The effectiveness of elastic tubing versus tyre resistance training as an adjunct to the standard manipulative training program at Durban University of Technology in the development of control of the dynamics of manipulation in chiropractic students

By

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Dissertation submitted in partial compliance with the requirements for the Masters' Degree in Technology: Chiropractic
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I, Tarryn Ruby Mey, do declare that this dissertation is representative of my own work in both conception and execution.

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_____ _21 Apr 2013_

DEDICATION

This research is dedicated to my Mom and Dad, Barbara and Rick Mey, for their unconditional and unwavering love and support. I will always love you.

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First and foremost I would like to thank God for blessing me with the ability to enter into this journey and the tenacity to see it through. I pray that I will be forever humbled and grateful for the many blessings that I have received.

To my parents, thank you for the sacrifices you have made to allow me to achieve my dreams, the support through the tough times, the love throughout the years, and your unfailing belief in me. I would not be the person I am today without your guidance, I love you both!

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ABSTRACT

Background: Motor learning theories indicate that training improves motor performance by reducing variability and increasing task control. Elastic tubing and tyre resistance training methods may allow for the development of control over the dynamics of spinal manipulation. This study thus aimed to determine whether training with elastic tubing and tyre resistance, in conjunction with the standard manipulative training at the Durban University of Technology, resulted in the development of control of the dynamics of manipulation compared to training with the standard training alone.

Methods: A quantitative, prospective, experimental cohort design was used. Fifty-three participants were randomly allocated into tyre or elastic tubing resistance training intervention groups, or the control group. All groups continued with the standard manipulative training at the Durban University of Technology. The dynamics of manipulation were measured with the Dynadjust pre-, mid- and post-training. The SPSS was utilised to compute the parametric and non-parametric analyses.

Results: The results showed no statistically significant differences over time for any of the measured dynamics of manipulation. None of the groups (excluding the control group for S-I manipulation) developed control of the relationships between the dynamics. Overall, there was no difference between the groups with regards to development of control of the dynamics.

Conclusion: The results suggest that the additional training methods, should be carefully considered when employed over a short term. Study limitations include the sample size and the effect of outliers, therefore any firm conclusions drawn from this study are required to be interpreted with caution.

Key Words: Students, learning, manipulation, psychomotor performance, training, motor skill

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DEFINITIONS LIST

Adjustment:

"A chiropractic procedure that utilises controlled force, leverage, direction, amplitude, and velocity, directed at specific joints or anatomic regions with the aim of influencing joint and neurophysiologic function" (Bergmann and Peterson, 2011; Gatterman and Hansen, 1994). Adjustments can be direct, semi-direct or indirect and manual or non manual. For the purpose of this dissertation the use of the term 'adjustment' refers to direct, manual adjustments. Direct adjustments have specific joint contact points and are characterised by a high velocity, low amplitude (HVLA) thrust (Bergmann and Peterson, 2002).

Arthrokinematics:

A division of mechanics that deals with the geometry of motion, displacement velocity, and acceleration related to articulations, without consideration of the forces that produce the motion (Bergmann and Peterson, 2002).

Articular:

Articular, as derived from "articulation" refers to a joint or a place of union between two or more bones (Moore and Dalley, 1999).

Articular Slack:

The joint play that is present in synovial joints and the surrounding soft tissues (Bergmann and Peterson 2002).

Biomechanics:

The study of structural, functional, and mechanical aspects of human movement, concerned mainly with static or dynamic external forces of human motion (Dagenais and Haldeman, 2012).

Chiropractor:

A health care practitioner that focuses on the diagnosis and treatment of neuromusculoskeletal disorders using spinal manipulation as the primary modality (Dagenais and Haldeman, 2012).

Complementary and Alternative Medicine (CAM):

A broad term used to describe interventions, practices, products, and health care systems that are not generally considered to be part of mainstream medicine (Dagenais and Haldeman, 2012).

Dynadjust:

A manipulative training tool designed by Orthoneuro Technologies (2011), which is able to measure some of the individual dynamics of manipulation including force, speed, line of drive and degrees of rotation. It is also able to measure elements of manipulation regarding tissue slack and depth of thrust. For the purposes of this study, the Dynadjust was used as a measurement tool and not a training tool.

Dynamics (of manipulation):

A branch of mechanics that is concerned with the loads and motions of interacting bodies (Bergmann and Peterson, 2002). For the purpose of this dissertation "the dynamics of manipulation" referred to: the time taken to perform a manipulation (speed), the force produced when performing a manipulation, line of drive (or the vector in which the thrust of the manipulation was directed), and the degrees of rotation applied when performing the manipulation (Bergmann and Peterson, 2002). Additionally, Orthoneuro Technologies (2011) included the relative depth of the manipulation, the removal of articular slack and the time for which articular slack is held as components of manipulation and therefore have been included as dynamics of manipulation within this dissertation.

Efficacy:

The ability of an intervention to result in meaningful outcomes under controlled settings (Dagenais and Haldeman, 2012).

Functional Muscle Training:

Strength training may cause adaptive changes within the nervous system that allow prime movers to activate more globally in specific movements (Saltin *et al*., 1977) and better coordinate the activation of relevant muscles (Goodpaster *et al*., 2006), thereby effecting a greater net force in the intended direction of movement (Leach, 2004).

Learning:

The result of processes associated with rehearsal or experience that cause permanent changes in a person's knowledge, skills, and behaviour (Poole, 1995).

Manual Therapy:

All procedures which involve direct contact of the hands with the body to treat either visceral or somatic structures with the use of mobilisation, manipulation, massage or traction. Manual therapies may be further broadly categorised into procedures that work mainly on the joint structures or the soft tissue components (Bergmann and Peterson, 2002).

Manipulation:

A manual procedure involving a directional thrust that aims to move a joint past the physiological range of motion whilst remaining in the anatomic limits of motion (Gatterman and Hansen, 1994), also referred to as Spinal Manipulative Therapy (SMT) (Dagenais and Haldeman, 2012). For the purpose of this dissertation the terms “manipulation” and “adjustment” will be used interchangeably.

Plane:

One of three imaginary anatomical constructs that are utilised as reference points in which particular movements are described according to the anatomical position of the body (Moore and Dalley, 1999).

Psychomotor Skills:

Skills that involve organised patterns of muscular activity guided by environmental input, also known as sensorimotor skills (Cratty and Noble, 2011). In research concerning psychomotor skills, special attention is given to the learning of coordinated activity involving the arms, hands, fingers, and feet (Cratty and Noble, 2011). The term “skill” refers to a movement that is reasonably complex and the performance of which requires at least a minimal amount of practice (Cratty and Noble, 2011).

Resistance Training:

Training designed to increase the body’s strength, power, and muscular endurance through resistance exercise (Robergs and Roberts 1996).

Speed:

For the purpose of this dissertation, speed is defined as the time taken to perform the specific manipulation.

CHAPTER ONE

INTRODUCTION

1.1 Introduction

Manipulation is the most specialised modality used by chiropractors (Descarreaux and Dugas, 2010; Haldeman, 2005; Bergmann and Peterson, 2002) and is considered a controlled health procedure that must be administered by a qualified practitioner (Dagenais and Haldeman, 2012; Chapman-Smith, 2000). Teaching of Spinal Manipulative Therapy (SMT) is thus fundamental in chiropractic training in order for students to adequately learn and master the skill (Chapman-Smith, 2000; Bergmann and Peterson, 1993).

Several studies have attempted to improve manipulative teaching techniques by investigating the effects of feedback strategies and different learning tools (Scaringe, Chen and Ross (2002). Authors including Rogers and Triano (2003), Triano et al., (2003), Triano et al., (2002), and Cohen et al., (1995), have sought to improve training programs by using mechanical training aids, didactic presentations and instructor modeling with verbal feedback (in various combinations).

Through this process, manipulation has been described by Triano et al., (2006), and Haas (1990), as a bimanual task requiring high levels of sensory and motor coordination (psychomotor skill). In clinical practice, sensory (palpatory) skill is acquired through clinical experience (Leathers, 2011), however skilled performance and coordination of the manipulation itself is acquired through intensive practice and experience (Triano et al., 2004).

In the above context and as a psychomotor skill, the manipulation was first described by Cohen et al., (1995), as requiring various elements of skill in performing the high velocity low amplitude (HVLA) maneuver. Terms such as fast (speed), force, precision, comfort and confidence were used to describe the characteristics of a skillful manipulation (Cohen *et al.,* 1995). The term “precision” used by Cohen *et al.,* (1995), implies that control of the dynamics of manipulation is necessary for skilful

manipulation. Triano *et al.*, (2004), summarised the terms defined by Cohen *et al.,* (1995) as skillful performance and coordination.

According to Fitts and Posner (1967), psychomotor skill develops in three stages. The first stage is the theoretical stage, where task performance is usually poor and uncoordinated and the student must concentrate on each movement before attempting to perform it. This concurs with the work of Triano *et al.*, (2004), who emphasised the importance of learning the fundamentals of manipulation prior to performance of SMT. This is particularly evident in that it enables students to focus on individual aspects of manipulation (Cohen *et al.,* 1995), rather than attempting to master the physical (Triano *et al.,* 2004) and intellectual task simultaneously.

According to this learning model, diligent practice allows for progression to the association (second) stage, where known movements are associated with the movement being learnt. This renders smoother movements and a higher level of student comfort (Cratty and Noble, 2011). In the final stage of learning, the autonomous (third) stage, concentration is no longer required to perform the movement, as the movement patterns become more strongly encoded in the motor cortex (Leach, 2004; Leach, 1994). During the autonomous stage the student can refine their skill through practice (Fitts and Posner, 1967). This is in keeping with Cratty and Noble (2011) who state that the acquisition of psychomotor skill involves the development of organized and coordinated patterns of muscular activity guided by environmental input.

A study done by Descarreaux and Dugas (2010) showed two distinct learning stages over a five year learning period in students trained using the traditional didactic and practical methods. The first stage occurred early in the learning process, and showed maximal improvement in the speed of force production of a manipulation. Stabilisation of peak force, or decreased level of variability, however took place over a longer period. The study suggested that reduced trial to trial variability, or increased control, of peak and preload forces occurred once fundamental aspects of SMT skill requirements had been met, indicating automaticity of performance.

In principle then, and according to the learning theories (Fitts and Posner, 1967), resistance training in movements simulating manipulations should allow students to develop organised patterns of functional muscular activity specific to manipulation and allow increased rate of progression from one stage to the next. Theoretically, this should then result in decreased trial-trial variability of the dynamics of manipulation for the specific manipulative techniques in which students are trained (Cohen *et al.,* 1995). Elastic tubing and tyre resistance training are two training techniques that provide resistance against which students can simulate manipulations, allowing them to rehearse the removal of articular slack, speed of thrust, depth of thrust, force imparted, line of drive and degree of rotation (Descarreaux and Dugas, 2010). Additionally it may be possible that students trained with elastic tubing resistance in multiple planes (as opposed to tyre training in one plane) are able to acquire more refined psychomotor skills (coordination) than those trained with tyre resistance in a single plane (Dagenais and Haldeman, 2012; Norkin and Levangie, 1992).

According to current literature, no studies have yet compared the level of control of the dynamics of manipulation in students trained using elastic tubing or tyre resistance (either to each other or to those without such training) despite similar techniques commonly being used in training (Harvey *et al.*, 2011; Cucciolillo, Gemmell and Gosselin, 2006; Descarreaux *et al.*, 2005; Young, Hayek and Philipson, 1998).

This study therefore aimed to determine the effectiveness of elastic tubing resistance training versus tyre resistance training as an adjunct to the standard manipulative training program at Durban University of Technology (DUT) in the development of control of the dynamics of manipulation in chiropractic students.

The above aim was achieved by comparing changes of the dynamics of manipulation from pre- to post- training, between the elastic tubing resistance training and the standard manipulative training; the tyre resistance training and the standard manipulative training and the elastic tubing and the tyre resistance training groups.

1.2 Aims, Objectives and Null Hypotheses

The aim of this study was to determine the effectiveness of elastic band resistance training versus tyre resistance training as an adjunct to the standard manipulative training program at Durban University of Technology (DUT) in the development of control of the dynamics of manipulation in chiropractic students.

The objectives and the null hypotheses of this study were:

Objective One:
To determine whether elastic tubing resistance training in multiple planes as an adjunct to standard manipulative training at DUT, versus standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation.

Null hypothesis:
Elastic tubing training in multiple planes as an adjunct to standard manipulative training at DUT, versus standard manipulative training at DUT, would not result in improved control of the dynamics of manipulation.

Objective Two:
To determine whether tyre resistance training in a single plane, as an adjunct to standard manipulative training at DUT, versus standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation.

Null hypothesis:
Tyre resistance training in a single plane, as an adjunct to standard manipulative training at DUT, versus standard manipulative training at DUT, would not result in improved control of the dynamics of manipulation.

Objective Three:
To determine whether elastic tubing resistance training in multiple planes as an adjunct to standard manipulative training at DUT, versus tyre resistance training in a single plane, as an adjunct to standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation.

Null hypothesis:
Elastic tubing resistance training in multiple planes as an adjunct to standard manipulative training at DUT, versus tyre resistance training in a single plane, as an adjunct to standard manipulative training at DUT, would not result in improved control of the dynamics of manipulation.

In terms of the results, it is important to note that the reference to control within the context of this study has two distinct concepts. The first is related to the ability to consistently achieve similar outcomes in terms of the dynamics of manipulation, i.e. a low force for each consecutive manipulation. The second concept relates to the control of the relationships between the dynamics of manipulation which aid in determining whether the student has been able to refine the combination of the different dynamics to attain coordinated outcomes between them.

1.3 Rationale

- Fyfe (2006) showed that inter-peer practicing of chiropractic techniques, including manipulation, was significantly related to the prevalence of lower back pain in the students studying Chiropractic at DUT. Furthermore Macanuel *et al.,* (2005), showed that students tend to experience a similar frequency, nature, and extent of injury as those seen in patients seeking treatment in Chiropractic practice; but are, however, more prone to lumbo-pelvic spinal injury. These studies suggest that students develop negative health sequelae as a result of being utilised as “mock” or simulated patients within the manipulative training aspect of chiropractic programs. Although these transient negative sequelae are similar to those that occur in patients receiving chiropractic treatment, they are considered more significant in this context as students are generally asymptomatic prior to being manipulated by trainee chiropractors. It would therefore be of value to investigate alternative training methods that could facilitate in the acquisition of the psychomotor skills related to manipulation. Improvement in the control within and between the dynamics of manipulation, so as to lessen the negative sequelae on chiropractic students without compromising the psychomotor learning skills

that chiropractic students are expected to learn and assimilate (Bergmann and Peterson, 2002), would achieve this aim.

- According to Triano *et al.,* (2004), manipulative skill progresses along a continuum from incompetent to safe, adequate, masterful, and innovative under complex clinical scenarios. Ideally in order for an individual to progress to specialist level the individual should undergo specific training in order to acquire at least adequate and preferably expert level of skill in the required tasks specific to their chosen discipline (Triano *et al.,* 2004). This is however only possible with task repetition (Fitts and Posner, 1967).
- Training with the proposed resistance methods (elastic tubing and tyre resistance) was thought to provide guided rehearsal in a functional activity relevant to SMT, thus allowing students to focus on control of speed, force, line of drive, and directional accuracy without the added intellectual task of the doctor-patient position. Precision, a low level of variability and coordination have been used to describe skillful manipulation, thus it could be deduced that increased control over the dynamics of manipulation would lend itself to improved manipulative skill (Triano *et al.,* 2004; Cohen *et al.,* 1995). Resistance training would, therefore, potentially enhance performance in student training and facilitate the process of psychomotor skill acquisition.
- Elastic tubing and tyre resistance training would provide muscular training (Robergs and Roberts, 1996) in movements that simulate the actions required for manipulations, potentially allowing students to master control over the fundamental dynamics of manipulation, thus providing a solid foundation on which to build manipulative skill.
- Positive results would thus provide a safe, efficient adjunct to the chiropractic manipulative training program, with elastic tubing and tyre resistance training serving as training aids to potentially develop improved control within and between the dynamics of manipulation in students, promoting competence in SMT and ultimately patient care in graduating students. Furthermore, the resistance methods would provide a simple, cost effective method for qualified Chiropractors to continually improve their control in terms of the dynamics of spinal manipulation.

1.4 Benefits

Based on the hypothesis of neuropsychomotor learning theories (Fitts and Posner, 1967), it was expected that training in either of the intervention groups would result in greater control of the dynamics of manipulation than when compared to the standard manipulative training group.

The use of resistance training aids in the intervention groups aimed to allow students to focus solely on improving their control of the dynamics of manipulation without the added intellectual burden of patient assessment and positioning, which according to Triano *et al.,* (2004), and Haas (1990), is beneficial in the process of learning a psychomotor skill. The resultant improved control within and between the dynamics of manipulation may optimize clinical training through internship and improve patient care (Harvey *et al.,* 2011).

Furthermore, Fyfe (2006), showed that inter-peer practicing of chiropractic techniques, including manipulation, was significantly related to the prevalence of low back pain in the students studying chiropractic, while Macanuel *et al.,* (2005), showed that students who receive manipulations by trainee chiropractors tend to experience a similar frequency, nature, and extent of injury as those seen in patients seeking treatment from chiropractors in practice. Thus, the use of resistance aids, rather than inter-peer practice, during the first two stages of psychomotor skill learning where movements are not yet autonomic and coordinated should theoretically decrease the risk of injury to the students during practice.

Thus, the study was structured with the potential to provide an avenue through which to improve the manipulative skills training program at DUT to ensure that students graduate with the highest level of control possible.

Cohen *et al.,* (1995), highlighted the importance of regular skill development for performance of SMT, thus positive findings would benefit qualified chiropractors by providing an easy, inexpensive method to improve and build on control of the dynamics of manipulation.

1.5 Limitations

All students were informed, prior to signing the Letter of Information and Informed Consent (Appendix A), that participation in the research required that no resistance training, or additional manipulative skills training, other than that covered in the training sessions and / or by the standard manipulative skills training program offered at DUT, was to be done for the duration of the study. Nevertheless, it is unclear whether students sought further training.

The participants' personal sporting activities and fitness training regimes were not taken into account and may have altered results.

If the study revealed improved control within and between the dynamics of manipulation with the use of resistance training, the improvement could not be extrapolated to the use of SMT in the context of a doctor-patient relationship (particularly in this study where patient factors related to the manipulative procedure were controlled by the use of the Dynadjust). Therefore, the effect of the different forms of training employed in this study cannot be interpreted in this context.

1.6 Conclusion

As can be seen from the introduction provided in this chapter, the use of auxiliary aids in the development of manipulative skill has been considered in the literature, however, a paucity of literature has compared these different methods (tyre resistance training with elastic tubing resistance training) in order to determine whether the theoretical constructs that underpin their use, produce the anticipated results in practice, compared to the standard manipulative training alone (didactic presentation and inter-peer practice).

Therefore, Chapter Two will present a review of the literature to support this study and the methodology as well as provide an extension of the rationale for this study. In contrast, Chapter Three presents the material and methods employed in this study, with Chapter Four presenting the results obtained as well as a discussion of the results in the context of the literature. Chapter Five will conclude the study and

supply the recommendations for practical application, as well as suggest improvements and recommendations for further studies.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

Manipulation is an ancient healing method that is known universally (Keating, 2001). It is the primary therapeutic modality applied in chiropractic (Dagenais and Haldeman, 2012; Bergmann and Peterson, 2002; Haldeman, 2005) and thus forms a fundamental aspect of chiropractic training (Bergmann et al., 1993; Bergmann and Peterson, 2002). In order to contextualise the role of manipulation, the following chapter will address manipulation from the vantage points of a definition, its context within manual therapy, clinical practice as well as training situations. The emphasis will be on the latter, as training of manipulative technique forms an integral component of the identity of the profession (Keating, 2001; Chapman-Smith, 2000; Coulter, 1999)

2.2 Manual Therapy and Manipulation

2.2.1 Definition of Manual Therapies

Manual therapies include all procedures which involve direct contact of the practitioner's hands with the patient's body in order to treat visceral or somatic structures with the use of mobilisation, manipulation, massage or traction. Manual therapies may be further categorised into procedures that work mainly on the joint structures or the soft tissue components (Bergmann and Peterson, 2011).

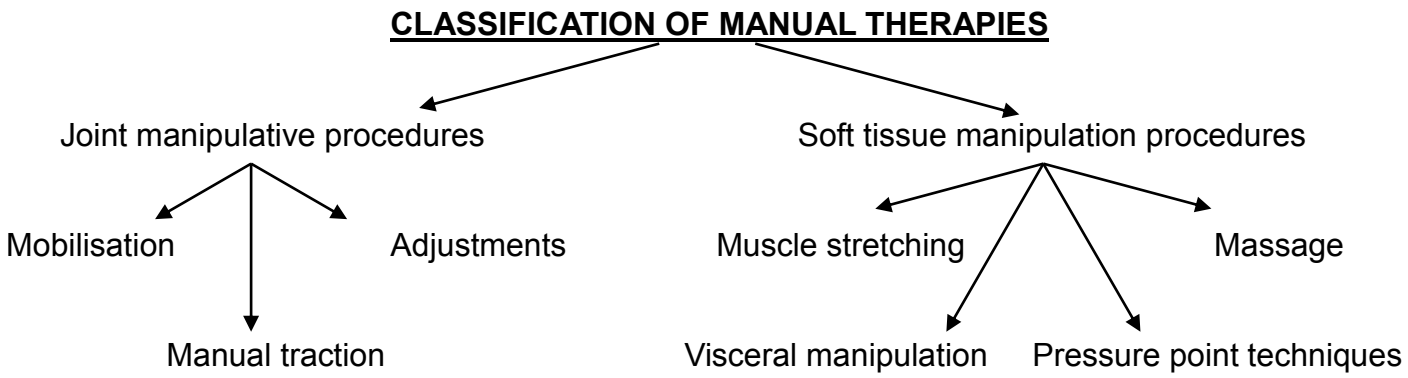

Figure 2.1 Classification of Manual Therapies (Bergmann and Peterson, 2002)

2.2.2 Definitions of Joint Manipulation

Bergmann and Peterson (2011), reviewed the literature and found there to be three definitions commonly used to describe joint manipulation. Firstly, it is broadly defined in a clinical context, to include all procedures in which the hands are used to influence the joints of the body; through the use of mobilisation, adjustments, manipulation, traction, or stimulation; with the aim of influencing improvement in the patient's health (Chapman-Smith, 2000). It has also been described as a specific manual procedure involving a directional thrust that aims to move a joint past the physiological range of motion whilst remaining in the anatomic limits of motion (Bergmann and Peterson, 2011; Vernon and Mrozek, 2005; Sandoz, 1976). This operational definition may be the most accepted as a result of the Delphi study by Gattermann and Hansen (1994) that aimed to develop chiropractic nomenclature through consensus. Finally, joint manipulation can be described in terms of the technique requirements and their demands on the practitioner. In this context manipulation is a skilful, dextrous treatment done by hand that aims to forcefully and passively move a joint beyond its active limit (Gattermann, 1995; Dagenais and Haldeman, 2012), or clinical limit (Vernon and Mrozek, 2005) of motion.

2.2.3 Definitions of Adjustment

Similarly, a review of the literature undertaken by Bergmann and Peterson (2011), and a Delphi study by Gattermann and Hansen (1994), found two common definitions used to describe the adjustment. Firstly, it has been described as any chiropractic therapeutic procedure using “controlled force, leverage, direction, amplitude, and velocity” (Bergmann and Peterson, 2011; Gatterman and Hansen, 1994); that is directed at specific joints or anatomic region with the aim of influencing joint and neurophysiologic function. Adjustments have also been described as a specific form of joint manipulation that makes use of either short or long lever techniques with specific anatomic contacts. According to this definition, the adjustment is characterised by a low amplitude dynamic thrust of which the amplitude, velocity and direction are controlled. The adjustment is usually accompanied by an audible articular crack (Bergmann and Peterson, 2011; Sandoz, 1976).

2.2.4 Terminology used in this study

For the purpose of this study, and due to the similarity of definitions of “manipulation” and “adjustment”, the term “manipulation” will encompass aspects of both definitions. Therefore, within the body of this study, “manipulation” is defined as a manual procedure that involves a directed thrust of “controlled force, leverage, direction, amplitude, and velocity” (Bergmann and Peterson, 2011; Gatterman, 2005); which aims to move a joint passed the physiological range of motion, without exceeding the anatomic limit (Sandoz, 1976).

2.2.5 The Subluxation Complex as a Manipulable Lesion

The vertebral subluxation complex (VSC) is the name given to the spinal joint lesion that is corrected through the use of manipulation by chiropractors (Chapman-Smith, 2000). It is a theoretical model of spinal joint dysfunction from a chiropractic clinical perspective that aims to incorporate the interconnection of inflammatory, degenerative, and pathologic changes in nerve, muscle, ligaments, blood vessels, and connective tissue (Gatterman, 2005). The VSC has been postulated to have an influence on the function of bodily systems and general health (Leach, 2004; Gatterman, 1995) and is described as a functional spinal lesion or dysfunction of the vertebral joints, rather than a structural one (Chapman-Smith, 2000).

The subluxation complex can however be applied to any joint as compared the vertebral subluxation complex which relates only to the spine. The components of subluxation incorporate (Leach, 2004; Gatterman, 2005):

- a degree of movement dysfunction,
- a degree of neurological and / or vascular dysfunction,
- a degree of associated muscular changes or myopathologies,
- a degree of histochemical change within the joint and
- often a degree of structural displacement

Within this context, hypomobility is the principle component of joint dysfunction that is addressed in chiropractic clinical practice, and is often referred to as a fixation (Gatterman, 1995). A modern model of the VSC organises the components of the VSC in a hierarchal fashion, with hypomobility represented at the apex of the hierarchy, as restoration of motion is the primary aim of clinical chiropractic (Gatterman, 2005). The controlled loads and forces directed to the joints of the spine during spinal manipulation are designed to “unbuckle” motion segments and reduce local mechanical stresses within the vertebral subluxation complexes (Triano, 2001). This particular function of manipulation is thought to result in many of the benefits of this intervention strategy.

2.2.6 Use and Benefits of Manipulation

Although the exact mechanism for Spinal Manipulative Therapy (SMT) is not yet fully understood, favourable clinical outcomes from the use of manipulation include; pain relief, reduction in oedema, increased functioning, and patient satisfaction (Morris, 2006; Gatterman, 2005; Leach, 2004; Triano, McGregor and Skogsbergh, 1997; Gatterman, 1995) Furthermore, local muscle tone, reflex-neurological, and biomechanical effects are other positive physiological effects induced by SMT that have been confirmed in a number of studies (Downie, Vemulpad and Bull, 2010; Leach, 2004). Several studies related to SMT have assessed the immediate biomechanical effects of tissue displacement or deformation caused by manipulation (Bergmann and Peterson, 2011; Haldeman, 2005; Vernon and Mrozek, 2005; Leach, 2004; Evans, 2002; Cramer and Darby, 1995; Shekelle, 1994). These effects include alteration of orientation and / or positioning of various anatomic structures (Leach, 2004; Cramer and Darby, 1995), increasing segmental range of motion (Rogers and Triano, 2003), unbuckling of structures, releasing of entrapped structures (Bergmann and Peterson, 2011; Haldeman, 2005), disruption of adhesions formed within the body (Leach, 2004; Evans, 2002; Shekelle, 1994), and re-establishment of normal spinal function (Rogers and Triano, 2003; Conway *et al.*, 1993). Other hypotheses regarding the mechanism of action of SMT focus on cellular and neurological responses to the biomechanical effects caused by manipulation (Khalsa *et al.,* 2006; Leach, 2004; Gatterman, 1995)**.** These hypotheses suggest that SMT is capable of stimulating reflex neurological pathways that result in the relaxation of hypertonic muscles and stimulate the release of anti-inflammatory agents. Supportive evidence suggests that primary afferent neurons in the para-spinal tissues, the motor control system, and central pain processing may be impacted by SMT (Pickar, 2002).

Thus, spinal manipulation has been shown to be of benefit (Brontfort *et al.*, 2010; National Institute of Health and Clinical Excellence: 2009; Negrini *et al.,* 2006*;* Australian Acute Musculoskeletal Pain Guidelines Group, 2003; The Norwegian Back Pain Network: 2002). These same effects are however also evident in extra-spinal therapy and spinal and extra-spinal rehabilitation therapy (Brantingham *et al.*, 2012; Brantingham *et al.*, 2009; Hoskins *et al.*, 2006; Triano, McGregor and Skogsbergh*,* 1997); as a means of controlling symptoms that may arise from

exacerbations and related musculoskeletal injuries that may occur during the treatment program (Triano, McGregor and Skogsbergh, 1997).

As a result of the above effects and benefits, surveys conducted in the United States in 1991 and 1997 showed that the most common medical conditions for which patients sought chiropractic treatment were back problems, neck problems, headaches, arthritis, ligamentous sprains, and muscular strains (Dagenais and Haldeman, 2012). The 1991 survey showed that chiropractic was the second most commonly reported Complementary and Alternative Medicine (CAM) therapy used, after relaxation techniques (Dagenais and Haldeman. 2012). In 1997, when this survey was repeated, it showed that the use of chiropractic treatment administered by professional chiropractors had grown considerably (Chenot *et al.,* 2007; Eisenberg *et al.*, 1998). Furthermore, according to Triano (2001), manipulation is being offered to a progressively widening case mix of patients, including geriatrics and post surgical patients.

From the above information it is evident that a significant number of patients rely on manipulation for the relief of symptoms and amelioration of their clinical conditions. Therefore, it is essential for chiropractors to be proficient in the delivery of this intervention tool in order to achieve the best clinical outcomes for the patient (Bergmann and Peterson, 2011). In order to achieve this, a two-fold process needs to be quantified and understood:

- The manner in which chiropractors are trained in the skill of manipulation and
- The manner in which a successful manipulation is delivered.

Thus, the following section deals with manipulative training, the assessment of the patient, and the concepts of successful manipulation in order to provide a platform for the reader to successfully interpret and understand the mechanisms behind each of these two components.

2.3 Manipulation in Clinical Practice

Before treating a patient using SMT, a thorough patient examination is required by the attending chiropractor (Dagenais and Haldeman, 2012). This examination should include, but is not limited to, assessment of the presence and / or absence of contraindications to manipulation, local kinematics, local discomfort, and provocative testing to the symptomatic area (Triano, McGregor and Skogsbergh, 1997). Manual palpation of the area is also required to assess for local tenderness and inflammation and identify areas of altered mobility and dysfunction (Dagenais and Haldeman, 2012; Schafer and Faye, 1990). After patient diagnosis if manipulation is indicated, the segment identified to be the manipulable lesion will be preloaded using a slow force, followed by a HVLA thrust (Chapman-Smith, 2000). The manipulation is generally accompanied by a cracking sound, however, the presence or absence of this is not considered an indication for whether an adjustment has been performed (Bergmann and Peterson, 2002; Vernon and Mrozek, 2005; Sandoz, 1976).

Efficient and properly administered manipulations are usually painless although the patient may experience transient discomfort as a result of the intervention (Bergmann and Peterson, 2002). Successful administration of manipulation is clinically determined by means of favourable therapeutic outcomes including local changes in pain, muscle tension, and flexibility (Triano, McGregor and Skogsbergh, 1997). Anatomical and physiological knowledge of the region being treated is essential when administering a manipulation (Cramer and Darby, 1995). An awareness and sensitivity of the depth of the thrust by the chiropractor administering the manipulation is necessary in order to prevent injury to the patient (Dagenais and Haldeman, 2012). Subsequently, the thrust is the component of manipulation that carries the greatest risk of joint injury to the patient (Chapman-Smith, 2000; Sandoz, 1976). This is because joints may be injured if the thrust exceeds the physiological range of joint motion, either through excessive force, depth, or pre-manipulative tension (Dagenais and Haldeman, 2012; Sandoz, 1976). The literature in manual therapy does not have prescribed optimal levels of force for mobilisations and manipulations as yet (Bergmann and Peterson, 2011; Lee, Moseley and Refshauge, 1990).

Thus, the main goal of spinal manipulation is to select and apply safe, comfortable, and specific manipulations, localised to a specific motion segment (Bergmann and Peterson, 2011; Triano et al., 2004; Bergmann and Peterson, 2002). In order for the manipulation to be specific, the chiropractor needs to have a thorough awareness of spinal and extremity joint anatomy (Bergmann and Peterson, 2011), biomechanics, and arthrokinematics (Chapman-Smith, 2000; Norkin and Levangie, 1992). These factors are important as the appropriate line of drive, velocity, and amplitude of manipulations are determined by a combination of the desired joint movement of the specific segment being treated, and examination of the surrounding joints and soft tissue (Bergmann and Peterson, 2011; Bergmann and Peterson, 2002; Norkin and Levangie, 1992).

As a result, pre-manipulative procedures have been designed to localise forces and to distract the joint so as to improve specificity and minimise the distractive forces imparted on adjacent joints during manipulation (Bergmann and Peterson, 2011). These procedures include the selection of appropriate doctor-patient positions and manipulative techniques for the region identified to be treated (Leach, 2004; Schafer and Faye, 1990). Removal of articular slack, or “joint slack”, the selection of appropriate contact points, and the selection of appropriate vectors are other pre-manipulative procedures that improve specificity (Bergmann and Peterson, 2011; Byfield, 2012). Pre-manipulative procedures are followed by the thrust, which is the main mechanism through which force is imparted to the joints (Bergmann and Peterson, 2002; Schafer and Faye, 1990).

When assessing the complex interactions that are required to select and implement a particular manipulative technique, it is also important to consider the elements or the dynamics of the manipulation. Cohen *et al.,* (1995), were the first researchers to define elements of skill in performing High Velocity Low Amplitude (HVLA) manipulation. Using the terms *fast*, *force*, *precision, comfort and confidence*, they isolated and described the characteristics of a skilful manipulation, *indicating that a low level of variability of the dynamics of manipulation contribute to skilled performance of manipulation*. The use of the term “precision” implies that control of the dynamics of manipulation is necessary for skilful manipulation. Triano *et al.*,

(2004), further summarised manipulation as the skilful performance and coordination of dynamics.

Each of the components associated with the delivery of the manipulation will now be discussed briefly, in order to set a context for those dynamics that were measured in this study (it should be noted that the patient, joint and practitioner specific characteristics as suggested by Haas (1990), were not considered in this study as they were factors that were controlled for by the method in which the students were measured over time).

2.3.1 Reduction of Articular Slack and Patient Positioning

Articular slack must be reduced during or before the administration of a manipulation, as this assists in localising tension in peri-articular tissues that may be impeding joint motion and limiting joint play, thus allowing the manipulative thrust to be targeted to the desired level. If pre-manipulative tension is not first established, the energy and force generated by the thrust may be dissipated into surrounding joints and soft tissues (Bergmann and Peterson, 2002). In this context, patient positioning and leverage are two essential factors that play a role in the removal of tissue slack and creation of pre-manipulative tension. Patients may be positioned in such a way that locks adjacent joints and localises manipulative forces over the segments of joint dysfunction identified during patient examination for treatment. This is done by positioning the patient so that the targeted joints are placed in positions which contribute to the distraction of the joint when a force is imparted to it (Bergmann and Peterson, 2002).

The measurement tool used in this research, the Dynadjust, is equipped with preset programmed parameters for the removal of tissue and articular slack (defined in this research as cue to thrust: Q2T). These preset parameters represent values that have been determined to be useful in training programs for various parts of the body and manipulation scenarios. They have been determined using by extensive collaboration and consideration of many investigators and test subjects (Triano, 1998). These preset parameters allow for a specific margin of error before being

considered excessive or insufficient (Orthoneuro Technologies, Accessed 12 June 2011).

2.3.2 Vector (Line of Drive)

The selection of appropriate vectors to induce corrective joint movements for specific motion segments is essential to prevent injury to the joint. Most manipulative vectors are directed parallel to articular planes, with some directed perpendicularly, (Bergmann and Peterson, 2002). Vectors also indicate the direction of the thrust (Schafer and Faye, 1990).

Vectors are described in anatomical terms, for example: Posterior to Anterior (P-A) (Byfield, 2012; Bergmann and Peterson, 2011; Schafer and Faye, 1990). Attention to correct vectors is necessary to ensure anatomically correct, specific, and efficient manipulations (Byfield, 2012). Misguided joint vectors may result in undesired joint compression or tension; or cavitation at motion segments above or below the targeted level (Bergmann and Peterson, 2002).

The Dynadjust measures line of drive as the amount of deviation from a perfectly straight line (measured in percentage, for purposes of this study converted into degrees: 45 degrees = 100 percent deviation), as well as rotational movements of the thrust (in degrees). For the purpose of this study, vectors for each adjustment were set as straight lines for ease of assessment (aiming for 0 degrees lateral or rotational deviation).

2.3.3 Thrust (Force and Speed)

When a joint is mobilised passively the range of motion is slightly increased in the direction of mobilisation (Isaacs and Bookhout, 2002; Chapman-Smith, 2000; Maitland, 1986; Sandoz, 1976). At the end of passive range of movement, when articular slack has been removed, a resistance known as the elastic barrier of resistance is felt (Chapman-Smith, 2000; Vernon and Mrozek, 2005; Sandoz, 1976). If mobilisation is forced beyond this point, a crack is perceived followed by a slight increase in the range of movement beyond the normal physiological limit (Gatterman, 2005; Sandoz, 1976). This added range of movement is called the paraphysiological space, beyond which a second ultimate barrier of resistance is felt (Gatterman, 2005; Chapman-Smith, 2000; Sandoz, 1976). This second barrier of resistance is represented by the stretched ligaments and joint capsule of the joint concerned and signifies the limit of anatomical integrity (Leach, 2004). Forced movement beyond this point would produce ligamentous sprain, which could result in partial or complete dislocation of the joint concerned (Sandoz, 1976).

The HVLA manipulation thus requires a high speed thrust using minimal force into the paraphysiological space. This allows for joint distraction and cavitation without exceeding the limit of anatomical integrity, thus preventing joint injury (Byfield, 2012; Bergmann and Peterson, 2002; Chapman-Smith, 2000; Sandoz, 1976). The manipulative force is generated through a combination of the practitioner's muscular effort and body weight transfer, although it is also affected by the resistance that is offered by the patent’s tissues as well as gravity and / or the patient’s body weight (Haas, 1990).

The Dynadjust is able to measure the peak force administered during the simulated manipulative thrust, as well as the recoil speed of the thrust and the depth of thrust.

2.4 Technical Procedure of a Manipulation

The application of a manual thrust has multiple different components to consider (Haas, 1990). Cohen *et al.*, (1995), identified and described the elements of skill (as related to the delivery of the manipulation or performing HVLA spinal manipulation); using the terms *fast* (time), *force, precision* (location and / or accuracy), *comfort* (for the patient and the practitioner*)* and *confidence* (of the practitioner). These various dynamics highlight the importance of being able to individually and in combination, appropriately, apply the dynamics of manipulation in a controlled manner in order to achieve the best outcome (Haas, 1990). As a result of the above components related to the delivery of a manipulation, Triano *et al.,* (2004), and Haas (1990), indicated that the level of spinal manipulative skill in managing these dynamics can range from incompetent, to safe, to adequate, to masterful, and finally, to innovative under complex clinical circumstances.

In terms of SMT, the most commonly discussed dynamics are considered to be high speed and a high rate of force production with regard to the thrust (Bergmann and Peterson, 2011). The reported variables considered to best represent skill acquisition are; time to peak force, peak force and rate of force production (Triano, Descarreaux and Dugas, 2012; Descarreaux *et al.,* 2005; Cohen *et al.*, 1995). However, other indicators of a high levels of automotive control appear to be related to the neuro-motor integration, and low trial-to-trial variability when performing the same manipulation consecutively (Descarreaux and Dugas, 2010). These latter methods of analysis are not as well understood as time to peak force, peak force and rate of force production, but are considered to be appropriate methods in recording and reporting on variability and control (Descarreaux and Dugas, 2010). These latter methods of evaluation (neuro-motor integration and low trial-to-trial variability) are appropriate in measuring the effect of training and or experience on the ability to refine the procedure of manipulation (Descarreaux and Dugas, 2010)

Thus, in this study, the effect of training for specific manipulations in specific directions using different training aids (viz. elastic tubing, tyre resistance) on the development of control (level of trial-to-trial variability) over the dynamics of manipulation for the specific manipulations trained was investigated.

2.5 Link between Clinical Practice and Technical Success of a Manipulation

It is generally accepted that the minimum requirements for skilled completion of a task include the ability to successfully produce a specific action on demand and the ability to adjust to the demand over a range of options and complex circumstances (Kovacs, 1997; Higgins, 1991). In most procedures that require manual skill there is an assumed relationship between safety, skill of operation, and outcome. Thus it follows that greater experience is strongly linked to reduced adverse effects and better clinical outcomes (Triano *et al.*, 2006; Birkmeyer *et al.*, 2003; Kovacs, 1997). Differences in clinical outcomes are therefore empirically believed to exist based on manipulative skill levels. Skill levels of chiropractors are presumed to be sharpened with regular practice after they have been correctly trained (Cohen *et al.,* 1995). Thus, the success of a manipulation is characterised by a reduction of patient symptoms and the restoration of function; but also by improved control and proficiency of the chiropractor.

Triano *et al.*, (2004), showed that training courses that sequentially build rehearsal experience with manipulative procedures and make use of systemic patient transfer and pre-positioning methods result in improved manipulative performance. Furthermore, it is hypothesised by Triano *et al.*, (2004), that skilled applications of manipulations, are likely to be safer and more clinically effective than those with little training. This concurs with research conducted by Cohen *et al.*, (1995), who suggested that skilful SMT is procedure-dependant, in that skilled performance in a rehearsed, familiar manipulative procedure does not ensure skilled performance in unfamiliar procedures. Thus, in order to achieve the best possible clinical outcomes, chiropractors need to be well trained and committed to continual manipulative skill development. Therefore clinically, successful and controlled administration of manipulation is determined by means of favourable therapeutic outcomes, including local changes in pain, muscle tension, and flexibility (Triano, McGregor and Skogsbergh*,* 1997). As a result, training in manipulative procedures is not only important in terms of developing control of the individual dynamics of manipulation, but also in terms of the formation of appropriate learned combinations of the various dynamics related to the delivery of any one or more manipulative procedures required in clinical practice.

2.6 Teaching manual therapies

2.6.1 The Theories behind Teaching Manual Therapies

The importance of incorporating motor learning principles in manipulative training has been demonstrated consistently (Descarreaux and Dugas, 2010) and thus manipulation is frequently studied using a motor control or learning paradigm (Descarreaux and Dugas 2010; Descarreaux *et al*., 2006; Triano *et al.*, 2003; Scaringe, Chen and Ross, 2002). Within the motor learning model, recent studies have shown similarities between learning processes involved in manipulation as a psychomotor skill, and in sports and other manual activities, for example surgery (Descarreaux and Dugas, 2010; Descarreaux *et al.*, 2006; Everbusch and Grantcharov, 2004; Triano *et al.*, 2003; Scaringe, Chen and Ross, 2002), where control of the dynamics of movement are critical and in some cases life threatening if not executed appropriately.

However, Cohen *et al.*, (1995), demonstrated a limitation in that expert level skills in known procedures are not usually transferable to new, un-learned manipulative procedures. Thus, SMT training has been seen to make use of various manipulation simulating devices in an attempt to facilitate the acquisition of the psychomotor skill in an array of manipulative procedures (Harvey *et al.*, 2011; van Zoest, States and Stappaerts, 2007; Cucciolillo, Gemmell and Gosselin, 2006; Triano *et al.,* 2006; Enebo and Sherwood, 2005; Descarreaux *et al.*, 2005; Rogers *et al*., 2003; Triano *et al.*, 2003; Triano *et al.*, 2002; Young, Hayek and Philipson, 1998). Elastic tubing and tyre resistance methods are examples of other low technology resistance tools that can be used in teaching students how to apply manipulative procedures.

This agrees with the literature on psychomotor development, where according to the learning model proposed by Fitts and Posner (1967), psychomotor development of any skills occurs in three stages. Poole (1995) later reviewed and summarised these thee stages of learning. The first stage is the theoretical stage, where task performance is usually poor and uncoordinated, and the student must concentrate on each movement before attempting to perform it. In this phase, diligent practice allows for progression to the association (second) stage, where known movements are associated with the movement being learnt, rendering smoother movements and

increased learner comfort (Catty and Noble, 2011), resulting in improved delivery of the action required. This agrees with Cratty and Noble (2011), who suggest that the acquisition of a psychomotor skill involves the development of organized patterns of muscular activity guided by environmental input. During the second stage, practice takes on primary importance as the learner begins to use internal feedback and relies progressively less on visual and verbal feedback from an external source (Fitts and Posner, 1967). With long term practice the student develops a "pre-programming" of the action, thus reducing the need for high mental effort in performance of the manual procedure. This occurs in the third and final stage, the autonomous stage. During this stage high levels of concentration are no longer needed to perform the movement as movement patterns become more strongly encoded in the motor cortex, and the level of trial-to-trial variability of the learnt movement decreases. In this stage the skill is refined further through practice (Fitts and Posner, 1967). Such rehearsal, gradually decreases trial-to-trial variability of the task being learnt, suggesting greater task control and inferring skilled performance (Muller and Sternad, 2009; Triano *et al.,* 2004).

In accordance with this learning model, Triano *et al.*, (2004), emphasised the importance of learning the fundamentals of SMT prior to performance, so that attention and focus can be paid to the individual aspects and dynamics of manipulation, rather than attempting to master physical and intellectual tasks simultaneously. This is not unlike the process required for surgeons to acquire the psychomotor skill of surgery. Clinical experience has shown that newly qualified surgeons need to perform a number of endoscopic procedures to gain competency (Everbusch and Grantcharov, 2004). In surgery, virtual reality endoscopic simulators have been used for several years in an attempt to facilitate the learning process of the psychomotor skill (Everbusch and Grantcharov, 2004; Grantcharov *et al.*, 2002). In a similar manner, this would suggest that guided training against elastic tubing and tyre resistance in movements simulating specific manipulations, would aid in the acquisition psychomotor development, and thus in the control of the dynamics of manipulation.

Additionally, it has been hypothesised that sport-specific resistance training results in neural adaptations in the specific trained action, and thus improved performance

(Judge, Moreau and Burke, 2003). Neural adaptations that result from intermittent resistance training in functional sporting activities may therefore be essential for improving the performance of technical aspects of the sporting skill (Kraemer, Duncan and Volek, 1998; Moritani, 1993; Hakkinen, 1989; Sale, 1998). This supports the suggestion that neural patterns of action and physiological adaptation (Leach, 2004; Triano *et al.,* 2003; Robergs and Roberts, 1996) could be reasonably expected in students training with tyre or elastic tubing resistance as compared to those who only received the standard manipulative training offered at DUT. As a result it would be expected that the tyre or elastic tubing resistance training groups would be better able to develop control of the manipulative techniques which were tested in this study. This assertion is based on the preceding discussion that indicates that resistance training in movements simulating specific manipulations should allow students to develop organised patterns of muscular activity in these movements(Goodpaster *et al*., 2006; Saltin *et al*., 1977; Robergs and Roberts, 1996) This concurs with the motor learning standpoint that an increase in the number of hours spent on procedural learning should result in better motor performance in tasks involving coordination (Schmidt and Wrisberg, 2004).

The term “precision” defined by Cohen *et al.*, (1995), describes an element of skilful manipulation, and implies that control of the dynamics of manipulation contributes to the development of manipulative skill. According to the motor learning theory, guided training should increase motor performance by reducing trial-to-trial variability of the learnt movements, indicating a higher level of task control (Poole, 1995; Fitts and Posner, 1967). Thus it could be hypothesised that the resistance training methods proposed would provide muscular rehearsal in a functional activity relevant to SMT, allowing students to focus on the dynamics of manipulation (viz. speed, force, time, line of drive and directional accuracy) without the added intellectual task of the doctor-patient position (Haas, 1990). In theory, this should allow students to replicate specific manipulations consecutively, indicating a low level of trial-to-trial variability between consecutive specific manipulations and thus control over the dynamics of manipulation. This is considered to reflect automaticity which is an element that reflects a high level of expertise (Descarreaux and Dugas, 2010).

Furthermore, manipulations can be done in multiple planes depending on the vector required for the specific joint (Bergmann and Peterson, 2002). *Thus students trained with elastic tubing resistance in multiple planes should acquire control of the dynamics of manipulation in all of the planes in which they train, where as those trained with tyre resistance in a single plane would only be expected to improve control over the dynamics of manipulation in the single plane in which they trained* (Cratty and Noble, 2011; Higgins, 1991; Kaufman, Wiegand and Tunick, 1987).

According to current literature however, no studies could be found, comparing the level of control of the dynamics of manipulation between students trained using elastic tubing or tyre resistance to those without such training**.**

2.6.2 Current Practices in the Teaching of Manual Therapies

Training of manipulation ranges from formalised courses which allow practitioners to qualify with a degree; to informal weekend seminars (Triano *et al.*, 2004), which are widely considered by professional leaders with experience of manual medicine as inadequate (Chapman-Smith, 2000). According to Triano *et al.*, (2004), this results in varied levels of skill which can influence the clinical outcome of treatment. Teaching of SMT is thus an essential aspect of chiropractic training, which commonly involves issues related to technical skills, safety, and effectiveness in the application of SMT procedures (Descarreaux and Dugas, 2010; Bergmann and Peterson, 2002). Traditionally, teaching progresses from theory; to instructional demonstration; to practice of the prescribed choreographed movements by the students on each other under supervision of qualified instructors (Harvey *et al.*, 2011; Descarreaux and Dugas, 2010; van Zoest, States and Stappaerts, 2007; Cohen *et al.*, 1995). During practice, students attempt to mimic doctor-patient positions, as well as the direction, amount and control of force imparted during the demonstration (Descarreaux and Dugas, 2010; Pringle, 2004). The parameters / dynamics observed during student assessment commonly include thrust vector, preload force, amplitude, velocity, and general coordination and positioning of the patient (Downie, Vemulpad and Bull, 2010).

Various combinations of instruction, demonstration and simulation of manipulation have been used in an attempt to teach manipulative skill (Harvey *et al.*, 2011; Descarreaux and Dugas, 2010; van Zoest, States and Stappaerts, 2007; Triano *et al*., 2004; Cohen *et al.*, 1995). A study by Harvey *et al.*, (2011) compared manipulative skill in students trained using only the doctor-patient positioning learning model (without thrust), to students trained with "complete practice" (doctor-patient positioning with thrust). The results clearly highlighted that students trained with "complete practice" acquired fundamental aspects of spinal manipulation skills earlier than those trained using the doctor-patient positioning model. These results suggest that those students interacting with each other and who are required to repeatedly interact with the activities expected of "complete practice" are more likely to develop through the phases of psychomotor learning than students who received training in the doctor-patient position only.

Similarly, Triano *et al.*, (2004), compared biomechanical parameter performance of groups of students exposed to different ratios of practical and didactic teaching techniques. The results showed that students trained with greater practical hours performed significantly better in the specific technique measured than students with greater didactic hours. These studies concur with the motor learning theories and literature that suggest that training and rehearsal in functional activities of a specific task aids in the learning process of a psychomotor skill (Schmidt and Wrisberg, 2004; Triano *et al.,* 2003; Fitts and Posner, 1967)

Furthermore, in order for students and qualified practitioners to progress along the continuum of motor learning to achieve "expert skill", literature suggests that certain feedback is required at different stages of learning (Downie, Vemulpad and Bull, 2010). The two main types of augmented feedback include Knowledge of Performance (KP) and Knowledge of Results (KR). KP refers to feedback regarding the movement performed while attempting to perform the manipulation, whereas KR refers to feedback regarding the outcome achieved. Such augmented feedback can be either qualitative or quantitative (Downie, Vemulpad and Bull, 2010) and is useful only if the student internalises it and links it to specific elements of the performance (Triano *et al.*, 2002). It is thus essential that appropriate feedback in the appropriate

forms is given at the appropriate stages of learning (Downie, Vemulpad and Bull, 2010; Triano *et al.*, 2002).

However, this implies that manipulative training that relies on the instructor's opinion of the procedure or a "student mock patient's" assessment of the procedure as feedback to the student is qualitative in nature (Downie, Vemulpad and Bull, 2010). Such feedback is limiting in that there are errors in feedback consistency due to instructor access; experience; observational powers, differing instructor opinions, and the lack of qualification of student mock patients to asses such complex skill as manipulation (Knobe *et al.*, 2012; Downie, Vemulpad and Bull, 2010). These limitations may result in limited progression of students (Downie, Vemulpad and Bull, 2010).

In contrast, quantitative assessment has been shown to be more effective than qualitative assessment in the acquisition of a psychomotor skill (Downie, Vemulpad and Bull, 2010). Thus, it has become standard practice that the dynamics of manipulation which are commonly measured when attempting to quantify the HVLA thrust include: force (specifically preload and peak forces) and time (Downie, Vemulpad and Bull, 2010; van Zoest, States and Stappaerts, 2007). Feedback regarding force and time, ranges from single-axis peak voltage readings (Scaringe, Chen and Ross 2002), to elaborate real-time force-time readouts (Descarreaux *et al.*, 2006). As a result augmented feedback has become an essential part of manipulative skills training, producing a higher standard of manipulative performance in students who receive it than in students who do not receive such training (Downie, Vemulpad and Bull, 2010; Triano *et al.*, 2003). Various alternate methods and apparatus have been used in combination with augmented feedback in order to improve manipulative skills training. Therefore, the next section discusses various forms of apparatus utilised to provide feedback and improve the control of the dynamics of manipulation.

2.6.3 Apparatus used to Improve Manual Therapy Teaching

Several studies have attempted to improve manipulative teaching techniques by investigating the effects of feedback strategies and learning tools (Scaring, Chen and Ross, 2002). Authors including Rogers and Triano (2003); Triano *et al.*, (2003); Triano *et al.*, (2002), and Cohen *et al.*, (1995) have endeavoured to improve training programs using various combinations of mechanical training aids, didactic presentations, and instructor modelling with verbal feedback.

Through this process, manipulation has been described by Triano *et al.*, (2006) as a bimanual task requiring high levels of sensory and motor coordination (psychomotor skill). In the context of manipulation, sensory (palpatory) skill is acquired through clinical experience (Leathers, 2011), however skilled performance and coordination is acquired through experience as well as intensive practice (Triano *et al.*, 2004).

The training aids used by various researchers range from simple rubberised cervical and thoracic spine manikins (Harvey *et al.*, 2011; Cucciolillo, Gemmell and Gosselin, 2006; Descarreaux *et al.*, 2005; Young, Hayek and Philipson, 1998), to complex interface instruments that measure 3D forces (van Zoest, States and Stappaerts, 2007), and elaborate modified treatment tables embedded with force plates and stabilising arms (Triano *et al.,* 2006; Triano *et al.*, 2003; Rogers and Triano, 2003; Triano *et al.*, 2002). The training apparatus used in some studies is itself the feedback device, i.e. students (Descarreaux *et al.*, 2006; Enebo and Sherwood, 2005; Scaringe, Chen and Ross, 2002; Rogers and Triano, 2003; Young, Hayek and Philipson, 1998).

Although tyre resistance and elastic tubing resistance are cost effective simple methods of resistance training that can be used in functional muscle training, and thus manipulative skills training; there is paucity in the literature assessing the effectiveness of these training aids in the development of control of the dynamics of manipulation. Therefore this study aimed to assess the effectiveness of elastic tubing versus tyre resistance training as an adjunct to the standard manipulative training program at Durban University of Technology in the development of control of the dynamics of manipulation in chiropractic students.

2.7 Measurement of Manipulation and the Success of Manipulation

The parameters commonly measured when attempting to quantify the HVLA thrust are force (specifically preload and peak forces) and time (Downie, Vemulpad and Bull, 2010), and the variables considered to best represent skill acquisition are; time to peak force, peak force and rate of force production (Triano *et al.*, 2011; Descarreaux *et al.,* 2005; Cohen *et al.*, 1995). Other indicators of a high level of skill appear to be related to neuro-motor integration and low trial-to-trial variability when performing the same manipulation consecutively (Descarreaux and Dugas, 2010). These measures, however, present technical challenges with quantitatively measuring manipulative forces and moments (Triano, 2001) as the total loads acting on the spine during a manipulation are the sum of many different individual loads acting on the spine (Triano, 2001).

As a result, Orthoneuro Technologies (2011), designed an instrument referred to as the Dynadjust, which is able to accurately measure the dynamics of the manipulation including the force of the thrust, the speed of the thrust, the line of drive (or lateral movements during the thrust) and the rotational movements during the thrust. Therefore this unit, which is easily portable, has software back up and allows for relatively quick feedback, can be utilised as either a training tool or a measurement device to assess improvement of the students' control of the dynamics of manipulation.

However, a caution needs to be added to the above, in that although this instrument is able to provide information on the force amplitude and direction of a simulated manipulation, it is only able to record the dynamics of the loads applied to it (Orthoneuro Technologies, 2011) and therefore does not take into account inertial loads from accelerating the body segment mass, and the internal muscular tension loads that may arise during the manipulation. Thus, any findings reached by assessing Dynadjust measurements may not be able to be correlated to the manipulation of a patient. It does however provide a constant "simulated patient" through which changes in student performance could be measured.

2.8 Conclusion

As a result of the above discussion, this research trained students in movements simulating manipulations using elastic tubing and tyre resistance. The aim was to determine if these training methods, as an adjunct to the standard manipulative training, assisted in the development of control of the dynamics of manipulation. An experimental cohort study design was used, using students as subjects. Therefore Chapter Three will present the materials and methods utilised in this study, with Chapter Four presenting the results and discussion of the study.

CHAPTER THREE

MATERIALS and METHODS

3.1 Introduction

This chapter deals with the process of data collection and the research methodology used to collect the data. The statistical analysis is also discussed in detail within this chapter. The data collected included all measurements taken with the Dynadjust.

3.2 Study Design

The research design used in this study was a quantitative, prospective, experimental cohort study. Based on this design the research was approved by the Institutional Research and Ethics Committee (IREC) at the Durban University of Technology (Appendix C), indicating that the research complied with the principle outlined in the Declarations of Belmont, Nuremburg and Helsinki (Johnson, 2005).

3.3 Advertising and Recruitment

3.3.1 Advertising

No advertising was required as students were recruited from the Durban University of Technology's Chiropractic program in the classroom setting after lecture time.

3.3.2 Recruitment

After the approval of this research study by the Institutional Research and Ethics Committee, the students were approached in the classroom setting by the researcher at a mutually agreed time by the researcher and lecturer concerned.

3.4 Sample

3.4.1 Sample Size, Allocation and Method

Students in the third and fourth year chiropractic classes were recruited and randomly assigned to either the tyre resistance or elastic tubing intervention groups or the standard manipulative training group. The opaque envelope method (Mouton and Babbie, 2006; Mouton 1996) was used and allocation was therefore concealed.

3.4.2 Sample Method and Group Allocation

All third and fourth year students were approached to participate in the study, once they had read and signed the Letter of Information and Informed Consent (Appendix A) the students selected a piece of paper from an opaque envelope, which indicated their group allocation. Thus each student had an equal chance of falling into each of the groups. Neither the student nor the researcher influenced the group allocation, thus providing the study with concealed allocation and appropriate randomisation (Mouton and Babbie, 2006).

3.4.3 Sample Characteristics

3.4.3.1 Inclusion Criteria

Students were included in the study if they:

- willingly volunteered to participate in the study and completed the Letter of Information and Informed Consent (Appendix A).
- were registered at the DUT for Chiropractic Principles and Practice III or Chiropractic Principles and Practice IV courses.

3.4.3.2 Exclusion criteria

Students were excluded from the study if they:

- were not willing to participate in the study and / or failed to complete the Letter of Information and Informed Consent (Appendix A).
- were injured or underwent surgery (to the upper extremity) which prohibited their participation in the study.
- were not registered for the required subjects listed in the inclusion criteria.
- failed to attend the Dynadjust training session and / or 80% of the required resistance training sessions.

3.5 Procedure for Data Collection

A meeting was scheduled with the lecturer of Chiropractic Principles and Practice course to arrange a mutually acceptable time during which to hold the training sessions.

Students were met in the classroom setting by the researcher and the Letter of Information and Informed Consent (Appendix A) was handed out at a mutually agreed time made available by the lecturer. All students interested in the study were required to read and sign the Letter of Information and Informed Consent before they were considered eligible for the study.

It was explicitly explained to the students that non willingness to participate in the study would not lead to any form of discrimination (from the researcher, lecturers or the program facilitators), and that those who did choose to participate would not have to sacrifice any lecture time in order to take part in the study.

All participating students received two hours of training on the Dynadjust device prior to collection of data to ensure familiarity and competence with the measurement tool.

Initial measurements were taken prior to the commencement of the training program. The training program consisted of twelve, thirty minute training sessions over six

weeks. Lack of interest and unwillingness from the students to participate in the study posed an issue of feasibility as the study required the students to sacrifice their time and commit to the nine week program consisting of six weeks of training and three weeks of measurement taking. In order to minimise a potential lack of interest, training sessions were held within normal university hours and measurement sessions were scheduled during a 'quiet' academic period for the third and fourth year students. A minimum of 80% attendance was set for participation and inclusion into the study.

Measurements by the Dynadjust device of the three groups were then taken mid- and post- training.

3.6 Interventions

3.6.1 Training Sessions

Training sessions for the intervention groups were held prior to, or after, Chiropractic Principles and Practice (CPP) practical lessons. Third and Fourth year students were trained separately as their CPP lessons were at different times. All three groups continued with the standard manipulative training curriculum offered at DUT. Each intervention group received two training sessions of thirty minutes per week over a six week period, making a total of twelve training sessions (Descarreaux *et al.,* 2006). There were two weeks in the program where public holidays and curriculum testing did not allow for the bi-weekly training sessions. During those two weeks, one hour training sessions were held instead. Mid- training measurements were taken after three weeks of training. During this week, the students did not receive training. The remaining three weeks of training continued after the mid- training measurements had been taken. Three hundred thrusts per hand were performed during each thirty minute training session, which is the equivalent of an average of 10 repetitions per hand, per minute. Each student was given a tracking sheet to keep record of the thrusts performed in each training session (Appendix D1 and D2). The number of thrusts / repetitions performed is in line with Kant (2006), who suggests in his study that to avoid repetitive strain injury, persons repeating manual tasks should not have more than 14-15 repetitions, per minute. His study required 10 sessions of 20-25 minutes intervention (Nussbaum *et al.*, 2001; Nussbaum and Johnson, 2002)

over a minimum of two weeks. A study by Shea *et al.*, (2000), showed that practicing motor skills over a number of days as opposed to daily practice was of significant benefit to students in the learning process. Hence the proposed study had two training sessions per week for six weeks, totaling 12 training sessions.

3.6.2 Tyre Resistance Group

Training sessions consisted of participants performing manual thrusts in a single direction (S-I) against the resistance of a tyre (Figure 3.1). As the tyre training did not require stabilisation, students were able to train alone. The participants were required to complete fifteen sets (twenty repetitions each) sets per hand. During training students were instructed to concentrate on aiming for a three centimeter depth of thrust. They were also instructed to focus on attempting to reproduce identical thrusts for each consecutive manipulation (i.e. mimic the same amount of force, at the same speed, without rotation or lateral deviation).

Figure 3.1 S-I Tyre Training Thrusts

3.6.3 Elastic Tubing Resistance Group

Training sessions consisted of participants performing manual thrusts in various directions against elastic tubing. The participants worked in pairs, with one participant acting as the anchor of the tube, and the other thrusting against its resistance. Once the required number of thrusts was completed the roles were reversed. Students were required to complete five sets (twenty repetitions each) of thrusts per hand, in three directions, viz. Superior to Inferior (S-I) (Figure 3.2); Posterior to Anterior (P-A) (Figure 3.3); and Lateral to Medial (L-M) (Figure 3.4). During training, students were instructed to concentrate on aiming for a three centimeter depth of thrust. They were also instructed to focus on attempting to reproduce identical thrusts for each consecutive manipulation (i.e. mimic the same amount of force, at the same speed, without rotation or lateral deviation). The ExerBand Company (PrePak Products) was informed of the use of their product in the research (Appendix B).

Figure 3.2
S-I Elastic Tubing Training Thrusts

Figure 3.3
P-A Elastic Tubing Training Thrusts

Figure 3.4
L-M Elastic Tubing Training Thrusts

3.7 Measurement Tool

3.7.1 Overview of Design and Capabilities of the Dynadjust

Orthoneuro Technologies (2011) designed an instrument referred to as the Dynadjust. This instrument has a cylindrical design that enables one end to slide into the other. This motion is resisted by a selection of interchangeable calibrated springs, which provide graded amounts of internal resistance. The device is used by pushing down on one end of the Dynadjust against the resistance of the spring, to simulate pre-manipulative tension, or removal of articular slack. The Dynadjust vibrates and illuminates a green light to signal that pre-manipulative tension (Q2T) has been achieved, a brief pause is required at this point, after which a thrust can be delivered into the device against the resistance of the spring. With the use of advanced electronics, the Dynadjust is able to accurately measure some of the individual dynamics of the manipulation including force, speed (time), line of drive and amount of rotation (Orthoneuro Technologies, 2011). The Dynajust is able to do this for several different manipulative simulations. To this end, the Dynadjust has 12 preset parameters, each having two specific settings; namely: Cue to Thrust distance (Q2T), and Depth of Thrust distance (DOT) which have preset margins for error. These margins for error allow for the assessment of the students accuracy when applying a specific simulated manipulation into the Dynadjust (Orthoneuro Technologies, 2011). Furthermore, the Dynadjust measures the length of time that pre-manipulative tension is held (RO). This collective feedback can be used to monitor the development of control of the individual dynamics of manipulation, as well as the control achieved between the dynamics of manipulation over time. The Dynadjust stores 18 thrusts per measurement session; providing 6 “warm up thrusts” followed by twelve recorded thrusts.

According to Triano (1998), the Dynadjust is reliable and valid, limited only by the parameters which it has been formulated to measure. Extensive collaboration and consideration of many investigators and test subjects have afforded the preset parameter settings (Triano, 1998), which represent values that have been determined to be useful in training programs for various different spinal segments and manipulation scenarios. For the purpose of this study, the Dynadjust was used a as a measurement tool, and the preset parameter chosen, provided a construct

within which to train students using the resistance methods. The development of control of the dynamics of manipulation could therefore be assessed using the Dynadjust for the specific manipulation for which the students trained.

Figure 3.5 Illustration of Design and Capabilities of the Dynadjust

3.7.2 Dynadjust Set Up

- Preset parameter number four was chosen which pertained to the thoracic vertebral manipulation. This parameter has a desired Q2T distance of three centimeters with a five millimeter margin for error and a desired DOT distance of three centimeter with a ten millimeter margin for error.
- Each Dynadjust comes with three different colour springs representing graded stiffness. The black spring is the stiffest, red is intermediate, and yellow is the least stiff. As this research aimed to assess the change in control over the dynamics of manipulation, the yellow spring was selected. This is because control of the dynamics of manipulation was considered to be more challenging against a low stiffness. The yellow spring was therefore seen to provide a more sensitive resistance against which to measure of the development of control.
- Recoil time recording was selected so that the thrust was timed from the start to the bottom of the thrust and back to the starting point.
- Tactile and visual stimuli were selected as the signals to indicate when Cue to Thrust (Q2T) distance was within the margins for error.
- The preset parameter used and the constant resistance provided by the selected spring within the device provided a practically constant construct (unlike a variable patient context). This allowed for students to be trained

using elastic tubing resistance and tyre resistance within a constant construct for particular simulated manipulations. Additionally, the device was able to measure the dynamics of manipulation applied to it, within the preset construct. This allowed for the assessment of the development of control of the dynamics of manipulation. Therefore this parameter was use for the measurement of the dynamics of manipulation in the three tested directions (further described in Section 3.7.3).

3.7.3 Measurement Procedure

- Each participant was given an alphanumeric code according to which group they fell into, either Tyre Group (TG) 1-18, Elastic Tubing Group (ETG) 1-18, or Standard Manipulative Training Group (SMTG) 1-17.
- Once participants had been divided into their respective groups, they received a two hour Dynadjust training session where they were given an overview of the capabilities and usage of the device. During this training session each participant was given an opportunity to practice delivering thrusts into the Dynadjust.
- Participants were instructed to push down on the device until they saw a green light appear and felt a vibration, this represented the Q2T distance for the preset parameter chosen. At this point they were instructed to pause, and then deliver a thrust into the device, aiming for three centimeters of depth. Participants were instructed to concentrate on attempting to deliver the same manipulation into the device at each consecutive manipulation (i.e. mimic the same amount of force, at the same speed, without rotation or lateral deviation).
- Three simple manipulative techniques were selected, in accordance with the directions of resistance training for simulation into the Dynadjust. This allowed for a comparison between the TG, ETG and the SMRG. The simulated manipulations chosen included:

1. Superior to Inferior (S-I): Students were instructed to place the Dynadjust vertically on a chiropractic manipulation bed and thrust vertically downward without rotation (Figure 3.6).

Figure 3.6 Illustration of the measurement of the S-I manipulation

2. Posterior to Anterior (P-A): Students were instructed to stand squarely facing a wall holding the Dynadjust against it and thrust horizontally into the wall without rotation (Figure 3.7).

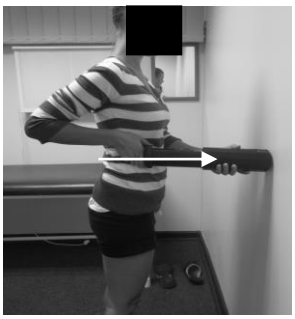

Figure 3.7 Illustration of the Measurement of the P-A manipulation

3. Lateral to Medial (L-M): Students were instructed to take a forward lunge position and stabilise the Dynadjust against the thigh of their forward leg and impart a thrust toward it without rotation (Figure 3.8).

Figure 3.8 Illustration of the Measurement of the L-M Manipulation

- The researcher explained and demonstrated to the students how to perform the manipulative simulations described above using the Dynadjust during the Dynadjust training session and at each subsequent measurement session.
- During each measurement session, each student simulated four manipulations in each direction (S-I; P-A; L-M) into the Dynadjust. The dynamics of manipulation were measured and recorded for each of these simulations by the Dynadjust.

3.7.4 Measurement Summary

- Once measurements had been taken the data was downloaded from the Dynadjust onto data sheets via the Orthoneuro Technologies website (Appendix E). The data for each simulated manipulation (S-I; P-A; L-M) for each student was then summarised onto excel spreadsheets in the following manner:
    - A range value (Esterhuizen, 2013; Woodall and Montgomery, 1999) for each dynamic (representing the trial-to-trial variability) was calculated from the four simulated manipulations (per S-I; P-A; L-M) for each student.
    - The mean / median range of each dynamic was selected from each intervention group (TG; ETG; SMTG) in order to determine the range value for each dynamic that best represented the groups' trial to trial variability (per S-I; P-A; L-M).
    - This procedure was followed at each measurement time point.

    - An average value (Esterhuizen, 2013) for each dynamic (representing the average magnitude of each dynamic) was calculated from the four manipulations (per S-I; P-A; L-M) for each student.
    - The mean / median average of each dynamic was selected from each intervention group (TG; ETG; SMTG) in order to determine the mean / median average value for each dynamic that best represented the groups' magnitude (per S-I; P-A; L-M).
    - This procedure was followed at each measurement time point.

Measurements were taken on the Dynadjust pre-, mid- and post- the six week the training program. The mid-training measurements were taken for the sole purpose of ensuring familiarity and competency with the measurement tool.

Table 3.1 Timetable for measurements and training sessions

	Third Year Students	**Fourth Year Students**
Week One: Pre-Training Measurements with Dynadjust	Monday 23rd July: after lecture	Thursday 19th July: after lecture
Week Two: Resistance Training	Wednesday 25th July: 12.15pm - 12.45pm	Monday 23rd July: 9.30am -10am
	Friday 27th July: 12.30pm - 13.00pm	Thursday 26th July: 11.45am - 12.15pm
Week Three: Resistance Training	Monday 30th July: 3.45pm - 4.15pm	Monday 30th July: 9.30am -10am
	Wednesday 1st August: 12.15pm -12.45pm	Thursday 2nd August: 11.45am - 12.15pm
Week Four: Resistance Training	Monday 6th August: 3.45pm - 4.15pm	Monday 6th August: 9.30am -10.30am
	Wednesday 8th August: 12.15pm -12.45pm	
Week Five: Mid-Training Measurements with Dynadjust	Monday 13th August: after lecture	Thursday 14th August: after lecture
Week Six: Resistance Training	Monday 20th August: 3.45pm - 4.15pm	Monday 20th August: 9.30am -10am
	Wednesday 22nd August: 12.15pm -12.45pm	Thursday 23rd August: 11.45am - 12.15pm
Week Seven: Resistance Training	Monday 27th August: 3.45pm - 4.15pm	Monday 27th August: 9.30am -10am
	Wednesday 29th August: 12.15pm -12.45pm	Thursday 30th August: 11.45am - 12.15pm
Week Eight: Resistance Training	Monday 3rd September: 3.45pm - 4.15pm	Monday 3rd September: 9.30am -10am
	Wednesday 5th September: 12.15pm -12.45pm	
Week Nine: Post-Training Measurements with Dynadjust	Monday 10th September: after lecture	Thursday 6th September: after lecture

3.8 Statistical Analysis of Data

The study aimed to assess the change in the level of control of the dynamics of manipulation (viz. force, time, line of drive and rotation) between the different intervention groups within the specific manipulations in which they were trained. In order to fully analyse the data recorded and provided by the Dynadjust, the level of control over the preset settings (Q2T and DOT), as well as RO (the amount of time for which Q2T was held) were also assessed. *The dynamics were assessed using ranges (Esterhuizen, 2013; Woodall and Montgomery, 1999) (see measurement summary in Section 3.7.4.), a decrease in the mean / median range of any of the dynamics from pre- to post- training within an intervention group for a particular manipulation (S-I or P-A or L-M); indicated a decrease in trial-to-trial variability of that specific dynamic for that specific manipulation, and thus an increase in control. In contrast, an increase in the mean / median range of any of the dynamics from pre- to post- training within an intervention group for a particular manipulation (S-I or P-A or L-M); indicated an increase in trial-to-trial variability of that specific dynamic for that specific manipulation, and thus a decrease in control. A constant mean / median range of any of the dynamics from pre- to post- training within an intervention group for a particular manipulation (S-I or P-A or L-M); indicated no trial-to-trial variability of that specific dynamic for that specific manipulation, and thus maintained control.*

SPSS version 20 (IBM SPSS Inc.) was used to analyse the data. A p value <0.05 was considered as statistically significant.

Parametric statistics were the preferred method for normally distributed data, however significantly non-normally distributed data would preferably be summarised and analysed using medians and non parametric tests to test the objectives. Data on each of the three manipulations were treated separately. In order to address the research objectives, the range measurements within each treatment group were tested for changes from pre- to post- training using Friedman tests.

The change in range from pre- to post- training (per dynamic) was then calculated and compared between the:

1. Elastic tubing group and standard manipulative training group,
2. Tyre resistance group and standard manipulative training group, and
3. Elastic tubing group and tyre group

using Mann-Whitney tests to determine whether the degree of change in range of the individual dynamics of manipulation that occurred within each group was statistically significant compared to the degree of change in range of the dynamics of manipulation in the other groups. To account for the effect of an increase in type 1 error due to multiple comparisons being made, the alpha level for significance was adjusted using the Bonferroni method to 0.0167 (i.e. 0.05 / 3) (Esterhuizen, 2013).

To determine the control of the manner in which the dynamics of manipulation were combined, the change in outcomes (ranges and averages as described in Section 3.7.4.) of the dynamics of manipulation from pre- to post- training were calculated. The Spearman's correlation coefficients were then calculated for each correlation that existed, between the changes in the dynamics (ranges and averages) over time within each respective group.

CHAPTER FOUR

RESULTS AND DISCUSSION OF RESULTS

4.1 Introduction

This chapter deals with the analysis and discussion of the results obtained in the study. The discussion includes the types of data used, abbreviations used within the chapter and the course of participation of the students throughout the research. The data collected was analysed according to the three groups as outlined in Chapter Three (Section 3.4.1), and the three simulated manipulations (as described in Chapter Three, Section 3.7.3), were analysed separately. A review after the results of the manipulations compared the three groups in terms of individual dynamics and the correlations between the dynamics. The chapter is concluded with an overview of performance of each group within the respective manipulations.

The chapter is set up to include both the results and the discussion of the results. This method of presentation was chosen due to the complex nature of the discussion surrounding the tables presented, which requires ease of reference to the tables within the appropriate sections. Thus, this chapter has several subsections which are outlined as follows (each subsection presenting results and discussion for each of three groups):

Section 4.2 : Data
Section 4.3 : Abbreviations and Definitions for Chapter Four
Section 4.4 : Sample Recruitment and Randomisation
Section 4.5 : The Objectives revisited and the Context of “Control”
Section 4.6 : Results
Section 4.6.1 : Superior to Inferior (S-I) Manipulation
4.6.1.1 : Analysis and Discussion of the Individual Dynamics
4.6.1.2 : Correlations
Section 4.6.2 : Posterior to Anterior (P-A) Manipulation

4.6.2.1 : Analysis and Discussion of the Individual Dynamics

4.6.2.2 : Correlations

Section 4.6.3 : Lateral to Medial (L-M) Manipulation

4.6.3.1 : Analysis and Discussion of the Individual Dynamics

4.6.3.2 : Correlations

Section 4.6.4 : Comparison between the groups and manipulations: discussion

Section 4.7 : Critical analysis of the outcomes of the study

4.2 Data

4.2.1 Primary Data

The primary data used in this study was obtained by taking measurements from the research participants on the Dynadjust as described in Chapter Three, Section 3.7.3. The data was then downloaded from the Dynadjust onto the Orthoneuro Technologies website where it was converted into individual data sheets per student (Appendix E). The data sheets were then summarised onto an excel spreadsheet (Section 3.7.4) and statistically analysed.

4.2.2 Secondary Data

The secondary data used in this study was obtained from a variety of sources, including; the internet, books, journal articles, dissertations, guidelines, and email correspondence with a statistician and Orthoneuro Technologies and its affiliates.

4.3 Abbreviations and Definitions for Chapter Four

av / ave: Average or "mean". The result obtained by adding all the scores within a distribution and dividing the total by the number of scores (Gravetter and Wallnau, 2009; Hinton 2004; Hinton 1995).

SMTG: Standard Manipulative Training Group (received standard manipulative training offered at DUT).

DOT: Depth of Thrust (measured in mm) is a preset parameter in the Dynadjust that represents the distance from the Cue to Thrust (Q2T), to the end of the thrust. For the preset parameter chosen for this research, the DOT was 30mm and the margin for error (MFE) was 10mm (Orthoneuro Technologies, 2011). "DOT shallow" indicated the DOT did not exceed a depth of 20mm. "DOT deep" indicated the DOT exceeded 40mm. (Read in conjunction with Q2T ad MFE).

Dynamics (of manipulation): A branch of mechanics that is concerned with the loads and motions of interacting bodies (Bergmann and Peterson, 2002). For the purpose of this dissertation "the dynamics of manipulation" referred to: the time taken to perform a manipulation (speed), the force produced when performing a manipulation, line of drive (or the vector in which the thrust of the manipulation was directed), the degrees of rotation applied when performing the manipulation, the relative depth of the manipulation, the removal of articular slack, and the time for which articular slack is held. For brevity, "dynamics of manipulation" may be referred to as "dynamics" within the body of the text.

ETG: Elastic Tubing Group (received elastic tubing resistance training).

F: Force (measured in Newtons) (Cutnell *et al.,* 2013), is a push or a pull on an object that results from the objects interaction with another object (Cutnell *et al.,* 2013). In terms of the manipulation, the force refers to the thrust applied to the joint (Bergman and Peterson, 2011).

L-M: Lateral to Medial manipulation (may be denoted as L-M or L-M manipulation) (described in Section 3.7.3).

LOD: Line of Drive (measured in degrees) refers to the lateral deviation of the vector of the thrust (Orthoneuro Technologies, 2011).

Median change of the range: The most typical representation of the change of range of a dynamic for a group.

MFE: Margin for Error**.** This applies to Q2T and DOT and is a specific pre-set parameter on the Dynadjust. For the specific manipulation chosen for this research, the Margin for Error allowed for 5mm excessive or inadequate depth for Q2T, and 10mm excessive or inadequate depth as a for DOT (Orthoneuro Technologies, 2011) (Read in conjunction with DOT and Q2T).

N: Refers to the sample size (Hinton, 2004).

P-A: Posterior to Anterior manipulation (may be denoted as P-A or P-A manipulation) (described in Section 3.7.3).

***p* value:** Indicates the statistical significance between two or more measures based on computed calculations (Campbell and Machin, 1999; Hinton, 2004; Hinton, 1995).

Q2T: Cue to Thrust (measured in mm) is a pre-set parameter in the Dynadjust that mimics the designated tissue pull / skin slack setting for a particular manipulation. For the preset parameter chosen for this research, the Q2T depth was 30mm with a MFE of 5mm (Orthoneuro Technologies, 2011). “Q2T early” indicated the manipulation was initiated before the preset parameter depth was reached. “Q2T late” indicated that the manipulation was initiated after the preset parameter depth had been bypassed. (Read in conjunction with MFE).

Range: Represents the distance between the largest score and the smallest score within a distribution (Gravetter and Wallnau, 2009; Hinton, 1995). For the purpose of this research range was used to determine trial-to-trial variability (Esterhuizen, 2013; Woodall and Montgomery, 1999) between consecutive manipulations within S-I; P-A; L-M. The change in range thus represents “control”.

RO: Time for which the Q2T was held (Orthoneuro Technologies, 2011).

Rotation / Rot: Rotational movements during the thrust (measured in degrees) (Orthoneuro Technologies, 2011).

S-I: Superior to Inferior manipulation (may be denoted as S-M or S-M

manipulation) (described in Section 3.7.3).

Sig.: The significance related to the statistical calculation that show the results of the calculation to be better than chance. Sig. is represented by the *p* value in all the tables (Campbell and Machin, 1999; Hinton, 2004).

Speed: Time taken to perform the specific manipulation (Not velocity).

T: Time (measured in ms) represents the speed of the manipulation from Q2T, to DOT and back (recoil) (Orthoneuro Technologies, 2011).

TG: Tyre Group (received tyre resistance training)

>: Greater than.

<: Less than.

4.4 Sample Recruitment and Randomisation

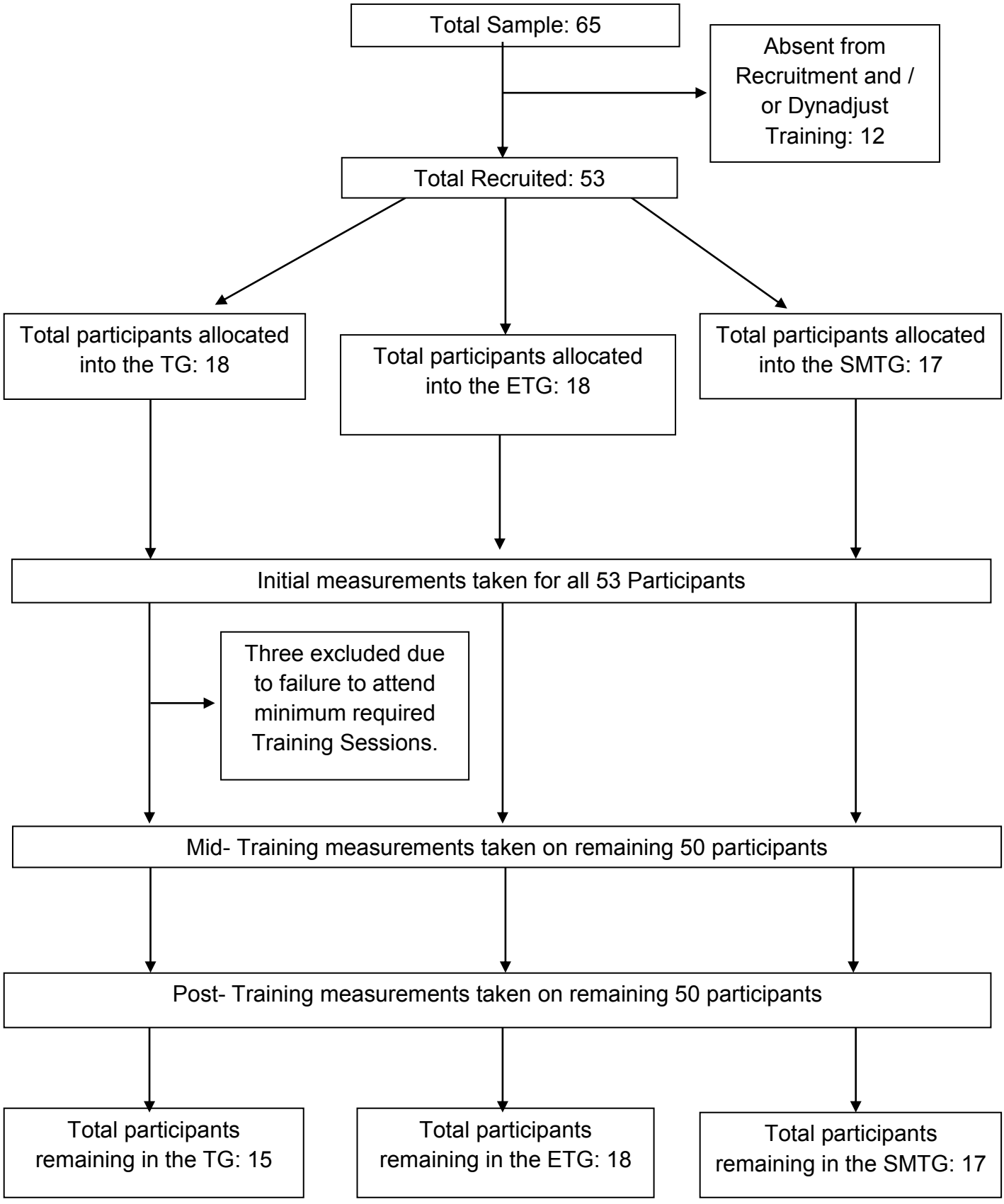

Figure 4.1 Consort Diagram (as per Moher, Schultz and Altman, 2001)

From the consort diagram (Figure 4.1), it can be seen that the majority of the students (54 / 63=86%) participated in the study at the outset. Three students did not meet the minimum criteria for study completion and were excluded from the research after the initial measurements were taken (3 / 54=6%). It was noted that all three excluded students were from the TG, leaving the TG with the least number of participants. This group still however met the minimum requirement of 12 participants per group as set out by Esterhuizen (2012) at the outset of the study.

Notwithstanding the randomisation process, it was noted that the three groups were not significantly different in terms of age, gender or level of prior training.

It was anticipated that there would be no bias related to the numbers of participants within the three groups, nevertheless statistical analysis controlled for the numbers of participants and any "skewing" effect that this may have had on the results (Esterhuizen, 2012).

4.5. The Objectives Revisited and the Context of "Control"

The objectives of this study were:

Objective One:

> To determine whether elastic tubing resistance training in multiple planes as an adjunct to standard manipulative training at Durban University of Technology (DUT), versus standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation

Objective Two:

> To determine whether tyre resistance training in a single plane, as an adjunct to standard manipulative training at DUT, versus standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation.

Objective Three:

> To determine whether elastic tubing resistance training in multiple planes as an adjunct to standard manipulative training at DUT, versus tyre resistance

training in a single plane, as an adjunct to standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation.

It is important to note that the reference to “control” within the context of this study had two distinct concepts. These are:

a. The control of the individual dynamics of a manipulation (e.g. F, T, LOD, Rotation, MFE Q2T and DOT). In this context, control was defined as a low level of trial-to-trial variability (Cohen *et al.*, 1995), and therefore a narrow range (Woodall and Montgomery, 1999) for each dynamic for each participating student (viz. low numerical value between the highest and lowest measurement values attributed to a particular dynamic). This range was derived by utilising the highest and the lowest scores achieved for each of the dynamics for each student for each manipulation (viz. S-I, P-A, L-M) at each time point. From these ranges, the median range for each dynamic was identified from within each group pre-, mid-, and post-training. Thus, the median (typical) range for each group (e.g. TG, ETG or SMTG) for a specific dynamic, in each manipulation could be compared from pre- to post-training. The interpretation of the change of the median range of a dynamic was as follows:

    1. A widening / increasing median range of the dynamics (or increased trial-to-trial variability) from pre- to post-training for a group (and by implication the students within the group) indicated a decreased ability of the group to repeatedly reproduce results of low variability, and thus decreased control.
    2. A narrowing / decreasing median range of the dynamics (or decreased trial-to-trial variability) from pre- to post-training for a group (and by implication the students within the group) indicated increased ability of the group to repeatedly produce results of low variability, and thus increased control.
    3. A static median range (or no trial-to-trial variability) from pre- to post-training for a group (and by implication the students within the group) indicated that control was maintained (did not increase or decrease).

Figure 4.2 **The interpretation of a constant median range of a dynamic over time**

The median range of a particular dynamic at points 1, 2 and 3 did not change. Thus the comparison over time did not show a statistical significance. However, the fact that the median range of the dynamic stayed constant over the three measurement periods indicates a constant level of variability[2] of the dynamic and thus maintained control[1].

In order to compare the change in the range of a particular dynamic from pre- to post-training *between* the groups, the change in the range for each dynamic for each student within each group was calculated.

Figure 4.3 **Change in the range of the dynamics and their interpretation: increasing or decreasing**

Change in the range of the dynamic = $z - x$.

If $z > x$ it will result in a positive change in the range of the dynamic, indicating an increase in the range over time. This shows an increase in variability of the dynamic (decreased control).

If $z < x$ it will result in a negative change in the range of the dynamic, indicating a decrease in the range over time. This shows a decrease in variability of the dynamic (increased control).

The median change in the range for each dynamic within each group was then identified as the change in the range that best represented the groups change.

These median changes in the ranges of each dynamic were then compared between the groups to determine if any significant difference existed between the groups with respect to the degree of change related to that particular dynamic.

For these analyses to occur, it should be noted that the Dynadjust provided a standard parameter within which to simulate the manipulations and was able to measure the dynamics of manipulation that were imparted into it when a manipulation was simulated.

b. The second element related to control is that of the correlations between the changes of the averages and the changes of the ranges of the various dynamics of manipulation. The correlations reflect how the changes in averages changed in relation to the changes in ranges, as well as whether the degree to which the averages and ranges of the dynamics changed, in relation to one another, was significant (Rodgers and Nicewander, 1988). In order for control over these inter-relationships to be attained (Higgins, 1991; Kaufman, Wiegand and Tunick, 1987); congruency of the correlations between the changes of the ranges and the changes of the averages that were statistically significant was required (Rodgers and Nicewander, 1988). This indicated that students had been able to refine the combination of the different dynamics to attain internal congruency between them. Therefore, if the students within one group over time were repeatedly able to combine the various dynamics in the same manner, they were able to achieve internal congruency of the dynamics. If over time the students within one group formed more than one combination of the various dynamics, internal incongruence of the dynamics was demonstrated.

As a result of the above discussion on control, the intervention groups (viz. TG, ETG and SMTG), were required to demonstrate a decreasing or constant median range of the individual dynamics of manipulation, as well as congruent relationships between the changes of the dynamics, in order to have effectively mastered overall control of the dynamics of manipulation.

4.6 Results

4.6.1 Superior to Inferior (S-I) Manipulation

4.6.1.1 Analysis and Discussion of the Individual Dynamics

4.6.1.1.1 Analysis and discussion of the individual dynamics for the S-I manipulation within each intervention group

Table 4.1 represents a comparison of the median ranges of the dynamics for the S-I manipulation pre-, mid-, and post-training, within each intervention group. Median range values were used to describe the most typical range values for the group for the dynamics at each time point as the data was skewed (non-normally distributed), making median analysis a better indication of the most typical values at each time point than mean analysis (Woodall and Montgomery, 1999; Esterhuizen, 2013).

Table 4.1 Comparison of the median ranges of the dynamics, within the intervention groups, for the S-I manipulation, over the training period.

			Time			*p* value
			Pre-training	Mid-training	Post-training	
			Median	Median	Median	
Intervention group	Tyre group	Range MFE Q2T	0	0	0	0.368
		Range MFE DOT	12	9	16	0.203
		Range T	436	458	387	0.549
		Range RO	399	351	206	0.420
		Range LOD (º)	1	1	1	0.278
		Range Rotation (º)	1	1	1	0.629
		Range F (N)	149	156	70	0.627
	Elastic tubing group	Range MFE Q2T	0	0	0	0.368
		Range MFE DOT	15	12	17	0.568
		Range T	234	301	271	0.513
		Range RO	183	256	213	0.801
		Range LOD (º)	1	0	1	0.214
		Range Rotation (º)	1	1	1	0.545
		Range F (N)	48	109	133	0.906
	Standard manipulative training group	Range MFE Q2T	0	0	0	0.135
		Range MFE DOT	17	17	15	0.824
		Range T	193	302	287	0.465
		Range RO	223	290	351	0.465
		Range LOD (º)	1	1	0	0.617
		Range Rotation (º)	1	1	1	0.273
		Range F (N)	123	150	219	0.327

4.6.1.1.2 Discussion in terms of the median ranges of the dynamics achieved over time within each group for the S-I manipulation

In terms of the median ranges of the dynamics, there were no statistically significant changes within any of the groups, from pre- to post-training for the S-I manipulation (*p* value column in Table 4.1). Thus, neither of the intervention groups, nor the SMTG, received training that was efficient in facilitating students in developing improved control of the individual dynamics for the S-I manipulation (this would be indicated by a statistically significant decrease in the median ranges of the dynamics over time). It is also apparent that neither the tyre resistance, nor the elastic tubing interventions were of any added benefit (denoted by statistical significance) to the standard manipulative training in terms of the development of improved control of the dynamics of manipulation for the S-I manipulation. Conversely, it is important to note that neither of the interventions adversely affected the standard manipulative training (this would be indicated by a statistically significant increase in the median ranges of the dynamics over time).

Although not denoted as statistically significant, a constant median range of a dynamic was seen to constitute maintained control of the dynamic from pre- to post-training within the group, as the student was able to reproduce a constant level of variability (Figure 4.2).

Thus, it may be stated that the students at best maintained their control of the dynamics of manipulation over time (as compared to the pre-training measures). Internally, it is however noted that a greater degree of control was maintained for some dynamics of manipulation (MFE Q2T showed a constant level of variability); while other dynamics of manipulation were more variable (e.g. F in the tyre group).

One limitation with regard to the generation of statistical significance may have been the duration of the training intervention period (Kraemer, Duncan and Volek, 1998). It is suggested that future studies consider an increased length of time for the intervention groups in order to increase the likelihood of any significant change, particularly as this study may have been limited in measuring the effects of the interventions on muscle physiology, which may have required a longer period of

training (Kraemer, Duncan and Volek, 1998; Robergs and Roberts, 1996). Another factor that needs to be considered in this context is the small sample size this study was limited to (viz. the maximum number of participants available for possible inclusion in this study was 65 students). An increased sample size would have aided in excluding outlier readings and thus would have been able to more accurately reflect the student population group. Furthermore, the reflection of a larger student population group may have enabled greater significance from the data.

As none of the changes in the median ranges of the dynamics were noted as being significant within each group, the study can only comment on the trends of control observed. In terms of the trends of control of the individual dynamics (with regard to changes of the median ranges), the following trends were seen within the groups for the S-I manipulation:

The TG showed (as explained in Figures 4.2 and 4.3):

- Decreased control of MFE DOT.
- Increased control of T, RO, and F.
- A constant level of control of MFE Q2T, LOD and Rot.

The ETG showed (as explained in Figures 4.2 and 4.3):

- Decreased control of MFE DOT, T, RO and F.
- A constant level of control of MFE Q2T, LOD and Rot.

The SMTG showed (as explained in Figures 4.2 and 4.3):

- Decreased control of T, RO and F.
- Increased control of MFE DOT and LOD.
- A constant level of control for MFE Q2T and Rot.

All groups showed constant level of variability for MFE Q2T and Rot for the S-I manipulation, indicating that all of the participants maintained the same level of control with regard to the application of simulated tissue slack (MFE Q2T) as well as rotational deviation when applying the S-I manipulation technique from pre- to post-training. The constant level of variability for MFE Q2T may be directly related to the instructions issued to the students. The instructions directed the students to pause at

the auditory and visual indication given by the Dynadjust when Q2T was reached (see Section 3.7.3). A level of maintained control of MFE Q2T is therefore afforded both by the design of the Dynadjust and the instructions given to the students, and was thus expected. For this reason the level of control of MFE Q2T has limited application in the analysis of the student's control of the individual dynamics of manipulation. The constant level of variability for Rot from pre- to post-training may be directly related to the fact that the S-I manipulation was the least complex manipulation (Norkin and Levangie, 1992) to be simulated (out of the three manipulations) and was the most stable (Section 3.7.3), thus the technique lent itself to a constant level of variability.

Although not statistically significant, the trends seem to suggest that the TG improved control over the greatest number of individual dynamics, followed by the SMTG and lastly the ETG. The TG also appears to have decreased the level of control over the least number of individual dynamics followed by the SMTG and then the ETG.

In terms of the trends of control seen within the groups, control of the following dynamics of manipulation was noted to have either collectively increased or collectively decreased: T, RO and F. With respect to MFE DOT and LOD, no pattern could be identified. The collective results presented here suggest that for the S-I manipulation, the change in range of the dynamics of T, RO and F may show a correlation when the relationships *between* them are analysed this contrasts with the dynamics of LOD and MFE DOT. This will however only be assessed in Section 4.6.1.2, when the correlations between the dynamics are discussed.

4.6.1.1.3 The inter-group statistical significance of the median change in the ranges of the dynamics over time for the S-I manipulation

Table 4.2 represents the inter-group statistical significance generated by the comparisons of the median changes in the ranges of the dynamics of manipulation, over the training period (viz. pre- to post-training), for the S-I manipulation between the groups. According to Esterhuizen (2013), a negative median change in range value represents that the range of the dynamic decreased over time within the group thus indicating improved control of the dynamic in question. Conversely, a positive median change in range value indicates that the range of the dynamic increased over time within the group, representing a regression of the amount of control of the dynamic in question (as explained in Section 4.5 a). The larger the unit value, the greater the change (improvement / regression) of control of the dynamic concerned.

It should be noted that the data was assessed using medians in an attempt to control for the presence of outlier readings (non-normally distributed data) (Esterhuizen, 2013). The median range of each dynamic of manipulation was used for the comparison of the change in the ranges of the individual dynamics of manipulation from pre- to post-training (Table 4.1). Similarly, the median change in the range of the dynamics of manipulation was used for comparison of the change in the range of the dynamics between the groups (Table 4.2). This resulted in the possibility that the median range utilised for the calculation of the first analysis was not necessarily associated with the median range utilised in the calculation of the second analysis. It is therefore possible that the trends of change of the median ranges of the dynamics of manipulation reflected in Table 4.1 may conflict with the results attained in Table 4.2. (e.g. median range of T from pre- to post-training in the SMTG tended to increase in Table 4.1, indicating regression of control; whereas the negative median change in range value for T in Table 4.2 indicated improved control of T).

Table 4.2 The inter-group statistical significance of the median change in the ranges of the dynamics over time for the S-I manipulation

	Intervention group			*p* value elastic versus control	*p* value tyre versus control	*p* value elastic versus tyre
	Tyre group	Elastic tubing group	Standard manipulative training group			
	Median	Median	Median			
Change range MFE Q2T	0.0	0.0	0.0	0.782	0.766	0.580
Change range MFE DOT	3.0	1.0	-4.0	0.369	0.478	0.873
Change range T	-54.0	7.5	-31.0	0.546	0.882	0.361
Change range RO	-24.0	35.5	-29.0	0.684	0.370	0.190
Change range LOD	0.5	0.0	0.0	0.335	0.331	0.845
Change range Rot	0.0	0.0	0.0	0.546	0.502	0.929
Change range F	-35.0	11.5	37.0	0.525	0.049	0.057

4.6.1.1.4 Discussion in terms of the inter-group statistical significance of median changes of the ranges of the dynamics over time, for the S-I manipulation.

The degree of the change in control (ranges) of the dynamics was not noted as being significantly different between the groups except for the degree of the change in control of F. The results revealed that in terms of median changes of the ranges of the dynamics, the inter-group statistical significance occurred between the TG and the SMTG (p=0.049) for the F dynamic. This indicates that there was a significant difference to which the TG and the SMTG were able to control F in the S-I manipulation. The negative value associated with the median change of the range of F in the TG compared to the positive value associated with the median change of range F in the SMTG allows for the deduction that the TG improved control of F to a significantly greater degree as compared to the SMTG which tended toward a decrease in the control of F (Esterhuizen, 2013).

This is in keeping with the trends of control obtained in Section 4.6.1.1.1 (Table 4.1). Thus, it can be concluded that the TG was able to attain control of F for the S-I manipulation to a statistically greater extent than the SMTG (i.e. the tyre training better enabled the students to control the dynamic of F than the standard manipulative training).

Furthermore, the near significant difference (p=0.057) between the SMTG and the ETG (with the ETG developing a decrease in control of F, as explained in Section 4.6.1.1.2), indicates that there may have been a statistically significant difference in terms of the median change of range F between these groups if there had been greater numbers of participants per group. It also indicates that the level of control of F obtained by the ETG was at a point between the SMTG and the TG, thus allowing for the lack of significance from either of these groups.

The control of F thus seemed to be most improved in the TG, with the ETG and the SMTG both tending toward a decrease in the ability to control of F for the S-I manipulation.

Firm conclusions regarding the relative improvements or regressions of control could not be drawn from the other dynamics as there were no significant differences in the median changes of the ranges of the other dynamics between the groups. Therefore it is suggested that increased participants, increased training time (i.e. over a longer period) (Kraemer, Duncan and Volek, 1998) and increased numbers of training repetitions (Robergs and Roberts, 1996) should be considered in future studies in order to increase the likelihood of obtaining statistical significance between the groups and to confirm the preliminary findings of this study. Furthermore, strategies to ensure student participation throughout the duration of the study in order to prevent exclusion need to be considered.

4.6.1.2 Correlations

4.6.1.2.1 General explanation regarding correlation analysis

From Table 4.1 it could be stated that the training had no significant effect on the median ranges of the individual dynamics of manipulation, from pre- to post-training, within any one group. This may be an effect of a small sample size and a short training period for the intervention groups. It is suggested that larger sample sizes and longer training programs for the intervention groups in future studies would need to be considered in order to verify the results presented here.

Notwithstanding this limitation, the inability for the study to attain significance of the change of the median ranges of the dynamics of manipulation, within the groups, form pre- to post-training, makes the assumption that each of these dynamics is an individual and independent factor, when in reality they are inter-dependent. Therefore in order to effectively analyse the congruency between the dynamics, it is necessary to look at the correlations between the changes of the dynamics with one another (utilising the changes in the averages and ranges for each dynamic). These correlations represent the statistically significant relationships between the changes in the ranges and the changes in the averages of the dynamics, from pre- to post-training (Rodgers and Nicewander, 1988).

In order for congruency[1] to exist in the correlations between the:
- changes of the averages and the changes of the averages
- changes of the averages and the changes of the ranges
- changes of the ranges and the changes of the ranges

of the dynamics of manipulation (from pre- to post-training); the analysis would need to reflect that increasing / decreasing ranges of particular dynamics are consistently, strongly and significantly[2] correlated[3] with increasing / decreasing averages or

[1] Congruence implies that the student has successfully mastered the relationship between the changes within the dynamics and could be expected to be able to consistently deliver the particular manipulative procedure (Higgins, 1991).
[2] A *p*-value of < 0.05 was considered as statistically significant.
[3] A correlation coefficient > 0.5, or < -0.5, was considered to be statistically significant (Esterhuizen, 2013). The closer the correlation coefficient approached 1 or -1, the stronger the correlation between the two variables (Esterhuizen, 2013).

ranges of the dynamics they are related to within the respective manipulations (Rodgers and Nicewander, 1988).

Thus in order to assess for internal congruency between the dynamics of a particular manipulation for each intervention group the following procedure was followed:

1. The significant and strong correlations between the changes in ranges and changes in averages of the dynamics were identified from the correlation tables (e.g. Table 4.4) and captured into summary tables (e.g. Table 4.3). This was done for each group for each manipulation. In the context of the analysis of the S-I manipulation the correlation summary for the TG is based on: Table 4.3 derived from Table 4.4; for the ETG: Table 4.5 derived from Table 4.6; and for SMTG: Table 4.7 derived from Table 4.8.
2. The relationship between the correlations was determined using the correlation coefficient, where a negative sign indicated an inverse relationship between two dynamics (as one value increased, the other decreased), and the absence of a negative sign represented a positive correlation between two dynamics (as one value increased or decreased, so the other increased or decreased respectively).
3. An analysis was made on the significant and strong correlations identified in points 1. and 2. In order for the analysis to have a departure point, a standardised outcome for a dynamic had to be chosen so that consistency of the mathematical correlations could be tested. The departure point for the correlation tables for each manipulation was based on the change in range F decreasing.
4. Once the analyses were complete, the tables of summarised statistically significant correlations (e.g. Table 4.3 for TG) were assessed for any incongruence of correlations. If the students within one group over time were repeatedly able to combine the various dynamics in the same manner, they were able to achieve internal congruency of the dynamics (demonstrating control of the relationships between the dynamics). If over time the students within one group formed more than one combination of the various dynamics, internal incongruence of the dynamics was demonstrated (indicating a lack of control of the relationships between the dynamics).

4.6.1.2.2 Correlations between the changes of the ranges and the changes of the averages of the dynamics of manipulation in the tyre group for the S-I manipulation

Table 4.3 Summary of the significant correlations between the dynamics in the tyre group for the S-I manipulation*

Range MFE DOT ↓	Av MFE DOT Shallow ↓				
Range T ↓	Av MFE DOT Deep ↑	***Av T*** ↓			
Av RO ↓	Av MFE DOT Deep ↑				
Av LOD ↑↓	***Av T*** ↑↓				
Range LOD ↑↓	***Av T*** ↑↓	***Av LOD*** ↑↓			
Av Rot ↓	Av RO ↓				
Range Rot ↓	Av RO ↓	Av Rot ↓			
Av F ↓	Range MFE DOT ↓	***Av T*** ↑	Av RO ↓	Range Rot ↓	
Range F** ↓	Av MFE DOT Deep ↑	Av RO ↓	Av Rot ↓	Range Rot ↓	Av F ↓

*The table represents correlations that have a significant *p*-value and a significant correlation co-efficient **only**.

**The analysis was completed in the context of range F decreasing.

The ↓ symbol indicates a decrease in the dynamic (based on the relationship with range F).

The ↑ symbol indicates an increase in the dynamic (based on the relationship with range F).

Dynamics in ***italics*** indicate internal discordance of the dynamic in question, as well as discordance in its relationships with the other dynamics in the manipulation.

Table 4.4 Correlations between the changes of the ranges and the changes of the averages of the dynamics in the tyre group for the S-I manipulation

Correlations[a]

			Change ave MFE Q2T early	Change ave MFE Q2T late	Change range MFE Q2T	Change ave MFE DOT deep	Change ave MFE DOT shallow	Change range MFE DOT	Change ave T	Change range T	Change ave RO	Change range RO	Change ave LOD	Change range LOD	Change ave rotation	Change range rotation	Change ave F	Change range F
Spearman's rho	Change ave MFE Q2T early	Correlation Coefficient	1.000	.	1.000**	-.124	.442	.371	.433	.433	.433	.433	.371	.434	.440	.458	.186	.247
		Sig. (2-tailed)	.	.	.	.660	.099	.173	.107	.107	.107	.107	.173	.106	.101	.086	.508	.374
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave MFE Q2T late	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range MFE Q2T	Correlation Coefficient	1.000**	.	1.000	-.124	.442	.371	.433	.433	.433	.433	.371	.434	.440	.458	.186	.247
		Sig. (2-tailed)	.	.	.	.660	.099	.173	.107	.107	.107	.107	.173	.106	.101	.086	.508	.374
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave MFE DOT deep	Correlation Coefficient	-.124	.	-.124	1.000	-.162	-.005	.129	-.530*	-.578*	-.273	-.007	-.072	-.098	-.246	-.286	-.688**
		Sig. (2-tailed)	.660	.	.660	.	.564	.985	.647	.042	.024	.324	.980	.799	.727	.376	.301	.005
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave MFE DOT shallow	Correlation Coefficient	.442	.	.442	-.162	1.000	.729**	.181	.253	.134	-.030	.032	.384	.323	.412	.321	.361
		Sig. (2-tailed)	.099	.	.099	.564	.	.002	.519	.363	.634	.916	.910	.158	.240	.127	.243	.186
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range MFE DOT	Correlation Coefficient	.371	.	.371	-.005	.729**	1.000	.045	.246	.193	.216	-.182	.027	.249	.249	.554*	.439
		Sig. (2-tailed)	.173	.	.173	.985	.002	.	.874	.376	.491	.439	.516	.924	.371	.370	.032	.101
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave T	Correlation Coefficient	.433	.	.433	.129	.181	.045	1.000	.550*	-.413	-.009	.749**	.747**	-.180	-.142	-.533*	-.354
		Sig. (2-tailed)	.107	.	.107	.647	.519	.874	.	.033	.126	.975	.001	.001	.521	.614	.041	.196
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range T	Correlation Coefficient	.433	.	.433	-.530*	.253	.246	.550*	1.000	.175	.447	.307	.294	-.067	.076	-.050	.354
		Sig. (2-tailed)	.107	.	.107	.042	.363	.376	.033	.	.533	.095	.265	.288	.812	.789	.860	.196
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave RO	Correlation Coefficient	.433	.	.433	-.578*	.134	.193	-.413	.175	1.000	.411	-.200	-.158	.637*	.745**	.711**	.736**
		Sig. (2-tailed)	.107	.	.107	.024	.634	.491	.126	.533	.	.128	.475	.575	.011	.001	.003	.002
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range RO	Correlation Coefficient	.433	.	.433	-.273	-.030	.216	-.009	.447	.411	1.000	.134	-.111	.143	.170	.145	.223
		Sig. (2-tailed)	.107	.	.107	.324	.916	.439	.975	.095	.128	.	.634	.693	.612	.544	.607	.423
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave LOD	Correlation Coefficient	.371	.	.371	-.007	.032	-.182	.749**	.307	-.200	.134	1.000	.662**	.062	.045	-.454	-.261
		Sig. (2-tailed)	.173	.	.173	.980	.910	.516	.001	.265	.475	.634	.	.007	.827	.872	.089	.348
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range LOD	Correlation Coefficient	.434	.	.434	-.072	.384	.027	.747**	.294	-.158	-.111	.662**	1.000	.050	.123	-.473	-.295
		Sig. (2-tailed)	.106	.	.106	.799	.158	.924	.001	.288	.575	.693	.007	.	.859	.662	.075	.285
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave rotation	Correlation Coefficient	.440	.	.440	-.098	.323	.249	-.180	-.067	.637*	.143	.062	.050	1.000	.907**	.470	.515*
		Sig. (2-tailed)	.101	.	.101	.727	.240	.371	.521	.812	.011	.612	.827	.859	.	.000	.077	.049
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range rotation	Correlation Coefficient	.458	.	.458	-.246	.412	.249	-.142	.076	.745**	.170	.045	.123	.907**	1.000	.563*	.537*
		Sig. (2-tailed)	.086	.	.086	.376	.127	.370	.614	.789	.001	.544	.872	.662	.000	.	.029	.039
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave F	Correlation Coefficient	.186	.	.186	-.286	.321	.554*	-.533*	-.050	.711**	.145	-.454	-.473	.470	.563*	1.000	.757**
		Sig. (2-tailed)	.508	.	.508	.301	.243	.032	.041	.860	.003	.607	.089	.075	.077	.029	.	.001
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range F	Correlation Coefficient	.247	.	.247	-.688**	.361	.439	-.354	.354	.736**	.223	-.261	-.295	.515*	.537*	.757**	1.000
		Sig. (2-tailed)	.374	.	.374	.005	.186	.101	.196	.196	.002	.423	.348	.285	.049	.039	.001	.
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Treatment group = Tyre group

In terms of the summary table (Table 4.3) and the correlation table (Table 4.4) for the TG for the S-I manipulation, it can be seen that in the analysis, with the change of range F being fixed to decrease, there was an internal incongruence of the changes of av T, resulting in an internal incongruence with the dynamics related to av T; namely av LOD and range LOD. This indicated that each of these dynamics had the possibility of increasing or decreasing with any one manipulation, which implies that the students in the TG were not able to consistently replicate the manipulative technique with the same combination of dynamics (congruency) when applying the S-I manipulation. This suggests that the relationships between range F and av T (as well as the related av LOD and range LOD) and the other dynamics were not linear in nature and therefore were not consistently applied by the students within the TG over time for the S-I manipulation. The same pattern can be seen if Table 4.4 were to be analysed by fixing another dynamic (other than range F decreasing) as a starting point for analysis, with the exception that the incongruence would be reflected in another set of related dynamics.

The analysis, thus implies that the students in the TG were inconsistent in mastering the relationships between the changes of the ranges and the changes of the averages of the dynamics of manipulation (resulting in incongruency), as there was more than one manner in which these were combined over time. Additionally, the effect of non-linear associations on these relationships is not excluded (Woodall and Montgomery, 1999; Triano, 1998). This is seen in Table 4.3, where the dynamics in ***italics*** indicate internal incongruence.

Therefore, in terms of internal congruence, the utilisation of tyre training as a supplement to the standard manipulative training is limited in training students to control the combination of the dynamics for the S-I manipulation. It is, nevertheless, interesting to note that the relationship of ranges T and F (with the exception of range RO) as noted in Table 4.1 to either collectively increase or decrease, is also reflected in the findings of the correlation table (Table 4.4), which implies that the trends portrayed by the two analyses assists in validating the method of analysis (Rodgers and Nicewander, 1988).

4.6.1.2.3 Correlations between the changes of the ranges and the changes of the averages of the dynamics of manipulation in the elastic tubing group for the S-I manipulation

Table 4.5 Summary of the significant correlations between the dynamics in the elastic tubing group for the S-I manipulation*

Range MFE DOT ↑↓	***Av MFE DOT Deep*** ↑↓	***Av MFE DOT Shallow*** ↑↓	
Range T ↓	Av T ↓		
Av RO ↑	Av T ↓		
Range RO ↓	Range T ↓		
Range LOD ↑↓	***Av LOD*** ↑↓		
Range Rot ↑↓	***Av Rot*** ↑↓		
Av F ↑	Av T ↓	Av RO ↑	
Range F** ↓	Range RO ↓		

*The table represents correlations that have a significant *p*-value and a significant correlation co-efficient **only**.

**The analysis was completed in the context of range F decreasing.

The ↓ symbol indicates a decrease in the dynamic (based on the relationship with range F).

The ↑ symbol indicates an increase in the dynamic (based on the relationship with range F).

Dynamics in ***italics*** indicate internal discordance of the dynamic in question, as well as discordance in its relationships with the other dynamics in the manipulation.

Table 4.6 Correlations between the changes of the ranges and the changes of the averages of the dynamics in the elastic tubing group for the S-I manipulation

Correlations[a]

			Change ave MFE Q2T early	Change ave MFE Q2T late	Change range MFE Q2T	Change ave MFE DOT deep	Change ave MFE DOT shallow	Change range MFE DOT	Change ave T	Change range T	Change ave RO	Change range RO	Change ave LOD	Change range LOD	Change ave rotation	Change range rotation	Change ave F	Change range F
Spearman's rho	Change ave MFE Q2T early	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave MFE Q2T late	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range MFE Q2T	Correlation Coefficient	.	.	1.000	.304	.000	.164	.210	.257	-.210	.351	-.024	-.259	.352	.406	-.304	.304
		Sig. (2-tailed)	.	.	.	.220	1.000	.515	.402	.303	.402	.154	.926	.300	.152	.095	.220	.220
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave MFE DOT deep	Correlation Coefficient	.	.	.304	1.000	.294	.589*	.481*	.320	-.394	.324	.111	.059	.135	.064	-.475*	-.017
		Sig. (2-tailed)	.	.	.220	.	.236	.010	.043	.195	.106	.189	.662	.815	.594	.801	.046	.948
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave MFE DOT shallow	Correlation Coefficient	.	.	.000	.294	1.000	.661**	.493*	.421	.004	.490*	-.083	.215	.170	.306	-.283	.088
		Sig. (2-tailed)	.	.	1.000	.236	.	.003	.038	.082	.987	.039	.744	.391	.500	.216	.254	.729
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range MFE DOT	Correlation Coefficient	.	.	.164	.589*	.661**	1.000	.449	.160	-.142	.286	-.130	.032	-.023	.402	-.451	-.029
		Sig. (2-tailed)	.	.	.515	.010	.003	.	.062	.525	.575	.251	.608	.899	.928	.098	.060	.909
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave T	Correlation Coefficient	.	.	.210	.481*	.493*	.449	1.000	.692**	-.507*	.205	-.132	.211	-.015	.128	-.789**	-.082
		Sig. (2-tailed)	.	.	.402	.043	.038	.062	.	.001	.032	.414	.602	.401	.954	.614	.000	.748
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range T	Correlation Coefficient	.	.	.257	.320	.421	.160	.692**	1.000	-.164	.651**	-.354	-.173	.347	.276	-.422	.430
		Sig. (2-tailed)	.	.	.303	.195	.082	.525	.001	.	.515	.003	.149	.492	.158	.267	.081	.075
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave RO	Correlation Coefficient	.	.	-.210	-.394	.004	-.142	-.507*	-.164	1.000	.156	-.150	-.341	-.074	-.015	.616**	.102
		Sig. (2-tailed)	.	.	.402	.106	.987	.575	.032	.515	.	.537	.554	.165	.772	.954	.006	.687
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range RO	Correlation Coefficient	.	.	.351	.324	.490*	.286	.205	.651**	.156	1.000	-.247	-.295	.325	.318	-.040	.711**
		Sig. (2-tailed)	.	.	.154	.189	.039	.251	.414	.003	.537	.	.323	.235	.188	.198	.874	.001
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave LOD	Correlation Coefficient	.	.	-.024	.111	-.083	-.130	-.132	-.354	-.150	-.247	1.000	.722**	.121	-.354	.146	-.182
		Sig. (2-tailed)	.	.	.926	.662	.744	.608	.602	.149	.554	.323	.	.001	.633	.149	.562	.470
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range LOD	Correlation Coefficient	.	.	-.259	.059	.215	.032	.211	-.173	-.341	-.295	.722**	1.000	-.122	-.433	-.222	-.354
		Sig. (2-tailed)	.	.	.300	.815	.391	.899	.401	.492	.165	.235	.001	.	.630	.072	.376	.150
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave rotation	Correlation Coefficient	.	.	.352	.135	.170	-.023	-.015	.347	-.074	.325	.121	-.122	1.000	.533*	.293	.313
		Sig. (2-tailed)	.	.	.152	.594	.500	.928	.954	.158	.772	.188	.633	.630	.	.023	.238	.206
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range rotation	Correlation Coefficient	.	.	.406	.064	.306	.402	.128	.276	-.015	.318	-.354	-.433	.533*	1.000	.017	.221
		Sig. (2-tailed)	.	.	.095	.801	.216	.098	.614	.267	.954	.198	.149	.072	.023	.	.947	.377
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave F	Correlation Coefficient	.	.	-.304	-.475*	-.283	-.451	-.789**	-.422	.616*	-.040	.146	-.222	.293	.017	1.000	.156
		Sig. (2-tailed)	.	.	.220	.046	.254	.060	.000	.081	.006	.874	.562	.376	.238	.947	.	.537
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range F	Correlation Coefficient	.	.	.304	-.017	.088	-.029	-.082	.430	.102	.711**	-.182	-.354	.313	.221	.156	1.000
		Sig. (2-tailed)	.	.	.220	.948	.729	.909	.748	.075	.687	.001	.470	.150	.206	.377	.537	.
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

a. Treatment group = Elastic tubing group

In terms of the summary table (Table 4.5) and the correlation table (Table 4.6) for the ETG for the S-I manipulation, it can be seen that in the analysis with the change of range F being fixed to decrease, there was an internal congruence as not all the dynamics were able to be linked to range F. It is, however, noted that the dynamics of: MFE DOT, av MFE DOT Shallow and Av MFE DOT Deep; range LOD and av LOD; and range Rot and av Rot, developed congruent significant relationships within separate pockets that could not be linked to range F.

This indicates that these relationships may have been affected by either extraneous factors (beyond the bounds of this study) or non-linear relationships between the dynamics (Woodall and Montgomery, 1999; Triano, 1998).

The analysis thus implies that the students in the ETG were inconsistent in mastering the relationships between the changes of the ranges and the changes of the averages of the dynamics of manipulation, as there was more than one manner in which these were combined over time. This is seen in Table 4.5, where the dynamics in ***italics*** indicate internal incongruence.

Therefore, although the ETG developed congruent significant relationships within pockets of the dynamics, the group was unable to attain overall congruency between the dynamics. The utilisation of elastic tubing training as a supplement to the standard manipulative training therefore does not allow for control of the overall combination of the dynamics for the S-I manipulation. Notwithstanding this, the findings of the correlation table (Table 4.6) show that the ranges T, RO and F behave similarly, which is consistent with the pattern seen in Table 4.1, which demonstrated that the ranges of these dynamics tend to collectively behave in the same manner. This re-enforces the assertion from the previous section that although the data show outcomes from different base analyses (viz. median of the ranges (Table 4.1) versus median change of the range of a dynamic (Table 4.6)), the trends remain consistent.

4.6.1.2.4 Correlations between the changes of the ranges and the changes of the averages of the dynamics of manipulation in the standard manipulative training group for the S-I manipulation

Table 4.7 Summary of the significant correlations between the dynamics in the standard manipulative training group for the S-I manipulation*

Range RO ↓	Av MFE DOT Deep ↑	Range T ↓	Av RO ↓		
Av LOD ↑	Av MFE DOT Deep ↑	Av MFE DOT Shallow ↓			
Range Rot ↑	Av MFE DOT Deep ↑	Av Rot ↑			
Av F ↓	Av T ↑	Av RO ↓	Range RO ↓		
Range F** ↓	Range T ↓	Av RO ↓	Range RO ↓	Av F ↓	

*The table represents correlations that have a significant *p*-value and a significant correlation co-efficient **only**.

**The analysis was completed in the context of range F decreasing.

The ↓ symbol indicates a decrease in the dynamic (based on the relationship with range F).

The ↑ symbol indicates an increase in the dynamic (based on the relationship with range F).

Dynamics in ***italics*** indicate internal discordance of the dynamic in question, as well as discordance in its relationships with the other dynamics in the manipulation.

Table 4.8 Correlations between the changes of the ranges and the changes of the averages of the dynamics in the standard manipulative training group for the S-I manipulation

Correlations[a]

			Change ave MFE Q2T early	Change ave MFE Q2T late	Change range MFE Q2T	Change ave MFE DOT deep	Change ave MFE DOT shallow	Change range MFE DOT	Change ave T	Change range T	Change ave RO	Change range RO	Change ave LOD	Change range LOD	Change ave rotation	Change range rotation	Change ave F	Change range F
Spearman's rho	Change ave MFE Q2T early	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave MFE Q2T late	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range MFE Q2T	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave MFE DOT deep	Correlation Coefficient	.	.	.	1.000	-.078	.435	.160	-.391	-.372	-.523*	.520*	.254	.473	.560*	-.208	-.355
		Sig. (2-tailed)	.	.	.	.	.766	.081	.539	.121	.141	.031	.033	.325	.055	.019	.422	.162
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave MFE DOT shallow	Correlation Coefficient	.	.	.	-.078	1.000	.209	-.064	-.090	-.278	-.126	-.679**	.102	-.109	-.241	-.293	-.192
		Sig. (2-tailed)	.	.	.	.766	.	.420	.808	.732	.279	.629	.003	.697	.677	.351	.253	.461
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range MFE DOT	Correlation Coefficient	.	.	.	.435	.209	1.000	.046	.190	-.251	.055	.109	.163	.282	.433	.069	.049
		Sig. (2-tailed)	.	.	.	.081	.420	.	.862	.466	.331	.833	.677	.533	.272	.082	.793	.851
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave T	Correlation Coefficient	.	.	.	.160	-.064	.046	1.000	.069	-.478	-.228	.173	-.355	-.038	-.154	-.529*	-.264
		Sig. (2-tailed)	.	.	.	.539	.808	.862	.	.794	.052	.379	.508	.162	.884	.556	.029	.307
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range T	Correlation Coefficient	.	.	.	-.391	-.090	.190	.069	1.000	.495*	.787**	-.165	-.229	-.276	-.275	.498*	.775**
		Sig. (2-tailed)	.	.	.	.121	.732	.466	.794	.	.043	.000	.527	.378	.284	.285	.042	.000
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave RO	Correlation Coefficient	.	.	.	-.372	-.278	-.251	-.478	.495*	1.000	.625**	-.042	-.107	-.108	-.089	.684**	.543*
		Sig. (2-tailed)	.	.	.	.141	.279	.331	.052	.043	.	.007	.873	.683	.681	.735	.002	.024
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range RO	Correlation Coefficient	.	.	.	-.523*	-.126	.055	-.228	.787**	.625**	1.000	-.228	-.080	-.260	-.181	.681**	.911**
		Sig. (2-tailed)	.	.	.	.031	.629	.833	.379	.000	.007	.	.379	.759	.314	.486	.003	.000
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave LOD	Correlation Coefficient	.	.	.	.520*	-.679**	.109	.173	-.165	-.042	-.228	1.000	.099	.254	.298	.058	-.164
		Sig. (2-tailed)	.	.	.	.033	.003	.677	.508	.527	.873	.379	.	.705	.326	.245	.825	.529
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range LOD	Correlation Coefficient	.	.	.	.254	.102	.163	-.355	-.229	-.107	-.080	.099	1.000	-.056	-.157	.128	.073
		Sig. (2-tailed)	.	.	.	.325	.697	.533	.162	.378	.683	.759	.705	.	.832	.547	.624	.781
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave rotation	Correlation Coefficient	.	.	.	.473	-.109	.282	-.038	-.276	-.108	-.260	.254	-.056	1.000	.526*	-.346	-.213
		Sig. (2-tailed)	.	.	.	.055	.677	.272	.884	.284	.681	.314	.326	.832	.	.030	.174	.412
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range rotation	Correlation Coefficient	.	.	.	.560*	-.241	.433	-.154	-.275	-.089	-.181	.298	-.157	.526*	1.000	-.022	-.190
		Sig. (2-tailed)	.	.	.	.019	.351	.082	.556	.285	.735	.486	.245	.547	.030	.	.933	.464
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave F	Correlation Coefficient	.	.	.	-.208	-.293	.069	-.529*	.498*	.684**	.681**	.058	.128	-.346	-.022	1.000	.716**
		Sig. (2-tailed)	.	.	.	.422	.253	.793	.029	.042	.002	.003	.825	.624	.174	.933	.	.001
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range F	Correlation Coefficient	.	.	.	-.355	-.192	.049	-.264	.775**	.543*	.911**	-.164	.073	-.213	-.190	.716**	1.000
		Sig. (2-tailed)	.	.	.	.162	.461	.851	.307	.000	.024	.000	.529	.781	.412	.464	.001	.
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

a. Treatment group = Control group

In terms of the summary table (Table 4.7) and the correlation table (Table 4.8) for the SMTG for the S-I manipulation, it can be seen that in the analysis with the change of range F being fixed to decrease, there was internal congruence between the relationships of the changes of ranges and changes of averages of the dynamics of manipulation (viz. there were no dynamics that reflected both an up and a down arrow / internal inconsistency and there were no groups of dynamics that created pockets of dynamics that were related to each other internally but not the remainder of the group). Additionally, there were no instances where individual dynamics were in conflict.

The analysis thus implies that the students in the SMTG were consistent in mastering the relationships between the change of the ranges and the changes of the averages of the dynamics of manipulation, as there was only one manner in which these were combined over time (congruency was achieved). This is seen in Table 4.7, where there were no dynamics noted in ***italics***.

Therefore, in terms of internal congruence, the utilisation of standard manipulative training is effective in training students to control the combination of the dynamics for the S-I manipulation. This along with the agreement between the inference made in the discussion related to Table 4.1 (in terms of the behavioural relationship between the ranges T, RO and F), and the findings of the correlation table (Table 4.8) for the SMTG in the S-I manipulation which shows the same behaviour; again suggests that there is limited negative effect, in the fact that these data show outcome trends from different base analyses (viz. median of the ranges versus median change of the range / average of a dynamic),

4.6.2 Posterior to Anterior (P-A) Manipulation

4.6.2.1 Analysis and Discussion of the Individual Dynamics

4.6.2.1.1 Analysis and discussion of the individual dynamics for the P-A manipulation within each intervention group

Table 4.9 represents a comparison of the median ranges of the dynamics for the P-A manipulation pre-, mid-, and post-training, within each intervention group (refer to Section 4.6.1.1 for the explanation of the median value analysis).

Table 4.9 Comparison of the median ranges of the dynamics, within the intervention groups, for the P-A manipulation, over the training period.

			Time			*p* value
			Pre-training	Mid-training	Post-training	
			Median	Median	Median	
Intervention group	Tyre group	Range MFE Q2T	0.0	0.0	0.0	1.000
		Range MFE DOT	13.0	11.0	11.0	0.223
		Range T	409.0	271.0	254.0	0.607
		Range RO	187.0	210.0	152.0	0.819
		Range LOD (º)	1.4	0.9	0.9	0.763
		Range Rotation (º)	2.0	1.0	2.0	0.291
		Range F (N)	144.0	140.0	46.0	0.627
	Elastic tubing group	Range MFE Q2T	0.0	0.0	0.0	0.779
		Range MFE DOT	11.5	10.5	9.5	0.306
		Range T	292.5	376.5	345.5	0.502
		Range RO	161.5	333.5	296.5	0.486
		Range LOD (º)	0.9	0.9	0.9	0.569
		Range Rotation (º)	1.5	2.0	2.0	0.929
		Range F (N)	92.0	138.0	146.5	0.348
	Standard manipulative training group	Range MFE Q2T	0.0	0.0	0.0	1.000
		Range MFE DOT	13.0	14.0	14.0	0.902
		Range T	56.0	314.0	388.0	0.571
		Range RO	167.0	197.0	415.0	0.230
		Range LOD (º)	1.4	1.4	0.9	0.888
		Range Rotation (º)	2.0	2.0	2.0	0.431
		Range F (N)	64.0	160.0	164.0	0.204

4.6.2.1.2 Discussion in terms of the median ranges of the dynamics achieved over time within each group for the P-A manipulation

There were no statistically significant changes for any of the median ranges of the dynamics, in any of the groups, from pre- to post-training for the P-A manipulation. Therefore, neither of the intervention groups, nor the SMTG, received training that was efficient in assisting students in developing improved control of the dynamics for the P-A manipulation (this would be indicated by a statistically significant decrease in the median ranges of the dynamics from pre- to post-training). It is also apparent that neither the tyre nor the elastic tubing interventions were of any added benefit to the standard manipulative training in terms of aiding in the development of improved control of the dynamics of manipulation for the P-A manipulation. Conversely, it is important to note that neither of the interventions adversely affected the standard manipulative training, which would be indicated by a statistically significant increase in the median ranges of the dynamics from pre- to post-training.

Although not denoted as statistically significant, a constant median range of a dynamic was seen to constitute maintained (but not improved) control of the dynamic from pre- to post- training within the group, as the student was able to reproduce a constant level of variability (by example Figure 4.2). It may therefore be stated that the lack of statistical significance regarding the change in the median ranges of the dynamics from pre- to post-training showed that the students' level of control varied only slightly over the training period, indicating that the students at best maintained the level of control of the dynamics that they began with.

Internally, it can however be seen that students were able to maintain a greater degree of control of some dynamics (e.g. MFE Q2T) while other dynamics were more variable (e.g. F in the tyre group).

The small sample size of the study and the length of the training program (Kraemer, Duncan and Volek, 1998) may have been limitations that hindered the generation of statistically significant changes of the median ranges within the groups from pre- to post-training. It is therefore suggested that future studies increase the length of the training program for the intervention groups in order to increase the likelihood of any significant change in the median ranges of the dynamics of manipulation. This is

because a longer training period may be required in order to have a notable effect on muscle physiology (Kraemer, Duncan and Volek, 1998; Robergs and Roberts, 1996). Furthermore an increased sample size would allow for the exclusion of outlier measurements and thus for statistical analysis of the data that more effectively represent the groups (using mean analyses).

As with the S-I manipulation, none of the changes of the median ranges of the dynamics from pre- to post-training were noted as being statistically significant. Thus the study can only comment on the trends observed with regard to control. These trends assess the comparisons of the median ranges of the dynamics for the P-A manipulation from pre- to post-training (Table 4.9). The following trends were noted within the three groups for the P-A manipulation:

The TG showed (as explained in Figures 4.2 and 4.3 in Section 4.6.1.1.1):

- Increased control of MFE DOT, T, RO, LOD and F.
- A constant level of control of MFE Q2T and Rot.

The ETG showed (as explained in Figures 4.2 and 4.3 in Section 4.6.1.1.1):

- Decreased control of T, RO, Rot and F.
- Increased control of MFE DOT.
- A constant level of control of MFE Q2T and LOD.

The SMTG showed (as explained in Figures 4.2 and 4.3 in Section 4.6.1.1.1):

- Decreased control of MFE DOT, T, RO and F.
- Increased control of LOD.
- A constant level of control of MFE Q2T and Rot.

Thus, all groups showed a constant level of variability for MFE Q2T for the P-A manipulation, indicating that all of the participants were able to control the application of simulated tissue slack removal (MFE Q2T) when applying the P-A manipulation technique. These results were expected due to the instructions given to the students and the auditory and visual stimulation cues given by the Dynadjust (refer to Section 4.6.1.1.1).

Based on the outcomes of the analysis of the median ranges of the dynamics over time, and the discussion of these findings, it could be stated that neither of the intervention

groups, nor the SMTG, were efficient in facilitating students in developing improved control of the dynamics of the S-I manipulation. This may be a direct effect of a small sample size and it is suggested that larger sample sizes in future studies would need to be conducted in order to verify the results presented here.

Notwithstanding the above, the trends seen in the analysis of individual dynamics, indicate that the TG improved the control of all dynamics with the exception of Rot which remained constant (MFE Q2T was expected to remain constant). This is in contrast to the ETG and the SMTG which had similar numbers of dynamics for which they showed a trend towards improved control; maintained control; and regressed control.

In terms of the trends of control (with regard to comparisons of the median ranges of the dynamics) seen within the groups, the median ranges of the following dynamics were noted to either collectively increase or collectively decrease within each group: T, RO and F. With respect to MFE DOT, LOD and Rot no consistent pattern could be identified. These collective results suggest that for the P-A manipulation, the changes in the ranges of the dynamics of T, RO and F should show a correlation when the relationships *between* them are analysed. This contrasts with the dynamics of LOD and MFE DOT. This will, however, only be assessed in Section 4.6.2.2 when the correlations between the changes of the averages and the changes of the ranges of the dynamics are discussed.

4.6.2.1.3 The inter-group statistical significance of the change in the median ranges of the dynamics over time

Table 4.10 represents the inter-group statistical significance generated by the comparisons of the median changes in the ranges of the dynamics, from pre- to post-training for the P-A manipulation (refer to Section 4.6.1.1.2 for explanation regarding the interpretation of positive and negative values).

Table 4.10 The inter-group statistical significance of the median change in the ranges of the dynamics over time for the P-A manipulation

	Intervention group			*p* value elastic versus control	*p* value tyre versus control	*p* value elastic versus tyre
	Tyre group	Elastic tubing group	Standard manipulative training group			
	Median	Median	Median			
Change range MFE Q2T	0.0	0.0	0.0	0.807	1.000	0.789
Change range MFE DOT	-3.0	-0.5	1.0	0.463	0.082	0.166
Change range T	0.0	102.0	0.0	0.858	0.370	0.421
Change range RO	-2.0	15.0	123.0	0.245	0.053	0.708
Change range LOD	0.0	0.0	0.0	0.525	0.261	0.682
Change range rotation	0.0	0.0	-1.0	0.258	0.655	0.556
Change range F	-7.0	42.0	52.0	0.568	0.040	0.155

4.6.2.1.4 Discussion in terms of the inter-group statistical significance of median changes of the ranges of the dynamics over time, for the P-A manipulation.

The results revealed a significant difference in the median change of the range F (p=0.040) between the TG and the SMTG from pre- to post-training, with the TG acquiring improved control over F (indicated by the negative change in range value) to a statistically significantly greater degree than the SMTG, which demonstrated less control over F (indicated by the positive change in range value) (Esterhuizen, 2013). This is in keeping with the trends noted from analysing Table 4.9.

The control of F was thus most improved by the TG, followed by the ETG (not to a point of statistical significance) which demonstrated regression of the control of F and lastly

by the SMTG (to a point of statistical significance when compared to the TG) which also demonstrated a regression in the amount of control of F.

In terms of the relative improvements or regression of control of the remaining dynamics of manipulation between the groups; firm conclusions could not be drawn as there were no significant differences in the median changes of the ranges of the other dynamics between groups. Therefore it is suggested that increased participants, increased training time (i.e. over a longer period) and increased numbers of training repetitions should all be considered in future studies in order to increase the likelihood of obtaining statistical significance between the groups and to confirm the preliminary findings of this study. Furthermore, strategies to eliminate student exclusion from the study due to failure to meet minimum criteria of participation in the study need to be considered.

4.6.2.2 Correlations

4.6.2.2.1 General explanation regarding correlation analysis

The general explanation regarding the correlation analysis is based on the discussion found in Section 4.6.1.2.1, however, it should be noted that in the context of the analysis of the P-A manipulation the correlation summary for the: TG is based on Table 4.11 derived from Table 4.12; ETG is based on Table 4.13 derived from Table 4.14; and SMTG, is based on Table 4.15 derived from Table 4.16).

4.6.2.2.2 Correlations between the changes of the ranges and the changes of the averages of the dynamics of manipulation in the tyre group for the P-A manipulation

Table 4.11 Summary of the significant correlations between the dynamics in the tyre group for the P-A manipulation*

Range MFE DOT ↑ ↓	***Av MFE DOT Shallow*** ↑ ↓			
Range T ↓	***Av T*** ↓			
Range RO ↓	Range T ↓			
Av LOD ↑	***Av T*** ↑			
Av Rot ↑	Av LOD ↑			
Range Rot ↓	***Av T*** ↓	Range T ↓		
Av F ↓	***Av T*** ↑	Av LOD ↑		
Range F** ↓	Range RO ↓	Av LOD ↑		

*The table represents correlations that have a significant *p*-value and a significant correlation co-efficient **only**.

**The analysis was completed in the context of range F decreasing.

The ↓ symbol indicates a decrease in the dynamic (based on the relationship with range F).

The ↑ symbol indicates an increase in the dynamic (based on the relationship with range F).

Dynamics in ***italics*** indicate internal discordance of the dynamic in question, as well as discordance in its relationships with the other dynamics in the manipulation.

Table 4.12 Correlations between the changes of the ranges and the changes of the averages of the dynamics in the tyre group for the P-A manipulation

Correlations[a]

			Change ave MFE Q2T early	Change ave MFE Q2T late	Change range MFE Q2T	Change ave MFE DOT deep	Change ave MFE DOT shallow	Change range MFE DOT	Change ave T	Change range T	Change ave RO	Change range RO	Change ave LOD	Change range LOD	Change ave rotation	Change range rotation	Change ave F	Change range F
Spearman's rho	Change ave MFE Q2T early	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave MFE Q2T late	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range MFE Q2T	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave MFE DOT deep	Correlation Coefficient	.	.	.	1.000	-.411	-.072	.143	-.068	.194	-.179	.343	.339	.466	.076	.097	-.330
		Sig. (2-tailed)	.	.	.	.	.128	.799	.610	.809	.489	.523	.211	.217	.080	.787	.732	.230
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave MFE DOT shallow	Correlation Coefficient	.	.	.	-.411	1.000	.706**	.109	.178	-.101	-.033	-.098	-.185	.011	.220	-.010	.184
		Sig. (2-tailed)	.	.	.	.128	.	.003	.700	.525	.721	.907	.728	.509	.969	.430	.973	.511
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range MFE DOT	Correlation Coefficient	.	.	.	-.072	.706**	1.000	-.082	-.066	-.143	-.319	-.370	-.046	.040	.142	.174	.037
		Sig. (2-tailed)	.	.	.	.799	.003	.	.770	.815	.611	.247	.174	.870	.887	.614	.536	.897
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave T	Correlation Coefficient	.	.	.	.143	.109	-.082	1.000	.525*	-.382	.254	.594*	.354	.472	.580*	-.782**	-.141
		Sig. (2-tailed)	.	.	.	.610	.700	.770	.	.044	.160	.362	.020	.196	.076	.023	.001	.616
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range T	Correlation Coefficient	.	.	.	-.068	.178	-.066	.525*	1.000	-.043	.682**	.145	.009	.270	.576*	-.304	.447
		Sig. (2-tailed)	.	.	.	.809	.525	.815	.044	.	.879	.005	.606	.975	.331	.025	.271	.095
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave RO	Correlation Coefficient	.	.	.	.194	-.101	-.143	-.382	-.043	1.000	-.104	.245	-.186	.146	-.250	.293	-.138
		Sig. (2-tailed)	.	.	.	.489	.721	.611	.160	.879	.	.713	.379	.507	.604	.369	.289	.625
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range RO	Correlation Coefficient	.	.	.	-.179	-.033	-.319	.254	.682**	-.104	1.000	-.111	.081	-.168	.351	-.046	.710**
		Sig. (2-tailed)	.	.	.	.523	.907	.247	.362	.005	.713	.	.694	.774	.550	.199	.869	.003
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave LOD	Correlation Coefficient	.	.	.	.343	-.098	-.370	.594*	.145	.245	-.111	1.000	.254	.560*	.185	-.542*	-.509
		Sig. (2-tailed)	.	.	.	.211	.728	.174	.020	.606	.379	.694	.	.361	.030	.509	.037	.053
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range LOD	Correlation Coefficient	.	.	.	.339	-.185	-.046	.354	.009	-.186	.081	.254	1.000	.188	.414	-.179	.066
		Sig. (2-tailed)	.	.	.	.217	.509	.870	.196	.975	.507	.774	.361	.	.503	.125	.524	.815
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave rotation	Correlation Coefficient	.	.	.	.466	.011	.040	.472	.270	.146	-.168	.560*	.188	1.000	.499	-.333	-.312
		Sig. (2-tailed)	.	.	.	.080	.969	.887	.076	.331	.604	.550	.030	.503	.	.058	.225	.258
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range rotation	Correlation Coefficient	.	.	.	.076	.220	.142	.580*	.576*	-.250	.351	.185	.414	.499	1.000	-.395	.185
		Sig. (2-tailed)	.	.	.	.787	.430	.614	.023	.025	.369	.199	.509	.125	.058	.	.145	.509
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave F	Correlation Coefficient	.	.	.	.097	-.010	.174	-.782**	-.304	.293	-.046	-.542*	-.179	-.333	-.395	1.000	.456
		Sig. (2-tailed)	.	.	.	.732	.973	.536	.001	.271	.289	.869	.037	.524	.225	.145	.	.088
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range F	Correlation Coefficient	.	.	.	-.330	.184	.037	-.141	.447	-.138	.710**	-.509	.066	-.312	.185	.456	1.000
		Sig. (2-tailed)	.	.	.	.230	.511	.897	.616	.095	.625	.003	.053	.815	.258	.509	.088	.
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Treatment group = Tyre group

In terms of the summary table (Table 4.11) and the correlation table (Table 4.12) for the TG for the P-A manipulation, it can be seen that in the analysis with the change of the range of F being fixed to decrease, there was an internal incongruence of av T. This is indicated in that av T had the possibility of increasing or decreasing with any one manipulation, which implies that the students were not able to consistently replicate the manipulative technique with the exact same combination of dynamics when applying the P-A manipulation. Furthermore, range MFE DOT and av MFE DOT Shallow showed an internal incongruence as they were not linked to range F either directly or through other dynamics within those that were significant. It is however noted that although there was no link between these dynamics and range F, they formed a congruent significant relationships in separate pocket.

This indicates that these relationships may have been affected by either extraneous factors (beyond the bounds of this study) or non-linear relationships between the dynamics (Woodall and Montgomery, 1999; Triano, 1998).

The analysis thus implies that the students in the TG were inconsistent in mastering the relationships between the change in the ranges and the change in the averages as there was more than one manner in which these were combined over time. This is seen in Table 4.11 where the dynamics in ***italics*** indicate internal incongruence of the dynamics.

Therefore, in terms of the internal congruence, the utilisation of tyre training as a supplement to the standard manipulative training seems to develop control of pockets of individual dynamics; however, there is limited control of the combination of how these dynamics are combined overall for the P-A manipulation.

It is again noted that the findings of a suggested relationship between ranges T, RO and F in Table 4.9 for the P-A manipulation, is in keeping with the findings of the correlation table, (Table 4.12), for the TG in the P-A manipulation where ranges T, RO and F behave in a similar manner. This implies, as for the P-A manipulation analyses, that although these outcomes were drawn from different base analyses (i.e. median of ranges and median change of ranges), the data is internally consistent.

4.6.2.2.3 Correlations between the changes of the ranges and the changes of the averages of the dynamics of manipulation in the elastic tubing group for the P-A manipulation

Table 4.13 Summary of the significant correlations between the dynamics in the elastic tubing group for the P-A manipulation*

Range MFE Q2T ↑↓	***Av MFE Q2T early*** ↑↓		
Range T ↑↓	***Av T*** ↑↓		
Av RO ↑↓	***Av MFE Q2T early*** ↑↓	***Av T*** ↓↑ **(inverse)**	
Range RO ↑↓	***Range T*** ↑↓		
Av Rot ↓	Av LOD ↓		
Av F ↑↓	***Range MFE Q2T*** ↑↓	***Av T*** ↓↑ **(inverse)**	
Range F** ↓	Range MFE DOT ↓	Av LOD ↓	

*The table represents correlations that have a significant *p*-value and a significant correlation co-efficient **only**.

**The analysis was completed in the context of range F decreasing.

The ↓ symbol indicates a decrease in the dynamic (based on the relationship with range F).

The ↑ symbol indicates an increase in the dynamic (based on the relationship with range F

Dynamics in ***italics*** indicate internal discordance of the dynamic in question, as well as discordance in its relationships with the other dynamics in the manipulation.

Table 4.14 Correlations between the changes of the ranges and the changes of the averages of the dynamics in the elastic tubing group for the P-A manipulation

Correlations[a]

			Change ave MFE Q2T early	Change ave MFE Q2T late	Change range MFE Q2T	Change ave MFE DOT deep	Change ave MFE DOT shallow	Change range MFE DOT	Change ave T	Change range T	Change ave RO	Change range RO	Change ave LOD	Change range LOD	Change ave rotation	Change range rotation	Change ave F	Change range F
Spearman's rho	Change ave MFE Q2T early	Correlation Coefficient	1.000	.	.807**	.347	-.072	.177	-.430	-.246	.538*	.218	-.121	.180	.056	-.118	.415	-.027
		Sig. (2-tailed)	.	.	.000	.159	.777	.483	.075	.325	.021	.386	.631	.475	.826	.641	.087	.915
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave MFE Q2T late	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range MFE Q2T	Correlation Coefficient	.807**	.	1.000	.139	-.059	.202	-.404	-.140	.301	.108	-.244	.035	-.050	.001	.523*	.166
		Sig. (2-tailed)	.000	.	.	.581	.815	.422	.096	.580	.225	.668	.329	.889	.844	.998	.026	.510
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave MFE DOT deep	Correlation Coefficient	.347	.	.139	1.000	-.046	.204	.111	-.131	.111	-.054	-.252	-.055	.045	-.247	-.015	-.411
		Sig. (2-tailed)	.159	.	.581	.	.857	.417	.661	.605	.661	.832	.314	.828	.860	.324	.954	.090
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave MFE DOT shallow	Correlation Coefficient	-.072	.	-.059	-.046	1.000	-.003	-.215	-.272	.264	-.293	-.043	.014	-.352	.118	-.146	-.252
		Sig. (2-tailed)	.777	.	.815	.857	.	.991	.391	.275	.291	.237	.866	.955	.152	.642	.563	.313
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range MFE DOT	Correlation Coefficient	.177	.	.202	.204	-.003	1.000	-.338	-.049	-.051	-.040	.259	.113	-.110	-.170	.437	.533*
		Sig. (2-tailed)	.483	.	.422	.417	.991	.	.170	.848	.842	.874	.299	.655	.664	.501	.069	.023
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave T	Correlation Coefficient	-.430	.	-.404	.111	-.215	-.338	1.000	.709**	-.626**	.195	-.116	-.178	.209	-.031	-.738**	-.207
		Sig. (2-tailed)	.075	.	.096	.661	.391	.170	.	.001	.005	.438	.646	.479	.405	.903	.000	.409
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range T	Correlation Coefficient	-.246	.	-.140	-.131	-.272	-.049	.709**	1.000	-.362	.622**	.103	-.215	.273	-.098	-.412	.240
		Sig. (2-tailed)	.325	.	.580	.605	.275	.848	.001	.	.140	.006	.685	.392	.273	.699	.090	.336
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave RO	Correlation Coefficient	.538*	.	.301	.111	.264	-.051	-.626**	-.362	1.000	.203	.031	.109	.006	-.082	.220	-.199
		Sig. (2-tailed)	.021	.	.225	.661	.291	.842	.005	.140	.	.418	.902	.668	.980	.746	.381	.428
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range RO	Correlation Coefficient	.218	.	.108	-.054	-.293	-.040	.195	.622**	.203	1.000	.179	.004	.357	-.224	-.199	.346
		Sig. (2-tailed)	.386	.	.668	.832	.237	.874	.438	.006	.418	.	.478	.987	.146	.373	.428	.160
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave LOD	Correlation Coefficient	-.121	.	-.244	-.252	-.043	.259	-.116	.103	.031	.179	1.000	.458	.519*	.316	.188	.601**
		Sig. (2-tailed)	.631	.	.329	.314	.866	.299	.646	.685	.902	.478	.	.056	.027	.201	.455	.008
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range LOD	Correlation Coefficient	.180	.	.035	-.055	.014	.113	-.178	-.215	.109	.004	.458	1.000	.345	.476*	.093	.151
		Sig. (2-tailed)	.475	.	.889	.828	.955	.655	.479	.392	.668	.987	.056	.	.161	.046	.714	.551
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave rotation	Correlation Coefficient	.056	.	-.050	.045	-.352	-.110	.209	.273	.006	.357	.519*	.345	1.000	.302	-.126	.201
		Sig. (2-tailed)	.826	.	.844	.860	.152	.664	.405	.273	.980	.146	.027	.161	.	.224	.618	.424
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range rotation	Correlation Coefficient	-.118	.	.001	-.247	.118	-.170	-.031	-.098	-.082	-.224	.316	.476*	.302	1.000	.195	.180
		Sig. (2-tailed)	.641	.	.998	.324	.642	.501	.903	.699	.746	.373	.201	.046	.224	.	.439	.475
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave F	Correlation Coefficient	.415	.	.523*	-.015	-.146	.437	-.738**	-.412	.220	-.199	.188	.093	-.126	.195	1.000	.420
		Sig. (2-tailed)	.087	.	.026	.954	.563	.069	.000	.090	.381	.428	.455	.714	.618	.439	.	.083
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range F	Correlation Coefficient	-.027	.	.166	-.411	-.252	.533*	-.207	.240	-.199	.346	.601**	.151	.201	.180	.420	1.000
		Sig. (2-tailed)	.915	.	.510	.090	.313	.023	.409	.336	.428	.160	.008	.551	.424	.475	.083	.
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Treatment group = Elastic tubing group

In terms of the summary table (Table 4.13) and the correlation table (Table 4.14) for the ETG for the P-A manipulation, it can be seen that in the analysis, with the change of range F being fixed to decrease, there was internal incongruence between the majority of the relationships of the changes of ranges and changes of averages of the dynamics of manipulation (viz. the direction of linear relationships were indeterminable (↓↑) or the relationships were of a non-linear nature) as these dynamics could not be linked directly or indirectly to range F. It is, however, noted that although there was no link between the majority of the dynamics and range F, the dynamics formed pockets of congruent significant relationships within the P-A manipulation. This indicates that these relationships were affected by either extraneous factors (beyond the bounds of this study) or non-linear relationships between these dynamics (Woodall and Montgomery, 1999; Triano, 1998).

The analysis thus implies that the students in the ETG were not consistent in mastering the relationships between the change in range F and the changes of the averages and the changes of the ranges of all the other dynamics in the S-I manipulation as there was more than one manner in which these were combined over time. This is seen in Table 4.13, where the multiple dynamics noted in ***italics*** indicate incongruence. Therefore, in terms of the development of internal congruence, the utilisation of elastic tubing training as a supplement to the standard manipulative training seems to develop control of pockets of individual dynamics however, there is limited development of control of the overall combination of these dynamics for the P-A manipulation.

In contrast to previous correlation tables, the suggested behavioural relationship between ranges T, RO and F in Table 4.9, is not in keeping with the findings of the correlation table (Table 4.14) for the ETG in the P-A manipulation, where ranges T, RO, and F act in a dissimilar manner. This implies, that the different bases (i.e. median of ranges and median change of ranges) from which the data were drawn, were not comparable. This implies that there is a variable / are variables that has / have influenced the relationship of these dynamics. It is, however, beyond the bounds of this study to identify this / these variable(s) and it is suggested that future studies look at this more closely.

4.6.2.2.4 Correlations between the changes of the ranges and the changes of the averages of the dynamics of manipulation in the standard manipulative training group for the P-A manipulation

Table 4.15 Summary of the significant correlations between the dynamics in the standard manipulative training group for the P-A manipulation*

Range MFE DOT ↑↓	***Av MFE DOT Deep*** ↑↓			
Range T ↓	Av T ↓			
Av RO ↑	Av T ↓			
Range RO ↓	Av T ↓	Range T ↓		
Range Rot ↑↓	***Av Rot*** ↑↓			
Av F ↑	Av T ↓	Range RO ↓	Range LOD ↓	
Range F** ↓	Range RO ↓			

*The table represents correlations that have a significant *p*-value and a significant correlation co-efficient **only**.

**The analysis was completed in the context of range F decreasing.

The ↓ symbol indicates a decrease in the dynamic (based on the relationship with range F).

The ↑ symbol indicates an increase in the dynamic (based on the relationship with range F).

Dynamics in ***italics*** indicate internal discordance of the dynamic in question, as well as discordance in its relationships with the other dynamics in the manipulation.

Table 4.16 Correlations between the changes of the ranges and the changes of the averages of the dynamics in the standard manipulative training group for the P-A manipulation

Correlations[a]

			Change ave MFE Q2T early	Change ave MFE Q2T late	Change range MFE Q2T	Change ave MFE DOT deep	Change ave MFE DOT shallow	Change range MFE DOT	Change ave T	Change range T	Change ave RO	Change range RO	Change ave LOD	Change range LOD	Change ave rotation	Change range rotation	Change ave F	Change range F
Spearman's rho	Change ave MFE Q2T early	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave MFE Q2T late	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range MFE Q2T	Correlation Coefficient	.	.	1.000	-.282	.000	-.421	-.070	-.420	.280	.070	.105	-.071	-.193	-.249	-.035	.070
		Sig. (2-tailed)	.	.	.	.273	1.000	.093	.789	.093	.276	.789	.688	.788	.457	.334	.894	.789
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave MFE DOT deep	Correlation Coefficient	.	.	-.282	1.000	-.034	.500*	.125	.127	-.112	.097	-.390	.299	.391	.466	-.217	.317
		Sig. (2-tailed)	.	.	.273	.	.897	.041	.634	.627	.668	.710	.121	.244	.121	.059	.402	.215
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave MFE DOT shallow	Correlation Coefficient	.	.	.000	-.034	1.000	.363	-.131	-.296	-.386	-.139	-.397	-.186	-.383	-.033	.077	.235
		Sig. (2-tailed)	.	.	1.000	.897	.	.152	.617	.249	.126	.594	.114	.475	.129	.900	.768	.363
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range MFE DOT	Correlation Coefficient	.	.	-.421	.500*	.363	1.000	-.281	-.145	-.146	-.271	-.289	.190	.162	.453	.103	.066
		Sig. (2-tailed)	.	.	.093	.041	.152	.	.274	.579	.576	.292	.261	.465	.535	.068	.694	.800
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave T	Correlation Coefficient	.	.	-.070	.125	-.131	-.281	1.000	.652**	-.525*	.637**	-.066	.262	.018	-.223	-.838**	.451
		Sig. (2-tailed)	.	.	.789	.634	.617	.274	.	.005	.031	.006	.801	.310	.944	.389	.000	.069
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range T	Correlation Coefficient	.	.	-.420	.127	-.296	-.145	.652**	1.000	-.152	.733**	.028	.091	.070	-.111	-.412	.483*
		Sig. (2-tailed)	.	.	.093	.627	.249	.579	.005	.	.560	.001	.914	.727	.789	.672	.101	.050
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave RO	Correlation Coefficient	.	.	.280	-.112	-.386	-.146	-.525*	-.152	1.000	-.064	.147	-.052	.128	.086	.466	-.154
		Sig. (2-tailed)	.	.	.276	.668	.126	.576	.031	.560	.	.808	.573	.843	.624	.743	.060	.554
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range RO	Correlation Coefficient	.	.	.070	.097	-.139	-.271	.637**	.733**	-.064	1.000	-.182	.102	-.315	-.398	-.581*	.760**
		Sig. (2-tailed)	.	.	.789	.710	.594	.292	.006	.001	.808	.	.485	.696	.218	.114	.014	.000
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave LOD	Correlation Coefficient	.	.	.105	-.390	-.397	-.289	-.066	.028	.147	-.182	1.000	.206	-.027	-.434	.000	-.443
		Sig. (2-tailed)	.	.	.688	.121	.114	.261	.801	.914	.573	.485	.	.427	.918	.082	1.000	.075
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range LOD	Correlation Coefficient	.	.	-.071	.299	-.186	.190	.262	.091	-.052	.102	.206	1.000	.220	.249	-.584*	-.033
		Sig. (2-tailed)	.	.	.788	.244	.475	.465	.310	.727	.843	.696	.427	.	.397	.336	.014	.899
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave rotation	Correlation Coefficient	.	.	-.193	.391	-.383	.162	.018	.070	.128	-.315	-.027	.220	1.000	.670**	.053	-.357
		Sig. (2-tailed)	.	.	.457	.121	.129	.535	.944	.789	.624	.218	.918	.397	.	.003	.840	.159
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range rotation	Correlation Coefficient	.	.	-.249	.466	-.033	.453	-.223	-.111	.086	-.398	-.434	.249	.670**	1.000	.239	-.188
		Sig. (2-tailed)	.	.	.334	.059	.900	.068	.389	.672	.743	.114	.082	.336	.003	.	.355	.469
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave F	Correlation Coefficient	.	.	-.035	-.217	.077	.103	-.838**	-.412	.466	-.581*	.000	-.584*	.053	.239	1.000	-.321
		Sig. (2-tailed)	.	.	.894	.402	.768	.694	.000	.101	.060	.014	1.000	.014	.840	.355	.	.209
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range F	Correlation Coefficient	.	.	.070	.317	.235	.066	.451	.483*	-.154	.760**	-.443	-.033	-.357	-.188	-.321	1.000
		Sig. (2-tailed)	.	.	.789	.215	.363	.800	.069	.050	.554	.000	.075	.899	.159	.469	.209	.
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

a. Treatment group = Control group

In terms of the summary table (Table 4.15) and the correlation table (Table 4.16) for the SMTG for the P-A manipulation, it can be seen that in the analysis, with the change of range F being fixed to decrease, there was an internal incongruence of the changes of: range MFE DOT and av MFE DOT Deep; and range Rot and av Rot, as these dynamics did not link to range F either directly or indirectly. It is, however, noted that although there was no link between these dynamics and range F, they formed pockets of congruent significant relationships within the P-A manipulation. This indicates that these relationships were affected by either extraneous factors (beyond the bounds of this study) or non-linear relationships between these dynamics (Woodall and Montgomery, 1999; Triano, 1998).

Therefore, although the SMTG developed congruent significant relationships within pockets of the dynamics the group was unable to attain overall congruency between the dynamics. The analysis thus implies that the students in the SMTG were inconsistent in mastering the relationships between the change in the ranges and the change in the averages of the dynamics of manipulation as there was more than one manner in which these were combined over time. This is seen in Table 4.20 where the dynamics in ***italics*** indicate internal incongruence.

Furthermore, it is noted that the findings of the suggested relationship between range T, RO and F (Table 4.9), are in line with the findings of the correlation table (Table 4.16) where ranges T, RO and F act in a similar manner. This implies, as for the S-I manipulation analyses, that although these trends were drawn from different base analyses (i.e. median of ranges and median change of ranges); the outcomes are internally consistent and therefore reflective of the same trend.

4.6.3 Lateral to Medial (L-M) Manipulation

4.6.3.1 Analysis and Discussion of the Individual Dynamics

4.6.3.1.1 Analysis and discussion of the individual dynamics for the L-M manipulation within each intervention group

Table 4.17 represents a comparison of the median ranges of the dynamics of the L-M manipulation from pre- to post-training, within each intervention group (refer to Section 4.6.1.1 for explanation of the use of median ranges in the analysis).

Table 4.17 Comparison of the median ranges of the dynamics, within the intervention groups, for the L-M manipulation, over the training period.

			Time			*p* value
			Pre-training	Mid-training	Post-training	
			Median	Median	Median	
Intervention group	Tyre group	Range MFE Q2T	0.0	0.0	0.0	0.135
		Range MFE DOT	7.0	9.0	8.0	0.607
		Range T	322.0	223.0	163.0	0.247
		Range RO	400.0	231.0	293.0	0.627
		Range LOD (º)	1.4	.9	1.4	0.191
		Range Rotation (º)	1.0	1.0	2.0	0.486
		Range F (N)	100.0	111.0	66.0	0.627
	Elastic tubing group	Range MFE Q2T	0.0	0.0	0.0	0.819
		Range MFE DOT	12.5	17.0	12.5	0.316
		Range T	492.0	389.0	373.0	0.486
		Range RO	445.5	401.5	332.5	0.513
		Range LOD (º)	1.8	1.6	1.4	0.125
		Range Rotation (º)	1.5	1.0	2.0	0.219
		Range F (N)	234.5	141.0	212.0	0.223
	Standard manipulative training group	Range MFE Q2T	0.0	0.0	0.0	0.913
		Range MFE DOT	13.0	9.0	15.0	0.197
		Range T	219.0	114.0	481.0	0.056
		Range RO	105.0	228.0	459.0	0.174
		Range LOD (º)	1.8	1.8	0.9	0.736
		Range Rotation (º)	2.0	1.0	1.8	0.628
		Range F (N)	152.0	142.0	175.0	0.161

4.6.3.1.2 Discussion in terms of the median ranges of the dynamics achieved over time within each group for the L-M manipulation

Table 4.17 reflects that there were no statistically significant changes for any of the median ranges of the dynamics, in any of the groups, from pre- to post- training for the L-M manipulation. This indicates that none of the groups, received training that was effective in aiding the students in the development of improved control of the individual dynamics for the L-M manipulation (this would be indicated by a statistically significant decrease in the median ranges of the dynamics over time). Thus, it is apparent (as for the P-A and the S-I manipulation simulations) that neither the tyre nor the elastic tubing interventions were of any additional benefit to the standard manipulative training in terms of the development of improved control of the dynamics of manipulation for the L-M manipulation. As recorded in the P-A and S-I manipulation simulations, it is important to note that neither of the interventions adversely affected the standard manipulative training (this would be demonstrated by a statistically significant increase of the median ranges of the dynamics over time).

Although not denoted as statistically significant, a constant median range of a dynamic was seen to constitute maintained, but not improved, control of the dynamic from pre- to post-training within the group, as the student was able to reproduce a constant level of variability (by example Figure 4.2). Thus, it may be stated that none of the interventions had any effect on the level of control of the dynamics that the students demonstrated from the outset, and that at best the students maintained the level of control with which they started. It is however apparent that students were able to maintain a greater degree of control of some dynamics (e.g. MFE Q2T) than others, that were more variable (e.g. F in the TG).

The small sample size and length of the training program have been noted as possible limitations of the study that may have obstructed the ability of the study to attain statistically significant results in terms of the change in median ranges of the dynamics from pre- to post-training within the groups. It is recommended that future studies increase the length of training in an attempt to allow the interventions to have a greater effect on muscle physiology (Kraemer, Duncan and Volek, 1998; Robergs and Roberts, 1996). A larger sample size should also be considered in order to allow for the

exclusion of outlier measurements which would allow for the data to be summarised and analysed in a manner that is more representative of the group's tendencies.

As per the S-I and P-A manipulations, none of the changes in median ranges were noted as being statistically significant within the groups, thus the study can only comment on the trends of control observed within each group. In terms of these trends of control, with regard to comparisons of the median ranges of the dynamics the following trends were noted within the groups for the L-M manipulation (Table 4.17):

The TG showed (as explained in Figures 4.2 and 4.3 in Section 4.6.1.1.1):

- Decreased control of MFE DOT and Rot.
- Increased control of T, RO and F.
- A constant level of control of MFE Q2T and LOD.

The ETG showed (as explained in Figures 4.2 and 4.3 in Section 4.6.1.1.1):

- Decreased control of Rot.
- Increased control of T, RO, LOD and F.
- A constant level of control of MFE Q2T and MFE DOT.

The SMTG showed (as explained in Figures 4.2 and 4.3 in Section 4.6.1.1.1):

- Decreased control of MFE DOT, T, RO and F.
- Increased control of LOD and Rot.
- A constant level of control of MFE Q2T.

Thus for the L-M manipulation, as for the P-A and S-I manipulations, all groups showed a constant level of variability for MFE Q2T, indicating that all of the participants were able to control the application of simulated tissue slack removal (MFE Q2T) when applying the L-M manipulation technique. These results were expected due to the instructions given to the students and the sensory and visual stimuli given by the Dynadjust (refer to Section 4.6.1.1.1). Although not statistically significant, the trends seem to suggest that the ETG improved control over the greatest number of individual dynamics, followed by the TG and lastly by the SMTG. The ETG also decreased control over the lowest number of dynamics followed by the TG and lastly the SMTG. Similarly, in terms of the trends of control (with regard to comparisons of the median ranges of the dynamics) seen within the groups, the following dynamics were noted to either

collectively increase or collectively decrease within each group; T, RO and F. With respect to MFE DOT, LOD and Rotation no consistent pattern could be identified.

The collective results presented here suggest that for the L-M manipulation the change in range of the dynamics T, RO and F may show a correlation when the relationships between them are analysed, this contrasts with the dynamics of LOD and MFE DOT. This will, however, only be assessed in Section 4.6.3.2 when the correlations between the dynamics are discussed.

4.6.3.1.3 The inter-group statistical significance of the change in the medians of the ranges over time for the L-M manipulation

Table 4.18 represents the inter-group statistical significance generated by the comparisons of the median changes of the ranges of the dynamics, from pre- to post-training for the L-M manipulation (refer to Section 4.6.1.1.2 for explanation regarding the interpretation of positive and negative values).

Table 4.18 The inter-group statistical significance of the median change in the ranges of the dynamics over time for the L-M manipulation

	Intervention group			*p* value elastic versus control	*p* value tyre versus control	*p* value elastic versus tyre
	Tyre group	Elastic tubing group	Standard manipulative training group			
	Median	Median	Median			
Change range MFE Q2T	0.0	0.0	0.0	0.757	1.00	0.789
Change range MFE DOT	1.0	-3.0	1.0	0.134	0.710	0.421
Change range T	-291.0	-29.0	115.0	0.096	0.016	0.486
Change range RO	-45.0	-35.0	40.0	0.032	0.033	0.735
Change range LOD	0.0	-0.5	-0.9	0.832	0.176	0.135
Change range Rot	1.0	0.0	-0.3	0.502	0.313	0.656
Change range F	-4.0	9.5	33.0	0.287	0.064	0.401

4.6.3.1.4 Discussion in terms of the inter-group statistical significance of median changes of the ranges of the dynamics over time for the L-M manipulation

The results reveal that an inter-group statistical significance occurred between the TG and the SMTG in terms of median changes of the ranges RO (p= 0.033) and T (p=0.016). The negative values associated with the median change of ranges T and RO in the TG, compared to the positive values associated with the median change of ranges T and RO in the SMTG allows for the deduction that the TG improved in terms of their control of these dynamics to a greater degree as compared to the SMTG which tended toward a decrease in he control of theses dynamics (Esterhuizen, 2013) for the L-M manipulation.

A statistically significant difference also occurred between the ETG and the SMTG for the dynamic RO (p= 0.032), the negative value associated with the median change of range RO in the ETG and the positive value associated with the median change in range RO for the SMTG indicates that the ETG was significantly more able to control the dynamic of RO than the SMTG which tended towards a decrease in control of RO.

This is in keeping with the trends for control noted in Section 4.6.3.1.1, Table 4.17. Thus it can be concluded that the TG was able to control T and RO to a statistically greater extent than the SMTG, and the ETG was able to control RO to a statistically greater extent than the SMTG. The control of RO thus seemed to be most controlled by the TG, followed by the ETG, and lastly by he SMTG (which showed regression in the amount of control over RO). The control of T followed the same pattern between the groups.

Firm conclusions with regards to the relative improvement or regression of control of the remaining dynamics between the groups cannot be drawn, as there were no significant differences in the median changes of the ranges of these dynamics between groups. Therefore it is suggested that increased participants, increased training time (i.e. over a longer period) and increased numbers of training repetitions in the study should be considered in future studies in order to increase the likelihood of obtaining statistical significance and to confirm the preliminary findings of this study. Furthermore, strategies to ensure student participation throughout the duration of the study in order to prevent exclusion need to be considered. These suggestions would allow for possible verification of the results achieved in those dynamics that had significant outcomes.

4.6.3.2 Correlations

4.6.3.2.1 General explanation regarding correlation analysis

The general explanation regarding the correlation analysis is based on the discussion found in Section 4.6.1.2.1, however, it should be noted that in the context of the analysis of the L-M manipulation the correlation summary for the TG is based on: Table 4.19 derived from Table 4.20; for the ETG is based on: Table 4.21 as derived from Table 4.22; and for the SMTG is based on: Table 4.23 as derived from Table 4.24.

4.6.3.2.2 Correlations between the changes of the ranges and the changes of the averages of the dynamics of manipulation in the tyre group for the L-M manipulation

Table 4.19 Summary of the significant correlations between the dynamics in the tyre group for the L-M manipulation*

Range MFE DOT ↑↓	***Av MFE DOT Shallow*** ↑↓		
Av RO ↑↓	***Av T*** ↓↑ **(inverse)**		
Range RO ↑↓	***Av RO*** ↑↓		
Av LOD ↑↓	***Av MFE DOT Deep*** ↑↓		
Range LOD ↑↓	***Av LOD*** ↑↓		
Range Rot ↑↓	***Range MFE DOT*** ↑↓	***Av Rot*** ↑↓	
Av F ↑↓	***Av T*** ↓↑ **(inverse)**	***Av RO*** ↑↓	

*The table represents correlations that have a significant *p*-value and a significant correlation co-efficient **only**.

**The analysis was completed in the context of range F decreasing.

The ↓ symbol indicates a decrease in the dynamic (based on the relationship with range F).

The ↑ symbol indicates an increase in the dynamic (based on the relationship with range F)

Dynamics in ***italics*** indicate internal discordance of the dynamic in question, as well as discordance in its relationships with the other dynamics in the manipulation.

Table 4.20 Correlations between the changes of the ranges and the changes of the averages of the dynamics in the tyre group for the L-M manipulation

Correlations[a]

			Change ave MFE Q2T early	Change ave MFE Q2T late	Change range MFE Q2T	Change ave MFE DOT deep	Change ave MFE DOT shallow	Change range MFE DOT	Change ave T	Change range T	Change ave RO	Change range RO	Change ave LOD	Change range LOD	Change ave rotation	Change range rotation	Change ave F	Change range F
Spearman's rho	Change ave MFE Q2T early	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave MFE Q2T late	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range MFE Q2T	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave MFE DOT deep	Correlation Coefficient	.	.	.	1.000	-.314	.063	.091	.122	.052	.346	.575*	.490	.375	.074	-.129	.456
		Sig. (2-tailed)	.	.	.	.	.254	.824	.746	.665	.854	.206	.025	.064	.168	.792	.646	.088
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave MFE DOT shallow	Correlation Coefficient	.	.	.	-.314	1.000	.668**	-.120	.031	-.010	.033	-.056	.352	.195	.374	.138	-.401
		Sig. (2-tailed)	.	.	.	.254	.	.006	.670	.914	.971	.907	.842	.199	.486	.169	.624	.139
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range MFE DOT	Correlation Coefficient	.	.	.	.063	.668**	1.000	.063	-.088	-.102	.134	-.162	.488	.275	.592*	.016	-.131
		Sig. (2-tailed)	.	.	.	.824	.006	.	.824	.756	.717	.633	.564	.065	.320	.020	.955	.642
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave T	Correlation Coefficient	.	.	.	.091	-.120	.063	1.000	.382	-.696**	-.379	.034	.327	-.075	-.498	-.829**	-.236
		Sig. (2-tailed)	.	.	.	.746	.670	.824	.	.160	.004	.164	.904	.234	.789	.059	.000	.398
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range T	Correlation Coefficient	.	.	.	.122	.031	-.088	.382	1.000	-.121	.125	.054	-.016	.285	-.381	-.293	.432
		Sig. (2-tailed)	.	.	.	.665	.914	.756	.160	.	.666	.657	.849	.955	.302	.162	.289	.108
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave RO	Correlation Coefficient	.	.	.	.052	-.010	-.102	-.696**	-.121	1.000	.679**	-.134	-.458	.127	.198	.736**	.371
		Sig. (2-tailed)	.	.	.	.854	.971	.717	.004	.666	.	.005	.634	.086	.651	.480	.002	.173
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range RO	Correlation Coefficient	.	.	.	.346	.033	.134	-.379	.125	.679**	1.000	.102	-.048	.296	.337	.357	.486
		Sig. (2-tailed)	.	.	.	.206	.907	.633	.164	.657	.005	.	.718	.864	.284	.220	.191	.066
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave LOD	Correlation Coefficient	.	.	.	.575*	-.056	-.162	.034	.054	-.134	.102	1.000	.653**	.311	-.024	-.181	.182
		Sig. (2-tailed)	.	.	.	.025	.842	.564	.904	.849	.634	.718	.	.008	.259	.933	.520	.516
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range LOD	Correlation Coefficient	.	.	.	.490	.352	.488	.327	-.016	-.458	-.048	.653**	1.000	.357	.273	-.302	-.097
		Sig. (2-tailed)	.	.	.	.064	.199	.065	.234	.955	.086	.864	.008	.	.191	.324	.273	.732
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave rotation	Correlation Coefficient	.	.	.	.375	.195	.275	-.075	.285	.127	.296	.311	.357	1.000	.528*	.185	.379
		Sig. (2-tailed)	.	.	.	.168	.486	.320	.789	.302	.651	.284	.259	.191	.	.043	.509	.164
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range rotation	Correlation Coefficient	.	.	.	.074	.374	.592*	-.498	-.381	.198	.337	-.024	.273	.528*	1.000	.461	.119
		Sig. (2-tailed)	.	.	.	.792	.169	.020	.059	.162	.480	.220	.933	.324	.043	.	.084	.673
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change ave F	Correlation Coefficient	.	.	.	-.129	.138	.016	-.829**	-.293	.736**	.357	-.181	-.302	.185	.461	1.000	.118
		Sig. (2-tailed)	.	.	.	.646	.624	.955	.000	.289	.002	.191	.520	.273	.509	.084	.	.676
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
	Change range F	Correlation Coefficient	.	.	.	.456	-.401	-.131	-.236	.432	.371	.486	.182	-.097	.379	.119	.118	1.000
		Sig. (2-tailed)	.	.	.	.088	.139	.642	.398	.108	.173	.066	.516	.732	.164	.673	.676	.
		N	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

a. Treatment group = Tyre group

In terms of the summary table (Table 4.19) and the correlation table (Table 4.20) for the TG in the L-M manipulation, it can be seen that, there was internal incongruence of the changes of all of the dynamics (in the context of range F, as range F had no relationship with any of the noted significant dynamics on Table 4.20, making a link between these dynamics impossible to establish). This implies that the manipulations were inconsistently applied in the context of range F.

It is, however, noted that although there was no link between the dynamics and range F, pockets of congruent significant relationships within the L-M manipulation were formed. This indicates that these relationships were affected by either extraneous factors (beyond the bounds of this study) or non-linear relationships between the dynamics (Woodall and Montgomery, 1999; Triano, 1998).

The analysis thus implies that the students in the TG were inconsistent in mastering the relationships between the changes in the ranges and the change in the averages (in the context of range F) as there was more than one manner in which these were combined over time. This is seen in Table 4.19 where the dynamics in ***italics*** indicate internal incongruence.

Therefore, in terms of the development of internal congruence, the utilisation of tyre training as a supplement to the standard curriculum training seems to develop control in pockets of individual dynamics however, it develops limited control of how these dynamics are combined overall for the L-M manipulation.

In contrast to previous correlation tables (and similar to the ETG group in the P-A manipulation), the suggested relationship between range T, RO and F in Table 4.17, is not in keeping with the finding of the correlation table (Table 4.20), where the ranges T, RO and F act in a dissimilar manner. These results indicate that the data was not comparable. It is however beyond the bounds of this study to identify the variable(s) that resulted in this outcome and it is suggested that future studies investigate these variables more closely.

4.6.3.2.3 Correlations between the changes of the ranges and the changes of the averages of the dynamics of manipulation in the elastic tubing group for the L-M manipulation

Table 4.21 Summary of the significant correlations between the dynamics in the elastic tubing group for the L-M manipulation*

Range MFE Q2T ↓	Av MFE Q2T early ↓		
Range MFE DOT ↓	Av MFE DOT Shallow ↓		
Range T ↑	Av MFE DOT Deep ↑	Av T ↑	
Range RO ↑	Range T ↑		
Range Rot ↑↓	***Av LOD*** ↑↓	***Av Rot*** ↑↓	
Av F ↓	Range MFE Q2T ↓	Av T ↑	
Range F ↓	Range MFE Q2T ↓	Av F ↓	

*The table represents correlations that have a significant *p*-value and a significant correlation co-efficient **only**.

**The analysis was completed in the context of range RO decreasing.

The ↓ symbol indicates a decrease in the dynamic (based on the relationship with range RO).

The ↑ symbol indicates an increase in the dynamic (based on the relationship with range RO).

Dynamics in ***italics*** indicate internal discordance of the dynamic in question, as well as discordance in its relationships with the other dynamics in the manipulation.

Table 4.22 Correlations between the changes of the ranges and the changes of the averages of the dynamics in the elastic tubing group for the L-M manipulation

Correlations[a]

			Change ave MFE Q2T early	Change ave MFE Q2T late	Change range MFE Q2T	Change ave MFE DOT deep	Change ave MFE DOT shallow	Change range MFE DOT	Change ave T	Change range T	Change ave RO	Change range RO	Change ave LOD	Change range LOD	Change ave rotation	Change range rotation	Change ave F	Change range F
Spearman's rho	Change ave MFE Q2T early	Correlation Coefficient	1.000	.	.841**	-.034	.234	.199	-.278	-.054	.077	.089	.026	.048	-.233	.219	.418	.382
		Sig. (2-tailed)	.	.	.000	.893	.349	.429	.264	.832	.760	.726	.920	.851	.352	.382	.085	.118
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave MFE Q2T late	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range MFE Q2T	Correlation Coefficient	.841**	.	1.000	-.244	.235	.068	-.411	-.132	.176	.033	-.196	-.181	-.223	.031	.523*	.519*
		Sig. (2-tailed)	.000	.	.	.329	.347	.787	.090	.602	.484	.895	.437	.472	.373	.903	.026	.027
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave MFE DOT deep	Correlation Coefficient	-.034	.	-.244	1.000	.047	.327	.468	.574*	-.020	.226	.360	.159	.167	.313	-.343	-.246
		Sig. (2-tailed)	.893	.	.329	.	.852	.186	.050	.013	.938	.367	.142	.530	.508	.207	.163	.326
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave MFE DOT shallow	Correlation Coefficient	.234	.	.235	.047	1.000	.699**	-.333	-.310	-.320	-.417	-.081	-.243	-.065	.192	.302	.281
		Sig. (2-tailed)	.349	.	.347	.852	.	.001	.177	.211	.196	.085	.749	.332	.799	.446	.224	.259
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range MFE DOT	Correlation Coefficient	.199	.	.068	.327	.699**	1.000	-.226	-.082	-.187	-.481*	.004	.168	-.293	.063	.094	.026
		Sig. (2-tailed)	.429	.	.787	.186	.001	.	.366	.746	.457	.043	.987	.505	.238	.803	.710	.919
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave T	Correlation Coefficient	-.278	.	-.411	.468	-.333	-.226	1.000	.564*	-.447	.307	.155	.082	.247	.021	-.866**	-.453
		Sig. (2-tailed)	.264	.	.090	.050	.177	.366	.	.015	.063	.216	.539	.745	.322	.933	.000	.059
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range T	Correlation Coefficient	-.054	.	-.132	.574*	-.310	-.082	.564*	1.000	.211	.645**	.229	-.103	-.066	.021	-.373	.074
		Sig. (2-tailed)	.832	.	.602	.013	.211	.746	.015	.	.401	.004	.361	.684	.795	.935	.128	.769
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave RO	Correlation Coefficient	.077	.	.176	-.020	-.320	-.187	-.447	.211	1.000	.484*	-.024	-.068	-.409	-.198	.441	.247
		Sig. (2-tailed)	.760	.	.484	.938	.196	.457	.063	.401	.	.042	.925	.790	.092	.430	.067	.324
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range RO	Correlation Coefficient	.089	.	.033	.226	-.417	-.481*	.307	.645**	.484*	1.000	.077	-.227	-.043	-.013	-.148	.077
		Sig. (2-tailed)	.726	.	.895	.367	.085	.043	.216	.004	.042	.	.760	.365	.866	.960	.559	.760
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave LOD	Correlation Coefficient	.026	.	-.196	.360	-.081	.004	.155	.229	-.024	.077	1.000	.304	.196	.732**	.015	.229
		Sig. (2-tailed)	.920	.	.437	.142	.749	.987	.539	.361	.925	.760	.	.220	.436	.001	.951	.360
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range LOD	Correlation Coefficient	.048	.	-.181	.159	-.243	.168	.082	-.103	-.068	-.227	.304	1.000	-.065	.246	-.267	-.280
		Sig. (2-tailed)	.851	.	.472	.530	.332	.505	.745	.684	.790	.365	.220	.	.798	.326	.285	.260
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave rotation	Correlation Coefficient	-.233	.	-.223	.167	-.065	-.293	.247	-.066	-.409	-.043	.196	-.065	1.000	.512*	-.135	-.099
		Sig. (2-tailed)	.352	.	.373	.508	.799	.238	.322	.795	.092	.866	.436	.798	.	.030	.594	.695
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range rotation	Correlation Coefficient	.219	.	.031	.313	.192	.063	.021	.021	-.198	-.013	.732**	.246	.512*	1.000	.129	.282
		Sig. (2-tailed)	.382	.	.903	.207	.446	.803	.933	.935	.430	.960	.001	.326	.030	.	.609	.257
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change ave F	Correlation Coefficient	.418	.	.523*	-.343	.302	.094	-.866**	-.373	.441	-.148	.015	-.267	-.135	.129	1.000	.692**
		Sig. (2-tailed)	.085	.	.026	.163	.224	.710	.000	.128	.067	.559	.951	.285	.594	.609	.	.001
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
	Change range F	Correlation Coefficient	.382	.	.519*	-.246	.281	.026	-.453	.074	.247	.077	.229	-.280	-.099	.282	.692**	1.000
		Sig. (2-tailed)	.118	.	.027	.326	.259	.919	.059	.769	.324	.760	.360	.260	.695	.257	.001	.
		N	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

a. Treatment group = Elastic tubing group

In terms of the above summary table (Table 4.21) and the correlation table (Table 4.22) for the ETG for the L-M manipulation, in the analysis with the change of range F being fixed to decrease, there was an internal incongruence between some of the dynamics (av Rotation, range Rotation and av LOD) as these dynamics were not linked to range F, making a link between them impossible to establish. It is, however, noted that although the aforementioned dynamics were not linked to range F, they formed pockets of significant congruent relationships within the L-M manipulation. This indicates that the relationships between the dynamics that formed pockets of congruent relationships within the L-M manipulation were affected by either extraneous factors (beyond the bounds of this study) or non-linear relationships between these dynamics.

The analysis thus implies that the students in the ETG were inconsistent in mastering the relationships between the changes in the ranges and the changes in the averages as there was more than one manner in which these were combined over time. This is seen in Table 4.21 where the dynamics in ***italics*** indicate internal incongruence.

Therefore, although the ETG developed congruent significant relationships within pockets of the dynamics, the group was unable to attain overall congruency between the dynamics. The utilisation of elastic tubing training as a supplement to the standard manipulative training is thus limited in the development of control of how these dynamics are combined overall for the L-M manipulation.

Similar to the L-M manipulation for the TG correlation analysis, the suggested relationship between ranges T, RO and F in noted in Table 4.17, is not reflected in the findings of the correlation table (Table 4.22); as ranges T, RO and F act in a dissimilar manner. The results thus indicate that the data was not comparable. This implies that there is a variable that has influenced the relationship of these dynamics. It is however beyond the bounds of this study to identify this extraneous / these extraneous variable(s) and it is suggested that future studies look at this more closely.

4.6.3.2.4 Correlations between the changes of the ranges and the changes of the averages of the dynamics of manipulation in the standard manipulative training group for the L-M manipulation

Table 4.23 Summary of the significant correlations between the dynamics in the standard manipulative training group for the L-M manipulation*

Range MFE Q2T ↑↓	***Av MFE Q2T early*** ↑↓	
Range T ↑↓	***Av MFE DOT Deep*** ↑↓	***Av T*** ↑↓
Range RO ↑↓	***Range MFE Q2T*** ↑↓	
Range LOD ↑↓	***Av LOD*** ↑↓	
Av F ↑↓	***Av MFE DOT Deep*** ↓↑ **(inverse)**	***Av T*** ↓↑ **(inverse)**
Range F ↓	Ave RO ↓	

*The table represents correlations that have a significant *p*-value and a significant correlation co-efficient **only**.

**The analysis was completed in the context of range F decreasing.

The ↓ symbol indicates a decrease in the dynamic (based on the relationship with range F).

The ↑ symbol indicates an increase in the dynamic (based on the relationship with range F).

Dynamics in ***italics*** indicate internal discordance of the dynamic in question, as well as discordance in its relationships with the other dynamics in the manipulation.

Table 4.24 Correlations between the changes of the ranges and the changes of the averages of the dynamics in the standard manipulative training group for the L-M manipulation

Correlations[a]

			Change ave MFE Q2T early	Change ave MFE Q2T late	Change range MFE Q2T	Change ave MFE DOT deep	Change ave MFE DOT shallow	Change range MFE DOT	Change ave T	Change range T	Change ave RO	Change range RO	Change ave LOD	Change range LOD	Change ave rotation	Change range rotation	Change ave F	Change range F
Spearman's rho	Change ave MFE Q2T early	Correlation Coefficient	1.000	.	.549*	-.230	.418	.256	-.153	.051	.408	.408	.408	.409	.411	.424	.306	.408
		Sig. (2-tailed)	.	.	.022	.374	.095	.321	.557	.846	.104	.104	.104	.103	.101	.090	.232	.104
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave MFE Q2T late	Correlation Coefficient	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		Sig. (2-tailed)	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range MFE Q2T	Correlation Coefficient	.549*	.	1.000	-.002	-.017	.241	-.010	.318	.364	.527*	.242	.205	.095	.046	-.086	.223
		Sig. (2-tailed)	.022	.	.	.992	.947	.351	.970	.213	.151	.030	.349	.430	.718	.860	.744	.391
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave MFE DOT deep	Correlation Coefficient	-.230	.	-.002	1.000	-.431	-.049	.292	.700**	.015	.061	-.099	.041	-.051	.118	-.551*	.443
		Sig. (2-tailed)	.374	.	.992	.	.084	.851	.255	.002	.955	.815	.704	.877	.847	.652	.022	.075
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave MFE DOT shallow	Correlation Coefficient	.418	.	-.017	-.431	1.000	-.308	-.138	-.295	.014	.181	.232	.342	.263	.161	.238	-.032
		Sig. (2-tailed)	.095	.	.947	.084	.	.229	.598	.250	.956	.488	.370	.179	.309	.537	.358	.904
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range MFE DOT	Correlation Coefficient	.256	.	.241	-.049	-.308	1.000	-.369	-.010	.353	-.028	-.141	-.026	-.489*	.036	.162	.227
		Sig. (2-tailed)	.321	.	.351	.851	.229	.	.145	.970	.165	.914	.588	.920	.047	.892	.534	.380
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave T	Correlation Coefficient	-.153	.	-.010	.292	-.138	-.369	1.000	.652**	-.221	.194	.145	-.006	.340	.405	-.588*	-.360
		Sig. (2-tailed)	.557	.	.970	.255	.598	.145	.	.005	.395	.456	.580	.981	.181	.107	.013	.155
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range T	Correlation Coefficient	.051	.	.318	.700**	-.295	-.010	.652**	1.000	-.051	.358	-.010	.200	.137	.260	-.468	.096
		Sig. (2-tailed)	.846	.	.213	.002	.250	.970	.005	.	.844	.158	.970	.441	.600	.314	.058	.715
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave RO	Correlation Coefficient	.408	.	.364	.015	.014	.353	-.221	-.051	1.000	.194	.179	.172	-.146	.052	.154	.618**
		Sig. (2-tailed)	.104	.	.151	.955	.956	.165	.395	.844	.	.456	.492	.509	.577	.842	.554	.008
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range RO	Correlation Coefficient	.408	.	.527*	.061	.181	-.028	.194	.358	.194	1.000	-.218	.055	.221	-.010	-.221	.412
		Sig. (2-tailed)	.104	.	.030	.815	.488	.914	.456	.158	.456	.	.400	.833	.395	.969	.395	.101
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave LOD	Correlation Coefficient	.408	.	.242	-.099	.232	-.141	.145	-.010	.179	-.218	1.000	.565*	.281	.564*	.034	-.069
		Sig. (2-tailed)	.104	.	.349	.704	.370	.588	.580	.970	.492	.400	.	.018	.274	.018	.896	.794
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range LOD	Correlation Coefficient	.409	.	.205	.041	.342	-.026	-.006	.200	.172	.055	.565*	1.000	.164	.390	.178	.168
		Sig. (2-tailed)	.103	.	.430	.877	.179	.920	.981	.441	.509	.833	.018	.	.530	.122	.494	.518
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave rotation	Correlation Coefficient	.411	.	.095	-.051	.263	-.489*	.340	.137	-.146	.221	.281	.164	1.000	.460	-.216	.012
		Sig. (2-tailed)	.101	.	.718	.847	.309	.047	.181	.600	.577	.395	.274	.530	.	.063	.406	.963
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range rotation	Correlation Coefficient	.424	.	.046	.118	.161	.036	.405	.260	.052	-.010	.564*	.390	.460	1.000	-.373	.011
		Sig. (2-tailed)	.090	.	.860	.652	.537	.892	.107	.314	.842	.969	.018	.122	.063	.	.140	.965
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change ave F	Correlation Coefficient	.306	.	-.086	-.551*	.238	.162	-.588*	-.468	.154	-.221	.034	.178	-.216	-.373	1.000	.012
		Sig. (2-tailed)	.232	.	.744	.022	.358	.534	.013	.058	.554	.395	.896	.494	.406	.140	.	.963
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17
	Change range F	Correlation Coefficient	.408	.	.223	.443	-.032	.227	-.360	.096	.618**	.412	-.069	.168	.012	.011	.012	1.000
		Sig. (2-tailed)	.104	.	.391	.075	.904	.380	.155	.715	.008	.101	.794	.518	.963	.965	.963	.
		N	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

a. Treatment group = Control group

In terms of the above summary table (Table 4.23) and the correlation table (Table 4.24) for the standard manipulative training group for the L-M manipulation, it can be seen that, in the analysis, with the change of the range of F being fixed to decrease there was an internal incongruence of the changes of all dynamics with the exception av RO (viz. range MFE Q2T and av MFE Q2T early; range T, av MFE DOT deep and av T; range RO and range MFE Q2T; range LOD and av LOD; and av F, av MFE DOT deep and av T) as these dynamics did not have a link to range F either directly or indirectly, making a link between them individually, impossible to establish. It is however noted that although the aforementioned dynamics were not linked to range F, they were able to form pockets of significant congruent relationships within the L-M manipulation. This indicates that the relationships between the dynamics that formed pockets of congruent relationships within the L-M manipulation were affected by either extraneous factors (beyond the bounds of this study) or non-linear relationships between the dynamics.

The analysis thus implies that the students in the SMTG were inconsistent in mastering the relationships between the change in the ranges and the change in the averages, as there was more than one manner in which these were combined over time. This is seen in Table 4.23 where the dynamics in ***italics*** indicate internal incongruence. Therefore, although the SMTG developed congruent significant relationships within pockets of the dynamics, the group was unable to attain overall congruency between the dynamics. The utilisation of the standard manipulative training is thus limited in the development of control of the combination of the dynamics overall for the L-M manipulation.

Similar to the L-M manipulation for the TG and ETG correlation analyses, the suggested relationship between ranges T, RO and F in Table 4.17 (to collectively behave in the same manner), does not correspond with the finding of the correlation table (Table 4.23) for the L-M manipulation, which show ranges T, RO and F to act in a dissimilar manner. The results thus indicate that the data was not comparable. This implies that there is a variable that has influenced the relationship of these dynamics. It is however beyond the bounds of this study to identify this / these variable(s) and it is suggested that future studies look at this more closely.

4.6.4 Comparison between the groups and manipulations: discussion

The following section highlights a summary of the findings and considers the outcomes in terms of the literature before commenting on the null hypothesis which was rejected as linked to the objectives stated in Chapter One.

Table 4.25 Comparison between the groups with regard to the development of control over the dynamics of manipulation for the S-I manipulation

S-I Manipulation	Tyre group	Elastic tubing group	Standard manipulative training group
Number of dynamics for which control increased, decreased and was maintained (trends)	3 increased 3 constant 1 decreased	0 increased 3 constant 4 decreased	2 increased 2 constant 3 decreased
	Range T, RO and F suggested to follow similar pattern collectively	Range T, RO and F suggested to follow similar pattern collectively	Range T, RO and F suggested to follow similar pattern collectively
Significant difference between groups with regard to control of individual dynamics	Improved control of F versus SMTG Other dynamics not significantly different	No significant difference between groups with regard to control of individual dynamics	Regression of control of F versus TG Other dynamics not significantly different
Correlations	Incongruent	Incongruent	Congruent
T, RO and F relationship confirmed	Yes	Yes	Yes

With regards to the outcomes of the S-I manipulation Table 4.33 indicates that:

The TG showed a trend of improved control for three dynamics (T, RO and F) and significantly improved control of F as compared to the SMTG. The correlation analysis confirmed the trend of ranges T, RO and F behaving in a similar manner. However, the coordination between the dynamics for the TG was poor and incongruent.

This compares with the ETG which had a similar combination of ranges T, RO and F that were comparable in the individual analysis and the correlation statistics, but with the tendency to regress collectively (indicating decreased control). Additionally, the ETG had a high number of dynamics that showed a trend towards regressed control and showed poor and incongruent coordination between the dynamics.

The SMTG had a similar combination of ranges T, RO and F that were comparable in the individual analysis and the correlation statistics, but with the tendency to regress

(indicating decreased control). The SMTG fared worse than the TG, but better than the ETG in terms of the trends of control of individual dynamics. The SMTG was shown to be significantly worse at controlling F than the TG. The SMTG's coordination between the dynamics was congruent and good, which was in contrast to that of the TG and ETG.

These results were unexpected as the literature would suggest that additional rehearsal / practise in a functional activity for a particular action should aid in the development of the psychomotor skill (Kraemer, Duncan and Volek, 1998; Fitts and Posner, 1967). As manipulation is a psychomotor skill (Triano *et al.*, 2006), and control is an element of manipulative skill (Cohen *et al.*, 1995; Triano *et al.*, 2006), additional specific resistance training (done by the tyre and elastic tubing groups) in the S-I direction within the parameters of the specific S-I manipulation for which the dynamics were measured should have resulted in improved control of the dynamics of the S-I manipulation in these two intervention groups when compared to the SMTG.

Additionally, Table 4.33 shows that the only significant difference between the intervention groups (TG and ETG) and the SMTG was in the fact that the TG was able to improve control over the dynamic F to a greater degree than the SMTG, although control of the dynamic of F itself within the TG did not significantly improve.

Therefore, the results for the control of the dynamics of manipulation for the S-I manipulation can be contextualised with the objectives in the following way:

Objective One:

> To determine whether elastic tubing resistance training in multiple planes as an adjunct to standard manipulative training at Durban University of Technology (DUT), versus standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation.

> The results showed that the ETG achieved a trend of increased control over fewer individual dynamics of manipulation than the SMTG. There was no statistical significance between the level of control the ETG was able to attain over the dynamics of manipulation as compared to the level of control the SMTG was able to attain over the dynamics of manipulation. Furthermore, ETG was not able to

achieve consistency of the relationships between the dynamics, whereas the SMTG was able to do so. Therefore, no conclusive difference could be found between these groups

Based on statistically significant findings, the null hypothesis is not rejected (viz. there is no difference between the groups).

Objective Two:

To determine whether tyre resistance training in a single plane, as an adjunct to standard manipulative training at DUT, versus standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation.

The results showed that the TG was able to achieve a trend of increased control over a greater number of individual dynamics than the SMTG. The TG was also significantly more able to control F than the SMTG. In terms of controlling the relationships between the dynamics, the SMTG performed better than the TG. Therefore, no conclusive difference could be found between these groups.

Based on statistically significant findings, the null hypothesis is not rejected (viz. there is no difference between the groups).

Objective Three:

To determine whether elastic tubing resistance training in multiple planes as an adjunct to standard manipulative training at DUT, versus tyre resistance training in a single plane, as an adjunct to standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation.

The results showed that the ETG achieved a trend of control over fewer individual dynamics than the TG. Furthermore, there was no significant difference in the ETG's ability to control any of the dynamics of manipulation as compared to the TG's ability to control any of the dynamics of manipulation. In terms of controlling the relationship between the dynamics, the groups performed equally as poorly as neither groups were able to attain internal consistency of the relationships within the manipulation. Therefore, the TG performed better than the ETG only in the

trend for improvement of control of the individual dynamics. Therefore, no conclusive difference could be found between these groups.

Based on statistically significant findings, the null hypothesis is not rejected (viz. there is no difference between the groups).

Thus, in terms of the efficacy of the intervention groups to improve control of the dynamics of manipulation for the S-I manipulation when compared to each other and to the SMTG, neither of the intervention groups, nor the SMTG was able to effectively improve overall control of the dynamics of manipulation. Qualitatively, the analysis indicates that the null hypothesis may be rejected if the recommendations (as set out in the following chapter) are addressed in future research.

Table 4.26 Comparison between the groups with regard to the development of control over the dynamics of manipulation for the P-A manipulation

P-A Manipulation	Tyre group	Elastic tubing group	Standard manipulative training group
Number of dynamics for which control increased, decreased and was maintained (trends)	5 increased 2 constant 0 decreased	1 increased 2 constant 4 decreased	1 increased 2 constant 4 decreased
	T, RO and F suggested to follow similar pattern collectively	T, RO and F suggested to follow similar pattern collectively	T, RO and F suggested to follow similar pattern collectively
Significant difference between groups with regard to control of individual dynamics	Increased control of F versus SMTG Other dynamics not significantly different	No significant difference between groups with regard to control of individual dynamics.	Decreased control of F versus TG Other dynamics not significantly different
Correlations	Incongruent	Incongruent	Incongruent
T, RO and F relationship confirmed	Yes	No	Yes

With regards to the outcomes of the P-A manipulation Table 4.34. indicates that:

The TG showed a trend of improved control for five dynamics (including T, RO, F), and significantly improved control of F as compared to the SMTG. The correlation analysis confirmed the trend of ranges T, RO and F behaving in a similar manner. However, coordination between the dynamics for the TG was poor and incongruent

This is in contrast with the ETG which had a similar combination of T, RO and F, acting in a similar manner, but with the tendency for the control of these dynamics to collectively regress. This was not corroborated in the correlation table (which showed these dynamics acted dissimilarly). The ETG had a high number of dynamics that showed a trend towards regressed control and showed poor and incongruent coordination between the dynamics.

The SMTG had a similar combination of T, RO and F that were comparable in the individual analysis and the correlation statistics, but with the tendency for control of theses dynamics to regress collectively. The SMTG had a comparable number of dynamics that showed a trend toward regressed control as the ETG. The coordination between the dynamics of manipulation for the SMTG was also poor and incongruent.

These results were unexpected as the literature would suggest that additional rehearsal and practise (such as resistance training) in a functional activity for a particular action should aid in the development of the psychomotor skill (Kraemer, Duncan and Volek, 1998; Fitts and Posner, 1967). As manipulation is a psychomotor skill (Triano *et al.*,

2006), and control is an element of manipulative skill (Cohen *et al.*, 1995; Triano *et al.*, 2006), additional specific resistance training (done by the elastic tubing group) in the P-A direction within the parameters of the specific P-A manipulation for which the dynamics were measured, should have resulted in improved control of the dynamics of the P-A manipulation in the ETG as compared to the TG and the SMTG.

Table 4.34 therefore shows that there was no significant difference between the ETG and the TG or the SMTG in the development of overall control of the dynamics of manipulation. Furthermore, it shows that the only significant difference that occurred between the groups for the P-A manipulation, occurred between TG and the SMTG in that the TG was able to improve control over the dynamic F to a greater degree than the SMTG, although control of the dynamic of F itself within the TG did not significantly improve.

The results for the control of the dynamics of manipulation for the P-A manipulation can be contextualised with the objectives in the following way:

Objective One:

> To determine whether elastic tubing resistance training in multiple planes as an adjunct to standard manipulative training at Durban University of Technology (DUT), versus standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation.

> It was found that the ETG and the SMTG achieved a trend of control over the same number of individual dynamics of manipulation. There was no statistical significance between the level of control the ETG was able to attain over the dynamics of manipulation as compared to the level of control the SMTG was able to attain over the dynamics of manipulation. Furthermore, neither the ETG nor the SMTG was able to achieve consistency of the relationships between the dynamics for the P-A manipulation. Therefore, no conclusive difference could be found between these two groups.

> Based on statistically significant findings, the null hypothesis is not rejected (viz. there is no difference between the groups).

Objective Two:

To determine whether tyre resistance training in a single plane, as an adjunct to standard manipulative training at DUT, versus standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation.

It was found that the TG achieved a trend of control over a greater number of individual dynamics than the SMTG. The TG was also significantly more able to control F than the SMTG. Furthermore, neither the TG nor the SMTG was able to achieve consistency of the relationships between the dynamics for the P-A manipulation. Therefore the TG was superior to the SMTG in the trends of development of control of the dynamics of manipulation as well as the degree to which it was able to control F as compared to the SMTG however, neither groups were able to achieve consistency between the dynamics for the P-A manipulation. Therefore, no conclusive difference could be found between these two groups.

Based on statistically significant findings, the null hypothesis is not rejected (viz. there is no difference between the groups).

Objective Three:

To determine whether elastic tubing resistance training in multiple planes as an adjunct to standard manipulative training at DUT, versus tyre resistance training in a single plane, as an adjunct to standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation.

It was found that the ETG achieved control over fewer individual dynamics than the TG. Furthermore, there was no significant difference in the ETG's ability to control any of the dynamics of manipulation as compared to the TG's ability to control any of the dynamics of manipulation. In terms of controlling the relationships between the dynamics, the groups performed equally as poorly as neither the ETG nor the SMTG were able to attain internal consistency of the relationships between the dynamics within the P-A manipulation. Therefore the TG performed better than ETG only in the individual dynamic improvement and no conclusive difference could be found between these two groups.

Based on statistically significant findings, the null hypothesis is not rejected (viz.

there is no difference between the groups).

Thus, in terms of the efficacy of the intervention groups to improve control of the dynamics of manipulation for the P-A manipulation compared to each other and to the SMTG, neither the intervention groups, nor the SMTG was able to effectively improve overall control of the dynamics of manipulation. These results are unexpected and similar to those seen for the S-I manipulation. Qualitatively, the analysis indicates that the null hypothesis may be rejected if the recommendations (as set out in the following chapter) are addressed in future research.

Table 4.27 Comparison between the groups with regard to the development of control over the

dynamics of manipulation for the L-M manipulation

L-M Manipulation	Tyre group	Elastic tubing group	Standard manipulative training group
Number of dynamics for which control increased, decreased and was maintained (trends)	3 increased 2 constant 2 decreased	4 increased 2 constant 1 decreased	2 increased 1 constant 4 decreased
	T, RO and F suggested to follow similar pattern collectively	T, RO and F suggested to follow similar pattern collectively	T, RO and F suggested to follow similar pattern collectively
Significant difference between groups with regard to control of individual dynamics	Increased control of T and RO versus SMTG Other dynamics not significantly different	Increased control of RO versus SMTG Other dynamics not significantly different	Decreased of control of T and RO versus TG Regression of control of RO versus ETG Other dynamics not significantly different
Correlations	Incongruent	Incongruent	Incongruent
T, RO and F relationship confirmed	No	No	No

With regards to the outcomes of the L-M manipulation, Table 4.35 indicates that:

The TG showed a trend of improved control for three dynamics (including T, RO, F), and significantly improved control of T and RO as compared to the SMTG. The correlation analysis did not confirm the trend of ranges T, RO and F behaving in the same manner collectively. Furthermore, coordination between the dynamics for the TG was poor and incongruent.

This compares with the ETG which showed a trend of improved control for four dynamics (including T, RO and F) and significantly improved control of RO as compared to the SMTG. The correlation analysis did not either corroborate the trend of T, RO and F behaving in a similar manner but rather showed these dynamics to act dissimilarly. Furthermore, coordination between the dynamics for the ETG was poor and incongruent.

These groups contrast with the SMTG which showed a trend of control of two dynamics which did not include T, RO or F. Rather, T, RO and F showed a trend of decreased control collectively. The SMTG was significantly worse at controlling T and RO than the TG and was significantly worse at controlling RO than the ETG. The correlation table did not corroborate the trend for T, RO and F to behave in a similar manner, and showed coordination between the dynamics of manipulation to be incongruent and poor.

These results were unexpected as the literature would suggest that additional rehearsal /

practise in a functional activity for a particular action / skill should aid in the development of the psychomotor skill (Kraemer, Duncan and Volek, 1998; Fitts and Posner, 1967). As manipulation is a psychomotor skill (Triano *et al.*, 2006), and control is an element of manipulative skill (Cohen *et al.*, 1995; Triano *et al.*, 2006), additional specific resistance training (done by the elastic tubing group) in the L-M direction within the parameters of the specific L-M manipulation for which the dynamics were measured, should have resulted in improved control of the dynamics of the L-M manipulation in the ETG as compared to the TG and the SMTG.

From the above L-M manipulation the following results were obtained with regards to the objectives:

Objective One:

To determine whether elastic tubing resistance training in multiple planes as an adjunct to standard manipulative training at Durban University of Technology (DUT), versus standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation.

It was found that the ETG achieved a trend of control over a greater number of individual dynamics of manipulation than the TG. The ETG was also significantly more able to control RO than the SMTG. Furthermore, neither the ETG nor the SMTG was able to achieve congruency of the relationships between the dynamics of the L-M manipulation. Therefore, no conclusive difference could be found between these two groups.

Based on statistically significant findings, the null hypothesis is not rejected (viz. there is no difference between the groups).

Objective Two:

To determine whether tyre resistance training in a single plane, as an adjunct to standard manipulative training at DUT, versus standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation.

The results showed that the TG achieved a trend of control over a greater number

of individual dynamics of manipulation than the SMTG. The TG was also significantly more able to control T and RO than the SMTG. Furthermore, neither the TG nor the SMTG was able to achieve congruency of the relationships between the dynamics of the L-M manipulation. Therefore, no conclusive difference could be found between these two groups.

Based on statistically significant findings, the null hypothesis is not rejected (viz. there is no difference between the groups).

Objective Three:

Determine whether elastic tubing resistance training in multiple planes as an adjunct to standard manipulative training at DUT, versus tyre resistance training in a single plane, as an adjunct to standard manipulative training at DUT, resulted in improved control of the dynamics of manipulation (viz. speed, force, line of drive and degrees of rotation).

The results showed that the ETG was able to achieve a trend of control over a greater number of individual dynamics than the TG. Furthermore, there was no significant difference in the ETG's ability to control any of the dynamics of manipulation as compared to the TG's ability to control any of the dynamics of manipulation. In terms of controlling the relationship between the dynamics, the groups performed equally as poorly as neither of the groups was able to attain internal congruency of the relationships within the manipulation. Therefore the TG performed better than the ETG only in the trends of improvement of the control of individual dynamics and no conclusive difference could be found between these two groups.

Based on statistically significant findings, the null hypothesis is not rejected (viz. there is no difference between the groups).

Thus, in terms of the efficacy of the intervention groups to improve control of the dynamics of manipulation for the L-M manipulation compared to each other and to the SMTG, neither the intervention groups, nor the SMTG was able to effectively improve overall control of the dynamics of manipulation. These results are

unexpected and similar to those seen for the S-I and P-A manipulations. Qualitatively, the analysis indicates that the null hypothesis may be rejected if the recommendations (as set out in the following chapter) are addressed in future research.

4.7. Critical analysis of the outcomes of the study

In order to conclude this chapter, a short critical analysis is given before Chapter Five presents the conclusions and recommendations. As can be seen from the review of objectives, the null hypothesis was not rejected for the three objectives outlined. A critical review of the methodology of the study provides the following insights:

- The methodology applied in the study required the students within the intervention groups (TG and ETG) to perform 300 thrusts per hand, per training session in order to standardise the training. The 300 thrusts per hand in the tyre group were however all performed in a single direction, whereas the 300 thrusts per hand in the ETG were divided into 100 thrusts in each direction. Thus the relative effect of muscle training (Robergs and Roberts, 1996) would have been greater in the TG for the direction in which they trained (S-I) as compared to the ETG in the three directions in which they trained (S-I; P-A; L-M). In light of this, in order to be able to equitably compare the relative effects of these training methods, the number of thrusts performed in training would need to be standardised in terms of number of thrusts per direction trained rather than number of thrusts per hand. Furthermore, it would be expected that the increased relative effect of muscle training in the tyre group for the S-I manipulation should have resulted in far greater significant findings in terms of the development of control of the dynamics of manipulation, as their training in the S-I direction was in effect three times the amount of the training of the elastic tubing training in the S-I direction. The lack of improved overall control of the dynamics for the TG in face of the advantage it had in training, underscores the conclusion that training with tyre resistance as an adjunct to the standard manipulative training does not aid in the development of control of the dynamics of manipulation.

- Tyre resistance training was chosen to be compared to elastic tubing resistance training as it was postulated that students would improve control of the dynamics of manipulation only in the directions in which they trained (i.e. tyre resistance training would result in improved control of the dynamics of manipulation for the S-I manipulation and elastic tubing resistance training would result in improved control of the dynamics of manipulation for the S-I; P-A and L-M manipulations)

(Kraemer, Duncan and Volek, 1998; Robergs and Roberts, 1996). The difference in resistance material of these two training aids may however have had more of an effect on the muscle training than the fact that they were used to train students in single versus multiple planes. Thus, any differences in the results of these training methods cannot be attributed to the fact that students were trained in different directions alone.

- The tyre resistance training occurred in a single plane on a stable platform, whereas the elastic tubing training required spatial awareness and conscious effort on the behalf of the students in order to ensure that the thrusts were performed in pure vectors. The stability of the tyre training method may lend itself to improving the control of the dynamics of manipulation in translatory or linear motions where as the elastic tubing resistance training may lend itself more to improving the control of the dynamics of manipulation in curvilinear motions (which were not tested on the Dynadjust) due to the demands of special awareness that were required (Kaufman, Wiegand and Tunick, 1987).

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study set to evaluate the effect of additional resistance training techniques for students being trained in manipulative therapy. Therefore, elastic tubing and tyre resistance training techniques were evaluated against the standard curriculum training in order to determine the effect of these training techniques in the development of control within and between the dynamics of manipulation. This was accomplished through a six week training program. Measurements of the dynamics of manipulation were taken before the resistance training commenced, mid-training (to ensure students remained competent and familiar with the measurement tool), and post-training. The various dynamics of manipulation that were assessed included time (T), force (F), line of drive (LOD), degrees of rotation(Rot), time for which tissue slack was held (RO),margin for error from target depth of thrust (MFE DOT deep, MFE DOT shallow, MFE DOT) and margin for error cue to thrust (MFEQ2T). These dynamics were assessed for control utilising ranges (therefore trial-to-trial) as well as in terms of the congruency between the dynamics.

In the evaluation of the outcomes of the study, it was found that contrary to the literature, there were no statistically significant differences with regards to the improvement of control for any of the individual dynamics in any of the groups for any of the manipulations performed. Additionally, there was only one group that developed internal congruency between the individual dynamics and this was the standard manipulative training group, which attained these outcomes in the S-I manipulation. Notwithstanding these results, there was a significant improvement of the tyre training group, with regards to change in the range F when compared to the Standard manipulative training group (in the P-A and S-I manipulations). This was also evident for the change in the ranges RO and T between the tyre group and the standard manipulative training group; and the change in the range RO between elastic tubing group and the standard manipulative training group (in the L-M manipulation).

Therefore, none of the groups were statistically better at attaining improved control overall from pre- to post-training. Additionally, it should be noted that the groups showed no significant signs of regression of control, thus indicating that control was maintained through the study at the baseline levels.

5.2 Recommendations

5.2.1 Methodological recommendations

- This study was a pragmatic study and compared training types according to those utilised within training institutions. This comparison has its limitations as there are differences between the groups that could not be accounted for in the analysis and discussion. These differences are :
    - The degree of resistance provided by the training tools within the groups.
    - The degree of training performed (number of repetitions) in each group and the subsequent effect on neuro-motor training provided by the training tools.

  Therefore, it is suggested that future studies consider these limitations when verifying the results of this study.

- A further limitation with regard to the generation of statistical significance may have been the duration of the training intervention period. It is suggested that future studies consider an increased length of time for the intervention groups in order to increase the likelihood of any significant change, particularly as this study may have been limited in measuring the effects of the interventions on muscle physiology, which may have required a longer period of training (Robergs and Roberts, 1997).

- From a statistical vantage point, future studies need to consider an increase in the sample sizes of the intervention groups. An increased sample size would allow for the exclusion of outlier readings (and utilisation of means rather than medians to draw analyses and conclusions) and would also enable a more accurate reflection of larger student population groups participating in these

activities. Furthermore, strategies to retain students and ensure their participation throughout the duration of the study need to be considered.

- Due to the limitation of the small sample size, the manner in which the data could be analysed was limited, as outliers could not be excluded without compromising the analysis possibilities. Thus, the study was limited to using median values, to summarise the data, which allowed only for typical values to be computed and analysed as opposed to averages (means). It is thus recommended that future studies of this type be conducted at larger training institutions where greater number of students can take part in the study. This would allow for outliers to be excluded and the use of averages to be used in computations and analyses.

- The study addressed the effect of the different resistance training methods on the level of variability of the dynamics of manipulation (control) between consecutive manipulations at different time points utilising ranges. Due to significant outliers in the data, statistical analysis was limited to the use of medians when analysing the data. The results were thus limiting in that they only provided information on whether the different training methods enabled participants to improve their control of the dynamics of manipulation (decrease trial-to-trial variability) and could not provide information regarding whether the control was achieved at clinically appropriate magnitudes.

- Statistically the use of ranges as a measure of variability is accepted (Woodall and Montgomery, 1988); however there is a paucity of literature (Moritani, 1993) around the application of this principle in a practical setting (such as manipulation). Further research would therefore need to be conducted in order to further validate the outcomes of this study.

5.2.2 Practical / professional recommendations

- In this study, students were not given feedback regarding the level of control at the different measurement stages as it has been shown that feedback has

an effect on performance and thus would have detracted from the efficacy of the various training methods. According to Descarreaux *et al.,* (2006) and Triano *et al.,* (2003) quantitative feedback given simultaneously with motor skill performance may result in better performance than delayed feedback or no feedback at all. Therefore it is suggested that future research consider and test this.

- Future studies could also consider the use of alternative training methods that are commonly utilised in the training of manipulative therapies (e.g. a bosu ball or gym ball or elastic tubing) and compare these to standard curriculum training.

- Future studies should also consider appropriate incentives for student participation in order to decrease the likelihood of participant attrition over the period of the study.

- Future studies should consider the development of reference ranges on the Dynadjust for the attainment of optimal manipulation dynamics, which could be utilised within the teaching setting to improve student progression through the stages of learning.

APPENDIX A

Letter of Information and Informed Consent to the Subject

Dear Student,

Welcome to my research study and thank you for your time in reading this letter and considering participation.

Title of Research Study:

The effectiveness of elastic band resistance training versus tyre resistance training as an adjunct to the standard manipulative training programme at Durban University of Technology in the development of control of the dynamics of manipulation in chiropractic students.

Principle Investigators:

Tarryn Mey (Tel no: 076 873 0516)

Supervisors:

Dr. Charmaine Korporaal (Tel no: 031 373 2611)

Dr. Reed Philips (reedp@dut.ac.za)

Brief Introduction and Purpose of Study:

The study aims to use the Dynadjust as a measurement tool to assess the results of band and tyre resistance training as an adjunct to the standard manipulative training programme at Durban University of Technology (DUT). The main purpose is to determine which method/s of training yields the most control over the dynamics of manipulation.

Outline of procedures:

All third and fourth year students will be given the opportunity to voluntarily take part in the study, which is at no cost to the students. If you choose not to participate in the study you will be excluded and will not be discriminated against by either the lecturer, or the researcher, in any way.

Should you voluntarily choose to participate in the research, you will be required to take part in a 6 week training program that will be held at the Durban University of Technology (DUT) in the practical room before and after Chiropractic Principles and Practice practical lectures. Each week two training sessions, of thirty minutes each, will be held. Prior to commencement of the training program, you will also receive a training session on the Dynadjust, which will be used for data capture.

Failure to attend the Dynadjust training session and/ or a minimum of 80% of the resistance training sessions will result in your withdrawal from the study. Should you incur any injuries during the course

of the study that prevent your participation in the resistance training programme, you will also be withdrawn.

Participating students will be divided into 3 groups. One will continue with the standard manipulative training programme employed by DUT and will not take part in the resistance training program. The other two groups will be assigned to either elastic band or tyre resistance training in addition to the standard manipulative training programme employed by DUT.

Measurements on the Dynadjust will be taken prior to commencement of the training program, half way through, and at the end. All measurements/ results will be concealed until the study is completed and you will not be updated with regard to your progress throughout the training. This method of data collection may simulate a test scenario and is thus potentially stressful for you. The researcher will do her best to minimise the stress.

Based on motor learning theories, the resistance training methods should help you develop greater control over the dynamics of manipulation and as an incentive; all students who choose to participate in the study will be given a resistance band at the end of the study.

No research related injuries are anticipated, although with both forms of resistance training being an exercise, it is expected that you may have transient stiffness related to your participation in the training programme. This is expected to subside as you continue with and become accustomed to the training programme.

I trust that you will consider taking part in the research.

Persons to Contact in the event of any problems or queries:

Principle Investigators:	Tarryn Mey	(Tel no: 076 873 0516)
Supervisors:	Dr. Charmaine Korporaal	(031 3732611)
	Dr. Reed Philips	(reedp@dut.ac.za)
Research Administrator		(031 3732900)

Statement of Agreement to participate in the Research study: I _____ (subjects name) _____ (ID number) have read this document in its entirety and understand its contents. Where I had any questions or queries, these have been explained to me by_____ to my satisfaction. Furthermore, I fully understand that I may withdraw from this study at any stage without any adverse consequences and my future health will not be compromised. I, therefore, voluntarily agree to participate in this study.

Name (print) _____ Signature: _____
Date: _____

Researcher's name _____ Researcher's signature: _____
Date: _____

Witness name (print) _____ Witness signature: _____
Date: _____

APPENDIX B

To whom it may concern, Prepak Products

Thank you for your time in reading this letter. I wish to inform you that I will be using your product (ExerBand) in my research project outlined below. Your product will not be named specifically at any point in the write up of the research or any subsequent publication. It is however required by our Institutional Research and Ethics Committee that we inform you of the use of your product.

Below is an outline of my proposed research topic:

Title and Purpose of Research Study:
The effectiveness of elastic band resistance training versus tyre resistance training as an adjunct to the standard manipulative training programme at Durban University of Technology in the development of control over the dynamics of manipulation in chiropractic students.

The study aims to use a devise called the Dynadjust as a measurement tool to assess the changes in the dynamics of manipulation in students trained with elastic band and tyre resistance as an adjunct to the standard manipulation training programme at DUT. The main purpose is to determine which method/s of training yields the most control over the dynamics of manipulation.

Outline of procedures:
All third and fourth year students registered for Chiropractic Principles and Practice (CPP) 3 and CPP 4 will be given the opportunity to take part in the study. If they do not wish to participate, or have any injuries that would prevent them from being able to participate in the training, they will be excluded.

Students who choose to participate in the study will be required to take part in a 6 week training program that will be held at Durban University of Technology (DUT) in the practical room before or after Chiropractic Principles and Practice practical lectures. Participating students will be divided into 3 groups. One group will continue with the standard curriculum training alone and will not take part in the resistance training program. The other two groups will be assigned to either band or tyre resistance training in addition to the standard curriculum training. Students who fall into the intervention groups will not be deprived of set practical lecture time in the curriculum, as lectures will commence before or after each 30 minute training session.

Students who wish to participate, will be required to complete pre, mid and post data collection on the Dynadjust. This method of data collection may simulate a test scenario and is thus potentially stressful for students; however the researcher will do her best to minimise the stress by ensuring familiarity with the tool and scheduling measurement days in periods of minimal academic stress. Due

to the fact that both forms of resistance training are exercises, it is expected that students may have transient stiffness related to their participation in the training programme. This is expected to subside as they continue with and become accustomed to the training programme.

No research related injury is anticipated, although with both forms of resistance training being a form of exercise, it is expected that students may have transient stiffness related to their participation in the training programme. This is expected to subside as they continue with and become accustomed to the training programme.

Based on motor learning theories, training with the fore mentioned resistance methods should allow students to develop greater control over the dynamics of manipulation. Such positive findings will provide motivation to add resistance training an adjunct to the standard manipulative training programme of DUT to yield superior manipulative skills on leaving the institution.

Students will be required to attend a Dynadjust training session as well as 80% of the training sessions. Failure to attend the stipulated training, and or injury that inhibits students from partaking in the training sessions will result in exclusion from the study.

In order to ensure confidentiality, students will be assigned an alphanumerical identity (ID) which will be used to store their measurements under on spreadsheets stored on the researcher's computer. The researcher will be the only individual with access to the list of corresponding names to the alphanumerical IDs.

Persons to Contact in the event of any problems or queries:

Principle Investigators:

Tarryn Mey	(Tel no: 076 873 0516)

Co-Investigators:

Dr. Charmaine Korporaal	(031 3732611)
Dr. Reed Philips	(reedp@dut.ac.za)

Research Administrator (031 3732900)

Many Thanks

……	**…….**
Tarryn Mey	**Dr C Korporaal**
Research student	**Research supervisor**

APPENDIX C

DURBAN UNIVERSITY of TECHNOLOGY

INSTITUTIONAL RESEARCH ETHICS COMMITTEE (IREC)

19 June 2012

IREC Reference Number: **REC 24/12**

Ms T R Mey
567 Currie Road
Musgrave

Dear Ms Mey

The effectiveness of elastic band resistance training versus tyre resistance training as an adjunct to the standard manipulative training programme at Durban University of Technology in the development of control of the dynamics of manipulation in chiropractic students.

I am pleased to inform you that Full Approval has been granted to your proposal REC 24/12, subject to the following amendment:

- Points 1 and 4 from the document titled 'corrections and recommendations IREC (4-06-2012)' should be included in the proposal.

The Proposal has been allocated the following Ethical Clearance number IREC 016/12. Please use this number in all communication with this office.

Approval has been granted for a period of one year, before the expiry of which you are required to apply for safety monitoring and annual recertification. Please use the Safety Monitoring and Annual Recertification Report form which can be found in the Standard Operating Procedures [SOP's] of the IREC. This form must be submitted to the IREC at least 3 months before the ethics approval for the study expires.

Any adverse events [serious or minor] which occur in connection with this study and/or which may alter its ethical consideration must be reported to the IREC according to the IREC SOP's. In addition, you will be responsible to ensure gatekeeper permission.

Please note that any deviations from the approved proposal require the approval of the IREC as outlined in the IREC SOP's.

Yours Sincerely

[redacted]

Dr D F Naude
Chairperson: IREC

APPENDIX D1

Group: ET

	Session 1		Session 2		Session 3		Session 4		Session 5		Session 6		Session 7		Session 8		Session 9		Session 10		Session 11		Session 12	
M-L																								
Set 1																								
Set 2																								
Set 3																								
Set 4																								
Set 5																								
Sign																								
P-A																								
Set 1																								
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Sign																								
S-I																								
Set 1																								
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Set 4																								
Set 5																								
Sign																								

Name of student:
Year of student

APPENDIX D2

Group: TG

	Session 1		Session 2		Session 3		Session 4		Session 5		Session 6		Session 7		Session 8		Session 9		Session 10		Session 11		Session 12	
P-A																								
Set 1																								
Set 2																								
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Set 13																								
Set 14																								
Set 15																								
Sign																								

Name of student:
Year of student

APPENDIX E

Hello, Tarryn

Last sign in: 2013-02-12 04:25:12

Download DynAdjust Sync Software

Set	Date	Successful
153	2012-10-08	91.7%
152	2012-10-08	66.7%
151	2012-09-14	75.0%
150	2012-09-14	8.3%
149	2012-09-14	58.3%
148	2012-09-14	16.7%
147	2012-09-14	75.0%
146	2012-09-14	75.0%
145	2012-09-14	50.0%
144	2012-09-14	50.0%
143	2012-09-14	58.3%
142	2012-09-14	0.0%
141	2012-09-14	66.7%
140	2012-09-14	50.0%
139	2012-09-14	75.0%
138	2012-09-14	91.7%
137	2012-09-14	91.7%
136	2012-09-14	8.3%
135	2012-09-14	41.7%
134	2012-09-14	75.0%
133	2012-09-14	8.3%
132	2012-09-14	0.0%
131	2012-09-14	66.7%
130	2012-09-14	41.7%
129	2012-09-14	83.3%
128	2012-09-14	33.3%
127	2012-09-14	41.7%
126	2012-09-14	75.0%
125	2012-09-14	25.0%
124	2012-09-14	91.7%
123	2012-09-14	0.0%
122	2012-09-14	83.3%
121	2012-09-14	8.3%
120	2012-09-10	66.7%
119	2012-09-10	25.0%
118	2012-09-10	100.0%
117	2012-09-10	25.0%
116	2012-09-10	41.7%
115	2012-09-10	83.3%

153 Total Sets

Set# 153 Exercise Name: CG 1

Dominant Hand: N/A

Notes:

Update Result Set

Queue to Thrust: 30mm MFE: 5mm Spring Selection: Yellow

Depth of Thrust: 30mm MFE: 10mm Timing: Standard

Successful Thrusts: 11 — 91.7%

Insufficient Depth: 0 — 0%

Excessive Depth: 1 — 8.3%

Loss of Pre-Tension: 0 — 0%

Avg. Thrust Time	120.8ms
Avg. Reaction Time	360.5ms
Avg. Deviation/Line	3.9%
Avg. Axial Rotation	1.7°
Avg. Force	364.5N

#	MFE Q2T	MFE DoT	T (ms)	RO (ms)	LoD (%)	AR°	F (N)
1	0	-6	125	539	3	1	517
2	0	6	160	500	5	0	316
3	0	12	139	315	1	1	418
4	0	-4	202	398	1	1	186
5	0	1	133	343	9	5	457
6	0	3	140	375	3	3	412
7	0	7	465	169	6	2	39
8	0	2	140	460	4	1	412
9	0	-5	113	361	2	0	633
10	0	-9	121	408	4	1	552
11	0	4	147	316	4	2	374
12	0	4	415	161	5	3	46

12 Thrusts

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