at 3 and 6 weeks. Study concluded that trunk extensor endurance training reduced pain and improved function at 3 weeks and authors suggested that endurance exercise is considered to expedite the recovery process for patients with an acute episode of low back pain.\(^98\)

An experimental study was conducted which included Classical Strength Exercises (CSE) consisting of stretching and strengthening exercises in control group and muscle endurance training consisting of warm-up, endurance exercises and cool down were applied in the experimental group. They found that in the 3\(^{rd}\) and 6\(^{th}\) week, back
muscle endurance time was significantly higher in the endurance group than that of the control group (p <0.05).\textsuperscript{215}