The Acute Effect of Dynamic Neural Mobilization Exercise versus Static Stretching on Muscular Strength and Power in Martial Artists

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DECLARATION

I Michael Ellefsen declare that this research report is my own work. It is being submitted for the degree of Master of medicine in the branch of Biokinetics at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.

Michael Ellefsen

Michael Ellefsen

29th day of July 2024

Date

DEDICATION

This research report is dedicated to the two most special people in my life. My wife Lisa and my beautiful baby daughter Faye. I’m sure the three of us will have plenty of good times being healthy and exercising together.

PRESENTATIONS ARISING FROM THIS STUDY

This study has not been presented at any conferences or academic meetings.

ABSTRACT

BACKGROUND: The effect of dynamic neural mobilisation exercise on muscular strength and power and jump power in martial artists is currently unknown. Stretching techniques are commonly used within exercise programmes, warm-ups, conditioning sessions, and cool-downs to achieve benefits and improve fitness. The benefits of stretching in some cases accompany consequences to strength and power, which may decrease subsequent physical performance, including competitive sport performance or even impact activities of daily living. Prolonged static stretching (>1 minute) causes stretch induced strength loss reducing performance of subsequent strength and power tasks, but it is not known whether neural mobilisation exercise also reduces strength and power. Biokineticists and others involved in exercise can make better decisions and plans to maximize benefits and minimize harms to their clients by knowing the effects of specific exercise techniques like static stretching and dynamic neural mobilisation exercise.

OBJECTIVES: To determine the acute effect of static stretching on muscular strength, power and jump power in martial artists. To determine the acute effect of dynamic neural mobilisation exercise on strength, power and jump power in martial artists. To determine whether there is a difference between the acute effects of static stretching and dynamic neural mobilisation exercise on muscular strength, power and jump power in martial artists.

METHODS: A randomised controlled trial measured the effects of static stretching and dynamic neural mobilisation exercise on 93 martial artists (75 male and 18 female, apparently healthy participants, aged 26.3 ± 4.5 years from Mixed Martial Arts, Jiu jitsu, Karate, Kung fu and Taekwondo). The sample was split into three equal groups (control, static stretching and dynamic neural mobilisation, n = 31) using randomisation software. Participants were randomised equally within gender and martial art to each group. At individual appointments, they received an information sheet, informed consent, biographic and screening questionnaire. Baseline testing included height, weight, BMI and three skinfolds. Warm-up was a five-minute stationary cycle (25 to 75 watts at 40 to 60% Heart Rate Reserve). Dominant then non-dominant leg isokinetics followed at 60, 180 and 300º.s^{-1} with familiarisation trials before each speed with inter-set (120 seconds) and inter-side rest (180 seconds). Counter Movement Jump (CMJ) immediately followed with three submaximal familiarisation trials and five maximal attempts. A 15-minute recovery-period of sitting or slow, gentle walking followed, before the control or experimental conditions. The control was 10 minutes of sitting or slow, gentle walking. The static stretching group did 1-minute of dominant leg supine assisted hamstring static stretch with cervical extension and ankle plantar flexion at the point of “maximum tolerated stretch”, alternated with the non-dominant leg for 5 sets and 10 minutes total. The dynamic neural mobilisation exercise group did 1 minute of seated dominant leg alternating knee extension flexion with neck, thoracic spine and ankle maintained in flexion and till the point of “maximum tolerated stretch” alternated with the non-dominant leg for 5 sets and 10 minutes total. Post-test Isokinetics and CMJ and a stationary cycle cool-down followed. Data analysis used SPSS. Paired t-tests compared pre-, and post-test means. One-Way between-subjects ANOVAs and Bonferroni post hoc tests compared post-test means. Descriptive statistics were generated for all variables. Data was tested for normality and outliers and significance was accepted at 95% (p = 0.05).

RESULTS: Ninety-three martial artists (age: 26.3 ± 4.5 years) were included in this study. **Anthropometry:** Body mass: 74.9 ± 14.4 kg, height: 173.5 ± 8.9 cm; body mass index: 24.8 ± 7.6 kg.m^{-2}, body fat percent: 14 ± 7.6%, fat mass: 10.8 ± 7.1 kg and lean mass: 64 ± 11.6 kg. **Muscle strength:** No significant differences were identified between post-test means for control, static stretching, and dynamic neural mobilisation (DNME) with one-way between-subjects analysis of variances (ANOVA). Significant decreases and increases ($p \leq 0.05$) were identified in the pre-post comparison with paired t-tests. In knee extension (dominant leg), significant changes were identified for absolute peak torque (aPT), peak torque / body weight (PT/BW) in all groups. The largest decreases were at 60º.s^{-1} (DNME and static stretching: ~∆ -10.6% and control group ~∆ -6.8%). In knee flexion (non-dominant) at 180º.s^{-1}, for the control group there were significant increases in absolute peak torque (78.13 ± 22.27 to 81.58 ± 23.02 NM, p = 0.02) and peak torque / body weight (102.31 ± 21.23 to 106.43 ± 20.09 Nm.kg^{-1}, p = 0.03), however there were no changes in the static stretch of DNME groups. In knee extension (non-dominant leg) at 60º.s^{-1}, static stretching significantly decreased aPT (189.12 ± 43.47 to 191.12 ± 40.56 Nm, $p < 0.001$) and PT/BW (295.76 ± 44.19 to 263.87 ± 39.78 Nm.kg^{-1}) without changes in the control or DDME groups. **Mean Power:** In knee flexion (dominant leg), DNME significantly decreased mean power at 60, 180 and 300º.s^{-1}, without changes in the static stretching or control group. In knee extension (non-dominant leg) and flexion (non-dominant leg), static stretching significantly increased mean power, without changes in the control or DNME group. **Jump power:** No significant changes in counter movement jump scores were identified in pre-post or post-post comparisons in any group.

Conclusion: In pre-post comparison, 10 minutes of both static stretching and dynamic neural mobilisation led to significant ($p \leq 0.05$) acute decreases in muscle strength and power for knee extension and flexion at 60, 180, 300º.s^{-1} in martial artists, even after prior physical exercise. Effects differed per leg and per speed and were in some cases accompanied by significant decreases in the control group. Only static stretching increased mean power in non-dominant leg knee flexion and extension at 300º.s^{-1}. Increases in the control group at 180º.$^{s-1}$ did not occur in static stretching or DNME groups. Jump power was unchanged. Between-subjects ANOVA identified no significant differences between post-test means for control and static stretching or dynamic neural mobilisation exercise, which could suggest small effect sizes or high sample variance. This study suggests that in pre-post comparison both static stretching and dynamic neural mobilisation similarly decreased performance, however post-post comparison identified no significant difference from control.

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LIST OF DEFINITIONS

1 Repetition maximum: A maximal strength test which aims to determine the maximum resistive load used to successfully perform a single repetition of a selected exercise to measure maximum strength.

Active stretch: A type of dynamic stretching which involves moving a limb through its full range to the end ranges and repeating several times.[1]

Afferent fibres: Neurons which carry information from sensory receptors to the central nervous system for processing.

Alpha (α) motor neuron: A neuron which has cell bodies in the ventral horn of the spinal cord, and which transmits efferent signal to skeletal muscle.

Biokinetics: The field of science concerned with the scientific prescription of exercise for the treatment and rehabilitation of injury and performance and the management of chronic disease.

Biokineticist: A Health Care Practitioner specialized in exercise rehabilitation and management of chronic disease, as registered with the Health Professionals Council of South Africa within the board of Physical Therapy, Podiatry and Biokinetics.[2]

Ballistic stretch: A type of dynamic stretching which involves rapid alternating movements or 'bouncing' at the end-range of motion.[1]

Constant torque stretch: A stretching technique using a specialized device to provide a constant load while stretching statically.

Concentric muscle action: A type of isotonic muscle action characterised by shortening with the development of tension.

Coefficient of variance: Cut off points, indicating upper limits of variability for repeated isokinetic maximal efforts, which may indicate submaximal efforts during strength testing.[3]

Dynamic stretching: A controlled movement through the range of motion of an active joint.

Deep tendon reflex: See stretch reflex.

Dynamic neural mobilization exercise: An active movement which aims to develop tension in the peripheral nerves.

Efferent fibres: Neurons which carry motor information from the central nervous system to recruit muscles.

Eccentric action: A type of isotonic muscle action characterised by lengthening of a muscle with the development of tension.

Extrafusal fibres: The force producing fibres within a skeletal muscle.[4]

Explosive strength: The ability to produce force as quickly as possible during a rapid voluntary muscular contraction.[5]

Flexibility: The range of motion available at a joint.[6]

Fast twitch fibres: Muscle fibres which have a higher contraction velocity and usually generate greater force, than slow twitch fibres.

Gamma (γ) motor neuron: A neuron which has cell bodies in the ventral horn of the spinal cord and received afferent signal from sensory receptors in skeletal muscle.

Golgi tendon organ: A sensory organ within human tendons, which senses the tensile force that tendon is under.

Gamma motor neuron: A motor efferent neuron which forms the output portion of the stretch reflex circuit.

Isokinetics: A method for measuring muscle performance characteristics while the speed of movement is controlled.

Isometric muscle force: The force generated by the contraction of muscle without an accompanying change in muscle length and usually measured with a dynamometer.

I**ntrafusal fibres**: Specialized fibres within a muscle spindle around which wrap afferents generate action potentials in response to mechanical stretching of the intrafusal fibres.[4]

Isometric action: A type of isotonic muscle action characterised by a generation of tension without a change in the muscle length.

Isotonic action: A type of muscle action where the external load remains the same, while the length of the muscle action changes including concentric and eccentric isotonic contractions.

Isolated static stretching: A static stretching protocol which is performed alone without an associated warm-up protocol.

Jump height: The maximum vertical height achieved during a jump attempt and the difference between minimum and maximum heights of the sole of the foot during jumping.

Passive stretch: A traditional type of static stretching which involves holding a specific position and degree of tension where a stretch sensation is elicited.[1]

Partner-assisted stretch: Stretching which involves a partner assisting the stretch movement by manually moving the person into a position of stretch.

Muscle extensibility: The ability of a muscle to extend to a predetermined end point.[7]

Muscle stiffness: The magnitude of change in tension per unit of change in length.[7]

Maximum voluntary contraction: The maximum force-generating capacity of a human muscle or group of muscle.[8]

Muscle spindles: Fusiform proprioceptors found within the perimysium of skeletal muscle and consisting of intrafusal fibres enclosed within a connective tissue capsule.[9]

Mean power: The average power score achieved during an isokinetic test.

Mono-synaptic stretch reflex: See stretch reflex.

Myotatic reflex: See stretch reflex.

Multiple repetition maximum: A sub-maximal strength test which aims to determine the maximum resistive load which can be used to successfully perform multiple repetitions of a selected exercise for the estimation of maximum strength.

Nervi nervorum: The intrinsic innervation of the peripheral nerves, which include mechanically sensitive nociceptive nerve endings, and are suggested the anatomical basis of physical sensation of the peripheral nerves themselves.

Neurodynamic mobilisation: See dynamic neural mobilisation exercise.

Neuromobilisation: See dynamic neural mobilisation exercise.

Nerve glide exercise: See dynamic neural mobilisation exercise

Neural mobilisation exercise: An exercise which aims to repetitively move the peripheral nerves through movements of the limbs or body.

Peak torque: The maximum value of torque achieved during an isokinetic test and expressed in Newton Meters (Nm).

Power: The rate of force generation, calculated as the quotient of power and time and expressed in Watts.

Post exercise potentiation: A theory which states that the history of muscle contractions influences the mechanical performance of subsequent contractions.[10,11]

Post exercise performance enhancement: A phenomenon that leads to acute improvements in muscle performance which occur more than 28 seconds after activity.[12,13]

Rate of force development: Calculated as the slope of the joint moment-time curve (change moment / change time).[14]

Range of motion: The amount of movement of available to a joint, expressed as degrees around an axis of rotation.

Relative peak torque: The ratio of peak torque: body weight.

Slow twitch fibres: Also fatigue resistant fibres. A type of skeletal muscle fibre characterised by greater aerobic activity and fatigue resistance.

Static stretching: Static stretching involves elongating a muscle until the point of sensation or discomfort is reached and then holding the elongated position for a certain amount of time.[1]

Stretch reflex: Also called the myotatic reflex, mono-synaptic stretch reflex, stretch reflex or the deep tendon reflex. The contraction of muscle in response to passive stretch by increasing its contractility.[15]

Slider: This term is used synonymously with nerve/neural slider. A nerve exercise involving generating tension in the nervous system by distracting on side of the peripheral nervous system away, whilst the remainder of the system remains stationary.[16]

Static passive torque: The torque applied to a force-meter by a body segment without active muscular contraction, usually due to the elasticity of tissues, for example the ankle plantar-flexor musculature.[17]

Static neural mobilization exercise: An exercise technique in which aims to mobilise the nerves then holds a static range of motion when “stretch sensation” reaches a predetermined intensity.

Strength: The ability of muscle to exert force.

Torque: Rotational aspect of a moment of force.

Total stretch time: The total amount of time spent stretching during a stretching routine.

Tensioner: Also, nerve/neural tensioner A nerve exercise involving generating tension in the nervous system by lengthening the proximal and distal sides of a nerve simultaneously.[16]

Volume: The total number of repetitions or work performed during an exercise. Usually, the repetitions of an exercise technique multiplied by the number of sets of the exercise technique performed.

Work: Calculated as the quotient of work and time.

Wattage: The unit of power.

LIST OF ABBREVIATIONS

1RM:	One Repetition Maximum
aPT:	Peak Torque
ANOVA:	Analysis of Variance
ANCOVA:	Analysis of Covariance
BMI:	Body Mass Index
CMJ:	Counter Movement Jump
CoV:	Coefficient of Variance
GTO:	Golgi Tendon Organ
MVC:	Maximum Voluntary Contraction
MMA:	Mixed Martial Arts
MP:	Mean Power
Nm:	Newton meter
DNME:	Dynamic Neural Mobilisation Exercise
PAPE:	Post Exercise Performance Enhancement
PT/BW:	Peak torque / Body Weight
RCT:	Randomized Controlled Trial
ROM:	Range of Motion
SS:	Static Stretching
SPSS:	Statistics Package for Social Sciences
VJ:	Vertical Jump
W:	Watts

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CHAPTER 1: PROBLEM IDENTIFICATION

The subtopics that will be covered in this chapter include:

1.1 Introduction and problem

Dynamic stretching is recommended during warm-up[18,19] to prepare for intense physical activities, such as martial arts.[20] Dynamic stretching, however, can decrease subsequent isokinetic peak torque, isokinetic power and counter movement jump power depending on stretch characteristics.[21] Neural tension can limit hamstring flexibility[22], may elicit sensation free hip range of motion[23], may lead to stretch-induced strength loss after static stretching exercise[24] and could contribute to stretch-induced strength loss subsequent to dynamic exercise by neurophysiological mechanisms, which may include dysregulation at the motoneuronal level.[25] Dynamic neural mobilisation exercises are similar to dynamic stretches, but focus on tensioning neural[16], rather than muscular structures[26], through specific joint positioning. Dynamic neural mobilisation exercises may be a useful tool in warm-up and martial arts training.

Martial arts involve a combination of muscular power[27] and flexibility[28] with successful competitors scoring highly in both attributes.[29–31] Successful performance of techniques, such as, jumps and kicks is related to isokinetic peak torque, mean power output and counter movement jump power.[16,32–34] Stretching is used for training in traditional and contemporary styles[28,32] with specific types of stretching leading to specific training outcomes and stretch specific types and characteristics to lead to specific effects.[33]

Common types of stretching include static, dynamic and ballistic stretches[34], although many other techniques, such as proprioceptive neuromuscular facilitation have been proposed.[35] Static stretching involves moving a limb to the end of its range of motion and holding position for 15 to 60 seconds.[36] Static stretches of durations greater than 60 seconds have been found to reliably decrease subsequent maximal isokinetic peak torque.[33] Dynamic stretching involves controlling the movement through the active range of motion of the joint.[37] Ballistic stretching involves a rapid uncontrolled movement that may include bouncing.[21] Stretching can lead to stretch-induced strength loss during subsequent strength tasks[33,36,38–40], counter movement jump[41], and is influenced by characteristics including velocity[42], duration[33,39], intensity[43–45] and neural tension.[24]

Neural mobilisation is a movement-based intervention, aimed at restoring the homeostasis in and around the nervous system.[46] Neural mobilisation exercises are found in qi-gong[47], pilates[48], yoga[49] and have been studied in athletic[50–53] and healthy populations[54,55], as tools to improve hamstring flexibility and post-exercise recovery.[56] Active neural mobilisation exercises include static and dynamic variations, as well as “sliders” and “tensioners”.[57] Static neural exercises involve moving until a pre-determined level of sensation, either the onset of sensation[23] or maximal tolerated sensation[24] and holding position for set time. McHugh et al. performed static stretching in a “muscular” vs. “neural” position and stretched till maximum tolerated intensity for 60 seconds and found that only “neural” positions induced stretch-induced strength loss.[24] Dynamic neural exercises involve repeating a cycle of movement until the onset of sensation, and then releasing for a set interval of time.[57] Sliders develop tension in one end of a peripheral nerve by lengthening that end and concurrently releasing the other, using a specific combination of joint positions.[16] Tensioners cause stretching in neural connective tissues by lengthening the nerve proximally and distally simultaneously.[16]

To the researcher’s knowledge, the acute effect of dynamic neural mobilisation exercise on isokinetic peak torque, power and counter movement jump power has not been studied. Insight into dynamic exercise allows biokineticists, sports physicians, sport scientists, coaches, and physiotherapists to effectively plan, implement and prescribe specific training programmes for fitness, rehabilitation and athletic conditioning and common dynamic stretches can be easily modified to emphasise neural structures. This study will help to fill the knowledge gap in the literature of static stretching, dynamic neural mobilisation exercise and muscular strength, power, and jump power.

1.2 Aim

To determine the acute effects of static stretching versus neural mobilisation exercise on muscular strength, power output and vertical jump power in martial artists.

1.3 Research question

The research question using the PICO framework[58] is: “In martial artists, what are the acute effect of static stretching and dynamic neural mobilisation exercise on muscle strength, power and jump power compared to a control condition and do they differ?”

1.4 Objectives

i. To determine the acute effects of static stretching on muscular strength, power and jump power in martial artists.
ii. To determine the acute effects of dynamic neural mobilisation exercise on muscular strength, power and jump power in martial artists.
iii. To determine whether there is a difference between the effects of static stretching and dynamic neural mobilisation exercise on muscular strength, power and jump power in martial artists.

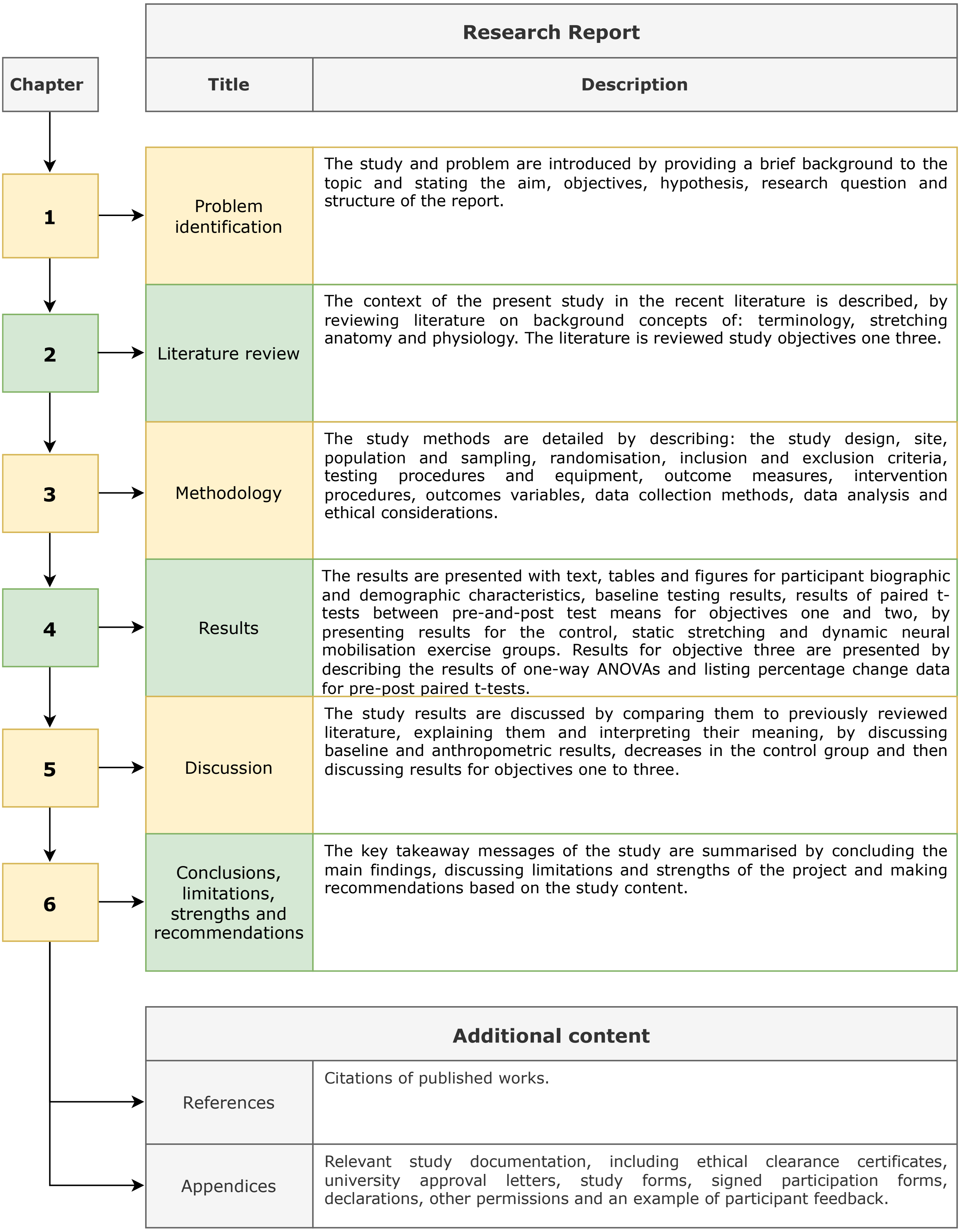
1.5 Hypothesis

H_0: An acute bout of dynamic neural mobilisation exercise does not result in a decrease in muscular strength, power or counter movement jump power, when compared to an acute bout of static stretching.

H_1: An acute bout of neural mobilisation exercise results in a decrease in muscular strength, power and counter movement jump power when compared to static stretching.

1.6 Structure of research report

This research report is structured around six chapters, as shown in Figure 1. These include problem identification, literature review, methodology, results, discussion and conclusion, strengths, limitations, and recommendations. The chapters are followed by references and appendices.



Research Report

Chapter	Title	Description
1	Problem identification	The study and problem are introduced by providing a brief background to the topic and stating the aim, objectives, hypothesis, research question and structure of the report.
2	Literature review	The context of the present study in the recent literature is described, by reviewing literature on background concepts of: terminology, stretching anatomy and physiology. The literature is reviewed study objectives one three.
3	Methodology	The study methods are detailed by describing: the study design, site, population and sampling, randomisation, inclusion and exclusion criteria, testing procedures and equipment, outcome measures, intervention procedures, outcomes variables, data collection methods, data analysis and ethical considerations.
4	Results	The results are presented with text, tables and figures for participant biographic and demographic characteristics, baseline testing results, results of paired t-tests between pre-and-post test means for objectives one and two, by presenting results for the control, static stretching and dynamic neural mobilisation exercise groups. Results for objective three are presented by describing the results of one-way ANOVAs and listing percentage change data for pre-post paired t-tests.
5	Discussion	The study results are discussed by comparing them to previously reviewed literature, explaining them and interpreting their meaning, by discussing baseline and anthropometric results, decreases in the control group and then discussing results for objectives one to three.
6	Conclusions, limitations, strengths and recommendations	The key takeaway messages of the study are summarised by concluding the main findings, discussing limitations and strengths of the project and making recommendations based on the study content.

Additional content

References	Citations of published works.
Appendices	Relevant study documentation, including ethical clearance certificates, university approval letters, study forms, signed participation forms, declarations, other permissions and an example of participant feedback.

Figure 1 Structure of the research report

CHAPTER 2: LITERATURE REVIEW

The subtopics that will be covered in this chapter include:

2.1 Introduction

This section reviews the literature on the acute effects of static stretching and dynamic neural mobilisation exercise in martial artists. Static stretching and dynamic neural mobilisation are briefly be introduced. Recent literature is discussed relating to the acute effect of static stretching, dynamic neural mobilisation exercise in martial artists. This, where possible, provides an understanding of the current state of knowledge of these effects in martial artists, recent developments and changes in thinking, a context for the current study and how it fills a gap in the literature. Where few or no articles matching the tests and population of the current study were identified, related articles were included.

2.2 Terminology

Stretching and neural mobilisation involve similar movements but are considered separately in the literature. Stretching targets muscles[1], while neural mobilisation targets the nervous system.[46] An exercise example of stretching technique is a seated hamstring stretch, while a sciatic slider is an example of a neural mobilisation technique. The mechanisms of stretching and neurodynamic mobilisation are also different. Stretching increases the distance between a muscles' anatomical origin and insertion,[1] while neurodynamic mobilisation increases nerve length by repositioning structures which surround the nerve (the mechanical interface).[59] Common subclassifications of stretching include static, dynamic and ballistic, while neurodynamic mobilisation can include dynamic or static tensioners, sliders, openers, closers. Static stretching involves holding a muscle in a lengthened position for a prescribed length of time.[60] Dynamic stretching involves controlling a moving limb through the active range of motion without bouncing,[61] while ballistic stretching is generally, rapid, uncontrolled and can included bouncing.[21]

Sliding mobilisations involve two or more joint movements, with some loading and others simultaneously unloading the nervous system.[62] An example is the sciatic slider technique. Tensioners slide nerves relative to surrounding structures by emulating neurodynamic tests,[63] usually with two or more joint movements, which simultaneously loading the nervous system. Neurodynamic openers reduce pressure on the nerves, while closers increase compression on the nervous system.[64] An example of a closing technique is an ipsilateral spinal lateral-flexion towards the targeted sciatic nerve, while contralateral spinal lateral-flexion would be a closing technique. Neurodynamic mobilisations can also be active or passive.[64]

During stretching and neurodynamic mobilisation, sensation is frequently used to determine the range of motion used. The sensation used in the literature various with some exercises reaching their end range of motion at the “onset of stretch sensation”, while others end at the “maximum tolerated stretch sensation”. Martial arts is a general phrase describing combat arts which emphasise health and philosophical development.[65,66] Examples of martial arts include karate, kung-fu, taekwondo, jiu jitsu and mixed martial arts.

2.3 Anatomy of stretching and dynamic neural mobilization exercise

Different modes of stretching have different effects on various anatomical structures and physiological systems. Dynamic stretching for example has been previously recommended to improve subsequent performance of power-based activities, while static stretching is discouraged due to its inhibitory effect on the same outcome.[38] The following section describes the main anatomical structures targeted by stretching and the physiological systems which underly changes to performance outcomes, such as muscle strength, power and jump power in martial artists.

2.3.1 Muscles

Traditional stretching techniques target musculotendinous units, which include muscles and the tendons to which they are attached.[1] Specific stretching techniques target specific muscle groups.[1] A hamstring stretch, for example, targets the hamstring femoris muscle group and is commonly used in martial arts to increase hip flexion range of motion to perform kicks and other movements.[28,67] Stretches normally increase the distance between the muscle origin and insertion until the muscle becomes stiff and a stretch sensation is perceived by the individual. In the hamstring stretch, the origin at the ischia is moved away from the insertions on the tibia stretching the hamstrings.

Skeletal muscle composition influences how they respond mechanically.[68] Muscles include cells called muscle fibres and according to the Hill muscle model, are made-up of a contractile element, a series elastic element and a parallel elastic element.[69] The contractile element include force-generating elements, such as filaments of contractile proteins, myosin and actin.[69,70] A peripheral nerve pierces the muscle covering (the epimysium) at the motor point and its branches terminate at synaptic junctions, connecting skeletal muscle to the nervous system and allowing voluntary contraction, and through various events influence of the contractile proteins.[9] Muscle contraction is fundamental to regulating muscle elongation during stretch.

The series elastic element includes connective tissue structures, which passively contribute to elasticity, including tendons, aponeuroses and myofilaments.[69,70] Molecular structures like the giant protein titin makes up the ultrastructure of a muscle fibre is important in elasticity.[71] A region of the titin protein called “the PEVK region” is primarily responsible for passive tension.[72] Nishikawa (2020), suggested that titin acts like a tuneable spring and its stiffness can be actively adjusted, despite being viewed as contributing passively.[73] Mechanical unfolding also allows titin to generate force to assist in elongation.[74] Both series and elastic components contribute muscle behaviour in response to stretch. The parallel elastic component includes connective tissues[70], including fascia.

2.3.2 Tendons

Tendons are elastic organs and involved in stretch.[75] They are structurally composed of collagenous fibres, grouped into fascicles, and surrounded by an inter-tendon matrix (the endotendon).[76] Fibres are made up of tendon fibrils, which are composed of collagen fibres. At rest collagen fibres have a crimped configuration.[77] The fibres can, however, straighten during stretching to improve tendon elasticity. As tensile loading increases crimping flattens (at 2% strain), then the tendon recoils (at 4% strain) and finally the tendon becomes damages (at 8 to 10% stain).[78] Cini (2021) in a meta-analysis of four studies concluded that acute static stretching does not significantly influence tendon stiffness.[79]

2.3.3 Peripheral nerves

Peripheral nerves elongate and move during stretching.[16] The spinal canal, for example, elongates by five[80] to nine[81] centimetres during forward bending. While muscles commonly pass over one or two joints[82], nerves may pass more and when joint surfaces become convex, the nerves may elongate.[83] Nerves are extensible and act telescopically during tensile loading in a process called "convergence", as neural tissue glides from areas of low to high tension.[84] Nerve movement is more complex than the movement of muscles and involves elements of tension, both longitudinal and transverse sliding, as well as compression.[84] Connective tissue layers contribute to their elasticity.[85] The perineurium, for example, is the dense connective tissue layer, mainly responsible for longitudinal strength and elasticity and allows 18 to 22% strain before tissue failure.[84,86] Nerve internal elements can also slide relative to adjacent structures[84], such as the sliding of fascicles against the interfascicular epineuria of neighbouring bundles.[84] The mesoneurium (a multi-layered loose connective tissue similar to a synovial membrane), which surrounds the nerve trunk further facilitates nerve sliding during stretching exercise.[87]

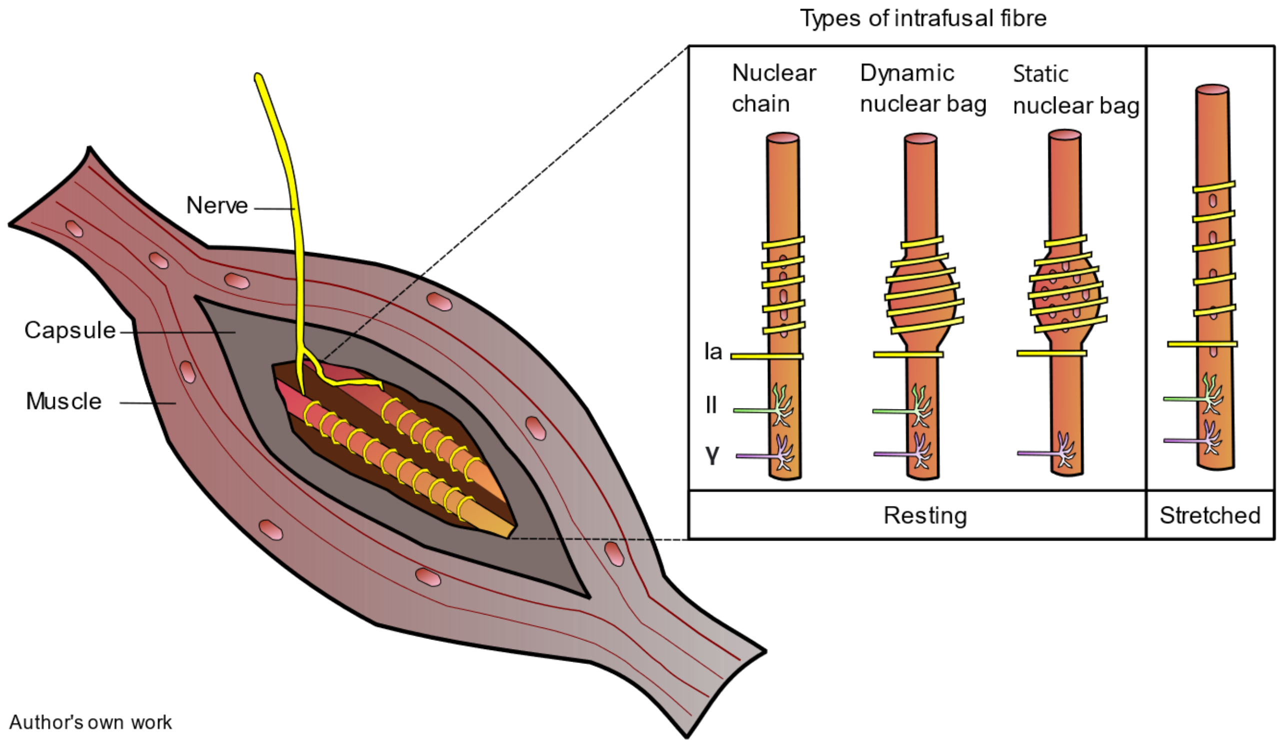
2.4 Physiology of stretching and dynamic neural mobilisation exercise

Muscles, tendons, and nerves are each mechanosensitive and respond to pressure and stretch.[88–90] Each organ includes specialised mechanoreceptors to detect mechanical tension. Muscles have muscle spindles; tendons have Golgi tendon organs and nerves have an intrinsic innervation called the nervi nervorum.[91] In muscles, elongating of muscle spindles, leads to a myotatic reflex, which facilitates muscle contraction to counteract excessive elongation. Stimulation of Golgi tendon organs, by tensile force, leads to a Golgi-tendon reflex, which inhibits muscle contraction.[92] The physiology of peripheral nerve intrinsic mechano-sensation is incompletely understood.

2.4.1 Muscle spindles

Muscle spindles (Figure 2) respond to elongation and respond differently to static and dynamic stretching.[93] They are made-up of groups of specialised muscle fibres in the muscle belly (intrafusal fibres) and enclosed within a connective tissue capsules and run parallel with regular (extrafusal) fibers.[94] Each capsule has about five to fourteen fibres, of which, there are three types.[93] Nuclear chain fibres and static nuclear bag fibres are innervated by group II afferents and detect a muscle's length.[95] Dynamic nuclear bag fibres are innervated by group II afferents and detect the rate of change of muscle length.[96] While all fibre types are important in stretching, dynamic nuclear fibres are especially important for the physiologic response to dynamic stretching.[94] The sensitivity of the spindles can be adjusted with alpha-gamma-coactivation.[4,94,97] When muscles shorten, slackening of the intrafusal fibres is prevented by increased fibre tension though alpha-gamma coactivation, else the fibres may not detect changes.[4]

Authors own work. Based on an original illustration in Prochazka (1996)[98]



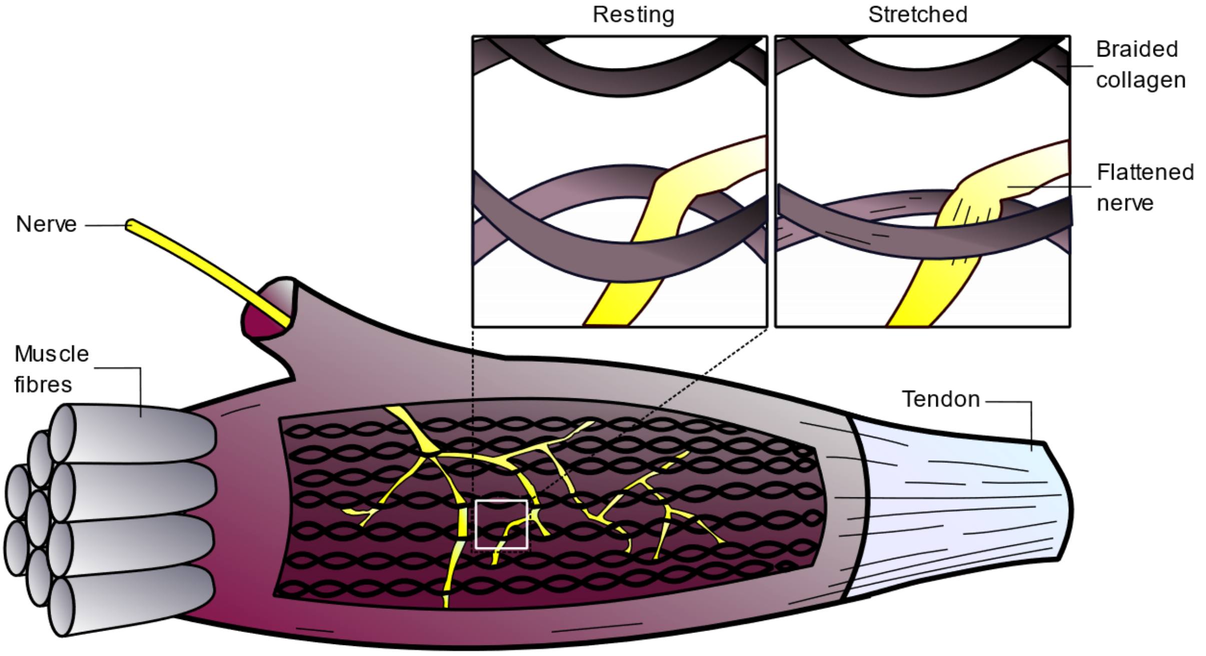
Author's own work

Figure 2 An illustration of a human muscle spindle and intrafusal fibres

2.4.2 Golgi Tendon Organs

Both muscle contraction and stretching increase tensile loading of tendons and mechanically stimulate the Golgi Tendon Organs (GTO) (Figure 3). These receptors sense the magnitude of tension within tendons and lead to reflexive inhibition of muscle action to decrease excessive forces.[92] GTOs include encapsulated braids of collagen which are series with ten to twenty muscle fibres at one end and with tendon collagen fibres at the other.[99] One or more type 1b sensory nerve fibres pierce the capsule, branch and intertwine with the collagen braids. The nerve fibres have flat sensory terminals, which rest between the braided collagen fibres and as these are tensioned, they become compressed and stimulated, leading to a GTO reflex.[92] The GTO reflex inhibits muscle activation to decrease tendon loading.[96] GTOs are involved with muscle spindles in regulating movements[100] during activities like static and dynamic stretching and dynamic neural mobilisation exercise.

Authors own work. Based on an original illustration in Prochazka (1996)[98]



Author's own work

Figure 3 An illustration of a human Golgi tendon organ showing the nerve and collagen fibres at resting length and stretched

2.4.3 Peripheral nerves

The mechanisms of mechano-sensation of peripheral nerves are incompletely understood, however, unmyelinated fibres (the nervi nervorum) in the sheaths of peripheral nerves appear to be involved in transmission of sensory information about the nerves.[91] The nervi nervorum are the intrinsic innervation of the epineurium and deeper structures[91,101] and include nociceptive fibres, which branch from the axon.[102] Peripheral nerve fibres include piezo mechanically-gated ion channels which may have a role in mechanosensation.[103] Nerve fibres become increasingly sensitive to stretching and pressure with inflammation, but are generally reported to be mechanically insensitive.[104,105] Provocative neural testing positions, do however, increase experienced sensations and reduce range of motion, even in healthy participants.[106] These sensations also have been reported to decrease with stretching routines in healthy people.[88] Information on the response of the muscular system to nerve stretching is limited.

Authors own work. Based on an original illustration by Lam et al. (2020)[107]

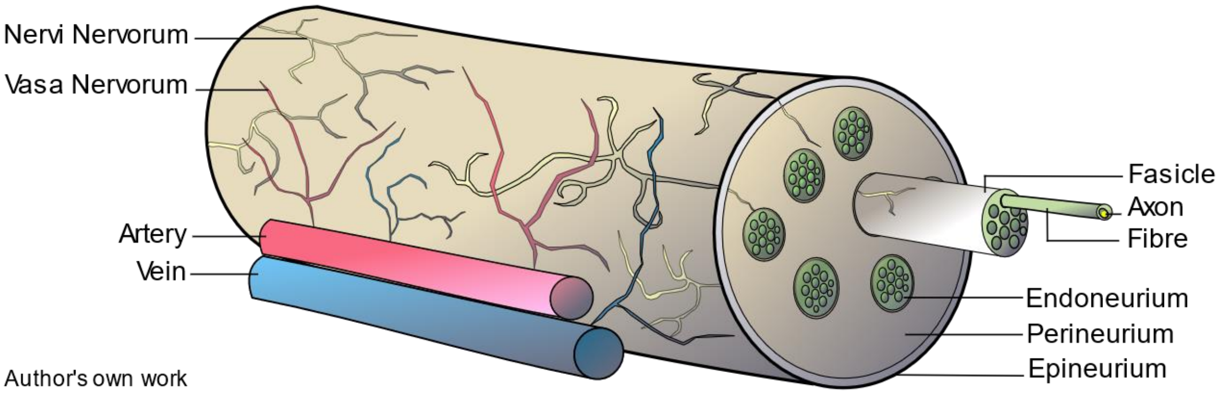


Figure 4 An illustration of the microanatomy of a peripheral nerve trunk with the nervi nervorum

2.5 Static stretching

This section will provide a context for objective 1: the acute effect of static stretching on muscle strength, power and jump power in martial artists. Context will be provided by reviewing overall findings on acute effects, muscle strength, including isokinetic, concentric, eccentric, and isometric strength. Power will be reviewed, including isokinetic mean power and other measures of power. Finally jump performance will be reviewed.

2.5.1 Overall findings on acute effects

Static stretching can immediately increase or decrease muscle strength, power and jump power[108], however these responses have been debated[38,40,108–110]. Early observations suggested that, in general, static stretching decreases subsequent performance.[111–113] Recommendations were commonly given to avoid static stretching and it's detrimental consequences prior to strength and power training.[38] Recent recommendations, however, advise including short (< 60 seconds), but not prolonged (≥ 60 seconds) static stretching, before physical activity[114], for its performance benefits.[108]

Decreased strength or power caused by stretching has been termed "stretch induced strength loss",[24] "stretch induced deficit",[115] or "stetch induced force loss".[25,116,117] Behm et al.[108] summarises studies to date and introduces the concept of a dose response relationship for performance detriment and static stretching with greater doses of stretch resulting in greater strength and power detriments. Several studies[118–121] have shown that stretch induced strength loss can be partially, but not completely attenuated with prior physical activity or warm-up.

2.5.2 Muscle strength

Strength is the "ability to exert force" and can be measured using different methods.[122] Isokinetic dynamometry is a common laboratory method to assess muscular strength and is considered the gold standard of strength testing.[123,124] Other common methods of measuring strength include: isotonic testing including one repetition maximum (1RM) and multiple repetition maximum testing, handheld dynamometry and hand grip strength.[125]

Historically, the hypothesis that static stretch led to detriment was relatively unknown. In a systematic review Shrier[126] systematically reviewed the literature and included 22 articles suggesting no benefit for static stretching and 20 articles suggesting performance detriment, all of which were published during the preceding seven years. The earliest example cited by Shrier[126] of a measured performance decrease identified was by Kokkonen et al.[112], who identified significant decreases (Δ -7%, $p < 0.05$) in 1RM isotonic knee flexion (Δ -8.1%, $p < 0.05$) in 15 male and 15 female college students (age = 22 ± 5 years). To the authors knowledge, the first study to examine the acute effect of stretching on muscle strength was by Wiktorsson-Möller et al.[127] who identified no significant differences ($p < 0.05$) between pre- and post-test measures in male volunteers ($n = 8$) for isometric and isokinetic knee extension strength at 30 and $180^{o}.s^{-1}$.

The next section describes the literature on the acute effect static stretching on isokinetic strength, by addressing concentric, eccentric, and isometric tests. The different types of contractions are included to provide a comparison for the studies of dynamic neural mobilisation exercise reviewed later. Few studies have been conducted on neural mobilisation and strength and those that do exist use a variety of strength measures. Most studies reviewed had a small sample size (n < 30) with varied and heterogenous designs. Most studies of the acute effects of static stretching on strength and power use small sample sizes (n < 30) and have varied and heterogenous designs.

1.2.1 Concentric strength

Early research on the acute effect of static stretching on concentric isokinetic peak torque focused on determining whether significant decreases ($p \leq 0.05$) occurred and measuring their magnitude. Findings have been contradictory with studies reporting decreases[128], increases[129] or no difference[130], with a recent review[108] concluding the outcome depends on a combination of factors.

Cramer et al.[128] tested the effect of four repetitions of four knee extensor static stretches (held for 30 seconds each), with a total stretch time of 16.1 minutes in volunteers (n = 21, 7 men, 14 women, age = 21.5 ± 1.3 years) and identified significant decreases ($p \leq 0.05$) in concentric knee extension absolute peak torque (aPT) at $60º.s^{-1}$ (Δ -2.8%) and $240º.s^{-1}$(Δ -4.2%). Decreases were also reported by Papadopoulos et al.[131] who compared 3 minutes of static or dynamic stretching, both with warm-ups), and reported significant decreases ($p < 0.01$) for concentric absolute peak torque for knee extensors and flexors in male non-athlete physical education students (n = 32, age = 20.7 ± 1.0 years) for knee flexion at $60º.s^{-1}$ (Δ -4.3%) and $180º.s^{-1}$ (Δ -5%) and at $60º.s^{-1}$ (Δ -4.4%) and $180º.s^{-1}$ (Δ -4.3%) for extension. In contrast to these findings, a recent study[132] identified no significant differences between the acute effects of static stretching and dynamic stretching on hip flexion and extension at 60 and $180º.s^{-1}$ concentric absolute peak torque at in 14 male handball players (age = 20.28 ± 1.06 years). Numerous similar studies[40,108] have been conducted, which are summarised by Behm and colleagues in a number of systematic reviews.

Once evidence support began to emerge that stretching may detriment performance, studies examining duration, interaction with warm-up, intensity, and in specific populations were conducted. These will be reviewed next.

To examine the influence of duration on stretch induced strength loss, Brandenburg[116] compared static stretching totalling for 90 seconds (Δ -2.7%) and 180 seconds (Δ -3.3%) identifying significant ($p < 0.05$), but similar magnitude decreases for concentric absolute peak torque at 120º.s^{-1} for static stretching totalling for in 16 recreationally trained males and females. Zakas et al.[133] compared short (45 seconds) and long duration stretches (300 seconds) and identified a significant decrease ($p \leq 0.001$) in concentric absolute peak torque for knee flexion only for long durations for 30º.s^{-1} (Δ -5.2%), 60º.s^{-1} (Δ -5.5%), 120º.s^{-1} (Δ -6.5%), 180º.s^{-1} (Δ -8.4%) and 300º.s^{-1} (Δ -12.9%) in 16 male pubescent soccer players. Ayala at al.[130] compared the effect of both static and dynamic stretching (total time = 270 seconds) and identified no significant differences for knee extension and flexion absolute peak torque at 60, 120 or 240º.s^{-1} in 49 active adults (age = 21.3 ± 2.5).

While studies of duration appear to have initially focused on long durations, comparisons to shorter durations have been done recently. Studies comparing durations of stretching, in the context of warm-ups may involve attenuation of stretch-induced strength loss. Examples include a study by Ebadi and Cetin[134] who compared programmes of low intensity jogging warm-up followed by a routine of 17 stretches, held for either 15, 30 or 45 seconds each, and for concentric aPT identified significant increases ($p \leq 0.05$) at 60 and 180º.s^{-1} for the 15 second duration and significant decreases ($p \leq 0.05$) at 60 and 180º.s^{-1} for the 45 second duration in 15 elite male athletes (10 football and 5 basketball, no age data available). Similarly, Vieira et al.[135] compared the effects of warm-up with stretches of either 20, 40 or 60 seconds of knee extensor and flexor stretches with a control group and identified no differences ($p \leq 0.05$) in concentric knee extension or flexion peak torque at 60, 180 or 300º.s^{-1} in 21 physically active men (age = 22.05 ± 2.09 years).

The interaction of warm-up and static stretching have received more attention in recent literature and suggest that warm-up can attenuate stretch-induced strength loss. Gonçalves et al.[129] compared warm-up with and without static stretching (120 seconds of hamstring, then 120 seconds of quadricep stretching) followed by 90 seconds of light running and similar to Ebadi and Çetin[134] identified significant increases in knee flexion (Δ +8.8%, $p = 0.001$) and extension (Δ +16.2%, $p = 0.006$) at 60º.s^{-1} in 32 Brazilian military men (age = 18.9 ± 0.5).

The effect of perceived stretch intensity on isokinetic concentric absolute peak torque appears to have received less attention than duration. Rodrigues et al.[136] compared a control (run plus general warm-up) to either a run plus warm-up with 2-repetitions of 30 seconds of sub-maximal (70% intensity) or maximal static (100% intensity) stretching on concentric knee extension aPT at 30º.s^{-1} and identified decreases ($p \leq 0.05$) between no-stretch and maximal stretch (∆ -10.5%), but not for the sub-maximal intensity in 22 male (age = 24 ± 3 years). Intensities above tolerated maximums have also been studied. Takeuchi and Nakamura[137] compared 20 seconds of static stretching at "point of discomfort" (100% intensity) and "maximum tolerated discomfort" (120% intensity) and identified no significant differences in concentric aPT at 60º.s^{-1} in 13 healthy men and 4 women (age = 21.2 ± 0.4 years).

In martial arts, the author is aware of only two trials have examined the acute effect of stretching on isokinetic concentric peak torque. Alp et al.[138] compared the effect of a warm-up with of 3 bouts of 30 seconds (90 seconds total) of static stretching and dynamic stretching and identified no significant differences in concentric knee and ankle aPT at 60 and 180º.s^{-1} in 14 male taekwondo athletes (age = 21.28 ± 0.91 years). Ćirić et al.[139] compared warm-ups with 10 minutes of stationary cycling and seven static stretches versus foam roller and proprioceptive neuromuscular facilitation stretches on knee extension aPT and identified no significant difference ($p = 0.767$) between the groups in 50 male professional and semi-professional athletes including (karate, boxing, taekwondo, track and field, track and soccer)(age = 15 to 27 years).

2.5.2.1 Eccentric strength

Isokinetic eccentric strength has received much less attention than concentric strength, with a small number of studies reporting eccentric strength outcomes. The earliest study identified in this literature review was that of Jensen et al.[140] identified significant decreases ($p < 0.05$) in knee extension eccentric aPT at 90º.s^{-1} (∆ -9%) when comparing the effects of static stretching (3 bouts of 20 seconds) of agonist, antagonist or no static stretching in semi-professional rugby players (n = 12, age = 21.7 ± 2.3 years).

Other studies have identified no effect. Winke et al.[141] examined the acute effect of 3 minutes (180 seconds) of knee flexor static stretching to the "point of discomfort" or 15 out of 20 on a modified Borg rating scale on isokinetic eccentric aPT at 60°.s^{-1} and

210°.s^{-1} and identified no significant differences between conditions in 13 women and 16 men (age = 27.2 ± 5.2 years). Cramer et al.[142] identified no significant difference compared to baseline eccentric aPT after 60 and 180º.s^{-1} after three assisted and one unassisted static stretch (total time = 21.2 ± 2.0 minutes) in thirteen women (age = 20.8 ± 0.8 years).

The effect of duration was examined by Brandenburg[116], who included measurements of eccentric aPT in his study comparing durations of 45 and 90 seconds of static stretch at the "point of mild discomfort" and identified significant decreases ($p < 0.05$) in knee flexion eccentric aPT in both conditions (~Δ -6%,) in 10 recreationally trained males (age = 23 ± 2.6 years) and six females (age = 21.8 ± 1.9 years).

2.5.2.2 Isometric strength

The earliest studies using isokinetic dynamometry to identify stretch-induced stretch loss included measures of isometric Maximum Voluntary Contraction (MVC). Fowles et al.[143] identified significant decreases ($p < 0.05$) in isometric maximum MVC over-time after prolonged partner-assisted static stretch (33 minutes), compared to baseline scores. Isometric MVC decreased immediately after (Δ -28%) and at 5 (Δ -21%), 15 (Δ -13%), 30 (Δ -12%), 45 (Δ -10%) and 60 minutes (Δ -9%) post-stretch in eight men (age = 22.3 ± 0.8 years) and four women (age = 20.3 ± 0.1 years), suggesting that the effects of stetch-induced strength loss diminish over time. In a study examining whether strength deficits remain over 2-hours, Power et al.[144] identified significant decreases ($p \leq 0.05$) in isometric MVC for knee extension between pre-, and post-test scores immediately after (Δ -9.5%) and 120 minutes after (Δ - 10.4%) static stretching of the quadriceps, hamstrings and ankle plantar flexors (total stretch time = 270 seconds each). A study, by Matsuo et al.[145], with a stretch duration between that of Fowles et al.[143] and Power et al.[144] reported a magnitude of strength decrease between the maximums reported by these two. He compared the effects of 6 minutes (300 seconds) of static and dynamic stretching at and identified significant ($p < 0.01$) and similar decreases in isometric knee flexion muscle force for both conditions (~Δ -14.5%) in 16 healthy young men (age = 22.2 ± 1.2 years). Siatras et al.[146] compared shorter durations of quadriceps static stretching and identified significant decreases ($p < 0.05$ to 0.001) in knee extension isometric muscle force after 30 seconds (Δ -8.5%) and 60 seconds (Δ - 16%) of stretching in 50 male participants (aged 19 to 23 years).

The effect of different intensities was examined by Kataura et al.[43] who compared 3 minutes of continuous hamstring static stretching at 80, 100 and 120% of “maximum tolerated stretch” and identified significant and similar decreases ($p \leq 005$) in knee flexion isometric MVC for 100% (Δ -3.3 ± 5.1 Nm), and 120% (Δ -2.9 ± 5.6%), but not 80% (Δ -1.2 ± 3.7 Nm, $p > 0.05$) in 18 healthy participants (nine men and nine women, age = 20.6 ± 1.2 years).

Very few studies have been conducted using handheld dynamometry. A single example was identified during the literature search. Palmer et al.[147] examined the effect of four 15 second constant-torque hamstring stretches and identified no significant differences ($p > 0.99$) in peak torque by hand-held dynamometry in eleven young healthy women (age = 24 ± 4 years).

Several have examined the effect of static stretching on grip strength and report mixed findings with increases, no change or decreases. Costa et al.[148] examined the effect of a single bout of wrist flexor static stretching (30 seconds) at “the limit of pain” and identified no significant differences in grip strength after intervention in ten untrained men (age = 22 ± 2 years). Yeslawath et al.[149] examined the effect of wrist flexor static stretching (three sets of 30 seconds) at the “point of mild discomfort” and identified significant increases ($p = 0.04$) in grip strength (Δ +10.4%) in 34 geriatric people (8 male and 26 female, aged: ~74 years). De Paula[150] compared the effects of two static stretch procedures on grip strength over time. Participants received either three sets of either 30 or 60 seconds of finger flexor static stretching (with a 20 second inter-set rest) and identified a significant ($p < 0.05$) decrease in handgrip strength (Δ -15%) immediately after stretch, which resolved 5 minutes after in 11 healthy men (age = 22 ± 1 years). Jelmini[151] examined the effect of 3 sets 45 second finger flexor static stretches at “the point of discomfort, not pain” on grip strength and identified significant decrease ($p \leq 0.05$), one-minute post-stretch (Δ -4.4%) in 13 male (age = 27 ± 10 years) and 14 female (age = 25 ± 6) participants.

Overall, for muscle strength, studies of the effects of static stretch on concentric isokinetic strength has been the main outcome used to quantify and describe the effects of static stretching on muscle strength.

2.5.3 Muscle power

2.5.3.1 Isokinetic mean power

Mean power has not received as much research attention as isokinetic peak torque. While no studies have specifically addressed the effect of static stretching on isokinetic mean power, it has been reported alongside other outcomes in various publications. Gesel et al.[152] compared the effect of static and ballistic stretching to a control group to determine their effect on isokinetic performance. Static stretching (total time = 2 minutes), but not ballistic stretching led to significant decreases ($p = 0.047$, Δ -8%) in isokinetic mean power in 13 males and nine females (combined ages = 21.9 ± 2.8 years) compared to control. Other studies did have not identified decreases in mean isokinetic power. Ayala et al.[130] compared no-stretch to static and dynamic stretching in 25 men (age = 21.3 ± 2.5 years) and 24 women (age = 20.4 ± 1.8 years). Static stretching included five exercises for different muscle groups on each leg, each held for 30 seconds at the "point of mild discomfort, but not pain". No significant differences in isokinetic mean power were identified.

2.5.3.2 Other measures of muscle power

Other measures of power include functional tests like sprinting and hoping and tests using equipment, such as force platforms. Many studies using other measures of power have been conducted, which may be due to the ease, accessibility, and affordability of field tests, such as timed sprint tests.

Young et al.[153] compared the acute effect of warm-ups with and without stretch (240 seconds) on concentric vertical jump and drop-jump performance with a force platform and found no significant decrease in concentric jump height and drop jump power in 26 participants (13 male and 3 female) (mean age: 26.0 ± 8.5 years). In a similar study, Young et al.[154] compared the acute effect of warm-ups of five minute run and 30 seconds static stretch with total times of either 1, 2, 3 or 4 minutes on drop jump height divided by time and identified significant decreases ($p < 0.05$) after the 2 (Δ -9.2%) and 4 minute (Δ -11%) procedures in twenty participants (12 men, 8 women, mean age = 22.8 ± 6.9 years). In a recent study with a shorter stretch duration, Azamifar et al.[155] also reported induced deficits. The authors compared the acute effect of 60 seconds of stretching (20 seconds each of plantar flexor, hamstring, and quadricep stretching) or stretching plus plyometric exercises on maximal vertical jump, isometric strength and balance in female soccer athletes with tight hamstrings (n = 20, age = 23.37 ± 1.58 years) and without tight hamstrings (n = 15 with normal hamstrings, age = 23.30 ± 1.75 years) and identified similar significant decreases ($p < 0.05$) for maximal vertical jump height (~∆ -3%).

Studies using short duration static stretch procedures or combining stretch with intense warm-up conditions can show no effect or even improvement of power. Vetter[156] compared six warm-ups, including walk or run and static stretch and walk or run plus static stretch and small jumps on vertical jump identified warm-ups other than those including static stretches tended to produce higher jumps ($0.003 \geq p \leq 0.001$) in 26 college-age participants (14 men (age = 22.30 ± 1.64 years) and 12 women (age = 21.70 ± 1.15 years).

Studies have also examined stretching combined with warm-up on other power measures. Oliveira et al.[157] examined the acute effect of 5-minute stretch (total time: 150 seconds per leg) after 10-minute warm-up on 20-meter sprint and counter movement jump power and found no significant differences for either in 22 male trained healthy athletes (age = 23.2 ± 5.0 years). Kendall et al.[158] compared warm-up plus static or dynamic stretch on anaerobic power with the Wingate protocol and identified no significant different ($p = 0.065$) after either intervention in ten recreationally active participants (5 men, 5 women, age = 23.3 ± 0.7 years).

2.5.4 Jump power

The literature on the acute effect of static stretching on jump performance is conflicting, with studies identifying, increases, decreases and no change after intervention. A substantial number of studies measuring vertical jump were identified, with Counter Movement Jump (CMJ) testing not as frequently reported.

Studies of CMJ report mixed findings. Stafylidis et al.[159] compared the acute effect of 15 or 60 seconds of vastus lateralis static stretching on CMJ power and squat jump power and identified no significant effect in 11 participants (8 men, 3 women, age = 25.5 ± 3.1 years). Other authors have identified improvements after stretching. Donti, Tsolakis et al.[160] examined the effect of baseline range of motion in 34 elite athletes (artistic gymnasts: 10 men, age = 24.4 ± 4.3 years, 14 women, age = 18.1 ± 2.6 years and rhythmic gymnasts: 10 women, age = 18.6 ± 1.6 years) on CMJ height following either a 15 or 30 second static stretch and 3 sets of 5 plyometric tuck-jumps and identified significant increases ($p = 0.012$) in CMJ after the long warm-up only (Δ +4.6 ± 0.9%).

Studies of vertical jump height also show mixed results. Palaniappan et al.[161] measured the effect of static stretching (total time: 120 seconds) on vertical jump height with a within-subjects design, by measuring baseline scores, then stretching and immediately collecting post-test scores and identified a significant increase ($p < 0.05$) in vertical jump height between pre-, and post-test (39.58 ± 7.48 cm to 43.99 ± 7.09 cm) in healthy male university students (n = 100, age = 18 to 25 years). Similarly, Saka et al.[162] compared the acute effect of static stretch of five different muscle groups (15 seconds each, total time: 150 seconds) on vertical jump height in people with and without chronic exposure to static stretching and identified similar significant improvements in groups (no-exposure: 27.67 ± 1.828 cm to 24.67 ± 1.83 cm, $p = 0.001$; exposure: 24.40 ± 2.11 cm to 26.60 ± 2.08 cm, $p = 0.014$) in 30 healthy participants (15 men and 15 women, age = 21.60 ± 2.26 years).

Various studies have found no change in performance. For example, Murphy et al.[163] compared the effects of a single 20 second set of static and dynamic stretch on vertical jump height and identified no significant differences on jump height for either group in 42 healthy, physically active men (age = 18 to 24). These findings were reported as improvements, however, even without significant statistical findings.[163] With similar outcomes, Balkawade et al.[164] compared interventions including warm-up and control, dynamic or static stretch components with 80 seconds of lower body stretches per side (total time: 160 seconds) and identified no significant effect of static stretch on vertical jump height in 60 physiotherapy students (aged 18 to 35 years).

Decreases in performance have also been reported. As an example, Hough et al.[165] identified a significant decrease ($p < 0.05$) in vertical jump height (Δ -4.19 ± 4.47%) after static stretching or dynamic stretching (total time: 7 minutes) in 11 healthy men (age = 21 ± 2 years).

The effect of static stretching on other tests, such as the 5-jump test have been reported. Chaouachi et al.[166] compared warm-up only to seven different combinations of warm-up plus stretching in national level athletes (n = 22, age = 20.6 ± 1.2 years) and identified no significant differences in a 5-jump test in post-test. In contrast, Haddad et al.[167] compared the effect control, static stretching and dynamic stretching (2 sets of 7 minutes and 30 seconds each) on explosive performance including a 5-jump test, after 24 hours, and identified a significant decrease ($p < 0.05$) between static stretching and control which remained 24 hours (Δ - 0.8%) after a static stretch intervention in male soccer players ($n = 16$, age = 18.2 ± 1.2 years).

2.6 Dynamic neural mobilisation exercise

This section will provide a context for objective 2: acute effect of dynamic neural mobilisation exercise on muscle strength, power and jump power in martial artists. It will do this by reviewing the literature on the general acute effects of neural mobilisation. The literature on neural mobilisation and isokinetics strength, mean power and jump power will then be reviewed.

2.6.1 Overall findings on acute effects

Neural mobilisation is a movement technique, which involves aligning human joints to maximise tension on certain peripheral nerves, rather than muscular structures. While neural mobilisation can be static or dynamic, the term “dynamic neural mobilisation exercise” in this study refers to neural mobilisation techniques, which are involve continuous dynamic movement and which are performed as unassisted exercise by the participant. The sensory mechanisms underlying stretch sensation of peripheral nerves is different than that of muscles or tendons and may have a different acute effect on muscle strength, power or jump power. To the authors knowledge the study on this topic discussing this topic was conducted by McHugh et al.[24]. Ellis et al.[62] provides an overview of “tensioners” in neural mobilisation or “neurodynamic techniques” in general and a comprehensive systematic review by Thomas et al.[88] describes the effects of muscle stretching on peripheral nerves, although includes no studies on muscle strength or power, or jump power. The next section describes the few studies on strength, power and jump power and neural mobilisation, however no studies including martial artists were identified.

2.6.2 Muscle strength

There are a limited number of studies on the acute effect of neural mobilisation on knee strength measured with an isokinetic dynamometer. Four articles were identified, including one with healthy participants, two with chronic back pain patients and one with stroke patients. These are included, due to the lack of other available findings.

McHugh et al.[24] used a repeated measures design (11 healthy participants, 10 men, 1 woman, age = 34 ± 12 years) to compare maximal isometric hamstring contractions at various positions, before and after five 1-minute hamstring stretches (total time: 5 minutes) in either a spinal-neutral or a neural tension position and identified a significant decrease ($p = 0.43$) between baseline and stretching with neural-tension (Δ -12%) and not between baseline and neutral position stretching (Δ -5%, $p = 0.43$). Contrary to the results for healthy participants, the findings in studies of chronic back pain identify improved or results similar to the control group. Cha et al.[168] examined the effect of sciatic nerve mobilisation (10 minutes) on isometric knee extension peak torque in patients with chronic back pain (n = 11, 5 men and 6 women) versus a control group (n = 11, 6 men and 5 women) and identified significant increases ($p < 0.05$) between control and neural mobilisation immediately (control: 64.85 ± 24.87 Nm; neural mobilisation: 86.70 ± 20.60 Nm) and after 1 hour (control: 64.36 ± 24.99 Nm; neural mobilisation: 83.00 ± 20.19 Nm).

A study[169] also on patients with chronic back pain (n = 24) also identified significant increases ($p < 0.05$) in both the control group (n = 12, 7 males and 5 females) of electric diathermy only and the experimental group (n = 12, 7 females and 5 males) of electric diathermy with neural mobilisation. Significant increases ($p < 0.05$) between pre- and post-test scores for isometric knee extensor peak torque for control (68.3 ± 25.1 Nm to 74.1 ± 27.8 Nm) and the experimental group (71.5 ± 18.1 Nm to 85.3 ± 19.3 Nm) with paired-tests, however, independent t-tests did not identify significant differences ($p < 0.05$) between the groups, suggesting neural mobilisation did not differ from control. A single study by Shin et al.[170] used a crossover randomised controlled trial design to compare patients with chronic stroke (n = 16, 9 men, 7 women, age = 59.4 ± 12.7) split into a control (10 minute static stretching) and experimental (10 minute assisted sciatic neural mobilisation) groups. Significant increases were identified for hand-held dynamometry knee extensor strength (15.32 ± 5.98 kg to 18.16 ± 6.95 kg, $p= 0.023$) and knee flexor strength (7.80 ± 4.80 kg to 8.15 ± 4.24 kg, $p = 0.011$) compared to the static stretching (control) group. The results of these studies on muscle strength suggest that the effect of neural mobilisation is variable and incompletely, while isometric data is available, none on isokinetic concentric or eccentric is available. The present study addresses this gap.

2.6.3 Muscle power

No studies were identified, which reported the effect of any type of neural mobilisation on isokinetic mean power. The present study will address this gap.

2.6.4 Jump power

Four studies have examined the acute effect of neurodynamic mobilisation on vertical jump performance, however, jump height remained unchanged in most cases. Nunes et al.[171] used a crossover randomised controlled trial of healthy participants (n = 30, 15 men, 15 women, age = 30.1 ± 6.7 years) to compare the acute effects of static stretching and sciatic, femoral and tibial nerve mobilisation and identified no significant differences between groups. In a study with similar findings, Aksoy et al.[172] compared 10 repetitions of 2 seconds static neural mobilisation and 2 seconds rest of either femoral or sciatic nerve mobilisation in young adults (n = 62, 47 males, 15 females, age = 21.31 ± 1.28 years) and identified significant increases ($p < 0.05$) for femoral neural mobilisation (31.74 ± 8.31 cm to 32.76 ± 8.45 cm) and for sciatic neural mobilisation (31.74 ± 8.31 cm to 32.76 ± 8.45 cm) in pre-post comparison, but identified no significant difference between techniques.

A study[173] of healthy college age students measuring vertical jump height before and after neurodynamic mobilisation also found no significant difference in jump height. In this study Waldhelm et al.[173] used a cross-sectional, quasi-experimental design with block assignments to compare the effects of neural gliding and dynamic stretching on scores including vertical jump height in healthy volunteers (n = 27, 16 men, 11 women, age = 23.6 ± 2.65 years). No significant differences were identified between the groups or between pre-, and post-test scores.

A single study[174] compared pre and post scores for neurodynamic mobilisation and Nordic eccentric hamstring stretches and found a significant improvement in vertical jump height in both conditions. Two studies, however, found significant improvements in hop performance. Ferreira et al.[175] used a randomised parallel and double-blinded trial to compare the acute effects of sliding neural mobilisation and tensioning neural mobilisation before, immediately after and 10 minutes after intervention in football players (n = 37). Both techniques resulted significant increases ($p < 0.05$) were identified for the single-leg hop test, 6-m timed hop test and cross-over hop test, which remained 30 minutes after the intervention.

2.7 Static stretching versus dynamic neural mobilisation exercise

This section relates to objective 3: to determine whether there is a difference between the effects of static stretching and dynamic neural mobilisation exercise on muscular strength, power and jump power in martial artists. To the authors knowledge no studies have yet compared the acute effects neural mobilisation and static stretching on muscle strength, power and jump power in martial artists or other populations.

2.8 Summary

The acute effects of static stretching on muscular strength and power have been well documented, however questions remain on specific issues, such as the characteristics of static stretch and their resulting effects. Neural dynamic mobilisation, by comparison has received less attention and further study is required on the topic. The acute effect of static stretching is understood to involve strength and power improvements with short duration stretch and reductions with long duration stretch. Studies to date on dynamic neural mobilisation exercise report mixed findings.

CHAPTER 3: METHODOLOGY

The subtopics that will be covered in this chapter include:

3.1 Study design

This study was a non-blinded randomised controlled trial. A sample of convenience was drawn from martial art gymnasiums/institutions and volunteers randomly assigned to a control group or one of two experimental groups. Each group received baseline measures, warm-up, pre-test, recovery period, intervention, post-test, and cool-down. All participants received the same procedures, except for group specific intervention or control procedure. Reporting of results followed the guidelines of the Consort Checklist.[176]

3.2 Site of study

The study was conducted at the Centre for Exercise Science and Sports Medicine at the University of Witwatersrand Education Campus in Parktown, Johannesburg.

3.3 Study population

A population of apparently healthy adult martial artists between the ages of 18 and 35 years was invited to participate in this study.

3.4 Sampling

A sample size calculation was conducted using Stata Statistical Software (StataCorp. 2017), which calculated a sample size of 62 participants. Alpha (α) was set at 0.05 to allow a 5% margin of error and Beta (β) was set at 80%[177] and an effect size of 0.35 was selected. The sample was split equally with 31 participants in each experimental group and a further 31 participants in the control group for a total of 93 participants. The calculation was based on expected difference between pre-post means of 4.4%[178], variance of 8%[179] and range of effect sizes from 0.77 to 1.32.[42]

3.5 Randomisation

Volunteers were grouped into 10 sub-groups, based on gender (male and female) and style (mixed martial arts, karate, Jiu jitsu, taekwondo and kungfu), which were chosen for convenience. For equal representation, sub-groups were randomized separately. The online software Research Randomizer generated two tables of non-recurring random numbers equal to the volunteer number in each sub-group and generated in sets of 3. Volunteers were listed in the order in which they volunteered and assigned a number from table 1, based on the numbers order of appearance. Numbers in the table 2 were assigned group positions in the recurring order of control; experimental 1 and experimental 2. Matching of numbers in tables 1 and 2 randomly assigned volunteers to groups with equal representation. The same process was used for all sub-groups. In the study, 93 participants were assigned into subgroups of mixed martial arts (n = 30, 27 males, 3 females), jiu jitsu (n = 30, 27 males, 3 females), karate (n = 24, 18 males, 6 females), taekwondo (n = 18, 15 males, 3 females). kungfu (n = 9, 3 males, 6 males).

3.6 Recruitment of participants

Participants were recruited from gymnasiums/institutions in Johannesburg from a maximum travel distance of 30km from the site of study. Gymnasiums/institutions signed participation forms (Appendix H). Gymnasiums/institutions were originally engaged with before the COVID-19 pandemic and after the South African national lockdown restrictions eased by September 2020, nine of fifteen gymnasiums/institutions who had originally agreed to participate before the pandemic, reported permanently ceasing operation were no longer able to participate. Due to the small number of martial artists who participated per gymnasium/ institution, the primary investigator approached additional gymnasiums/institutions which met the travel distance criteria to be involved with the study. Recruitment was done in English by the primary investigator. Contact details for volunteers were gathered from the gymnasiums/institutions and volunteers were contacted individually and invited to participate. Coercion and a sense of obligation were mitigated by explaining that involvement or withdrawal was voluntary, all results confidential and non-participation would not disadvantage volunteers. Ninety-three participants were included in the study. Schools/ institutions were extended the participation offer to students and a list compiled with names added for each volunteer to a minimum of 93 participants. Volunteers were contacted to arrange individual testing times.

3.7 Inclusion and exclusion criteria

Table 1 below shows the inclusion and exclusion criteria of the study. Overall, 123 martial artists volunteered for the study. Thirty volunteers were excluded. Inclusions and exclusions are detailed in Figure 5 below.

Table 1 Inclusion and exclusion criteria

Inclusion	Exclusion
Gender: male and female	Travel distance: travels from more than 30km to reach the university from the place of their residence.
Chronological age: adults aged 18 to 35 years.	Level of involvement: less than one month of martial arts experience.
School membership: must be a member of a martial arts school which has agreed to participate.	Isokinetic variance: More than one isokinetic Coefficient of Variance (CoV) of ≥ 20% per test speed (60,180 or 300º.s^{-1}.
	Apparently healthy: no current performance limiting injuries or serious performance limiting injuries.

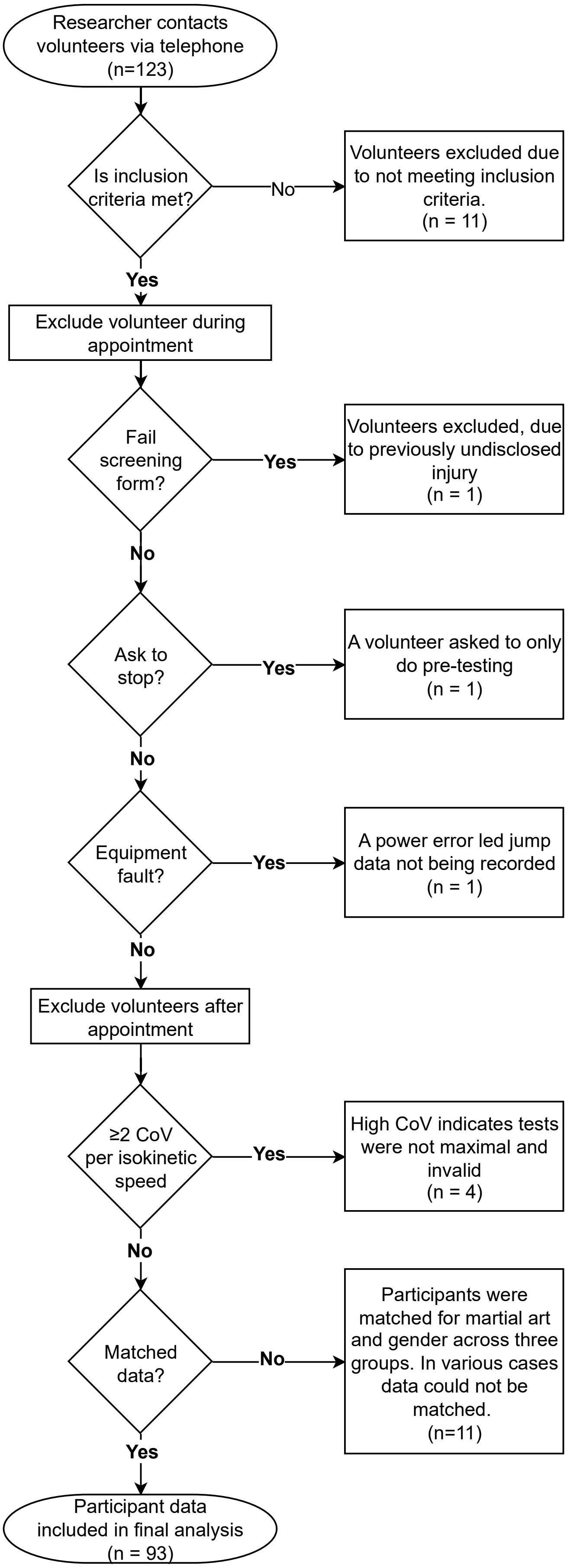


Figure 5 Flowchart of inclusions and exclusions

3.8 Testing procedures and equipment

Testing procedures and order are shown in Figure 6 below. Procedures were explained to participants on arrival for testing. They read and completed the information leaflet (Appendix D) and informed consent (Appendix E) and biographic and pre-participation screening (Appendix F). All participants received baseline measurements, active warm-up, pre-test battery and a 15-minute recovery period (see details below). Participants then received their group specific intervention or control, followed immediately by the post-test battery and an active cool-down. Verbal feedback on testing results was provided to participants and they were offered to be sent an optional electronic report (Appendix P). A travel remuneration was calculated using the following formula:

$$3.61\ ZAR * kilometers\ travelled$$

Kilometres travelled included distance to and from the site of testing, according to the software: Google Maps. A refreshment and water were offered to participants at the end of the appointment.

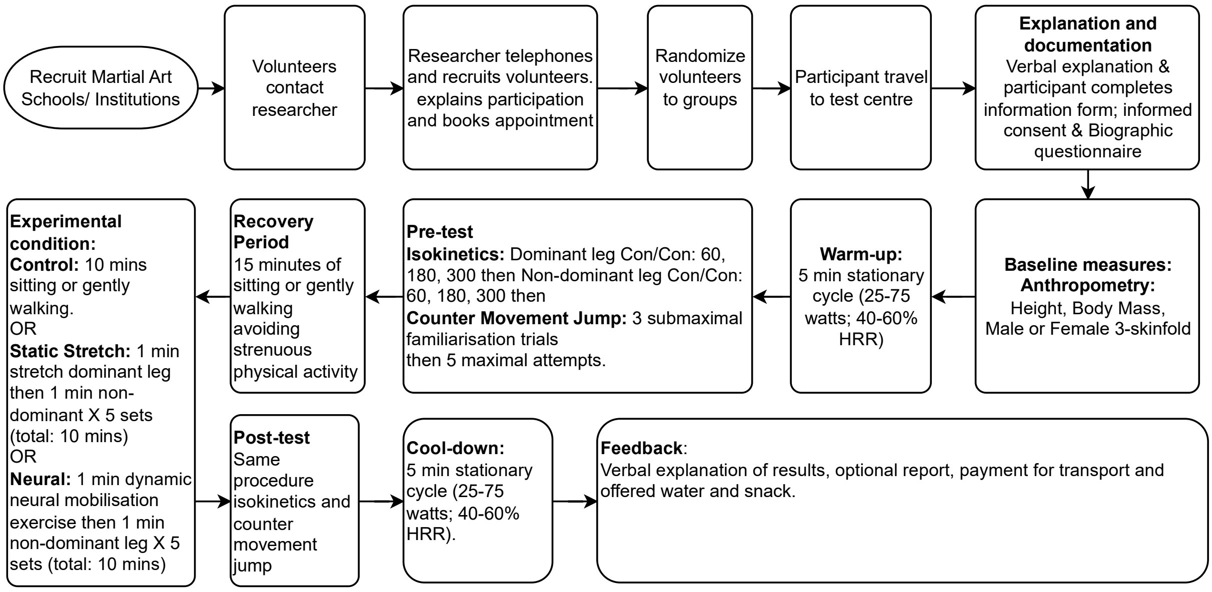


Figure 6 Flow chart of the study design and testing procedure

3.9 Outcome measures

3.9.1 Baseline measurements

Body composition measures are used to normalise isokinetic peak torque data,[180] determine jump power[181] and suggest average body composition of the sample [182].

Resting heart rate was measured with a heart rate monitor (FT2, Polar Electro, Kempele, Finland) to determine warm-up and cool-down intensity. Anthropometric procedures followed international standards for anthropometric assessment [183] with representative measures taken on the right side of the body. Height and body mass were measured with a stadiometer with height rod (Seca, Italy) and Body Mass Index (BMI) calculated with the equation: $\mathrm{BMI}=\ \mathrm{body\ mass/height}^{2}$**.** Body density was calculated with a generalised equation for men.[184] $1.10938\text{-}0.0008267\times\sum 3\mathrm{SK}+0.0000016\times\sum 3\mathrm{SK2}\text{-}0.0002574\times \mathrm{age}$ (where ∑3SF = chest + abdomen + thigh) and women.[185] $1.099421\text{-}0.0009929\times\sum 3\mathrm{SF}+0.0000023\times\sum 3\mathrm{SF2}\text{-}0.0001392\times \mathrm{age}$ (where ∑3SF = tricep + suprailiac + thigh). Skinfolds were measured with a Cescorf Harpenden Calliper (Cescorf Anthropometrica, Brazil). Body fat percentage was calculated from body density using the Siri equation.[186] $\%\mathrm{fat}=495\mathrm{body\ density}\text{-}450$. The measurements included:

1. Height: recorded to the nearest cm with the height rod touching the vertex of the head with the participant standing heels together on the scale.[183]
2. Body mass: recorded to the nearest 0.1 kg with the participant standing on a scale with minimal additional clothing.[183]
3. Chest skinfold: A diagonal fold; half the distance between the anterior axillary line and the nipple in men.[187]
4. Abdominal skinfold: A vertical fold; 2 cm to the right of the umbilicus.[187]
5. Thigh skinfold: a vertical fold, on the anterior midline of the thigh, midway between the superior border of the kneecap and the hip.[187]
6. Tricep skinfold: A vertical fold, on the posterior midline of the upper arm, midway between the acromion and olecranon processes with the arm relaxed to the side.[187]
7. Suprailiac skinfold: A diagonal fold, in line with the natural angle of the iliac crest, taken on the anterior axillary line just above crest of the ilium.[187]

3.9.2 Warm-up procedure

A 5-minute warm-up was used on a cycle ergometer (Monark Ergomedic 828E, Monark Exercise, Vansbro, Sverige) at a self-determined workload of 25 to 75 watts.[188] A range of wattages was used to accommodate varying levels of fitness, with a higher wattage required to elicit the necessary heart rate increases in persons with higher aerobic capacities. A wattage range of 25 to 75 watts aligns to the first stage of the

YMCA sub-maximal fitness test and considered appropriate for a range of athletic abilities.[189] Heart rate was monitored with a Polar FT2 heart rate watch to ensure participants remained within 40 to 60% of their heart rate reserve,[187] as higher intensities have been shown to reduce subsequent performance.[190] Heart rate reserve was calculated with the equation: $\mathrm{HRTarget=220\text{-}age\text{-}HRrestTarget\ intensity100+\ HRrest}$.[191]

3.9.3 Pre and post intervention test procedures

The following procedures followed baseline measurements and warm-up.

3.9.4 Isokinetic testing

Isokinetic testing is an objective, valid, reliable and safe method for measuring muscular strength and power.[192] The force velocity relationship of skeletal muscle, dictates that lower speed maximal contractions to produce greater torque, while higher speeds contractions produce less torque.[193] Stretch-induced strength loss affects isometric and low speed isokinetic tests more than high speed tests,[194] necessitating the measurement of a variety of speeds to observe velocity specific effects. A Biodex System 3 Professional Isokinetic Dynamometer (Biodex Medical Systems, Shirley, New York, United States of America) was used. After verbal explanation, participants were seated and fitted with stabilisation straps to prevent extraneous movements which could decrease peak torque scores.[195] The axis of rotation was aligned to the lateral epicondyle of the knee on the participant’s dominant leg. Familiarisation trials were performed before each test speed with two repetitions at 50% effort, two repetitions at 75% effort and 1 repetition at 100% effort.[182] A low repetition protocol was used to assess muscular strength at low speeds and moderate repetitions at higher speeds to assess power[196] using one set of concentric / concentric knee flexion / extension with five repetitions at $60°.s^{-1}$; ten repetitions at $180°.s^{-1}$ and fifteen repetitions at $300°.s^{-1}$. The inter-set rest period was 120 seconds and the inter-side rest period was 180 seconds.[197] Visual and verbal feedback can influence test results[198] and were given during each test. A verification of the dynamometer’s calibration was done each day before testing by attaching the Biodex calibration weight to the dynamometer in a horizontal position and measuring the torque exerted on the dynamometer in isometric mode using the calibration verification option in the Biodex software application.

3.9.5 Counter movement jump testing

The counter movement jump is a valid and reliable method for measuring leg power[199]. Jump height and time were recorded by the Counter Movement Jump Mat System (Fusion Sport, Coopers Plains, Australia). The participant stood still and barefoot on the centre of the mat with hands on the hips for the entire test. The jump was made in one continuous movement, by bending the hips, knees and ankles and then jumping as high as possible without any pausing. The depth of the preparation was decided by the participant and horizontal movements were avoided.[200] Three submaximal familiarisation trials preceded five maximal trials. The highest of the jumps was taken as the maximal attempt with 15 seconds of rest between each trial to ensure reproducibility of results.[201]

3.9.6 Recovery period

Participants rested for a recovery period of 15 minutes after pre-testing to remove the influence of fatigue on post-test results. Participants were asked to rest by sitting quietly or walking slowly and gently and avoiding strenuous movements. Recovery from fatigue occurs within 1 to 3 minutes[202–206] for standard isokinetic testing and with a work: rest ratio of 1:3 for endurance isokinetic testing.[197] Attenuation, but not removal of the magnitude of stretch-induced strength loss have been observed following warm-up[120] and fatiguing maximal training[118]. A 15-30 minute recovery period has been used previously to study the acute effects of stretching on stretch-induced strength loss.[42,45,128,142,146,178,194,207–210]

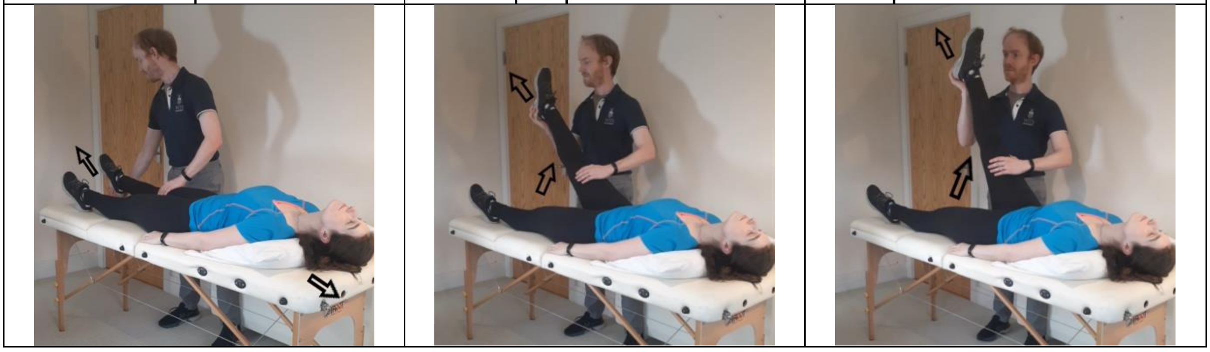
3.10 Intervention procedures

3.10.1 Control protocol

Participants in the control group were asked to rest by sitting quietly or walking slowly and gently and avoiding strenuous movements for 600 seconds or 10 minutes.

3.10.2 Static stretching protocol

Participants laid supine on a plinth and the researcher explained the intervention. Stretches on the dominant leg were alternated with stretches on the non-dominant leg. The cervical spine and ankles were maintained in extension and plantar flexion to avoid peripheral nerve tension during stretching, by asking the participant to “look upward” and “point the toes”. The researcher assisted the participant to perform the assisted hamstring stretch moving into hip flexion with full knee extension. Participants indicated when they had reached the point of maximum tolerated stretch, and the position was held for 60 seconds. The non-dominant leg was then stretched, while the dominant leg rested. Each leg was stretched for 5 repetitions of 60 seconds for a total time of 300 seconds per leg or 10 minutes of total stretch time.[211] A stop watch (Volkano VK-5007-BK, China) was used to time the intervention. The static stretch movement is shown in Figure 7 below.



Initial position | Hip in partial flexion | Hip flexed then extends

Permission was granted for use of this photograph by those who appear in it. See Appendix O

Figure 7 Photographs of the static stretch procedure

3.10.3 Dynamic neural mobilisation exercise protocol

Participants sat on the edge of a plinth and the researcher explained and demonstrate the active “slump” exercise. Five familiarisation trials were used per leg, starting with the dominant leg. Participant maintained moving the chin towards the chest, flexion of thoracic spine and dorsiflexion the ankle throughout. The exercise was performed by alternating knee extension until the point of maximum tolerated stretch and relaxation into knee flexion. If greater intensity was required, the participant was asked to lean the chest towards the knees. A metronome was used to maintain an exercise rate of 30 cycles per minute (60 beats.min^{-1}). The dominant leg was mobilised for 60 seconds, followed by the opposite leg. 5 sets 60 seconds stretching were used for a total stretch time of 300 seconds per leg or 10 minutes total. A stopwatch (Volkano VK-5007-BK, China) was used to time the intervention. The dynamic neural mobilisation movement is shown in Figure 8 below.

Initial position

Knee begins extending

Knee fully extends then flexes

Permission was granted for use of this photograph by those who appear in it. See Appendix O

Figure 8 Photographs of the dynamic neural mobilisation exercise procedure

3.10.4 Cool down procedure

An active light-moderate cool down of 5 minutes was performed immediately after the post-intervention assessment. The cool down intensity was 40 to 60% of Heart Rate Reserve[212] and followed the same procedure as the warm-up. A cool down helps to promote cardiovascular and respiratory recovery.[213]

3.11 Outcome variables

The independent continuous variables are static stretch, neural mobilisation exercise and control durations. The dependent continuous variables are dominant and non-dominant isokinetic absolute peak torque and peak torque / body weight and mean power in knee concentric / concentric extension / flexion at 60, 180 and 300°.s^{-1} and counter movement jump power. The descriptive continuous variables are height; body mass; body mass index, body fat percentage, fat mass and lean mass. Descriptive categorical variables are gender and martial art style.

3.12 Data collection methods

All data collection was done by the researcher. Data was written on paper recording sheets (Appendix G) after baseline, pre and post-test measures. Printed isokinetic reports were kept with recording sheets in a file. All data was captured after testing onto an Excel spreadsheet (Microsoft, USA).

3.13 Data analysis

Data was analysed with SPSS software version 29.0 (IBM, USA). For objectives 1 and 2, paired t-tests were used to determine the effect of control condition, static stretching and neurodynamic mobilisation on isokinetic strength, power and jump power. For objective 3, ANOVA was used to determine whether means differed between groups and a Bonferroni test determined if groups differed significantly. The central limit theorem states that with a sufficiently large number of observations ($n \geq 30$) the distribution of datasets, approximate normal distributions and parametric tests can remain valid, even in the case of non-normally distributed data. [214] Descriptive statistics included means and standard deviations. Data was tested for normality using skewness, kurtosis, histograms, and the Shapiro-Wilk test. Levene's test was used to test for equality of variances. The data was assessed for outliers using histograms, boxplots and the 3(IQR) criterion. Anthropometric data has been described with reference to gender and martial art style.

3.14 Ethics

Ethics clearance was applied for with the Witwatersrand University Human Research Ethics Committee (Medical) (Appendix B). Fairness was ensured by giving the control group the opportunity to receive an intervention of their choice, according to guidance of the Declaration of Helsinki.[215] As isokinetic testing involved maximal exercise, warm-ups and cool-downs were provided to reduce risks of injury and participants informed about risks of post-exercise soreness. The researcher was qualified in first aid should the need have arisen. Written informed consent (Appendix E) was gathered before participation and each person given the opportunity to ask questions and informed that they are free to withdraw from the research at any time without prejudice. Reference numbers were assigned to participants to maintain confidentiality, rather than using identifying information. Information was kept securely throughout the research process and at the conclusion of the study, all identifying information was destroyed.

CHAPTER 4: RESULTS

The subtopics that will be covered in this chapter include:

4.1 Introduction

This chapter presents the results the study. First, participant biographic and demographic characteristics and baseline testing results including participant anthropometric characteristics are presented. Results are given for paired t-tests between pre- and post-test means for control, static stretching, and dynamic neural mobilisation exercise groups. Results of between-subjects One-way ANOVA between post-test means for each group are given. Finally absolute percentage change data between pre- and post-test means for each group are presented.

4.2 Participant biographic and demographic characteristics (n = 93)

The gender distribution of the sample was 81% male and 19% female, due to sampling of convenience. Table 2 details the number of participants per gender and the martial art style they reported they participated in. The sample comprised of 29% MMA, 29% Jiu jitsu, 19.4% karate, 6.5% kungfu and 16.1% taekwondo. Table 4 details the number of participants per gender, who reported their martial art experience category as “recreational” (59.1%), “national” (21.5%), “international” (17.2%) or “elite” (2.2%).

Table 2 Frequencies of self-reported martial art style and gender characteristics of sample (n = 93)

	Females (n = 18)		Males (n = 75)		Total participants (n = 93)	
Self-reported martial art style	n	%*	n	%*	n	%*
Mixed Martial Arts	3	17	24	32	27	29
Jiu jitsu	3	17	24	32	27	29
Karate	6	33	12	16	18	19
Taekwondo	3	17	12	16	15	16
Kungfu	3	17	3	4	6	6
Total	18		75		93	

* Percentages have been rounded to the nearest integer.

Table 3 Self-reported martial arts experience category for female, male and total participants (n = 93)

	Females (n = 18)		Males (n = 75)		Total participants (n = 75)	
Self-reported experience level	n	%*	n	%*	n	%*
Recreational	10	56	45	60	55	59
National	1	6	19	25	20	22
International	5	28	11	15	16	17
Elite	2	11	0	0	2	2
Total	18		75		93	

* Percentages have been rounded to the nearest integer.

4.3 Baseline testing

4.3.1 Participant age and anthropometric characteristics

The sample anthropometric characteristics are shown in Table 4 below. The mean age for all participants was 26.3 ± 4.5 years (females = 26.6 ± 4.7 years, males = 24.5 ± 4.5 years). The mean body mass for all participants was 74.9 ± 14.4 kg (females = 63.9 ± 13.7 kg, males = 77.5 ± 13.4 kg). The mean height for all participants was 173.5 ± 8.9 cm (females = 163.3 ± 6.4 cm, males = 175.9 ± 7.6 cm). The mean body mass index for all participants was 24.8 ± 0.4 kg.m^{-2} (females = 23.9 ± 1.16 kg.m^{-2}, males = 25.0 ± 0.4 kg.m^{-2}. The mean body fat percentage for all participants was 14.0 ± 7.6% (females = 22.3 ± 7.9%, males = 12.0 ± 6.0%). The mean fat mass for all participants was 10.8 ± 7.1 kg (females = 15.0 ± 8.9 kg, males = 9.8 ± 6.2 kg). The mean lean mass for all participants was 64.0 ± 11.6 kg (females = 48.8 ± 6.0 kg, males = 67.7 ± 9.5 kg).

Table 4 Participant age and anthropometric characteristics (n = 93)

	Females (n = 18)			Males (n = 75)			Total participants (n = 93)		
Variables	Mean ± SD	Min	Max	Mean ± SD	Min	Max	Mean ± SD	Min	Max
Age (years)	26.6 ± 4.7	20	34	24.5 ± 4.5	18	35	26.3 ± 4.5	18	35
Body mass[a] (kg)	63.9 ± 13.7	51.5	110	77.5 ± 13.4	52.3	116	74.9 ± 14.4	51.5	116
Height (cm)	163.3 ± 6.4	153	196	175.9 ± 7.6	153	173	173.5 ± 8.9	153	196
BMI (kg.m^{-2})	23.9 ± 1.16	18.8	40.2	25 ± 0.4	17.6	35.8	24.8 ± 0.4	17.6	40.2
Body fat (%)	22.3 ± 7.9	11.6	39.8	12 ± 6	3.4	30.1	14 ± 7.6	3.4	39.8
Fat mass (kg)	15 ± 8.9	6.1	43.9	9.8 ± 6.2	2.3	33.6	10.8 ± 7.1	2.3	43.9
Lean mass (kg)	48.8 ± 6	40.9	66.3	67.7 ± 9.5	49.7	101	64 ± 11.6	40.9	101

[a] The term “body mass” is used by convention. This refers to the “body weight” of a person measured using a scale.
SD = Standard Deviation; BMI = Body Mass Index

4.4 Paired t-tests between pre- and post-test means

Paired two-tailed t-tests were performed to compare means before and after intervention for the control, static stretch, and dynamic neural exercise groups. Effect size (Cohen’s d) was calculated using the formula:

$$\mathrm{d} = \frac{\text{mean difference}}{\text{SD of mean difference}}.$$

The results of the paired two-tailed t-tests are presented in the following sections for paired t-tests between pre- and post-test means for the control group, then static stretching group and then dynamic neural mobilisation exercise group. Results for each group will be described and shown in accompanying tables. The data is visualised in a series of bar charts.

4.5 Control group

Several statistically significant differences ($p \leq 0.05$) were identified for the control group. Significant differences were identified in certain variables for isokinetic dynamometry at 60 (5 repetitions), 180 (10 repetitions) and 300º.s^{-1} (15 repetitions) with small to moderate effect sizes ($0.373 > d < 0.783$). No significant differences were noted for Counter Movement Jump.

Table 5 shows the control group’s results for isokinetic testing at 60º.s^{-1}. Significant decreases were identified for knee extension dominant leg absolute peak torque (211.02 ± 56 to 196.8 ± 53.36 Nm, d = 0.692, t (30) = 3.853, p<0.001) and peak torque / body weight (276.08 ± 48.33 to 257.02 ± 42.8, d = 0.738, t (30) = 4.107, p<0.001) and for dominant leg knee flexion peak torque / body weight (145 ± 29.99 to 139.04 ±

28.66 $Nm.kg^{-1}$, d = 0.400, t (30) = 2.229, p = 0.033). The differences listed above are visualised in Figure 9, Figure 10, and Figure 11. No significant differences were identified in the non-dominant leg.

Table 5 Paired t-test results between pre- and post-test means for concentric/concentric knee flexion/extension isokinetic dynamometry at $60^{o}.s^{-1}$ for 5 repetitions in the control group in martial artists (n = 31)

		Absolute peak torque (Nm)				Peak torque / body weight ($Nm.kg^{-1}$)				Mean power (W)			
Test	Leg	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p
Ext.	D	211.02 ±56	196.8 ±53.36	-6.7	<0.001*	276.08 ±48.33	257.02 ±42.8	-6.9	<0.001*	141.35 ±38.08	136.04 ±35.69	-3.8	0.057
	ND	195.34 ±58.3	192.62 ±55.04	-1.4	0.413	254.54 ±50.51	250.49 ±43.32	-1.6	0.346	130.6 ±38.13	132.74 ±37.72	1.6	0.434
Flex.	D	110.45 ±30.45	106.85 ±32.8	-3.3	0.099	145 ±29.99	139.04 ±28.66	-4.1	0.03*	74.72 ±20.91	74.8 ±22.42	0.1	0.967
	ND	98.13 ±28.36	101.62 ±30.18	3.6	0.095	128.65 ±27.65	132.43 ±25.54	3.9	0.131	68.27 ±20.9	70.92 ±21.73	3.9	0.078

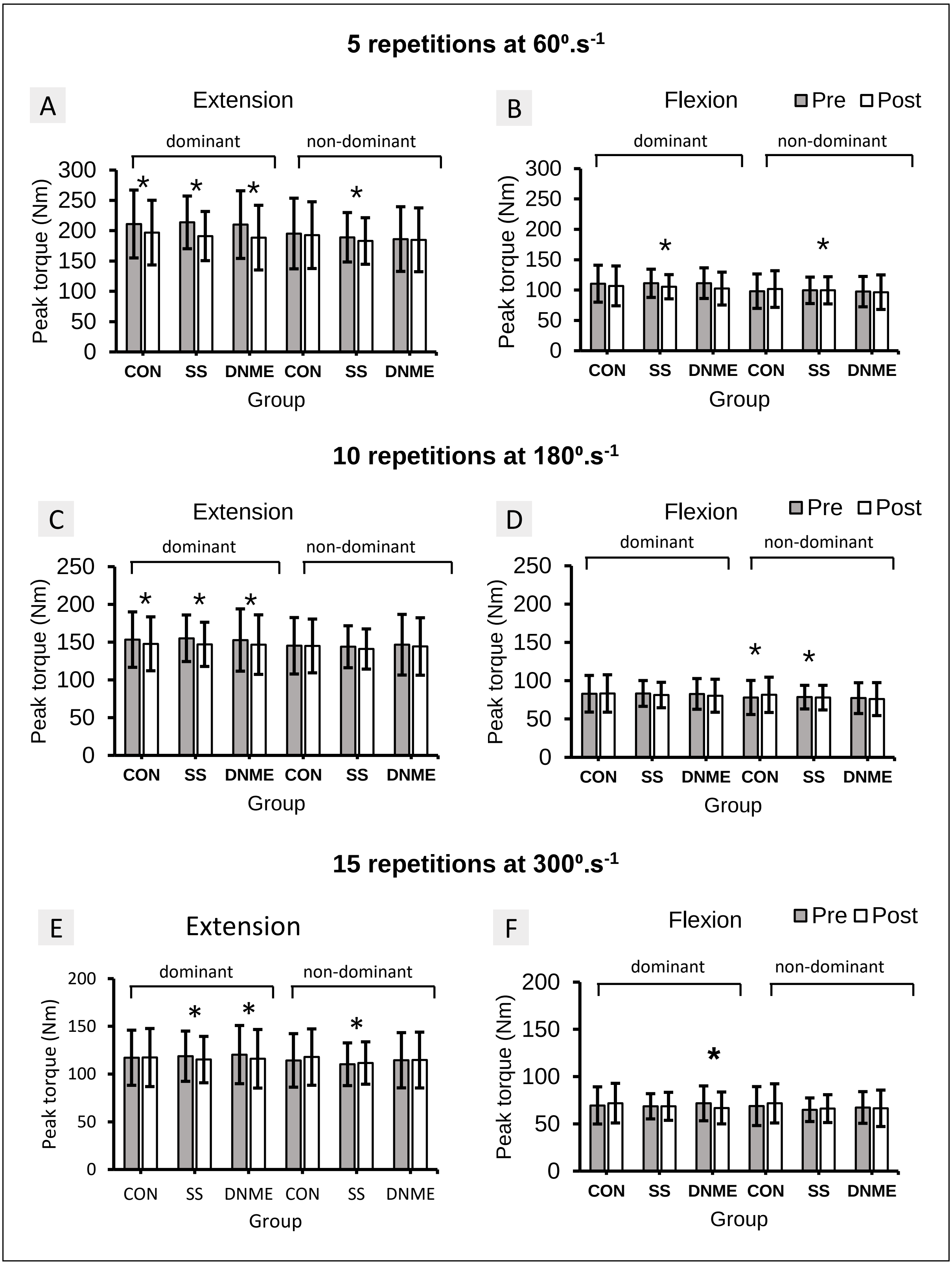
D = Dominant; ND = Non-dominant; Ext. = Knee extension; Flex. = Knee extension; SD = Standard Deviation; Δ = change
* Significantly different between pre and post ($p < 0.05$)

Table 6 shows the control group's results for isokinetic testing for 10 repetitions at $180^{o}.s^{-1}$. Significant decreases were identified for dominant leg knee extension for absolute peak torque (153.36 ± 36.72 to 147.81 Nm ± 35.73, d = 0.658, t (30) = 3.3662, $p < 0.001$), peak torque / body weight (200.95 ± 31.4 to 193.28 ± 28.2 $Nm.kg^{-1}$, d = 0.696, t (30) = 3.877, $p < 0.001$) and mean power (267.99 ± 68.02 to 256.96 ± 66.27 W, d = 0.783, t (30) = 4.359, $p<0.001$). Significant increases were identified for non-dominant leg knee extension absolute peak torque (78.13 ± 22.27 to 81.58 ± 23.02 Nm, d = 0.441, t (30) = 2.455, p = 0.02) and peak torque to body weight (102.31 ± 21.23 to 106.43 ± 20.09 $Nm.kg^{-1}$, d = 0.409, t (30) = 0.059, p=0.03). The differences listed here are visualised in Figure 9, Figure 10, and Figure 11. No other significant differences were identified.

Table 6 Paired t-test results between pre- and post-test means for concentric/concentric knee flexion/extension isokinetic dynamometry at $180^{o}.s^{-1}$ for 10 repetitions in the control group in martial artists (n = 31)

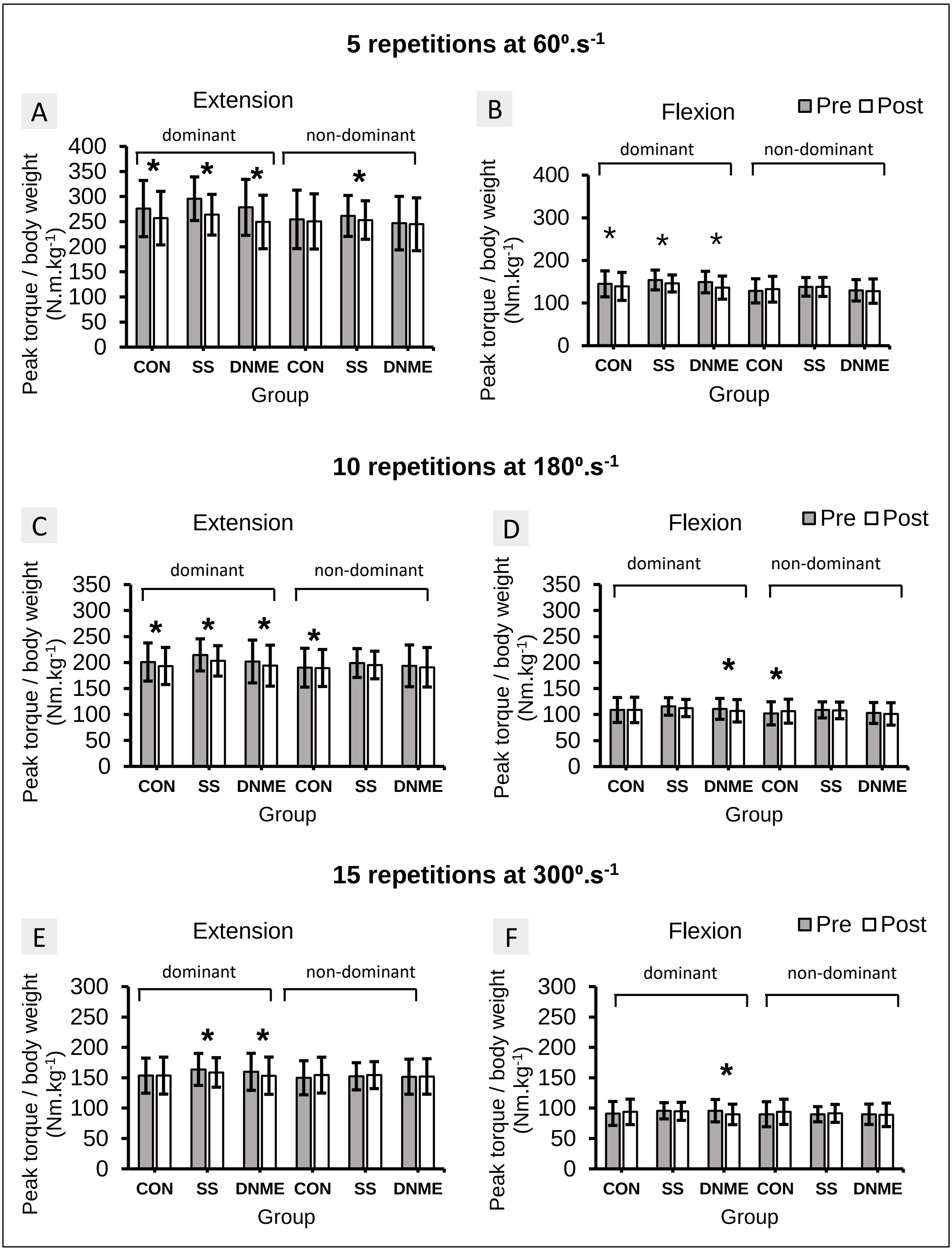
		Absolute peak torque (Nm)				Peak torque / body weight ($Nm.kg^{-1}$)				Mean power (W)			
Test	Leg	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p
Ext.	D	153.36 ±36.72	147.81 ±35.73	-3.6	<0.001*	200.95 ±31.4	193.28 ±28.2	-3.8	<0.001*	267.99 ±68.02	256.96 ±66.27	-4.1	<0.001*
	ND	145.19 ±37.38	144.95 ±35.62	-0.2	0.905	190.05 ±33.42	189.45 ±28.91	-0.3	0.804	247.62 ±59.99	250.29 ±59.39	1.1	0.554
Flex.	D	82.98 ±23.92	83.35 ±24.41	0.4	0.797	108.75 ±23.11	108.86 ±21.98	0.1	0.953	142.8 ±42.35	140.79 ±43.25	-1.4	0.545
	ND	78.13 ±22.27	81.58 ±23.02	4.4	0.02*	102.31 ±21.23	106.43 ±20.09	4.0	0.03*	132.51 ±39.31	137.9 ±38.68	4.1	0.096

D = Dominant; ND = Non-dominant; Ext. = Knee extension; Flex. = Knee extension; SD = Standard Deviation; Δ = change
* Significantly different between pre and post ($p < 0.05$)



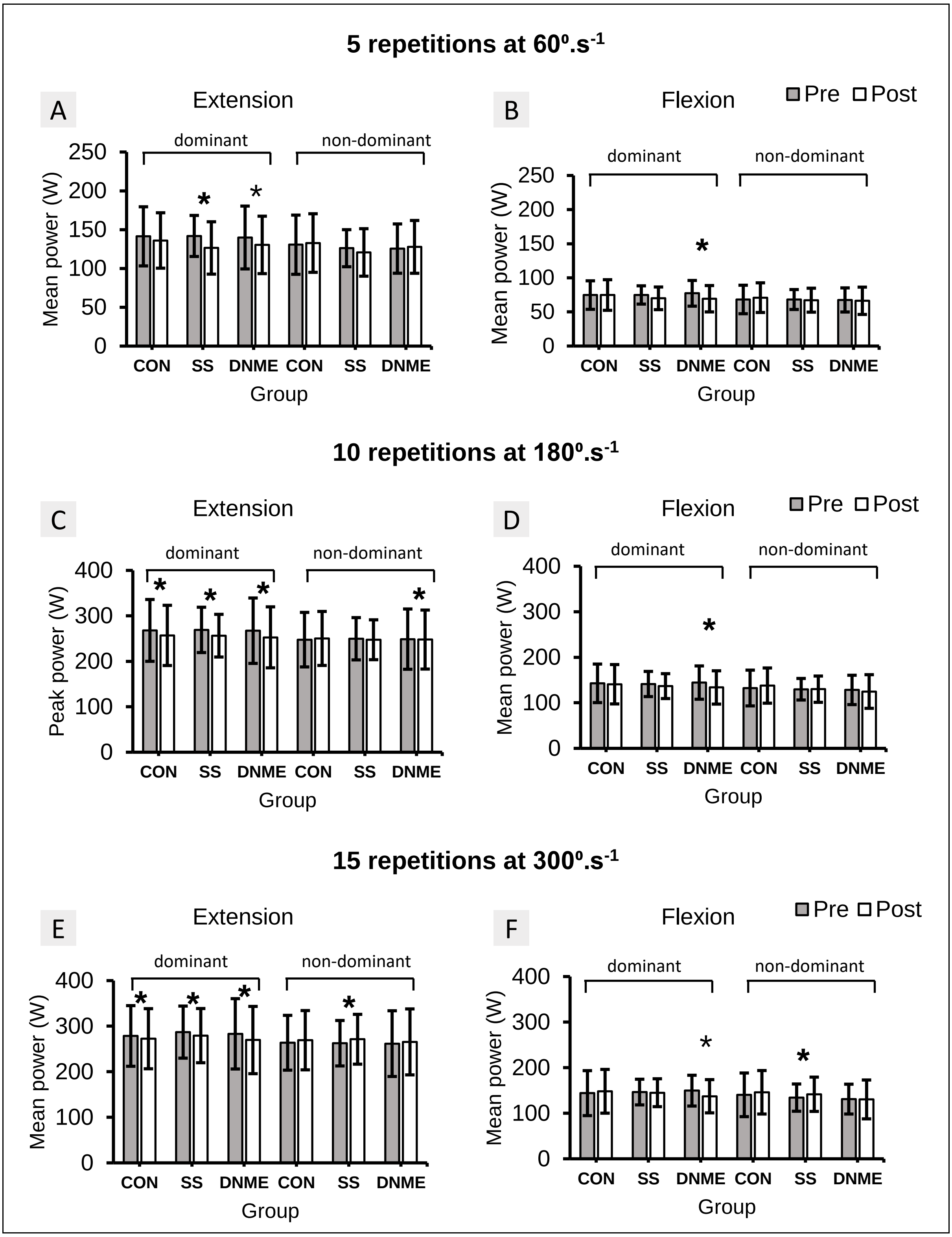
CON = Control; SS = Static Stretching; DNME = Dynamic Neural Mobilisation Exercise
* = Significant differences (p ≤0.05)

Figure 9 Absolute peak torque (Nm) pre-, and post-test means in the dominant and non-dominant legs in control, static stretching and dynamic neural mobilisation exercise groups for concentric/concentric knee extension or flexion at 60, 180 and 300⁰.s-1 (n = 31)



CON = Control; SS = Static Stretching; DNME = Dynamic Neural Mobilisation Exercise
* = significant difference ($p \leq 0.05$)

Figure 10 Peak torque / body weight ($Nm.kg^{-1}$) pre-, and post-test means in the dominant and non-dominant legs in control, static stretching, and dynamic neural mobilisation exercise groups for concentric/concentric knee extension or flexion at 60, 180 and $300^0.s^{-1}$ (n = 31)



CON = Control; SS = Static Stretching; DNME = Dynamic Neural Mobilisation Exercise
* = significant difference (p≤ 0.05

Figure 11 Mean power (W) pre-, and post-test means in the dominant and non-dominant legs in control, static stretching and dynamic neural mobilisation exercise groups for concentric/concentric knee extension and flexion at 60, 180 or 300⁰.s^{-1} (n = 31)

Table 7 shows the control group's results for isokinetic testing for 15 repetitions at 300º.s^{-1}. A significant decrease was identified for dominant leg knee extension mean power (278.56 ± 66.52 to 272.49 ± 65.98 W, d = 0.373, t (30) = 2.077, p = 0.046). No other significant differences were identified. The differences listed here are visualised in Figure 9, Figure 10, and Figure 11.

Table 7 Paired t-test results between pre- and post-test means for concentric/concentric knee flexion/extension isokinetic dynamometry at 300º.s^{-1} for 15 repetitions in the control group in martial artists (n=31)

		Absolute peak torque (Nm)				Peak torque / body weight (Nm.kg^{-1})				Mean power (W)			
Test	Leg	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p
Ext.	D	117.12 ±28.88	117.31 ±30.43	0.2	0.898	153.49 ±26.64	153.5 ±27.65	0.0	0.996	278.56 ±66.52	272.49 ±65.98	-2.2	0.046*
	ND	114.31 ±28.04	117.81 ±29.51	3.1	0.055	149.97 ±26.04	154.32 ±27.28	2.9	0.060	263.64 ±60.12	269.22 ±65.07	2.1	0.130
Flex.	D	69.5 ±19.67	71.91 ±20.98	3.5	0.123	91.22 ±18.74	93.83 ±18.73	2.9	0.197	144.14 ±49.36	148.18 ±48.01	2.8	0.282
	ND	68.79 ±20.61	71.66 ±20.72	4.2	0.076	89.95 ±19.62	93.94 ±20.54	4.4	0.075	140.4 ±47.91	146 ±47.72	4.0	0.128

D = Dominant; ND = Non-dominant; Ext. = Knee extension; Flex. = Knee extension; SD = Standard Deviation; Δ = change
* Significantly different between pre and post ($p < 0.05$)

Table 8 shows the differences between pre and post control condition means for counter movement jump scores. No significant differences were identified for the counter movement jump tests.

Table 8 Paired t-test results for pre- and post-test means for the highest scores of 5 maximal attempts of counter movement jump in the control group in martial artists (n = 31)

variable	Mean ± SD (pre)	Mean ± SD (post)	Δ (%)	p
height (cm)	35.04 ± 6.58	35.49 ± 6.15	1.27	0.373
power (W)	3574.03 ± 815.21	3534.53 ± 783.62	-1.12	0.352
power: body mass (W/kg)	46.18 ± 5.79	46.53 ± 5.42	0.76	0.402
Impulse (kg.s^{-1})	202.29 ± 43.69	199.52 ± 42.39	-1.39	0.246

* No significant differences were identified between pre-, and post-test means.

4.6 Objective 1: Static stretching

Paired two-tailed t-tests were used to assess the difference between pre- and post-test means for the static stretching group. Significant differences were identified for some, but not all variables at 60 (5 repetitions), 180 (10 repetitions) and 300º.s^{-1} (15 repetitions) with small to large effect sizes (0.428 > d < 1.254).

Table 9 shows the differences between concentric / concentric isokinetic testing for 5 repetitions at 60º.s^{-1} before and after the static stretching condition. Significant decreases were identified for knee extension absolute peak torque in the dominant

(213.7 ± 43.47 to 191.12 ± 40.56 Nm, d = 1.163, t (30) = 6.48, p<0.001) and non-dominant leg (189.12 ± 40.78 to 183.01 ± 38.38 Nm, d = 0.541, t (30) = 3.01, p = 0.005). Non-dominant knee flexion absolute peak torque decreased significantly (111.08 ± 23.26 to 105.42 ± 19.96, d = 0.428, t (30) = 2.38, p = 0.024). Significant decreases were identified for peak torque / body weight for knee extension in the dominant leg (295.76 ± 44.19 to 263.87 ± 39.78 Nm.kg^{-1}, d = 1.254, t (30) = 6.98, p<0.001), non-dominant leg (261.41 ± 40.2 to 253.27 ± 39.4 Nm.kg^{-1}, d = 0.524, t (30) = 2.92, p = 0.007) and for knee flexion in the dominant leg (154.08 ± 26.91 to 145.99 ± 20.97 Nm.kg^{-1}, d = 0.463, t (30) = 2.58, p = 0.015). Mean power significantly decreased for dominant leg knee extension (141.85 ± 26.44 to 126.41 ± 33.72 W, d = 0.521, t (30) = 2.90, p = 0.007). No other significant differences were identified in the static stretch group for isokinetics at 60º.s^{-1}. The differences listed here are visualised in Figure 9, Figure 10, and Figure 11.

Table 9 Paired t-test results between pre- and post-test means for concentric/concentric knee flexion/extension isokinetic dynamometry at 60º.s^{-1} for 5 repetitions in the static stretching group in martial artists (n=31)

		Absolute peak torque (Nm)				Peak torque / body weight (Nm.kg^{-1})				Mean power (W)			
Test	Leg	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p
Ext.	D	213.7 ±43.47	191.12 ±40.56	-10.6	<0.001*	295.76 ±44.19	263.87 ±39.78	-10.8	<0.001*	141.85 ±26.44	126.41 ±33.72	-10.9	0.006*
	ND	189.12 ±40.78	183.01 ±38.38	-3.2	0.005*	261.41 ±40.2	253.27 ±39.4	-3.1	0.006*	126.07 ±23.87	120.63 ±30.57	-4.3	0.182
Flex.	D	111.08 ±23.26	105.42 ±19.96	-5.1	0.02*	154.08 ±26.91	145.99 ±20.97	-5.3	0.01*	74.88 ±13.38	69.94 ±16.61	-6.6	0.091
	ND	99.52 ±21.79	99.53 ±22.37	0.0	0.995	138.01 ±25.11	137.87 ±24.81	-0.1	0.948	68.19 ±14.59	67.23 ±17.56	-1.4	0.651

D = Dominant; ND = Non-dominant; Ext. = Knee extension; Flex. = Knee extension; SD = Standard Deviation; Δ = change
* Significantly different between pre and post ($p < 0.05$)

Table 10 shows the differences between concentric / concentric isokinetic testing for 10 repetitions at 180º.s^{-1} before and after the static stretching intervention. A significant decrease was identified for absolute peak torque for dominant leg knee extension (155.16 ± 30.85 to 147.08 ± 29.27 Nm, d = 0.786, t (30) = 4.38, p < 0.001), Peak torque / body weight decreased significantly for dominant leg knee extension (214.66 ± 31.64 to 203.15 ± 28.26 Nm.kg^{-1}, d = 0.895, t (30) = 0.895, p=<0.001). Mean power decreased significantly for dominant leg knee extension (269.12 ± 49.86 to 256.39 ± 46.94 W, d = 0.770, t (30) = 4.29, p < 0.001). No other significant differences were identified for the static stretching group for isokinetics at 180º.s^{-1}. The differences listed here are visualised in Figure 9, Figure 10, and Figure 11.

Table 10 Paired t-test results between pre- and post-test means for concentric/concentric knee flexion/extension isokinetic dynamometry at 180^{0}.s^{-1} for 10 repetitions in the static stretching group in martial artists (n = 31)

		Absolute peak torque (Nm)				Peak torque / body weight (Nm.kg^{-1})				Mean power (W)			
Test	Leg	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p
Ext.	D	155.16 ±30.85	147.08 ±29.27	-5.2	<0.001*	214.66 ±31.64	203.15 ±28.26	-5.4	<0.001*	269.12 ±49.86	256.39 ±46.94	-4.7	<0.001*
	ND	143.88 ±27.8	140.92 ±26.6	-2.1	0.051	198.94 ±26.79	195.2 ±27.78	-1.9	0.053	249.62 ±46.52	247.41 ±43.87	-0.9	0.427
Flex.	D	83.38 ±16.84	81.32 ±16.6	-2.5	0.215	115.54 ±18.73	112.52 ±17.63	-2.6	0.170	141.31 ±27.64	136.68 ±27.34	-3.3	0.107
	ND	78.57 ±15.42	77.92 ±16.07	-0.8	0.671	108.99 ±17.41	107.96 ±17.5	-0.9	0.613	129.84 ±23.66	129.97 ±28.86	0.1	0.962

D = Dominant; ND = Non-dominant; Ext. = Knee extension; Flex. = Knee extension; SD = Standard Deviation; Δ = change
* Significantly different between pre and post ($p < 0.05$)

Table 11 shows the differences between concentric / concentric isokinetic testing for 15 repetitions at 300^{0}.s^{-1} before and after the static stretching intervention. Significant decreases were identified for dominant leg knee extension absolute peak torque (118.72 ± 26.31 to 115.18 ± 24.29 Nm, d = 0.47, t (30) = 2.63, p = 0.013), peak torque / body weight (163.78 ± 25.98 to 158.77 ± 21.74 Nm.kg^{-1}, d = 0.482, t (30) = 2.68, p = 0.012) and mean power (287 ± 57.15 to 279.27 ± 59.5 W, d = 0.473, t (30) = 2.64, p = 0.013). Significant increases were identified for non-dominant leg mean power for both knee extension (262.62 ± 49.9 to 271.3 ± 54.68 W, d = -0.473, t (30) = -2.63, p = 0.013) and knee flexion (134.29 ± 29.89 to 141.66 ± 37.63 W, d = -0.400, t (30) = -2.23, p = 0.034). No other significant differences were identified. The differences listed here are visualised in Figure 9, Figure 10, and Figure 11.

Table 11 Paired t-test results between pre- and post-test means for concentric/concentric knee flexion/extension isokinetic dynamometry at 300^{0}.s^{-1} for 15 repetitions in the static stretching group in martial artists (n = 31)

		Absolute peak torque (Nm)				Peak torque / body weight (Nm.kg^{-1})				Mean power (Watts)			
Test	Leg	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p
Ext.	D	118.72 ±26.31	115.18 ±24.29	-3.0	0.01*	163.78 ±25.98	158.77 ±21.74	-3.1	0.01*	287 ±57.15	279.27 ±59.5	-2.7	0.01*
	ND	110.28 ±22.38	111.59 ±22.19	1.2	0.285	152.41 ±21.28	154.32 ±21.83	1.3	0.251	262.62 ±49.9	271.3 ±54.68	3.3	0.01*
Flex.	D	68.57 ±13.35	68.56 ±14.82	0.0	0.995	95.6 ±18.51	94.69 ±14.83	-1.0	0.680	146.5 ±28.18	145.04 ±30.61	-1.0	0.701
	ND	64.93 ±12.49	66.12 ±14.73	1.8	0.303	89.93 ±12.58	91.33 ±15.17	1.6	0.380	134.29 ±29.89	141.66 ±37.63	5.5	0.03*

D = Dominant; ND = Non-dominant; Ext. = Knee extension; Flex. = Knee extension; SD = Standard Deviation; Δ = change
* Significantly different between pre and post ($p < 0.05$)

Table 12 shows the differences between pre and post intervention results for counter movement jump testing. No significant differences were identified.

Table 12 Paired t-test results for pre- and post-test means for the highest scores of 5 maximal attempts of counter movement jump in the static stretching group in martial artists (n = 31)

Variable	Mean ± SD (pre)	Mean ± SD (post)	Δ (%)	p
Height (cm)	38.37 ±7.8	37.6 ±8.39	-2.05	0.319
Power (W)	3565.9 ±722.51	3551.35 ±807.49	-0.41	0.872
Power: body mass ratio (W/kg)	49.19 ±6.98	48.34 ±7.37	-1.75	0.196
Impulse (kg.s^{-1})	198.16 ±38.2	198.42 ±42	0.13	0.956

* No significant differences were identified between pre-, and post-test means.

4.7 Objective 2: Dynamic neural mobilisation exercise

Table 13 shows the differences between pre-test and post-test means for concentric / concentric isokinetics knee extension / flexion for 5 repetitions at 60^{0}.s^{-1} before and after the dynamic neural exercise condition. Significant decreases were identified in the dominant leg for knee extension in absolute peak torque (210.01 ± 55.79 to 188.54 ± 53.37 Nm, d = 1.302, t (30) = 7.251 , p < 0.001), peak torque / body weight (278.58 ± 46.88 to 249.41 ± 44.5 Nm.kg^{-1}, d = 1.257, t (30) = 6.999, p < 0.001) and mean power (139.87 ± 40.49 to 130.32 ± 37 W, d = 1.05, t (30) = 5.848, p < 0.001). Significant decreases were also identified in the dominant leg for knee flexion absolute peak torque (111.32 ± 25.23 to 102.41 ± 27.08 Nm, d = 0.9, t (30) = 5.18, p < 0.001), peak torque / body weight (149.19 ± 27.91 to 136.2 ± 24.99 Nm.kg^{-1}, d = 0.981, t (30) = 5.463, p < 0.001) and mean power (77.3 ± 18.83 to 69.35 ± 19.32 W, d = 1.05, t (30) = 5.848, p < 0.001). No significant differences were identified for the non-dominant leg. The differences listed here are visualised in Figure 9, Figure 10, and Figure 11.

Table 13 Paired t-test results between pre- and post-test means for concentric/concentric knee flexion/extension isokinetic dynamometry at 60^{0}.s^{-1} for 5 repetitions in the dynamic neural mobilisation group in martial artists (n = 31)

		Absolute peak torque (Nm)				Peak torque / body weight (Nm.kg^{-1})				Mean power (W)			
Test	Leg	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p
Ext.	D	210.01 ±55.79	188.54 ±53.37	-10.2	<0.001*	278.58 ±46.88	249.41 ±44.5	-10.5	<0.001*	139.87 ±40.49	130.32 ±37	-6.8	<0.001*
	ND	186.18 ±53.34	184.94 ±52.68	-0.7	0.602	247.04 ±49.53	244.8 ±45.59	-0.9	0.465	125.58 ±31.73	127.81 ±34.01	1.8	0.225
Flex.	D	111.32 ±25.23	102.41 ±27.08	-8.0	<0.001*	149.19 ±27.91	136.2 ±24.99	-8.7	<0.001*	77.3 ±18.83	69.35 ±19.32	-10.3	<0.001*
	ND	97.41 ±25.02	96.49 ±28.46	-0.9	0.564	129.87 ±25.07	128 ±26.97	-1	0.368	67.58 ±17.66	66.34 ±20.02	-2	0.228

D = Dominant; ND = Non-dominant; Ext. = Knee extension; Flex. = Knee extension; SD = Standard Deviation; Δ = change
* Significantly different between pre and post (p < 0.05)

Table 14 shows the differences between pre- and post-test means for concentric / concentric knee extension / flexion isokinetics for 10 repetitions at 180º.s^{-1} before and after the dynamic neural exercise condition. Significant decreases were identified in the dominant leg for knee extension absolute peak torque (152.8 ± 41.25 to 146.75 ± 39.45 Nm, d = 0.555, t (30) = 3.091, p = 0.004), peak torque / body weight (201.94 ± 30.36 to 193.94 ± 30.08 Nm.kg^{-1}, d = 0.556, t (30) = 3.098, p < 0.004) and mean power (267.37 ± 71.94 to 252.71 ± 67.09 W, d = 0.583, t (30) = 3.248, p = 0.003). Significant decreases were also identified in the dominant leg in knee flexion for peak torque / body weight (110.95 ± 21.22 to 107.22 ± 21.1 Nm.kg^{-1}, d = 0.393, t (30) = 2.19, p = 0.03) and mean power (144.46 ± 36.59 to 133.75 ± 36.58 W, d = 0.733, t (30) = 4.081, p < 0.001). No significant differences were identified in the non-dominant leg. The differences listed here are visualised in Figure 9, Figure 10, and Figure 11.

Table 14 Paired t-test results between pre- and post-test means for concentric/concentric knee flexion/extension isokinetic dynamometry at 180º.s^{-1} for 10 repetitions in the static stretching group in martial artists (n = 31)

		Absolute peak torque (Nm)				Peak torque / body weight (Nm.kg^{-1})				Mean power (W)			
Test	Leg	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p
Ext.	D	152.8 ±41.25	146.75 ±39.45	-4.0	0.004*	201.94 ±30.36	193.94 ±30.08	-4.0	0.004*	267.37 ±71.94	252.71 ±67.09	-5.5	0.003*
	ND	146.6 ±40.19	144.24 ±38.04	-1.6	0.206	193.62 ±32.2	190.84 ±30.08	-1.4	0.264	248.78 ±66.31	247.85 ±64.88	-0.4	0.779
Flex.	D	82.79 ±20.04	80.38 ±21.54	-2.9	0.068	110.95 ±21.22	107.22 ±21.1	-3.4	0.03*	144.46 ±36.59	133.75 ±36.58	-7.4	<0.001*
	ND	77.27 ±20.12	76 ±21.52	-1.6	0.303	103.03 ±18.56	101.2 ±20.88	-1.8	0.281	128.32 ±32.24	124.87 ±36.96	-2.7	0.127

D = Dominant; ND = Non-dominant; Ext. = Knee extension; Flex. = Knee extension; SD = Standard Deviation; Δ = change
* Significantly different between pre and post (p < 0.05)

Table 15 shows the differences between pre-test and post-test means for concentric / concentric isokinetics for 15 repetitions at 300º.s^{-1} before and after the dynamic neural exercise condition. Significant differences were identified only in the dominant leg. Significant decreases were identified in the dominant leg in knee extension for absolute peak torque (120.41 ± 30.5 to 116.02 ± 30.69 Nm, d = 0.542, t (30) = 3.019, p = 0.005), peak torque / body weight (159.77 ± 26.6 to 153.43 ± 26.25 Nm.kg, d = 0.583, t (30) = 3.246, p = 0.003) and mean power (283.21 ± 77.18 to 269.57 ± 73.84 Nm.kg^{-1}, d = 0.694, t (30) = 3.863, p < 0.001). In dominant leg knee flexion significant decreases were identified in absolute peak torque (71.69 ± 18.44 to 66.82 ± 16.88 Nm, d = 0.682, t (30) = 3.796, p < 0.001), peak torque / body weight (95.77 ± 17.75 to 89.64 ± 18.66 Nm.kg^{-1}, d = 0.715, t (30) = 3.982, p < 0.001) and mean power (149.59 ± 33.81

to 137.32 ± 36.47 W, d = 0.738, t (30) = 4.11, p < 0.001). No other significant differences were identified. The differences listed here are visualised in Figure 9, Figure 10, and Figure 11.

Table 15 Paired t-test results between pre- and post-test means for concentric/concentric knee flexion/extension isokinetic dynamometry at 300^{o}.s^{-1} for 15 repetitions in the dynamic neural mobilisation exercise group in martial artists (n = 31)

		Absolute peak torque (Nm)				Peak torque / body weight (Nm.kg^{-1})				Mean power (W)			
Test	Leg	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p	Mean ± SD (Pre)	Mean ± SD (Post)	Δ (%)	p
Ext.	D	120.41 ±30.5	116.02 ±30.69	-3.6	0.005*	159.77 ±26.6	153.43 ±26.25	-4.0	0.003*	283.21 ±77.18	269.57 ±73.84	-4.8	<0.001*
	ND	114.47 ±28.93	114.7 ±29.24	0.2	0.884	151.74 ±24.37	152.15 ±24.87	0.3	0.841	261.7 ±72.11	265.48 ±72.39	1.4	0.458
Flex.	D	71.69 ±18.44	66.82 ±16.88	-6.8	<0.001*	95.77 ±17.75	89.64 ±18.66	-6.4	<0.001*	149.59 ±33.81	137.32 ±36.47	-8.2	<0.001*
	ND	67.32 ±16.76	66.45 ±19.28	-1.3	0.493	89.87 ±16.24	88.91 ±21.17	-1.1	0.573	131.02 ±32.74	130.34 ±42.66	-0.5	0.854

D = Dominant; ND = Non-dominant; Ext. = Knee extension; Flex. = Knee extension; SD = Standard Deviation; Δ = change
* Significantly different between pre and post (p < 0.05)

Table 16 shows the differences between means for the counter movement jump test before and after the dynamic neural mobilisation condition. No significant differences were identified. The differences listed here are visualised in Figure 9, Figure 10, and Figure 11.

Table 16 Paired t-test results for pre- and post-test means for the highest scores of 5 maximal attempts of counter movement jump in the dynamic neural mobilisation group in martial artists (n = 31)

Variable	Mean ± SD (pre)	Mean ± SD (post)	Δ (%)	p
Height (cm)	36.81 ± 7.25	36.04 ± 7.29	-2.12	0.319
Power (W)	3566.38 ± 778.83	3509.23 ± 747.26	-1.63	0.872
Power: body-mass ratio (W/kg)	47.78 ± 5.82	47.18 ± 6.02	-1.27	0.196
Impulse (kg.s^{-1})	203.08 ± 48.36	196.63 ± 40.37	-3.28	0.956

* No significant differences were identified between pre-, and post-test means.

4.8 Objective 3: the difference between static stretching and dynamic neural mobilisation exercise

4.8.1 One-way between-subjects ANOVA between post-test means

One-way between-subjects ANOVAs were conducted to compare differences between post-test means for isokinetic concentric / concentric knee extension / flexion dynamometry at 60 (5 repetitions), 180 (10 repetitions) and 300^{o}.s^{-1} (15 repetitions) and counter movement jump scores. Post-test means were compared between the control, static stretching, and dynamic neural mobilisation groups. The group variable was the fixed factor, and the dependent variables were either absolute peak torque (aPT), peak torque / body weight peak (PT/BW) torque, or mean power (MP). ANOVAs were conducted for both dominant and non-dominant legs and for both knee extension and flexion means. No significant differences were identified in post-test scores between groups.

Table 17 shows the post-test means for isokinetic peak torque / body weight and mean power for 5 repetitions at 60º.s^{-1} for the control, static stretch, and dynamic neural mobilisation exercise groups. One-way between-subjects ANOVAs were conducted to compare the post intervention means. No significant differences were identified for any variables.

Table 17 Results of one-way between-subjects ANOVAs comparing the post-test means of isokinetic dynamometry for 5 repetitions of 60º.s^{-1} concentric/ concentric knee flexion or extension isokinetic dynamometry for the control, static stretching, and dynamic neural mobilisation exercise groups (n = 31)

			Control	Static stretching	Dynamic neural mobilisation exercise
	Direction	Leg	Mean ± SD (Post)	Mean ±SD (Post)	Mean ± SD (Post)
Absolute peak torque (Nm)	Extension	Dominant	147.81 ± 35.73	147.08 ± 29.27	146.75 ± 39.45
		Non-dominant	144.95 ± 35.62	140.92 ± 26.6	144.24 ± 38.04
	Flexion	Dominant	83.35 ± 24.41	81.32 ± 16.6	80.38 ± 21.54
		Non-dominant	81.58 ± 23.02	77.92 ± 16.07	76 ± 21.52
Peak torque / body weight (Nm.kg-1)	Extension	Dominant	193.28 ± 28.2	203.15 ± 28.26	193.94 ± 30.08
		Non-dominant	189.45 ± 28.91	195.2 ± 27.78	190.84 ± 30.08
	Flexion	Dominant	108.86 ± 21.98	112.52 ± 17.63	107.22 ± 21.1
		Non-dominant	106.43 ± 20.09	107.96 ± 17.5	101.2 ± 20.88
Mean power (W)	Extension	Dominant	256.96 ± 66.27	256.39 ± 46.94	252.71 ± 67.09
		Non-dominant	250.29 ± 59.39	247.41 ± 43.87	247.85 ± 64.88
	Flexion	Dominant	140.79 ± 43.25	136.68 ± 27.34	133.75 ± 36.58
		Non-dominant	137.9 ± 38.68	129.97 ± 28.86	124.87 ± 36.96

* No significant differences were identified between groups.

Table 18 shows the post-test means for isokinetic peak torque / body weight and mean power for 10 repetitions at 180º.s^{-1} for the control, static stretch, and dynamic neural mobilisation exercise groups. One-way ANOVAs were conducted to compare the post intervention means. No significant differences were identified for any variables.

Table 18 Results of one-way between-subjects ANOVAs comparing the post-test means of isokinetic dynamometry for 10 repetitions of 180º.s^{-1} concentric/ concentric knee flexion or extension isokinetic dynamometry for the control, static stretching, and dynamic neural mobilisation exercise groups (n = 31)

			Control	Static stretching	Dynamic neural mobilisation exercise
	Direction	Leg	Mean ± SD (Post)	Mean ±SD (Post)	Mean ± SD (Post)
Absolute peak torque (Nm)	Extension	Dominant	147.81 ± 35.73	147.08 ± 29.27	146.75 ± 39.45
		Non-dominant	144.95 ± 35.62	140.92 ± 26.6	144.24 ± 38.04
	Flexion	Dominant	83.35 ± 24.41	81.32 ± 16.6	80.38 ± 21.54
		Non-dominant	81.58 ± 23.02	77.92 ± 16.07	76 ± 21.52
Peak torque / body weight (Nm.kg-1)	Extension	Dominant	193.28 ± 28.2	203.15 ± 28.26	193.94 ± 30.08
		Non-dominant	189.45 ± 28.91	195.2 ± 27.78	190.84 ± 30.08
	Flexion	Dominant	108.86 ± 21.98	112.52 ± 17.63	107.22 ± 21.1
		Non-dominant	106.43 ± 20.09	107.96 ± 17.5	101.2 ± 20.88
Mean power (W)	Extension	Dominant	256.96 ± 66.27	256.39 ± 46.94	252.71 ± 67.09
		Non-dominant	250.29 ± 59.39	247.41 ± 43.87	247.85 ± 64.88
	Flexion	Dominant	140.79 ± 43.25	136.68 ± 27.34	133.75 ± 36.58
		Non-dominant	137.9 ± 38.68	129.97 ± 28.86	124.87 ± 36.96

* No significant differences were identified between groups.

Table 19 shows the post-test means for isokinetic peak torque / body weight and mean power for 15 repetitions at 300º.s^{-1} for the control, static stretch, and dynamic neural mobilisation exercise groups. One-way ANOVAs were conducted to compare the post intervention means. No significant differences were identified for any variables.

Table 19 Results of one-way between-subjects ANOVAs comparing the post-test means of isokinetic dynamometry for 15 repetitions of 300º.s^{-1} concentric/ concentric knee flexion or extension isokinetic dynamometry for the control, static stretching, and dynamic neural mobilisation exercise groups (n = 31)

			Control	Static stretching	Dynamic neural mobilisation exercise
	Direction	Leg	Mean ± SD (Post)	Mean ±SD (Post)	Mean ± SD (Post)
Absolute peak torque (Nm)	Extension	Dominant	117.31 ± 30.43	115.18 ± 24.29	116.02 ± 30.69
		Non-dominant	117.81 ± 29.51	111.59 ± 22.19	114.7 ± 29.24
	Flexion	Dominant	71.91 ± 20.98	68.56 ± 14.82	66.82 ± 16.88
		Non-dominant	71.66 ± 20.72	66.12 ± 14.73	66.45 ± 19.28
Peak torque / body weight (Nm.kg-1)	Extension	Dominant	153.5 ± 27.65	158.77 ± 21.74	153.43 ± 26.25
		Non-dominant	154.32 ± 27.28	154.32 ± 21.83	152.15 ± 24.87
	Flexion	Dominant	93.83 ± 18.73	94.69 ± 14.83	89.64 ± 18.66
		Non-dominant	93.94 ± 20.54	91.33 ± 15.17	88.91 ± 21.17
Mean power (W)	Extension	Dominant	272.49 ± 65.98	279.27 ± 59.5	269.57 ± 73.84
		Non-dominant	269.22 ± 65.07	271.3 ± 54.68	265.48 ± 72.39
	Flexion	Dominant	148.18 ± 48.01	145.04 ± 30.61	137.32 ± 36.47
		Non-dominant	146 ± 47.72	141.66 ± 37.63	130.34 ± 42.66

* No significant differences were identified between groups.

Table 20 shows the post-test means for the counter movement jump test variables for the control, static and dynamic neural mobilisation groups. One-way ANOVAs were conducted to compare the post intervention means. No significant differences were identified.

Table 20 Results of one-way between-subjects ANOVAs comparing the post-test means of highest scores of 5 maximal attempts of counter movement jump between the control, static stretching, and dynamic neural mobilisation exercise groups (n = 31)

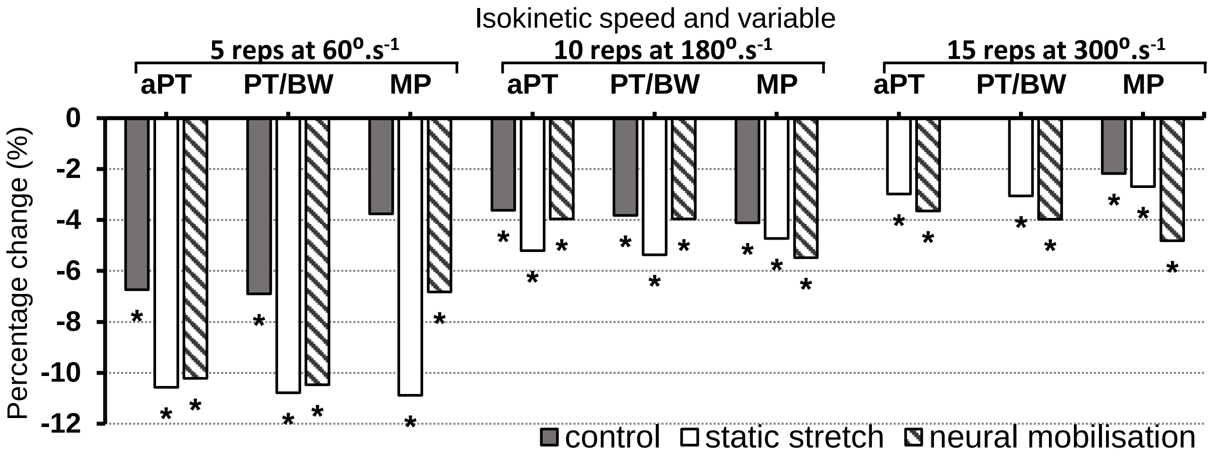
	Control	Static stretching	Dynamic neural mobilisation exercise
Variable	Mean ± SD (post)	Mean ± SD (post)	Mean ± SD (post)
Height (cm)	35.49 ± 6.15	37.6 ± 8.39	36.04 ± 7.29
Power (W)	3534.53 ± 783.62	3551.35 ± 807.49	3509.23 ± 747.26
Power: Body-mass ratio (W/kg)	46.53 ± 5.42	48.34 ± 7.37	47.18 ± 6.02
Impulse (kg.s^{-1})	199.52 ± 42.39	198.42 ± 42	196.63 ± 40.37

*No significant differences were identified with One-Way ANOVA.

4.8.2 Differences between pre-test and post-test means

Figure 12 to Figure 15 visualise the percentage change between pre- and post-test means for the Absolute Peak Torque (aPT), Peak Torque / Body Weight (PT/BW) and Mean Power (MP) at 60 (5 repetitions), 180 (10 repetitions) and 300º.s^{-1} (15 repetitions) for knee extension and flexion in the dominant and non-dominant legs for control, static stretching and dynamic neural mobilisation exercise (% difference = $\left(\frac{mean(post)*100}{mean(pre)}\right) - 100$. The data is presented in Table 5 to Table 15 in the previous sections.

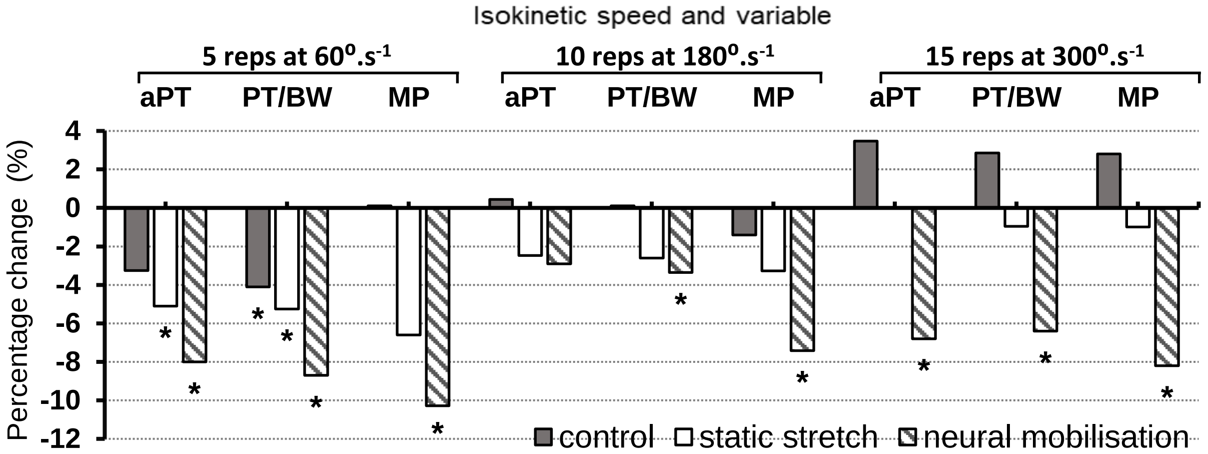
For knee extension in the dominant leg, the percentage of absolute change between pre-, and post-test means for control, static stretching and DNME (n = 31) for aPT, PT/BW and MP at 60, 180 and 300º.s^{-1} are visualised in Figure 12. For aPT at 60º.s^{-1} significant decreases ($p \leq 0.05$) were identified for control (Δ -6.7%), static stretch (Δ - 10.6%) and DNME (Δ - 10.2%), at 180º.s^{-1} for control (Δ -3.6%), static stretching (Δ - 5.2%) and DNME (Δ -4.0%) and at 300º.s^{-1} for static stretching (Δ -3.0%) and DNME (Δ -3.6%) For PT/BW, significant decreases occurred at 60º.s^{-1} for control (Δ -6.9%), static stretching (Δ -10.8) and DNME (Δ -10.5%), at 180º.s^{-1} for control (Δ -3.8%), static stretching (Δ -5.4%) and DNME (Δ -4.0), and at 300º.s^{-1} for static stretching (Δ -3.1%), and DNME (Δ -4.0). For mean power significant decreases were identified at 60º.s^{-1} for static stretching (Δ -10.9%) and DNME (Δ -6.8%), at 180º.s^{-1} control (Δ -4.1%), static stretching (Δ -4.7%) and DNME (Δ -5.5%) and 300º.s^{-1} for control (Δ -2.2%), static stretching (Δ -2.7%) and DNME (Δ -4.8%).



* Significant difference (p≤0.05); aPT = Absolute Peak Torque; PT/BW = Peak Torque / Body Weight; MP = Mean Power

Figure 12 Knee extension (dominant leg): percentage change between pre- and post-test means for isokinetic variables, speeds, and groups (n = 31)

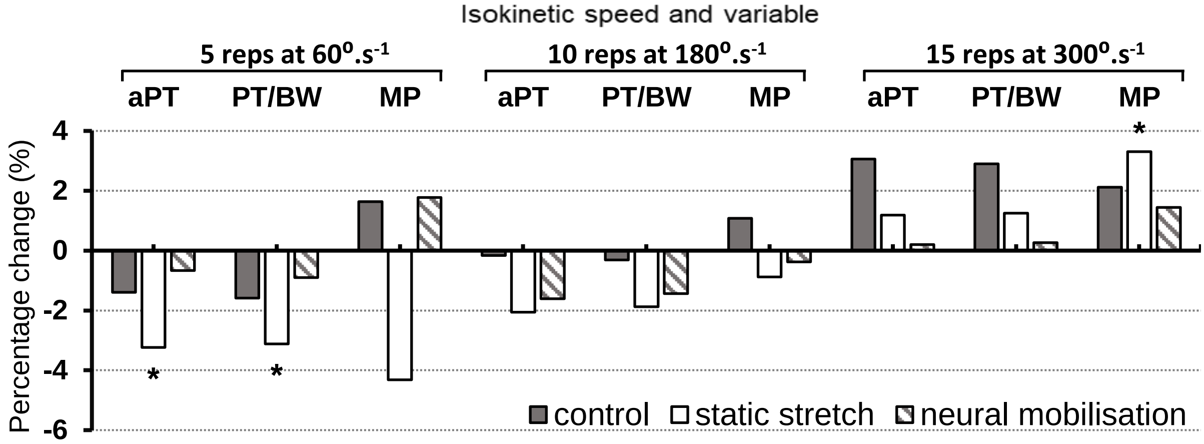
For knee flexion in the dominant leg, the percentage of change between pre-, and post-test means for control, static stretching and DNME (n = 31) for absolute peak torque (aPT), peak torque / body weight (PT/BW) and mean power (MP) at 60, 180 and 300º.s^{-1} are visualised in Figure 13. For aPT at 60º.s^{-1} significant decreases ($p \leq 0.05$) were identified for static stretching (Δ -5.1%) and DNME (Δ -8.0%) groups and at 300º.s^{-1} for the DNME group (Δ -6.8%). For PT/BW significant decreases were identified at 60 º.s^{-1} in the control (Δ -4.1%), static stretching (Δ -5.3%) and DNME (Δ -8.7%) groups, at 180º.s^{-1} in the DNME group (Δ -3.4%) and at 300º.s^{-1} in the DNME group. For MP significant decreases occurred for DNME at 60 (Δ -10.3%), 180 (Δ -7.4%) and 300º.s^{-1} (Δ -8.2%).



* Significant difference (p≤0.05); aPT = Absolute Peak Torque; PT/BW = Peak Torque / Body Weight; MP = Mean Power

Figure 13 Knee flexion (dominant leg): percentage change between pre- and post-test means for isokinetic variables, speeds, and groups (n = 31)

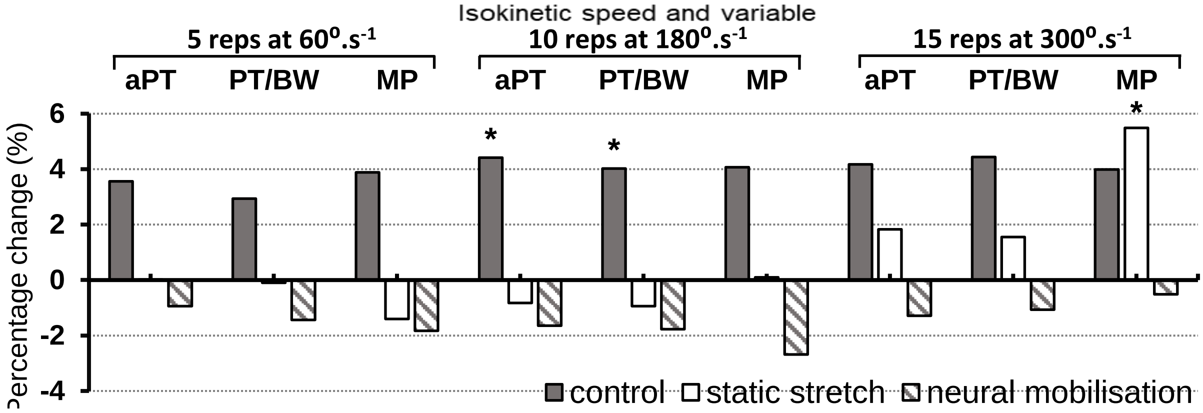
For knee extension in the non-dominant leg, the absolute percentage change between pre-, and post-test means for control, static stretching and DNME (n = 31) for absolute peak torque (aPT), peak torque / body weight (PT/BW) and mean power (MP) at 60, 180 and 300º.s^{-1} are visualised in Figure 14. At 60º.s^{-1} significant decreases (p≤0.05) occurred for aPT (∆ -3.2%) and PT/BW (∆ -3.1%) with static stretching. At 300º.s^{-1} a significant increase (p=0.01) occurred for MP (∆ +3.3%) also with static stretching.



* Significant difference (p≤0.05); aPT = Absolute Peak Torque; PT/BW = Peak Torque / Body Weight; MP = Mean

Figure 14 Knee extension (non-dominant leg): percentage change between pre- and post-test means for isokinetic variables, speeds, and groups (n = 31)

For knee flexion in the non-dominant leg, the absolute percentage change between pre-, and post-test means for control, static stretching and DNME (n = 31) for absolute peak torque (aPT), peak torque / body weight (PT/BW) and mean power (MP) at 60, 180 and 300º.s^{-1} are shown in Figure 15 . At 180º.s^{-1} significant increases (p≤0.05) occurred in the control group for aPT (∆ +4.4%) and PT/BW (∆ +4.0%). At 300º.s^{-1} a significant increase (p=0.03) occurred for MP in the static stretching group (∆ +5.5%).



* Significant difference (p≤0.05); aPT = Absolute Peak Torque; PT/BW = Peak Torque / Body Weight; MP = Mean

Figure 15 Knee flexion (non-dominant leg): percentage change between pre- and post-test means for isokinetic variables, speeds, and groups (n = 31)

CHAPTER 5: DISCUSSION

The subtopics that will be covered in this chapter include:

5.1 Introduction

This section discusses and interprets the findings of the current study to position the present findings within the recent literature. It achieves this by first discussing the baseline and anthropometric findings and addressing the implications of significant differences identified in the control group. Each study objective is then discussed in sequence. The discussion of each objective includes interpreting significant and non-significant findings and relating these to the published literature. Each objective includes a discussion of strength, power and jump power and addresses in order static stretching, dynamic neural mobilisation exercise and then how findings of the two conditions differ.

5.2 Discussion of participant baseline and anthropometric results

5.2.1 Sample size, gender, and self-reported martial art experience

This study had a larger sample size (n= 93) than most other studies examining the acute effects of a stretching intervention on isokinetic performance .[40,42,43,45,129,131–135,137,141,146,178,179,207,210,216–219] Only several studies assessing the effect of stretching on isokinetic performance have included woman[43,137,179,217]. Only the study by Costa et al.[217] included more female participants (n = 22). This study included only martial artists, while no other studies reviewed examined the effect of stretching on isokinetic performance in artists.

This study included a mixed sample of 19% female (n = 18) and 89% male (n = 75) participants. Various other studies have included men and women, however, this study has included the greatest absolute number of women within a mixed sample. With mixed samples, Takeuchi et al.[137] included 13 male and 4 female participants, Kataura et al.[43] included an sample with equal gender distribution of 9 male and 9 female participants and Marek et al.[179] presented the only study with more female (n = 10) than male (n = 9). Various studies have limited the sample to either male or female, however most studies have a smaller sample size than the current study. Costa et al.[217] had the largest female sample (n = 22), followed by Winke et al.[141] (n = 13) and Egan et al.[207] (n = 11).

The present study included 75 male participants, which is more than has been included in similar studies of men and women, as well as studies of men only[45,129,134,136,146,179,218–222]. In the present study, gender differences in isokinetic peak torque, mean power and counter movement jump scores introduce increased variability into the combined male and female sample mean, because have on average significantly lower scores than males.[223,224] While the present study includes a sample of women larger or comparable to other studies[43,137,179,217] of isokinetics and stretching, the relative proportion of females in the total sample remains low (~ 19%), limiting the variation of the total sample mean towards the mean of the female subsample. Although gender differences in stretch-induced strength loss were hypothesised by McHugh et al.[24], these were beyond the focus of this study.

5.2.2 Anthropometric findings

5.2.2.1 BMI classifications

In the present study, participants had a combined mean BMI of 24.8 ± 0.4 $kg.m^{-2}$, a mean body fat percentage of 14.0 ± 7.6% and a mean lean mass of 67.7 ± 9.5 kgs. While mean BMI is close to the overweight classification (overweight ≥ 25.0 $kg.m^{-2}$)[225], both body fat percent and lean mass were are lower than expected[6]. For BMI, body fat percentage and lean mass, male participants scored 25.0 ± 0.4 $kg.m^{-2}$, 12.0 ± 6% and 67.7 ± 9.5 kg, while females scored 23.9 ± 1.16 $kg.m^{-2}$, 22.3 ± 7.9% and 48.8 ± 6 kg. For individual's aged 20 to 30 years, these body fat percent scores fall between the 70 to 75th percentile or "Good" category for men and 45th to 50th percentile or "fair" category for women. Podstaeski et al. [226] suggests that choice of sport among Polish university age students is related to body mass, height, BMI and motor fitness, which suggests even novice level athletes may have anthropometric characteristics associated with martial arts success.

5.2.2.2 Anthropometric findings of male participants

For males, a low body fat percent combined with BMI classification of “overweight” implies a higher lean mass and suggests additional muscle. Nichas (2017) examined 101 national and international South African male karate athletes (18 to 65 years) and reported for participants aged 18 to 25, a mean bodyfat percent of 10.65 ± 5.50% and a lean mass 66.73 ± 9.09 kgs[227], which are consistent with the findings of the present study.

5.2.2.3 Anthropometric findings of female participants

For females, both BMI and lean body mass were within “healthy” or “average” ranges for the general population. To the authors knowledge, there is no anthropometric data available for female South African martial artists. In a study[228] of 154 female Polish Judo, Jiu jitsu, Karate, Taekwondo and fencing athletes, BMI’s ranging from 20.7 to 23.9 $kg.m^{-2}$ were reported. Bridge et al.[229] reviewed the literature on taekwondo and reported that body fat percentage was 16% and 20.3% for novice and experienced practitioners respectively. In this study, 55% (n = 10) of female participants classified themselves as “recreational level”, with the remaining 45% classified as “national level or higher. An European study[228] of the anthropometric characteristics for female combat athletes suggest the BMI of participants in this study is within the expected range while body fat percentage is slightly higher than expected.

5.2.2.4 Sample findings compared to South African and European norms

Compared with South African normative values, the mean BMI of female participants in this study (24.8 ± 4.5$kg.m^{-2}$) was much lower compared to the mean BMI (29 $kg.m^{-2}$) for females aged 19 to 24 years reported in the SANHANES-1 trial[230], even though the same study reported mean BMI among females was highest in the same province in which this study was conducted (Gauteng). Conversely male participants had a higher BMI (25 ± 0.4 $kg.m^{-2}$) than SANHANES-1[230] (23.9 $kg.m^{-2}$), this score considered with the lower mean body fat percentage and increased lean mass, implies the increased BMI is associated with physical activity related health benefits. The mean BMI in the European Union for males of all ages is 26.79 $kg.m^{-2}$ is and women 26.5

kg.m^{-2}, with 37.1% of males and 27.7% of females aged 15 to 29 years having a BMI ≥ 25kg.m^{-2}. These results imply that both male and female South African martial artists receive important physical activity related health benefits relative to the other South Africans and Europeans.

5.2.2.5 Body mass index, lean mass, strength and power

In the present study BMI, fat free mass and body fat percentage may contribute to the isokinetic and counter movement results measured, although determining correlations between these variables was beyond the scope of the present study. Previous studies have identified correlations between anthropometric variables and performance with measures of whole body lean mass and segmental lean mass positively correlated with isokinetic peak torque[231,232] and counter movement jump power.[233,234] In the present study, however, dominant leg mean isokinetic extension peak torque scores (211.02 +56 Nm) were lower than male South African norms[182] (235 ±34.4 Nm) and the standard deviation larger, despite a high lean mass identified in male participants relative to military personnel[182], karatikas[227] and American men (aged 20 to 30).[235] These difference in peak torque, may reflect recreational level athletes with lower strength than the South African norms, which were based upon South African National Defence Force applicants. The difference in standard deviation likely reflects the inclusion of various self-reported experience levels, but also the mixed male and female sample. Comparable isokinetic norms for South African women are not available. BMI in previous literature[232] is less positively correlated to strength or even moderately to strongly negatively correlated in certain populations, such as in people with obesity.[236] As BMI in the present study was at the borderline between the overweight and normal weight categories, the impact on performance is not clear. The anthropometric findings of this study, appear to support health benefits of physical activity for martial artists, such increased lean mass and decreased body fat percentage relative to norms, but not increased strength, relative to South African military applicants and with more benefit apparent in male than female participants.

5.2.3 Control group significant differences

In this study, several significant decreases were identified between pre-, and post-test means in the control group. These occurred in some, but not all cases and influence the interpretation results. Significant decreases in the control group decrease the magnitude of the mean difference, in the context of concurrent significant decreases in an experimental group, narrowing the difference between groups and making inter-group statistically significant differences more difficult to detect. In this section specific significant differences identified in the control group will be discussed, related to the published literature and their implications for interpreting the study findings discussed. This will be followed by a brief discussion of factors which may have contributed to these differences.

5.2.4 Significant decreases in dominant leg knee extension

Several significant decreases ($p \leq 0.05$), and two significant increases ($p \leq 0.05$) were identified in the control group ($n = 31$). The majority of cases where the control group had significant decreases occurred in dominant leg knee extension, for aPT and PT/BW at 60º.s^{-1} and 180º.s^{-1} with significant Mean Power at 180º.s^{-1} and 300$^{º-1}$ with only a single other control group significant decrease in the same leg for knee PT/BW at 60º.s^{-1}. No similar studies were identified during the literature review, which reported similar decreases in the control group, however many studies[42,128] used within-subjects designs. If the decreases were due to fatigue, these findings suggest fatigue after isokinetic testing most impacted dominant leg knee extension, then flexion, significant decreases on the non-dominant leg. Although the author is unaware of studies examining this topic. Hughes et al.[237] suggests that endurance training decreases the neural drive associated with strength training, leading to decreased strength performance. Inter-leg morphological and isokinetic strength asymmetry has been documented in martial artists[238,239] and other sports[240,241], but Isokinetic strength[242–244], mean power[242,243] and endurance[242] are greater in the dominant leg in martial artists, which implies the decreases in the dominant leg are not due to asymmetries in fatigue-resistance. If these decreases were due to “accumulated fatigue”, the final set (the non-dominant leg), would have decreased performance more than the leg preceding it, which it did not. It is possible that these decreases are either due to performance decreases caused by testing the contralateral leg (called as cross-over fatigue[245–247]) or a “cooling down” of the both legs during the recovery period, with the non-dominant leg then facilitated by prior testing of the dominant leg, as observed by Neltner et al.[248] Whichever effect is responsible, the implication was decreased performance during post-testing, which influences interpretation of this results.

5.2.5 Significant decreases in dominant leg isokinetic knee flexion

A significant decrease was also identified in knee flexion at 60º.s^{-1} for aPT (145 ± 29.99 to 139.04 ± 28.66 Nm) with a smaller absolute percentage change (~ Δ -4%) compared to dominant leg knee extension (~ Δ -7%). Massamba et al.[249] compared exercise induced fatigue in the hamstring and quadriceps in healthy male participants (n = 12, age = 26 ± 4 years) after 5 minutes of maximal exercise. MVC decreased more in quadriceps (Δ -67 ± 9%) compared to hamstring (Δ -51 ± 10%, p < 0.001). This occurred in the present study, and while not to the same magnitude, to a similar proportion (the hamstring fatigued 76% of the amount of the quadricep, versus 57% in the present study).

5.2.6 Significant decreases in non-dominant leg isokinetic knee flexion

Decreases in the non-dominant leg occurred for knee flexion aPT (78.13 ± 22.27 to 81.58 ± 23.02 Nm, p = 0.02) and PT/BW (102.31 ± 21.23 to 106.43 ±20.09 Nm.kg^{-1}, p = 0.03). Different decreases in the non-dominant leg may be a function of morphological and functional asymmetry. Mala et al.[240] identified significant differences (p < 0.05) between the morphological characteristics of elite athletes (n =132) in judo, karate, fencing, wrestling, taekwondo, and kickboxing, which may contribute to inter-leg differences in strength, power and fatigability.

5.2.7 Possible causes for changes in the control group

5.2.7.1 Fatigue

Fatigue may be responsible for the significant decreases in the control group. These changes may suggest excessive effort and insufficient recovery time (total time: 25 minutes, including rest and experimental condition), as shown by Schwenderr, et al.[202] previously. Martial arts frequently compete, while fatigued, however, which makes the present study’s findings applicable to real-world training. The findings of this study are consistent with those of Kay et al.[118] who specifically studied stretch-induced strength loss alongside concurrent fatigue and found that the decreases, due to maximal isokinetic contractions (Δ -6.6%, p = 0.01) and those from static stretching (Δ -5.8%, p = 0.01) were summative (Δ -12.4%), although prior maximal concentric contractions did reduce the magnitude of stretch-induced strength loss. This means that clear inter-group differences in this study may have been minimised by the same-day pre-post testing procedure. This may also imply martial artists can reduce performance detriments due to stretching or dynamic neural mobilisation exercise with sufficient a same day warm up.

5.2.7.2 Recovery period

Few studies have documented the acute effect of isokinetic tests on fatigue and the recovery of muscle function over time. Schwenderr, et al.[202] examined fatigue by asking active males (n = 16, mean age = 29.2) to three bouts (with 1-minute inter-bout breaks of continuous isokinetic repetitions, until isokinetic force output decreased below 50% of the initial peak score for 3 repetitions. Participants who fatigued most also took the longest time to recover to 80% MVC. Over 8 minutes, participants who fatigued the least (∆ MVC: 88 ± 4%), recovered to approximately 100% MVC, while those with moderate fatigue (∆ MVC: 71 ± 6%) recovered to 87% MVC and those with the greatest fatigue (∆ MVC: 64 ± 8%), recovered to only 68%. These findings suggest less-fit athletes (such as "recreation level", n = 55), would require increased recovery time to attenuate fatigue. The data was collected in 2020, shortly after the COVID-19 national shutdown of the fitness industry, which may also have contributed to low levels of fitness.

5.2.7.1 Other factors

Several possible confounders may cause decreases in the control group other than fatigue. These will be discussed briefly in the following section. Same-day pre-post testing may have influenced results. Nelson et al.[194] used same-day, high-volume testing using 5 isokinetic (60, 90, 150, 210 and 270º.s^{-1}) with 4 maximal isokinetic repetitions (20 repetitions total), separated by 15 minutes in college students (n = 15, 10 men, 5 women, age = 22 to 28 years. Various authors[146,178,210] have used same-days testing with five-minute stationary cycle warm-ups and two to three isokinetic test speeds with three familiarisation trails before each speed and three maximal efforts per speed. These studies used smaller exercise volumes than the present study however supports the inclusion of cycle warm-up, as well as multiple isokinetic speeds. Other factors that may decrease subsequent performance are mental fatigue, the cool-down effect, and sport-related anxiety. The testing experience lasted approximately 1 hour and 15 minutes per participant. The rest period between pre- and post-test may also have attenuated the effect of the stationary cycle warm up as participants "cooled down". Mental fatigue from prolonged paying prolonged attention could have decreased endurance performance[250] Anxiety can impact performance[251] and attending a laboratory for the first time may have impacted testing results.

5.3 Objective 1: The acute effect of static stretching on muscular strength, power and jump power in martial artists

In the present study acute, several significant differences were identified in the static stretching group between pre- and post-test means. These included both significant decreases and increases. Some, but not all these differences occurred with concurrent changes in the control group. This section will discuss and interpret the specific findings for the static stretching group, in the context of the published literature and martial arts. A brief discussion on factors influencing findings will follow.

5.3.1 Static stretching and differences in isokinetic peak torque

Pre-post comparisons in this study identified significant decreases in absolute peak torque at 60, 180 and $300^{o}.s^{-1}$. These differences did not occur consistently in all speeds, in extension and flexion and in dominant and non-dominant legs. These results are, however, consistent with the findings of previous literature, which has frequently identified similar differences in both knee extension[117,131,179,252] and knee flexion.[134,217,221,253] Nelson et al.[194] tested five speeds (60, 90, 150, 210 and $270^{o}.s^{-1}$) and concluded that the effects of static stretching were speed-specific effecting only slower speeds (60 and $90^{o}.s^{-1}$). Cramer et al.[178], however, identified significant decreases at both 60 and $240^{o}.s^{-1}$ and stated that the effects of static stretching may not be as speed-specific as Nelson et al.[194] had proposed. This study identified pre-post changes at all speeds (60, 180 and $300^{o}.s^{-1}$), which were not accompanied by changes in the control condition. These results also replicate the findings of Cramer et al.[178], as significant decreases were identified at each speed.

5.3.2 Peak torque / body weight decreases in the dominant leg

This study identified decreased peak torque / body weight at $60^{o}.s^{-1}$ (213.70 ± 43.47 to 191.12 ± 40.47 $Nm.kg^{-1}$, $p < 0.001$) and $300^{o}.s^{-1}$ (163.78 ± 25.98 to 158.77 ± 21.74 $Nm.kg^{-1}$, $p = 0.01$). Few other studies similar studies have reported peak torque / body weight, rather reporting absolute peak torque. Cogley et al.[219], for example, identified contrary findings showed significant increases in peak torque / body weight in knee extension at $60^{o}.s^{-1}$ (Δ +20.6%) and $300^{o}.s^{-1}$ (Δ +14%) after dynamic stretching followed by 10 minutes of dominant leg hamstring stretching to “tolerable, but not painful" intensity. Compared with the control group, peak torque decreased similarly at 300º.s^{-1}, but with an apparently larger pre-post effect at 60º.s^{-1} (Δ -7% versus -12%). This may suggest a larger detrimental effect of dynamic neural mobilisation exercise versus traditional dynamic stretching.

5.3.3 Peak torque decreases in the non-dominant leg

This study identified several significant differences in the non-dominant leg after the static stretching intervention and were not accompanied by significant changes in the control condition. Comparisons to the literature are difficult, because data for the non-dominant leg is seldomly reported for similar studies. Small reductions (-Δ 3%) were identified for non-dominant knee extension absolute peak torque (189.12 ± 40.78 to 183.01 ± 38.38 Nm, p = 0.005) and peak torque / body weight (261.41 ± 40.2 to 253.27 ± 39.4 Nm.kg^{-1}). Cramer et al.[128] did not stretch the contralateral limb but reported significant decreases at 60º.s^{-1} (209.0 to 196.3 Nm) and 240º.s^{-1} (129.3 to 125.9) ($p \leq 0.05$). Behm et al.[254] conducted a systematic review of the literature, including six studies reporting the non-dominant limb and reported decreases in both stretched and unstretched (contralateral) legs (Δ -6.7% ± 7.1%) and unstretched (Δ -4.0 ± 4.9%).These changes appear of similar magnitude to those identified in this study.

5.3.4 Increases in isokinetic mean power

In this study, significant increases in mean power were identified at 300º.s^{-1} for non-dominant knee extension (Δ +3 %, 262.62 ± 49.9 to 271.3 ± 54.68 W, p = 0.01) and knee flexion (Δ +5 %, 134.29 ± 29.89 to 141.66 ± 37.63 W, p = 0.03). These findings are contrary to the few studies[130,179,207] on the acute effects of static stretching, which report reductions in mean power. These were the only of increasing mean power noted in this study. The increases occurred without corresponding increases in absolute or peak torque / body weight in the static stretching group, which may imply changes to participants endurance and fatigue profile. The non-dominant 300º.s^{-1} test was the last isokinetic test in the sequence, after dominant 60, 180 and 300º.s^{-1} tests, non-dominant 60 and 180º.s^{-1} and the final 120 second interest-rest period. This increase may reflect Post Exercise Performance Enhancement (PAPE). Blazevich et al.[12] differentiate post exercise potentiation, which has a short half-life of approximately 28 seconds and PAPE, which can occur later due to increased muscle temperature, muscle and fibre water content and muscle activation. In a review, Boullosa et al.[255] examined studies of the post exercise potentiation in endurance activity and suggested it may counter the negative effects of fatigue. The results of this study are consistent with previous studies and report no effect of static stretching on jump performance.

5.3.5 The interaction of concurrent fatigue and strength-induced strength loss

Previous research has reported on the interaction of absolute peak torque deficits caused by fatigue and those of stretch-induced strength loss. The findings of this study appear to replicate similar findings of Kay et al.[118] These authors identified decreased muscle force after fatiguing concentric contractions (Δ -5.8%). Subsequent static stretching led to an additional strength decrease (Δ -6.6%) with a total decrease of -12%. In the control group of this study, in dominant leg knee extension absolute peak torque decreased (Δ - 6.7%), and static stretching decreased by a greater magnitude (Δ - 10.6%), which suggests that static stretch led to an additional change (Δ -3.9%), although this cannot be stated confidently without significant changes identified in the ANOVA.

5.3.6 Attenuating performance improvements with static stretching

In this study, for the control group, at $180^{o}.s^{-1}$, significant improvements were identified in non-dominant leg knee extension absolute peak torque (78.13 ± 22.27 to 81.58 ± 23.02 Nm, p = 0.02) and peak torque / body weight (102.31 ± 21.23 to 106.43 ± 20.09 $Nm.kg^{-1}$, p = 0.03) which support the results of Cramer et al.[178] who reported similar findings. This may suggest that the warm-up and same-day pre-test minimised stretch-induced strength loss, resulting in performance improvements at certain speeds. Behm et al.[256] reported a five-minute cycle warm-up with static stretching did not alter performance and concluded that static-stretch attenuated the positive effects of warming-up. Page[1] interpreted the findings of this study by suggesting that warm-up attenuated the negative effects of stretch induced strength loss., however no changes occurred with static stretching, suggesting that static stretching attenuated performance improvements identified in this leg. This may suggest that with sufficient prior activity, the negative effects of even prolonged static stretching can be removed in certain cases.

5.4 Objective 2: The acute effect of dynamic neural mobilisation exercise on muscular strength, power and jump power in martial artists

The present study identified significant decreases between pre- and post-test means for peak torque and mean power at certain speeds, but not for Counter Movement Jump (CMJ) scores. All significant decreases in the neural group occurred only in the dominant leg and non in the non-dominant leg. To the authors knowledge, no previous studies have identified decreases in these variables in response to Dynamic Neural Mobilisation Exercise (DNME) within any population, including martial artists.

5.4.1 Significant decreases only occurred in the dominant leg

Significant decreases were identified for DNME, but notably, only in the dominant leg, but not the non-dominant. These decreases effected both knee flexion and extension, absolute peak torque, peak torque / body weight and mean power, and effected all speeds, with the largest magnitude percentage changes between pre-, and post-test variable noted at 60º.s^{-1} with smaller magnitude changes at 180 and 300º.s$^{-1.}$ To the authors knowledge differential effects of a stretching type of intervention have not previously been reported in the literature.

McHugh et al.[24] measured compared the effect of 5 minutes of non-neural stretching and stretching in a neural-position on maximal isometric hamstring contraction at 100º, 80º, 60º and 40º knee flexion and reported no change due to non-neural stretch and a significant decrease (∆ -12%) in the neural group. The magnitude of stretch-induced strength loss identified in this study during slow speed (60$^{º-1}$) isokinetic contractions (~ -12%) is consistent with the isometric finding of Hugh et al.[24], however this study noted similar findings for knee extension, as well as flexion. Decreases in muscle strength at low speed have implications for strength-performance. A comparable decrease in muscle strength during isotonic exercise from 100% effort to 90% effort equates to the difference between performing a 1 repetition maximum effort versus a five-repetition maximum effort.[257]

Yun-hyeok et al.[170] used hand-held force dynamometry to measure knee extension and flexion muscle force after acute sciatic slider exercises in patients with chronic stroke (n = 16) and identified significant improvements in knee extensor (∆ +18%, p = 0.23, 18%) and knee flexor (∆ +8%, p = 0.011), which contrast with the significant decreases identified in the present study. The decreases identified by Yun-hyeok et al. [170] may suggest performance increases due to a warm-up effect related to dynamic stretching type movements, which can increase performance.[258]

5.4.2 Significant decreases occurred at 180 and 300º.s^{-1}

The present study also identified stretch induced strength loss at higher speeds (180 and 300º.s^{-1}), however no similar studies are available to compare these findings with. For absolute peak torque and peak torque / body weight, where they decreased without corresponding decreases in the control condition, results are suggestive that the magnitude of change ~Δ -4 to -7% is smaller than that identified at slow speed (~Δ -12%). This suggests that prolonged dynamic neural mobilisation exercise may decrease subsequent strength in martial artists and should be avoided before activities requiring high speed.

5.4.3 Significant differences in isokinetic mean power

The present study identified significant differences in isokinetic mean power at all speeds in both knee extension and flexion, due to neural mobilisation. This "stretch induced power loss" has not been reported in previous literature, but findings suggest the magnitude of the deficit ranges from approximately -5% to -9%. In this study significant decreases in mean power due to DNME were accompanied by significant decreases in either aPT or PT/BW or both. Because mean power is a function of maximum force produced and sustained force production, it may suggest that the decreases in power are a consequence of decreases in peak torque and not due to changes in muscle endurance. It is interesting to note that in non-dominant knee flexion, significant improvements occurred in the control condition at 180º.s^{-1}, however these were not noted in the DNME and static stretching groups, suggesting that prolonged stretching or neural mobilisation attenuated the benefits experienced by the control group.

5.4.4 No differences occurred for counter movement jump

For jump performance, the findings of this study are consistent with several authors[172,173,259], who have reported that neural mobilisation has no effect on jump performance. This study used Counter Movement Jump testing, while other Aksoy et al.[172] compared the acute effect of femoral nerve mobilisation and sciatic nerve mobilisation on vertical jump and horizontal jump performance and found no significant difference between means before and after intervention. Waldhelm et al.[173] compared the effects of stretching bilateral sciatic neural gliding and dynamic stretching on vertical jump and other performance measures found no significant differences between groups. Pereira et al.[259] compared the two different durations of a neural mobilisation intervention on measures including hop tests and single-leg vertical jump and identified no difference between durations.

5.5 Objective 3: differences between the acute effects of static stretching and dynamic neural mobilisation exercise

One-way ANOVAs between post-test means were not significant suggesting both static stretching and dynamic neural mobilisation exercise are not different from control. Pre- and post-test comparisons, however, suggest similar reductions in absolute peak torque for control (∆ -4 to -7%), static stretching (∆ -3 to -12%) and neural dynamic mobilisation exercise (∆ -4 to -11%), though greater decreases only appear to occur at 60º.s^{-1} and not at higher speeds.

5.5.1 Differences between pre-post and post-post analysis results

During the literature, the author identified no studies, which specifically compared static stretching or other stretching techniques to any type of neural mobilisation, which used isokinetic dynamometry or counter movement jump testing. In the present study, one-way ANOVAs compared post-test means, without consideration of pre-test means, because an interaction was detected between pre-test and post-test means, violating the assumption of factorial ANOVAs or analysis of covariance. Previous authors[260,261] have used one-way ANOVAs in isokinetic trials. Insignificant differences between post-test means suggests mean differences were too small or with large standard deviations in the post-test analysis to detect. Other isokinetic studies[261,262] have used factorial ANOVAs and did not report interactions between pre-post variables. If baseline means influence stretch induced strength loss the hypothesis would be that higher baseline scores (possibly as a function of expertise) would lead to a greater magnitude of stretch induced strength loss. To the authors knowledge no studies have been conducted to test this hypothesis.

5.5.2 Different comparative effects for specific speeds and legs

In several, but not all cases, paired t-tests comparing pre-, and post-test means identified different outcomes in neural dynamic or static stretching conditions.

Reductions due to DNME without changes in the static stretching group occurred only in the Dominant leg and in knee flexion. Reductions due to static stretching occurred only in the non-dominant leg, but in both knee extension and flexion. This finding suggests that the effect of static stretching and DNME differs in certain cases. DNME decreased mean power at all velocities in the dominant leg, while static stretching did not. This implies DNME has a greater effect in reducing mean power than static stretching. Because decreases did not occur in the non-dominant leg the implication is that either only the dominant leg is affected, or reductions in the dominant leg were attenuated, by the time of testing. To the authors knowledge, no studies comparing reporting inter-leg differences in stretch-induced strength loss, or inter-leg differences in its attenuation have been conducted previously.

5.5.3 Different comparative pre-post effects on isokinetic peak torque variables

Absolute and peak torque / body weight results also differed between static stretching and DNME in several cases. DNME caused significant decreases in peak torque / body weight of dominant leg knee flexion at 180º.s^{-1} and 300º.s^{-1}, while static stretching caused no change. This finding has not been reported previously. This suggests that DNME may, in some cases, decrease peak torque of the knee flexors more than static stretching. At 180º.s^{-1} for dominant leg knee flexion, significant differences were identified for peak torque / body weight, but not absolute peak torque, which may be attributable to increased variation in body mass. To the author’s knowledge, simultaneous significant decreases in absolute peak torque and insignificant decreases in peak torque / body weight have not been reported previously, as most studies report either absolute peak torque, or peak torque / body weight, but not both. Decreases in knee flexor peak torque / body weight are an important, even without significant decreases in absolute peak torque are an important finding, because peak torque / body weight is a more functional indicator of performance. Decreased strength of the knee flexors, relative to body weight, suggests martial arts activities will become more taxing after stretching, because while strength has decreased, body weight remains constant, with functional movements like “kata” or kicks[263] becoming more difficult.

5.5.4 Different comparative pre-post effects on isokinetic mean power

Mean power decreased for static stretching group, but not the DNME group in the non-dominant leg at 300º.s^{-1}. Previous studies have not reported this finding. This suggests that either static stretching especially effects the non-dominant leg or stretch induced decreases in mean power, due to static stretching in the non-dominant leg may be less attenuated less by prior exercise than strength-loss due to dynamic neural mobilisation. Previously velocity specific decreases in isokinetic peak torque after stretching were identified, with largest decreases at lower speeds, but no previous studies have reported similar findings for isokinetic mean power.

CHAPTER 6: CONCLUSIONS, LIMITATIONS, STRENGTHS AND RECOMMENDATIONS

The subtopics that will be covered in this chapter include:

6.1 Conclusions

This study identified significant differences ($p \leq 0.05$) between pre- and post-test means for strength and power, which differed between groups, suggesting group specific effects, and identified no significant differences in post-post comparison, suggesting equivalent post-test means and similar effects between groups.

This study showed in pre-post comparison that dynamic neural mobilisation exercise (DNME) and static stretching led to significant ($p \leq 0.05$) decreases in absolute isokinetic peak torque of approximately 10 percent at slow speeds (60º.s^{-1}), while the magnitude of significant decreases ($p \leq 0.05$) in the control group was approximately 7 percent, with lower magnitude decreases of between 1 and 6 percent for higher speeds. Significant ($p \leq 0.05$) pre-post differences were identified in both dominant and non-dominant legs at all speeds, although post-test scores were not significantly different.

In pre-post comparison DNME led to significant ($p \leq 0.05$) decreases in mean power at 300º.s^{-1} in dominant knee flexion, unlike static stretching which had no effect. In contrast, static stretching caused significant increases ($p \leq 0.05$) in non-dominant knee extension and flexion at 300º.s^{-1}, while DNME and control did not and led to no improved scores at all, while both static stretching and control did.

In pre-post comparison, DNME caused significant ($p \leq 0.05$) decreases only in the dominant leg, while static effected both dominant and non-dominant legs. Significant increases ($p \leq 0.05$) in the control and static stretching groups in non-dominant knee flexion may suggest post exercise performance enhancement and non-significant differences with static stretching and DNME may suggest an attenuation of this beneficial effect. CMJ power remained unchanged in all cases.

Post-post one-way ANOVA between all groups was not significant in all cases, even where non-significant pre-post results in the control group were accompanied by significant ($p \leq 0.05$) differences in the static stretching and DNME group. These results suggest dynamic stretching, DNME are equivalent to the control condition. The difference between these pre-post and post-post outcomes may imply large standard deviations and/or small effect sizes.

The null hypothesis that an acute bout of dynamic neural mobilisation exercise does not result in a decrease in muscular strength, power or counter movement jump power, when compared to an acute bout of static stretching is supported by the results of this study. In pre-post comparison, the DNME, and static stretching conditions led to significant decreases ($p \leq 0.05$) in some cases, and in others suggested no difference. In post-post comparison DNME, like static stretching and control, led to similar mean scores for strength, power and jump power similarly. These findings support acceptance of the null hypothesis.

6.2 Limitations

This study had several categories of limitations which influenced the study results. This section discusses study design, sampling, and technical limitations.

6.2.1 Study design

- Same-day test and retest was used in this study. This is a limitation, because while same-day testing makes the results highly relevant to real world martial arts settings, such as warming up and then competing, the pre-test battery led to decreases in the control group, which made the detection of small differences more difficult.
- The 15 minutes recovery period may have influenced results. A time-interval was not possible, due to the need to keep the total appointment time for participant reasonable. This was insufficient to remove the effects of fatigue, performance enhancement and possible attenuation effects on the experimental interventions.

- Familiarisation trials preceded tests and may have influenced results. A separate familiarisation appointment was not possible for this study, as many participants faced barriers, such as long complex travel to the testing centre, familiarisation trials were performed between intervention and test and may have slightly influenced results.
- Spreading appointments throughout the day may have influenced results. Time-of-day can affect maximal exercise performance[222]. This was not possible in this study, as participants came from diverse backgrounds, such as work or study and had to schedule an appointment around their often-busy schedules.
- Double blinding was not used, which increased the risk of bias. Efforts were taken to not suggest to patients any possible outcomes, however, the primary investigator conducted all testing personally, due to personnel and financial constraints.

6.2.2 Sampling

- Additional martial arts gymnasiums/ institutions had to be sought to be involved, due to the COVID-19 pandemic. Many organisations who were contacted before the National Lockdown period shutdown permanently, as restrictions eased. Additional organisations had to be sought to recruit participants.
- The size of the control group was limited. With two experimental groups of 33 participants, a control group of 66 participants could have been gathered. This was not however possible, due to limited availability of the research staff for testing.
- The gender distribution of the study was uneven. This decreased the homogeneity of scores and increased the variance of the sample, decreasing the sensitivity of the statistical tests to detect significant differences. This was due to a greater male participation rate at martial arts organisations contacted. Female participants from the Muslim community cited religious dress and custom, as a barrier to participation.
- The martial art styles represented were uneven. This decreases homogeneity of the data and was a function of certain styles being more popular and common (i.e. karate) than others (i.e. kung fu).
- Equally representing martial arts and genders for those participants who volunteers led to many excluded datasets in the study. Within a gender (e.g.

female) and martial style (e.g. jiu jitsu), three volunteers were required to be randomised to the three groups (control, static stretching, and dynamic neural mobilisation exercise). A single unfilled group allocation (either for control, static stretch or DNME) in a specific subgroup (e.g. female mixed martial arts, led to the remainder of participants (possibly up to two others) being unable to be included). This led to many exclusions and made sampling enough participants more difficult.

- Isokinetic Coefficients of Variance (CoV) led several exclusions, which limited inclusion of datasets. CoVs can indicate submaximal attempts and invalidate maximal tests and may have been avoidable with sufficient familiarisation.

6.2.3 Technical limitations

- Several equipment technical issues caused testing appointments to be suspended temporarily, while routine maintenance was carried out. These included a mechanical fault of the Biodex isokinetic dynamometer seatback fore / aft handle, a need to replace the dynamometer computer motherboard battery, a connection issue with a dysfunctional computer USB-A port, a single case of data not uploaded from the Fusion Smart Mat system to the cloud, due to a connectivity issue and several interruptions to the power supply of the isokinetic laboratory, due to South African national loadshedding. All test results included in the dataset were collected from high quality equipment, while it was operating normally.

6.3 Strengths

6.3.1 Study design

- Study design elements like, random assignment, including a control and experimental groups, and both pre- and post-testing made gathering more insights possible than with other designs. The pre-post element is included in similar studies, but usually in a repeated measures design. Repeated measures designs[218,219] without a separate control group would not have detected the effects of previous testing that were detected in this study.
- South African martial artists were the population used in this study. A small number of studies including martial artists have used isokinetics. This study fills a gap in the literature, providing additional insight into the effect of stretching

and neural mobilisation techniques on strength and power in martial artists, but also useful pre-test data.

- Static stretch and dynamic neural mobilisation exercise are especially relevant for sports requiring flexibility, strength, and power. This study provides applied data useful for the sporting context.
- A large sample size (n = 93) was used and based on a power calculation. Similar studies on static stretching included 10 to 20 participants. Appropriate sample sizes are needed to achieve the statistical power required to detect small effect sizes within the context of large standard deviations[264]. The sample size of 31 individuals per group, allowed for the power to detect smaller effects as significant while including both genders and various self-reported experience levels, which leads to greater standard deviations, due to more heterogenous participants.
- Care was taken to give participants a quality experience. Many participants and organisations stated on how grateful they were to be involved. Participants appreciated getting verbal explanations of their results after their appointments and having a chance to ask questions and access specialised testing, which would normally not have been available to them. They were given the choice to be sent extensive written feedback. They received remuneration for their time and were offered waters and a refreshment at the conclusion of their appointment.
- The study included recreational level participants. Data on competitive martial artists is more available than that of recreational level athletes. This data is relevant to a larger population.
- Gold standard equipment was used for testing strength and mean power with reliable and accurate isokinetic dynamometry (Biodex System 3 Professional Isokinetic Dynamometer, Shirley, New York, United States of America) and jump performance (Smart Mat: Coopers Plains, Australia), rather than field tests. These add objectivity, validity, reliability and confidence to the data collected.
- Male and female participants from several martial arts were included. Different martial arts codes and genders increases data heterogeneity but makes the results more applicable to multiple sporting contexts.

6.3.2 Findings

- This study identified significant ($p \leq 0.05$) pre-post decreases in isokinetic mean power with static stretch and dynamic neural mobilisation. Mean power results are seldom included in similar static stretch studies, and this is the first study to report this data for dynamic neural mobilisation exercise.
- Absolute and peak torque / body weight isokinetic data was reported. Absolute peak torque is more comparable to other studies, however peak torque / body weight data is seldomly reported for similar studies and is an applied indicator of performance relative to body size, which may be more interpretable for athletes.
- This study was the first to measure the acute effects of dynamic neural mobilisation in a healthy population with concentric isokinetic dynamometry. This is important because it clarified the impact of this common exercise on performance.
- Data for dominant and non-dominant legs, as well as knee extension and flexion were reported. Similar studies frequently report only a single leg and movement pattern. Reporting both gives a more comprehensive view of effects. To the authors knowledge this is the largest-to-date RCT to measure the acute effect of static stretching which has reported non-dominant leg data. Including flexion and extension gives insight into agonist and antagonist effects.

6.4 Recommendations

Based on the outcomes of the present study, the following recommendations can be made:

1.2.2 Recommendations for isokinetics studies

- A separate familiarisation day to introduce participants to the facility, equipment and testing could reduce the learning effect and anxiety.
- A forty-eight-hour (or longer) rest-period between pre-testing and post-testing could decrease changes to the control group.
- With same-day pre-, and post-testing, a recovery period of several hours may reduce changes to control further.

- A research assistant who is unaware of the study outcomes may further control bias, by blinding the researcher.
- Using standardised instructions, using a pre-recorded video, or spoken script, may further decrease bias in the study.
- Increasing the size of the control group may improve power to identify midrange effects.[265] This study used a control group equal to the size of one intervention group (n = 31), but group have increased this to equal the participants in both experimental groups for increased power (n = 62).
- Risk management planning for likely, and unlikely risks (such as power interruptions and COVID-19) may improve scheduling efficiency.
- Decreasing sample heterogeneity, by including participants to include either male or female participants, a narrow age range, a single sport code, body weight range and/ or experience level would decrease sample variance and improve the ability to detect significant differences.
- Some participants needed more coaching than others. Especially during moving in rhythm with metronome. This should be planned for and expected.

1.2.3 Recommendations based-on findings of the study

- Contacting women's martial art organisations, such as "ladies kickboxing" groups, may increase the number of female participants to increase sample homogeneity and reduce variance. This was attempted in this study, however non-were available to be involved.
- Emphasising familiarisation for the 180º.s^{-1} isokinetic test is recommended. Participants frequently experiences high Coefficient of Variations scores (CoV ≥ 20%) and reported this movement was difficult. This may decrease the number of exclusions, due to high CoV.
- Developing and using a standard checklist and taxonomy of terms to report when describing studies could improve specificity of stretch studies. During literature review, studies frequently used different terminology for concepts, which limited their usefulness. Some important concepts include stretches used, order of stretches, side stretched, side dominance, intensity of stretch, range of motion, active stretching or assisted, number of repetitions and sets, duration of hold, speed of stretch, total volume of stretching and total time spent stretching per side and in overall.

- Developing and using a standardised checklist for reporting isokinetic test results would increase study usefulness. During literature review, studies often did not include all relevant information. Some important concepts include, bilateral or unilateral testing, leg dominance, familiarisation procedure, test speed, contraction type (concentric vs. eccentric and isokinetic vs. isometric or isotonic), joint and movement pattern, and variable involved, and feedback given.
- Further research is recommended to address gaps in the literature highlighted during this study. Topic areas and gaps in the literature for future studies to address are listed in Table 21 Recommended topic areas and gaps in the literature to address in future studies below.

Table 21 Recommended topic areas and gaps in the literature to address in future studies

Topic area	Gap #	Gaps in the literature
DNME	1	The effects of unilateral DNME on the dominant vs. non-dominant leg
	2	The effects of different durations of DNME
	3	The effects of different intensities of DNME
	4	The non-local effects of DNME
	5	The effects of static vs. dynamic neural mobilisation
	6	The effects of assisted vs. unassisted neural mobilisation
	7	Replicate the present study with a smaller more homogenous.
	8	The effect of DNME on functional activities, such as sprinting
Static stretching	9	Developing reporting standards for stretching studies
Stretch induced strength loss	10	The duration of stretch-induced strength and power loss effects
	11	The effect of experience level or stretching experience on strength loss
	12	The effect of chronic stretching on strength-loss
	13	Does chronic DNME practice decrease the acute effects of DNME?
Isokinetics	14	The learning difficulty and/ or coachability of different isokinetic speeds
	15	Developing reporting standards for isokinetic studies

6.5 Take-home message

Dynamic neural mobilisation exercise has a similar effect to static stretching and control after pre-testing or prior activity 15 minutes before.

Pre-post results are suggestive that dynamic neural mobilisation and static stretching may reduce both strength and power performance, compared to baseline, with a higher magnitude at slow speeds. Post exercise performance enhancement appears to occur after static stretching, but not dynamic neural mobilisation exercise and while static stretching appears to cause stretch induced strength loss in both dominant and non-dominant legs, dynamic neural mobilisation appears to impact the dominant leg and knee flexion pattern more consistently.

These results suggest that martial artists can perform a warm-up including 5 minutes cycling and 3 sets of maximal concentric contractions per leg or the same with 10 minutes static stretching or the same with 10 minutes dynamic neural mobilisation exercise immediately before strength and power activities, if preceded by sufficient warm-up activities 15 minutes before.

Pre-post results are however may suggest performance decreases and due to static stretching and dynamic neural mobilisation, which could influence performance. Further research is recommended.

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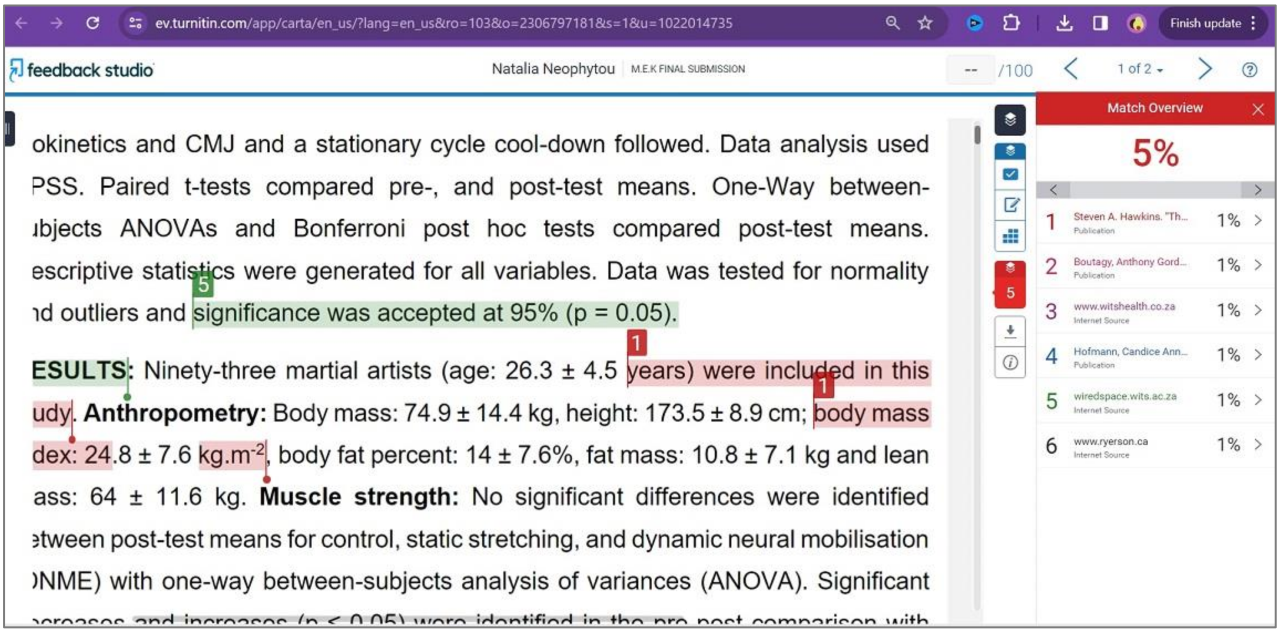
APPENDICES

APPENDIX A

Turnitin report and receipt



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feedback studio — Natalia Neophytou | M.E.K FINAL SUBMISSION — -- /100 — 1 of 2

okinetics and CMJ and a stationary cycle cool-down followed. Data analysis used PSS. Paired t-tests compared pre-, and post-test means. One-Way between-ıbjects ANOVAs and Bonferroni post hoc tests compared post-test means. escriptive statistics were generated for all variables. Data was tested for normality ıd outliers and significance was accepted at 95% (p = 0.05).

ESULTS: Ninety-three martial artists (age: 26.3 ± 4.5 years) were included in this udy. **Anthropometry:** Body mass: 74.9 ± 14.4 kg, height: 173.5 ± 8.9 cm; body mass dex: 24.8 ± 7.6 $kg.m^{-2}$, body fat percent: 14 ± 7.6%, fat mass: 10.8 ± 7.1 kg and lean ass: 64 ± 11.6 kg. **Muscle strength:** No significant differences were identified etween post-test means for control, static stretching, and dynamic neural mobilisation)NME) with one-way between-subjects analysis of variances (ANOVA). Significant ecreases and increases (p < 0.05) were identified in the pre-post comparison with

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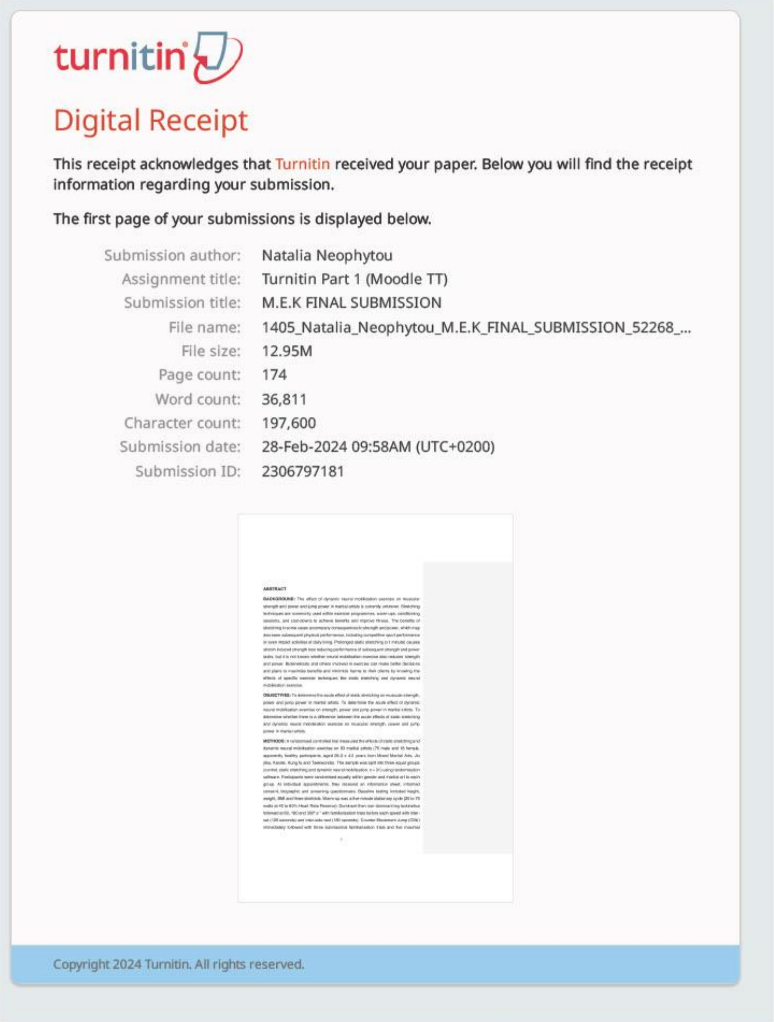

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APPENDIX B

Human Research Ethics Committee (HREC medical) certificate

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

R14/49 Mr Michael Keith Ellefsen

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

CLEARANCE CERTIFICATE NO. M190620 MED19-06-023

NAME: **(Principal Investigator)**	Mr Michael Keith Ellefsen
DEPARTMENT:	Centre for Exercise Science and Sport Medicine
PROJECT TITLE:	The acute effect of dynamic neural mobilization exercise versus static stretching on muscular strength and power in martial artists
DATE CONSIDERED:	28/06/2019
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Natalia Neophytou
APPROVED BY:	Dr C Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	18/12/2019

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office Secretary in Room 301, Third floor, Faculty of Health Sciences, Phillip Tobias Building, 29 Princess of Wales Terrace, Parktown, 2193, University of the Witwatersrand. I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee. **I agree to submit a yearly progress report**. The date for annual re-certification will be one year after the date of convened meeting where the study was initially reviewed. In this case, the study was initially reviewed June and will therefore be due in the month of June each year. Unreported changes to the application may invalidate the clearance given by the HREC (Medical).

Principal Investigator Signature

Date

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX C

School of Therapeutic Sciences approval of title

UNIVERSITY OF THE
WITWATERSRAND,
JOHANNESBURG

Private Bag 3 Wits, 2050
Fax: 027117172119
Tel: 02711 7172076

Reference: Mrs Sandra Benn
E-mail: sandra.benn@wits.ac.za

06 January 2021
Person No: 1973152
PAG

Mr MK Ellefsen
Unit 95, Fairbridge Complex
Danielle Street
Fairland
2195
South Africa

Dear Mr Michael Ellefsen

Master of Science in Medicine: Approval of Title

We have pleasure in advising that your proposal entitled *The acute effect of dynamic neural mobilization exercise versus static stretching on muscle strength and power in martial artists* has been approved. Please note that any amendments to this title have to be endorsed by the Faculty's higher degrees committee and formally approved.

Yours sincerely

Mrs Sandra Benn
Faculty Registrar
Faculty of Health Sciences

APPENDIX D

Information leaflet

Part A.

STUDY NUMBER: M190620

STUDY TITLE: THE ACUTE EFFECT OF DYNAMIC NEURAL MOBILIZATION EXERCISE VS. STATIC STRETCHING ON MUSCLE STRENGTH AND POWER IN MARTIAL ARTISTS.

INVESTIGATOR: Michael Ellefsen

INSTITUTION: University of Witwatersrand, School of Therapeutic Sciences, Centre for Sport Medicine, and Exercise Science.

DAYTIME AND AFTERHOURS TELEPHONE NUMBER:

084 995 0005

To the potential Participant: This consent form may contain words that you do not understand. Please ask the study staff to explain any words or information that you do not clearly understand. You may take home **an unsigned copy of this consent** form to think about or discuss with family or friends **before making your decision.**

Part B.

1. INTRODUCTION:

Good day, my name is Michael Ellefsen, I am a master's Student at the University of Witwatersrand, Centre for Sports Medicine, and Exercise Science. I would like to **invite** you to consider participating in a research study, entitled "The acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists".

1. Before agreeing to participate, it is important that you read and understand the following explanation of the purpose of the study, the study procedures, benefits, risks, discomforts, and precautions as well as the alternative procedures that are available to you, and your right to withdraw from the study

at any time. This information leaflet is to help you decide if you would like to participate. You need to understand what is involved before you agree to take part in this study.

1. If you have any questions, do not hesitate to ask me.
2. You should not agree to take part unless you are satisfied about all the procedures involved.
3. You may not participate in another investigational medicine research study, nor take any other investigational medicine during your participation in this study.
4. You should not have participated in an investigational medicine research study within the past 30 days.
5. Please be open with me regarding your health history since you may otherwise harm yourself by participating in this study.
6. If you decide to take part in this study, you will be asked to sign this document to confirm that you understand the study. You will be given a copy to keep.
7. If you have a personal doctor, please discuss with, or inform him/her of your possible participation in this study. If you wish, I can also notify your personal doctor in this regard.

2. PURPOSE OF THE STUDY:

- Exercise coaching and training depends on evidence about the effects of specific exercises and stretches. As a martial arts student you are involved in regular exercise training which may lead to improvements in your physical fitness. I would like you to consider taking part in the research of the effects of specific types of stretching exercises called dynamic neural mobilization and static stretching.
- The purpose of this study is to determine the immediate effect of static stretching vs. dynamic neural mobilization exercise on muscular strength and power in martial artists.
- This study will compare static stretching with dynamic neural mobilization.

3. LENGTH OF THE STUDY AND NUMBER OF PARTICIPANTS:

- The study will be performed in 1 country.
- Approximately 93 participants will participate in this study in South Africa.
- The participants will be between the ages of 18 and 35 years.
- The total amount of time required for your participation in this study will be a maximum of 1.5 hours.
- You will be asked to visit me 1 time during the study at the Centre for Exercise Science and Sports Medicine at the University of Witwatersrand, Parktown campus, Johannesburg.

4. PROCEDURES:

- If you agree to take part in this study, you will first be asked questions and examined to see if you qualify for this study.
- During participation in this study, you will receive basic measurements including your height, weight and measurements of your body fat and resting heart rate. Height and weight will be measured by asking you to stand on a scale and having a height rod placed on your head. Heart rate will be measured by asking you to sit quietly for 5 minutes while a belt, placed on the skin of your chest measures your heart rate. Body fat will be measured using a calliper to measure three pinches of skin at the upper, middle, and lower body. A warm-up will be performed by having you cycle on a stationary exercise bicycle for 5 minutes at a medium intensity. A strength testing will involve being fitted to a computerized strength test machine and performing knee exercises by pushing and pulling your leg against resistance. A jumping test will be performed by having you stand on a computerized mat and jump powerfully into the air. You will rest after the tests for a period of 15 minutes. After resting you will receive either a 10 minute rest period or a 10 minute stretching session led by the researcher, after which you will repeat the strength and jumping tests. Finally, you will receive a 5-minute cool-down also on a stationary exercise bicycle.

5. WILL ANY OF THESE STUDY PROCEDURES RESULT IN DISCOMFORT OR INCONVENIENCE?

- Vigorous or unaccustomed physical activity can result in muscular stiffness and muscular soreness immediately after the exercise, which normally lasts up to 24 hours after the exercise. Delayed Onset Muscle Soreness (DOMS) can occur after heavy exercise and may involve severe muscular stiffness or ache which onsets 24 to 48 hours after exercise and usually lasts up to 72 hours after exercise. There is a small possibility of muscle or joint injury from participation in vigorous exercise, such as joint sprains or “pulled” muscles.

6. RISKS OF PHYSICAL EXERCISE:

- In previous studies of physical activity, some participants have experienced symptoms including muscular aches, strains, tears, joint injuries as well as feelings of dizziness from exertion. These risks are however low and not more than would be expected if one does basic physical exercise, and less than with martial arts training.

6. UNFORSEEN RISKS:

- The study of exercise is investigational and there may be unexpected risks or side effects. You should immediately contact me if any side effects occur throughout your participation in the study.

7. BENEFITS:

- The potential benefit from your participation in this study may be to improve your muscular flexibility temporarily.
- However, you may not benefit from this study.
- Your participation in this study will help contribute to medical knowledge that may help other martial artists who like you seek to improve their physical performance and ability through exercise training.

8. ARE THERE ANY WARNINGS OR RESTRICTIONS CONCERNING MY PARTICIPATION IN THIS STUDY?

- If you are pregnant, you may not take part in this study.
- Vigorous or unaccustomed exercise may result in post exercise fatigue. Care should be taken to ensure adequate rest and recovery after training.

9. RIGHTS AS A PARTICIPANT IN THIS STUDY:

9.1 VOLUNTARY PARTICIPATION

- Your participation in this study is entirely voluntary and you can decline to participate, or stop at any time, without stating any reason.

10. NEW FINDINGS

- I will provide you with any additional information that becomes available during the study, which may affect your willingness to continue with the study.

11. WITHDRAWAL

- I retain the right to withdraw you from the study if it is considered to be in your best interest.
- If you did not give an accurate history or did not follow the guidelines of the study and the regulations of the study facility, you may be withdrawn from the study at any time.

12. EMERGENCY CARE AND HOSPITALIZATION:

- If you seek emergency care or hospitalization is required at any time during the study, please inform the researcher so that first aid and assistance can be given. If hospitalization is required,

- If the participant has medical aid, they will be transported to the nearest private hospital. The cost of treatment will be covered by the participant and their medical aid.
- If the participant does not have medical aid, the participant will be transported to the nearest Government hospital.

13. REIMBURSEMENT FOR STUDY PARTICIPATION

- You will not be paid to participate in this study, but you will be reimbursed for your cost to travel to the site of study and return home**.** Travel costs will be calculated per kilometre travelled according to the maximum tax-free rate allowable by SARS for travel remuneration of employees, which is 361 cents per kilometre. Distance travelled will be calculated using the online software Google maps, as the shortest distance from your residential location to the testing site.

14. ETHICAL APPROVAL:

- This clinical study protocol has been submitted to the University of the Witwatersrand, **Human Research Ethics Committee (Medical) (HREC-M)** and written approval has been granted by the committee.
- The study has been structured in accordance with the **Declaration of Helsinki** (last update October 2013), which deals with the recommendations guiding researchers in biomedical research involving human participants. A copy may be obtained from me should you wish to review it.

15. SOURCE OF ADDITIONAL INFORMATION

- For the duration of the study, you will be under the care of Michael Ellefsen. If at any time during participation, you feel the onset of unpleasant symptoms, please do not hesitate to inform me.

  The telephone number through which you can reach me is 084 995 0005

- If you want any information regarding your **rights as a research participant, or complaints regarding this research study,** you may contact Prof. Clement Penny, Chairperson of the University of the Witwatersrand, Human Research Ethics Committee (HREC), which is an independent committee established to help protect the rights of research participants at (011) 717 2301.
- For **research information** you can contact Michael Ellefsen at 084 995 0005 or michael@ellefsen.za.net

16. CONFIDENTIALITY:

- All information obtained during the curse of this study, including personal data and research data will be kept strictly confidential. Data that may be reported in scientific journals will not include any information that identifies you as a participant in this study.
- This information will be reviewed only by authorized representatives of Michael Ellefsen.
- The information might also be inspected by the National Health Research Ethics Council (NHREC), University of the Witwatersrand, Human Research Ethics Committee (HREC) or by your personal doctor.
- Therefor you hereby authorize me to release your research information to the National Health Research Ethics Council (NHREC), and the University of the Witwatersrand, Human Research Ethics Committee (HREC).
- Any information uncovered regarding your test results or state of health as a result of, your participation in this study will be held in strict confidence. You will be informed of any finding of importance to your health or participation in this study, but this information will not be disclosed to any third party in addition to the ones mentioned above without your written permission.

17. PERSONAL DOCTOR/ SPECIALIST NOTIFICATION OPTION:

Please indicate below, whether you want me to notify your personal doctor or your specialist of your participation in this study:

- **YES**, I want you to inform my personal doctor/ specialist of my participation in this study.
- **NO**, I do not want you to inform my personal doctor/ specialist of my participation in this study.
- **I do not have** a personal doctor/ specialist.

18. **PARTICIPANT QUESTIONS:**

Did the participant raise any questions?

YES / NO

IF YES – What where they:

APPENDIX E

Informed consent

- I hereby confirm that I have been informed by the researcher Michael Ellefsen about the nature, conduct, benefits, and risks of clinical study (#): “The acute effect of dynamic neural mobilization exercise versus static stretching on muscular strength and power in martial artists”.
- I have also received, read, and understood the above written information (Participation Information Leaflet and Informed Consent) regarding the clinical study.
- I am aware that the results of the study including personal details regarding my sex, age, date of birth and initials will be anonymously processed into a study report.
- In view of the requirements of research, I agree that the data collected during this study can be processed in a computerized system by Michael Ellefsen.
- I may, at any stage, without prejudice, withdraw my consent and participation in the study.
- I have received sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.

PARTICIPANT:

Printed Name	Signature / Mark or Thumbprint	Date and Time

I Michael Ellefsen, herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study.

mailto:michael@ellefsen.za.net

APPENDIX F

Biographic and screening questionnaire

Participant Reference Number	

1. Introduction

This page will ask you for information to determine whether you meet the participation requirements for this research and allow the researcher to communicate with you.

Age																				
Age (years)																				
Contact details																				
Cell #																				
Other contact #																				

Email address (please write carefully and legibly)															
Email address															

Please complete the following questions, by **circling** the correct answer.

Biographic information				
Are you male or female?	FEMALE	MALE		
Are you between 18 and 35 years old?	YES	NO		
Which Martial Art are you involved in?				
MMA	Jiu Jitsu	Karate	Kung-fu	taekwondo
What is your level of participation?				
Recreational	National	International	Elite	
Sport participation				

Do you participate in regular sport activity?	YES	NO
Are you a current member of a martial arts school?	YES	NO
Injury status		
Do you have a current injury?	YES	NO

If you answered YES to the question above, please give a brief description of your injury in this box.

Thank you for completing this questionnaire. Please check whether all your information is correct.

APPENDIX G

Recording sheet

Date	
Time	
Participant reference number	

Baseline		
Resting measurements		
Resting heart rate		b.min^{-1}
Height		cm
Body mass		Kgs

Anthropometry				
Skinfolds		Measure 1	Measure 2	Measure 3
Male	Chest (mm)			
	Abdomen (mm)			
	Thigh (mm)			
Female	Tricep (mm)			
	Suprailiac (mm)			
	Thigh (mm)			

Counter movement jump	
Pre-testing	
Trial 1	
2	
3	

4	
5	
Post-testing	
Trial 1	
2	
3	
4	
5	

APPENDIX H

Signed school participation forms

School participation letter

I Shaun Lombard (FULL NAME), on behalf of the martial arts school Alberton Wing Tzun (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name Shaun Lombard
Signature:
Date: 2021-02-02
Email address: Slawl@ebnas.co.za Cell: 0824455204

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.
Registered Biokineticist,
Accredited Anthropometrist.
CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

School participation letter

I M, Katz (FULL NAME), on behalf of the martial arts school Andre's Taekwondo Academy (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name Marissa Katz P.P.
Signature:
Date: 24/11/20
Email address: rissyKatz@gmail.com Cell: 0823566545

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.
Registered Biokineticist,
Accredited Anthropometrist.
CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

School participation letter

I MALCOLM MACMILLAN (FULL NAME), on behalf of the martial arts school ARTE SUAVE ALBERTON (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name MALCOLM MACMILLAN
Signature:
Date: 18/01/2021
Email address: MALCOLM@ICON.BIZ Cell: 0605082606

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.
Registered Biokineticist,
Accredited Anthropometrist.
CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

School participation letter

I DAVID SPAGNOLO (FULL NAME), on behalf of the martial arts school ELITE (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name DAVID SPAGNOLO
Signature: Spagnolo
Date: 11/01/2021
Email address: davidspagnolo79@gmail.com Cell: 082 7865754

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.
Registered Biokineticist,
Accredited Anthropometrist.
CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

School participation letter

I Rodney Swanepoel (FULL NAME), on behalf of the martial arts school Fight Right Gym (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name Rodney Swanepoel
Signature:
Date: 21 Oct 2020
Email address: Swanepoelrodney23@gmail.com Cell: 082 458 1016

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.
Registered Biokineticist,
Accredited Anthropometrist.
CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

School participation letter

I C. Jagger (FULL NAME), on behalf of the martial arts school Goju Ryu Roodepoort. (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name C. JAGGER

Signature:

Date: 26 Nov 2021

Email address: Cell:

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.
Registered Biokineticist,
Accredited Anthropometrist.
CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

School participation letter

I James Boston Gemmell JBG_ (FULL NAME), on behalf of the martial arts school Gracie Barry Illovo (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name James
Signature: Gemmell
Date: 30/09/2020
Email address: info@graciebarry.co.za Cell: 0733012685.

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.
Registered Biokineticist,
Accredited Anthropometrist.
CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

Appendix A School participation Form

School participation letter

I Jordan Arnold (FULL NAME), on behalf of the martial arts school Fight Fit Malitia (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name Jordan
Signature:
Date: 2/11/2020
Email address: jordanarnold1998@ gmail com Cell: 076 870 6090

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.
Registered Biokineticist,
Accredited Anthropometrist.
CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

School participation letter

I Jordan Arnold (FULL NAME), on behalf of the martial arts school Fight Fit Malitia (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name Jordan

Signature:

Date: 2/11/2020

Email address: jordanarnold1998@gmail.com Cell: 076 870 6090

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.
Registered Biokineticist,
Accredited Anthropometrist.
CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

School participation letter

I NORMAN MAGUA (FULL NAME), on behalf of the martial arts school MTG TAEKWON-DO (NAME OF SCHOOL) accept the offer to participate in the research study “the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists”, which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name NORMAN MAGUA
Signature:
Date: 23/09/2020
Email address: magua.taekwondo~~.co.za~~@gmail.com Cell: 083 226 1836

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.
Registered Biokineticist,
Accredited Anthropometrist.
CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

School participation letter

I W.A. Wannenburg (FULL NAME), on behalf of the martial arts school SA JKA (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name Wendy Wannenburg

Signature:

Date: 18/3/2021

Email address: karatewendy@gmail.com Cell: 082 679 3637

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.
Registered Biokineticist,
Accredited Anthropometrist.
CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

School participation letter

I Justice Fallet (FULL NAME), on behalf of the martial arts school True Combat. (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name Justice

Signature:

Date: 14/01/22

Email address: Cell: 0670757524

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.
Registered Biokineticist,
Accredited Anthropometrist.
CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

School participation letter

I SULIMAN SAID (FULL NAME), on behalf of the martial arts school SAID'S KARATE & KICKBOXING, (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name (Head Instructor) SOKE SOLLY SAID

Signature:

Date: 13th MARCH 2019

Email address: hanshi@kenfudevy.com Cell: 0833149941

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.

Registered Biokineticist,

Accredited Anthropometrist.

CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

Research Participation letter

I Jeanie Abbott (FULL NAME), on behalf of the martial arts school Red Dragon Academy (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neurodynamic mobilization vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name: Jeanie
Signature:
Date: 5 Sept 2018

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.

Registered Biokineticist,

Accredited Anthropometrist.

CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

Research Participation letter

I Wiekus Swart (FULL NAME), on behalf of the martial arts school Tap Out Academy (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neurodynamic mobilization vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name: Wiekus Swart

Signature: 082 331 9653

Date: 07-03-2018

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.

Registered Biokineticist,

Accredited Anthropometrist.

CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

Research Participation letter

I Grant Woollatt (FULL NAME), on behalf of the martial arts school Shaolin martial arts centre (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neurodynamic mobilization vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name: Grant Woollatt

Signature:

Date: 01/09/2018

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.

Registered Biokineticist,

Accredited Anthropometrist.

CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

I Mary Jamieson (FULL NAME), on behalf of the martial arts school Northcliff Karate Academy (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neurodynamic mobilization vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name: Mary Jamieson Northcliff Karate Academy.

Signature:

Date: 03-08-2018

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

northcliffkarate@vodamail.co.za

082 781 7121.

Michael Ellefsen, BCom, BA (HONS), EIM.

Registered Biokineticist,

Accredited Anthropometrist.

CELL: 084 995 0005

EMAIL: michael@ellefsen.za.net

School participation letter

I Simon Rutte (FULL NAME), on behalf of the martial arts school I.F.S. Integrated Fighting Systems (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name (Head Instructor) Simon Rutte

Signature:

Date: 25/03/19

Email address: simon.rutte1@gmail.com Cell: 082 735 5393

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.

Registered Biokineticist,

Accredited Anthropometrist.

CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

School participation letter

I Jeandré Joubert (FULL NAME), on behalf of the martial arts school Shugyo-fit (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name: Jeandré

Signature:

Date: 26/05/2019

Email address: jeandre.shugyo@gmail.com Cell: 064 586 6986

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.

Registered Biokineticist,

Accredited Anthropometrist.

CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

I Ryan Davies (FULL NAME), on behalf of the martial arts school Primal Gym (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name (Head Instructor) Liale ~~Anderson~~ Francis / Ryan Davies

Signature:

Date: 25/03/2019

Email address: wolfpack@primalgym.co.za Cell: 0826781371

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.

Registered Biokineticist,

Accredited Anthropometrist.

CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

I Bobby Karagiannidis. (FULL NAME), on behalf of the martial arts school BJMMA.

(NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name (Head Instructor) Bobby Karagiannidis

Signature:

Date: 25 March 2019

Email address: Bobby@bjmma.co.za Cell: 0825612647.

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.
Registered Biokineticist,
Accredited Anthropometrist.
CELL: 084 995 0005 **EMAIL:** michael@ellefsen.za.net

I EMMA WENTZEL (FULL NAME), on behalf of the martial arts school SEISHIN MARTIAL ARTS ACADEMY (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name (Head Instructor) EMMA WENTZEL

Signature:

Date: 26/03/2019

Email address: emma@seishinma.co.za Cell: 083 681 9918

Should you have any questions, please contact the Michael Ellefsen on the contact details below.

Michael Ellefsen, BCom, BA (HONS), EIM.

Registered Biokineticist,

Accredited Anthropometrist.

CELL: 084 995 0005 EMAIL: michael@ellefsen.za.net

School participation letter

I Julia Wright (FULL NAME), on behalf of the martial arts school International Taekwon-Do Fedderation South Africa (ITFSA) (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name (Head Instructor) Julia Wright (Secretary General)

Signature:

Date: 10/4/2019

Email address: jwright@itfsa.co.za Cell: 0733116846

School participation letter

I George Wong (FULL NAME), on behalf of the martial arts school Seido Karate (NAME OF SCHOOL) accept the offer to participate in the research study "the acute effect of neural mobilization exercise vs. static stretching on muscle strength and power in martial artists", which is planned to be conducted by Michael Ellefsen in 2019, as part of the Masters of Science in Medicine (Biokinetics) at Witwatersrand University. I confirm students from my school will be offered the opportunity to participate in this research experiment.

Name (Head Instructor) George Wong

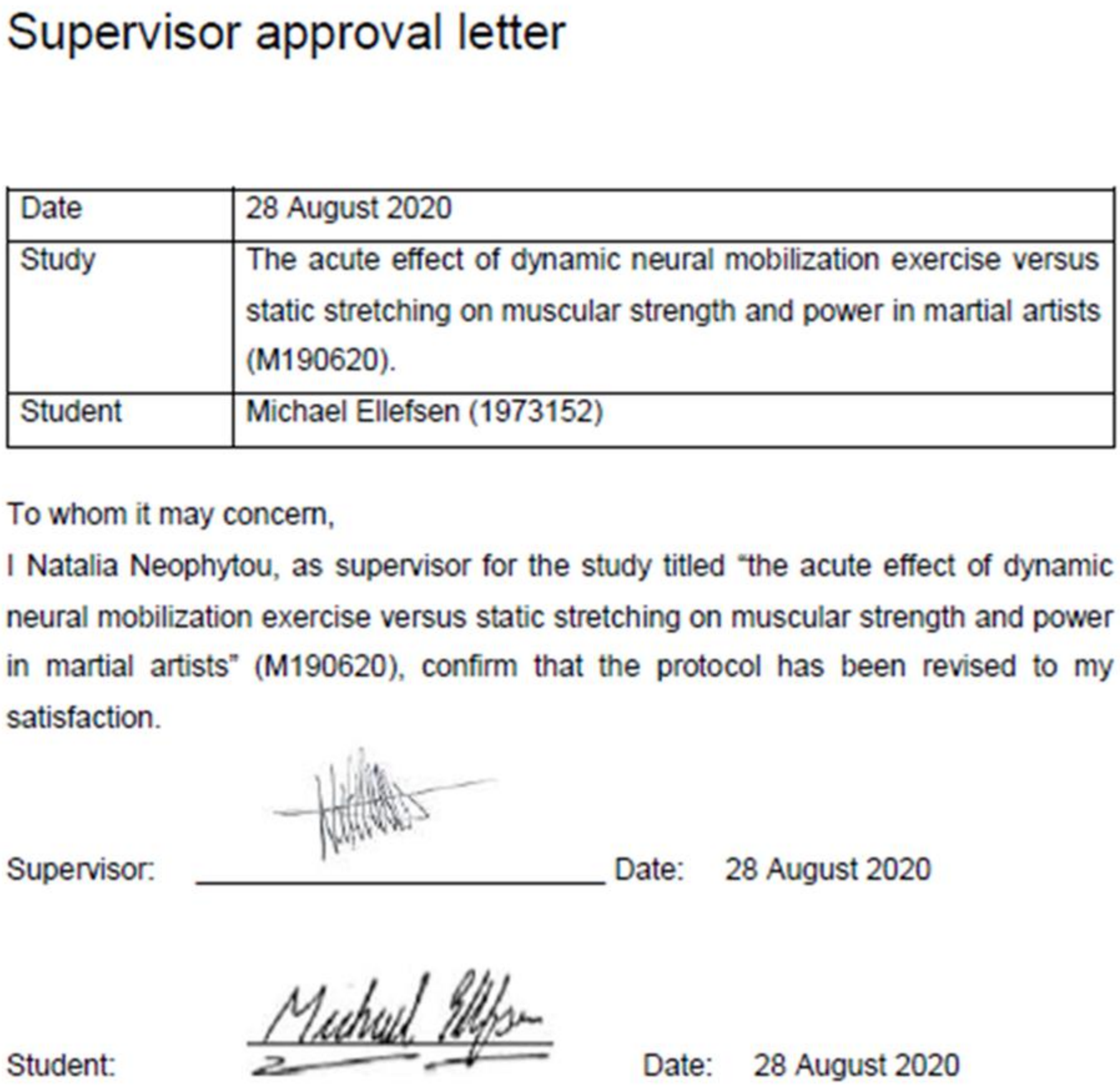
Signature: GW

Date: 27/3/2019

Email address: georgiew@iafrica.com Cell: 0836018328

APPENDIX I

Supervisor approval letter to School of Therapeutic Sciences



Supervisor approval letter

Date	28 August 2020
Study	The acute effect of dynamic neural mobilization exercise versus static stretching on muscular strength and power in martial artists (M190620).
Student	Michael Ellefsen (1973152)

To whom it may concern,

I Natalia Neophytou, as supervisor for the study titled "the acute effect of dynamic neural mobilization exercise versus static stretching on muscular strength and power in martial artists" (M190620), confirm that the protocol has been revised to my satisfaction.

Supervisor: ____________________ Date: 28 August 2020

Michael

Student: Date: 28 August 2020

APPENDIX J

Permission to use facilities

DATE: 27 March 2019

TO: Prof. D. Constantinou
H.O.D, Centre for Exercise Science and Sports Medicine (CESSM)
University of Witwatersrand, Parktown Campus
Johannesburg, South Africa.

SUBJECT: Permission to use facilities

Dear Prof. Constantinou,

I, Michael Ellefsen, hereby request permission to use CESSM equipment and facilities for my proposed study: “the acute effect of neural mobilization exercise versus static stretching on muscular strength and power”.

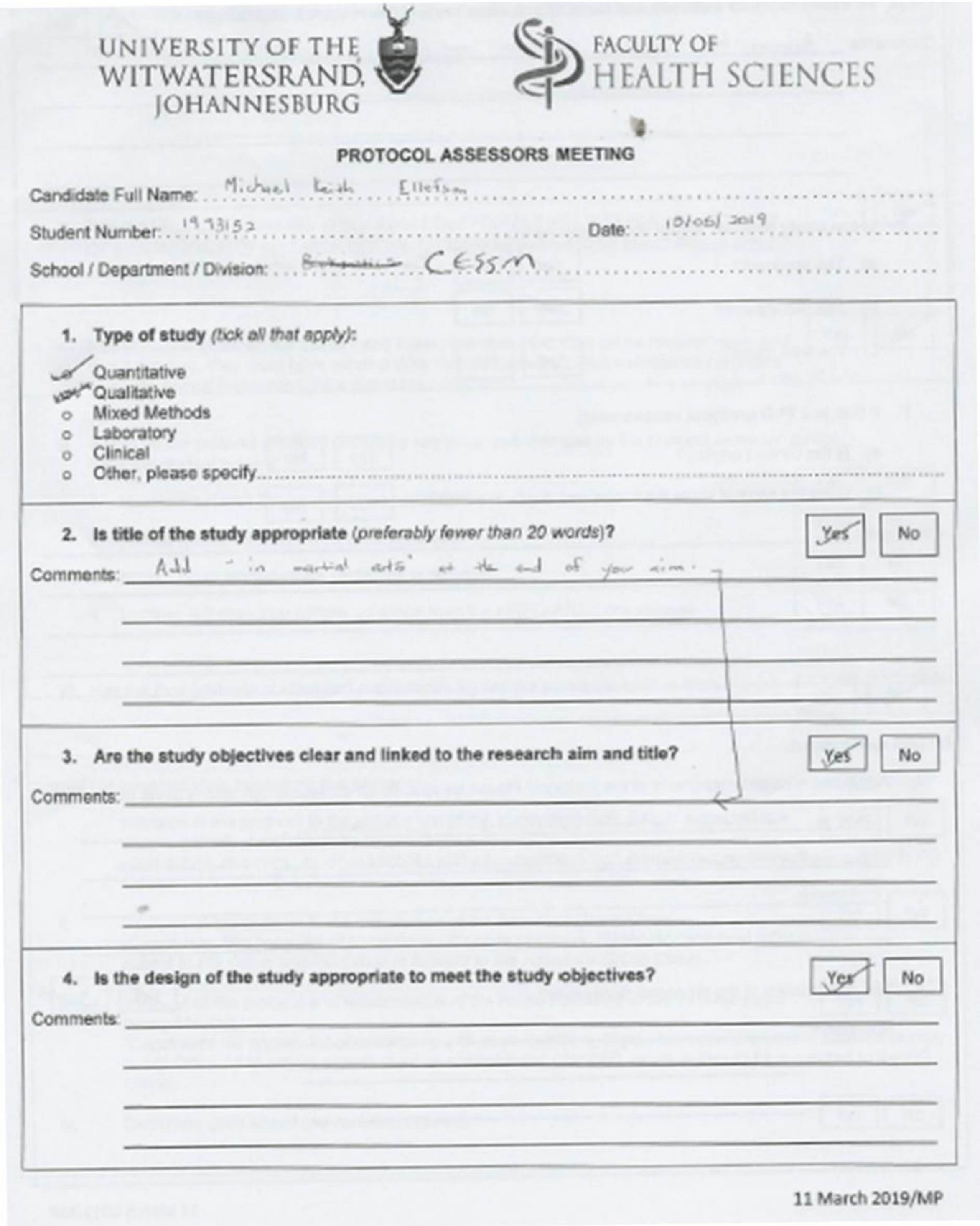
I, Demitri Constantinou **(NAME)** hereby grant permission to use CESSM facilities and equipment for this study.

15/04/2019

SIGNATURE **DATE**

APPENDIX K

School of Therapeutic Sciences: protocol assessor meeting feedback



UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

PROTOCOL ASSESSORS MEETING

Candidate Full Name: Michael Keith Ellefsen

Student Number: 1993152 Date: 10/06/2019

School / Department / Division: ~~[illegible]~~ CESSM

1. **Type of study** *(tick all that apply)*:

☑ Quantitative
☒ Qualitative
○ Mixed Methods
○ Laboratory
○ Clinical
○ Other, please specify……

2. **Is title of the study appropriate** (*preferably fewer than 20 words*)? ☑ Yes ☐ No

Comments: Add "in martial arts" at the end of your aim.

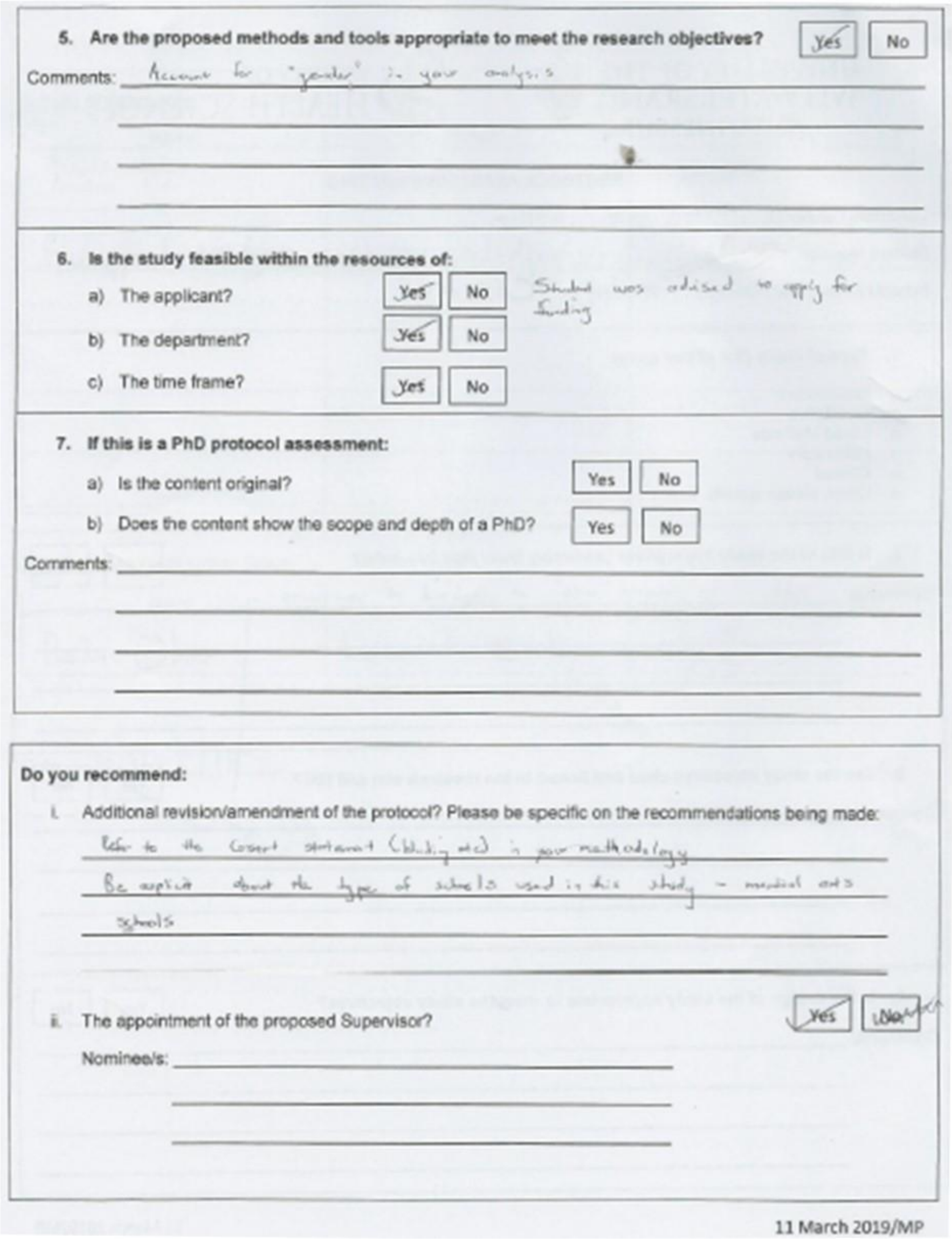
3. **Are the study objectives clear and linked to the research aim and title?** ☑ Yes ☐ No

Comments:

4. **Is the design of the study appropriate to meet the study objectives?** ☑ Yes ☐ No

Comments:

11 March 2019/MP



5. Are the proposed methods and tools appropriate to meet the research objectives? [✓ Yes] No

Comments: Account for "gender" in your analysis

6. Is the study feasible within the resources of:

a) The applicant? [✓ Yes] No — Student was advised to apply for funding

b) The department? [✓ Yes] No

c) The time frame? [✓ Yes] No

7. If this is a PhD protocol assessment:

a) Is the content original? ☐ Yes ☐ No

b) Does the content show the scope and depth of a PhD? ☐ Yes ☐ No

Comments:

Do you recommend:

i. Additional revision/amendment of the protocol? Please be specific on the recommendations being made:

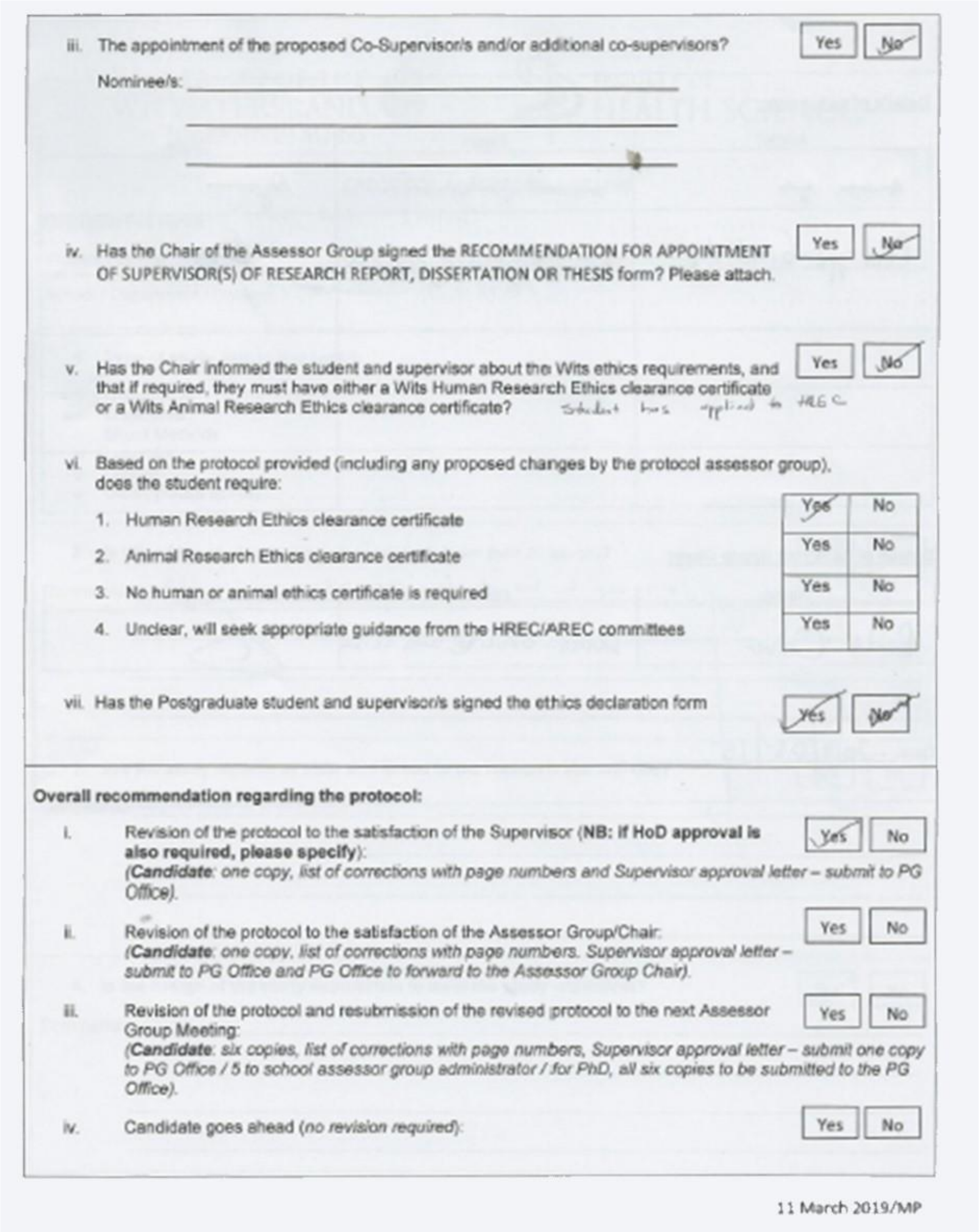
Refer to the Consent statement (blinding etc) in your methodology

Be explicit about the type of schools used in this study – medical arts schools

ii. The appointment of the proposed Supervisor? [✓ Yes] No

Nominee/s:

11 March 2019/MP



iii. The appointment of the proposed Co-Supervisor/s and/or additional co-supervisors? Yes [✓ No]

Nominee/s: ______________________

____

____

iv. Has the Chair of the Assessor Group signed the RECOMMENDATION FOR APPOINTMENT OF SUPERVISOR(S) OF RESEARCH REPORT, DISSERTATION OR THESIS form? Please attach. Yes [✓ No]

v. Has the Chair informed the student and supervisor about the Wits ethics requirements, and that if required, they must have either a Wits Human Research Ethics clearance certificate or a Wits Animal Research Ethics clearance certificate? Student has applied for HREC Yes [✓ No]

vi. Based on the protocol provided (including any proposed changes by the protocol assessor group), does the student require:

1. Human Research Ethics clearance certificate	[✓ Yes]	No
2. Animal Research Ethics clearance certificate	Yes	No
3. No human or animal ethics certificate is required	Yes	No
4. Unclear, will seek appropriate guidance from the HREC/AREC committees	Yes	No

vii. Has the Postgraduate student and supervisor/s signed the ethics declaration form [✓ Yes] [✓ No]

Overall recommendation regarding the protocol:

i. Revision of the protocol to the satisfaction of the Supervisor (**NB: if HoD approval is also required, please specify**): [✓ Yes] No
*(**Candidate**: one copy, list of corrections with page numbers and Supervisor approval letter – submit to PG Office).*

ii. Revision of the protocol to the satisfaction of the Assessor Group/Chair: Yes No
*(**Candidate**: one copy, list of corrections with page numbers. Supervisor approval letter – submit to PG Office and PG Office to forward to the Assessor Group Chair).*

iii. Revision of the protocol and resubmission of the revised protocol to the next Assessor Group Meeting: Yes No
*(**Candidate**: six copies, list of corrections with page numbers, Supervisor approval letter – submit one copy to PG Office / 5 to school assessor group administrator / for PhD, all six copies to be submitted to the PG Office).*

iv. Candidate goes ahead (*no revision required*): Yes No

11 March 2019/MP

Details of Assessors:

Name:	Email:	Sign:
Anushka Ajith	anushka.ajith@wits.ac.za	
Philippe Gradidge	philippe.gradidge@wits.ac.za	

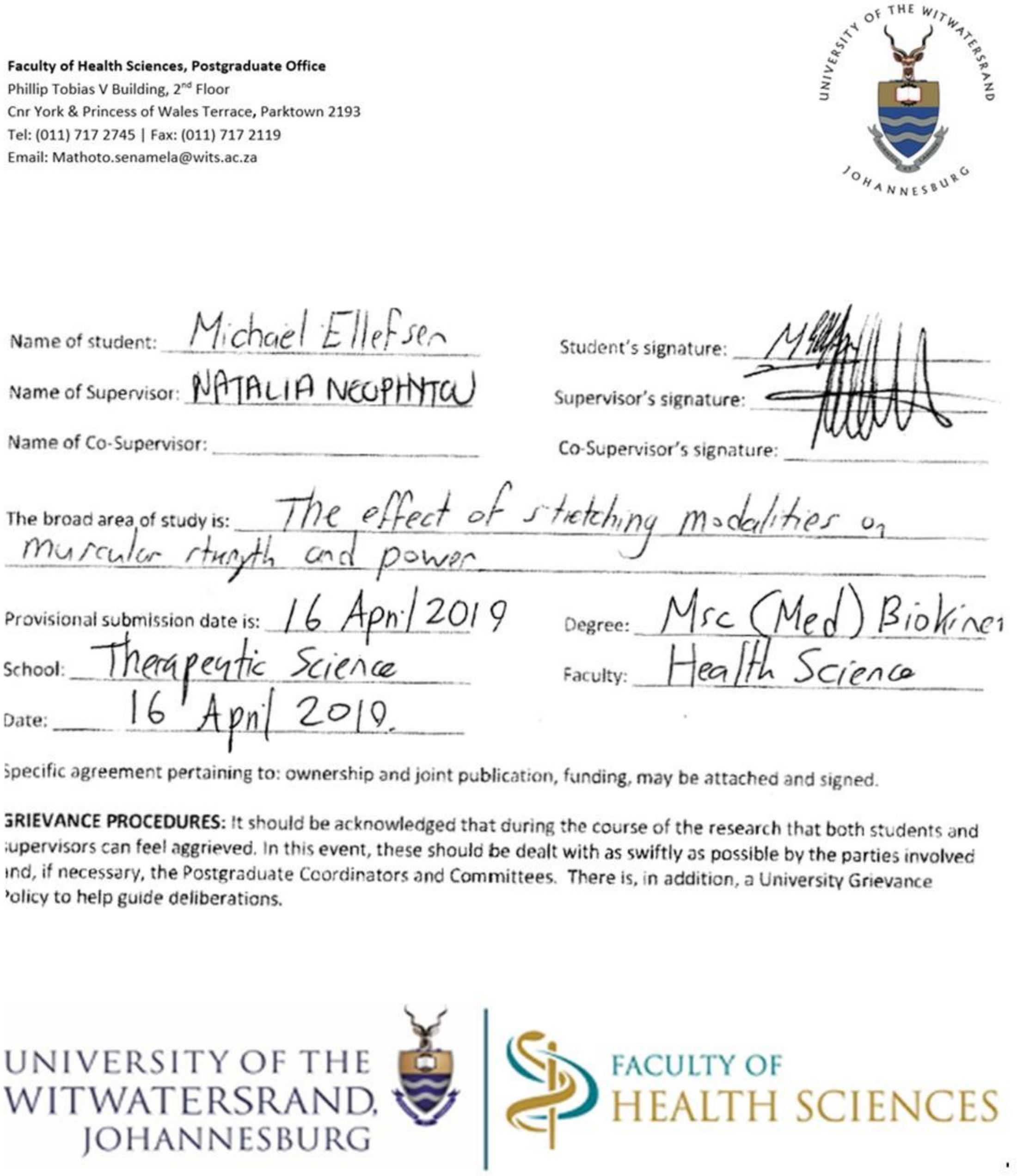
Details of Assessor Group Chair:

Name:	Email:	Sign:
Benita Olivier	benita.olivier@wits.ac.za	

Date: 2019/05/15

APPENDIX L

Appointment of supervisor



Faculty of Health Sciences, Postgraduate Office
Phillip Tobias V Building, 2nd Floor
Cnr York & Princess of Wales Terrace, Parktown 2193
Tel: (011) 717 2745 | Fax: (011) 717 2119
Email: Mathoto.senamela@wits.ac.za

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

Name of student: Michael Ellefsen

Student's signature:

Name of Supervisor: NATALIA NEOPHYTOU

Supervisor's signature:

Name of Co-Supervisor:

Co-Supervisor's signature:

The broad area of study is: The effect of stretching modalities on muscular strength and power

Provisional submission date is: 16 April 2019

Degree: Msc (Med) Biokine

School: Therapeutic Science

Faculty: Health Science

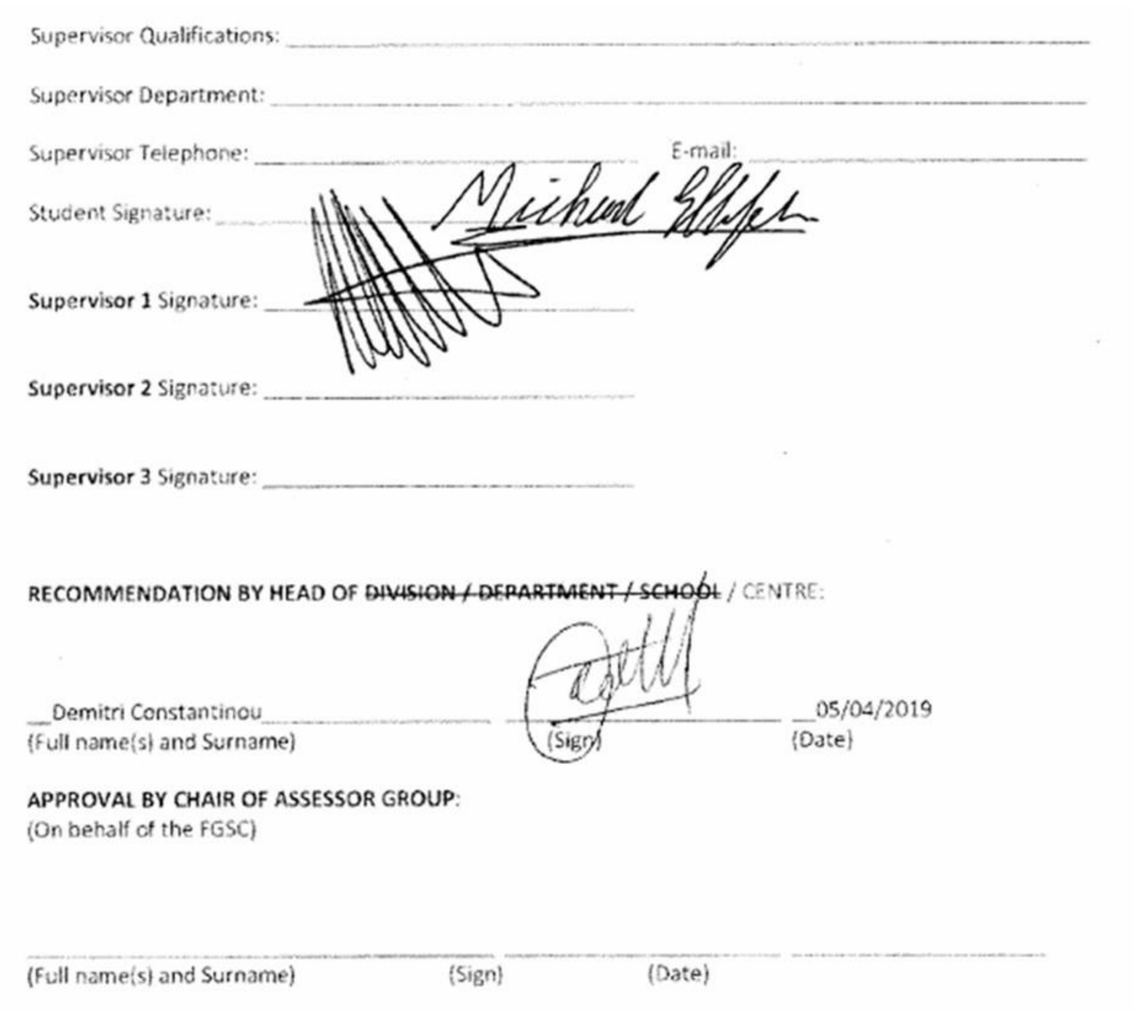
Date: 16 April 2019.

Specific agreement pertaining to: ownership and joint publication, funding, may be attached and signed.

GRIEVANCE PROCEDURES: It should be acknowledged that during the course of the research that both students and upervisors can feel aggrieved. In this event, these should be dealt with as swiftly as possible by the parties involved nd, if necessary, the Postgraduate Coordinators and Committees. There is, in addition, a University Grievance olicy to help guide deliberations.

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES



Supervisor Qualifications: ____________________

Supervisor Department: ____________________

Supervisor Telephone: ____________________ E-mail: ____________________

Student Signature: Michael

Supervisor 1 Signature: ____________________

Supervisor 2 Signature: ____________________

Supervisor 3 Signature: ____________________

RECOMMENDATION BY HEAD OF ~~DIVISION / DEPARTMENT / SCHOOL~~ / CENTRE:

__Demitri Constantinou____________________ ____________________ __05/04/2019

(Full name(s) and Surname) (Sign) (Date)

APPROVAL BY CHAIR OF ASSESSOR GROUP:

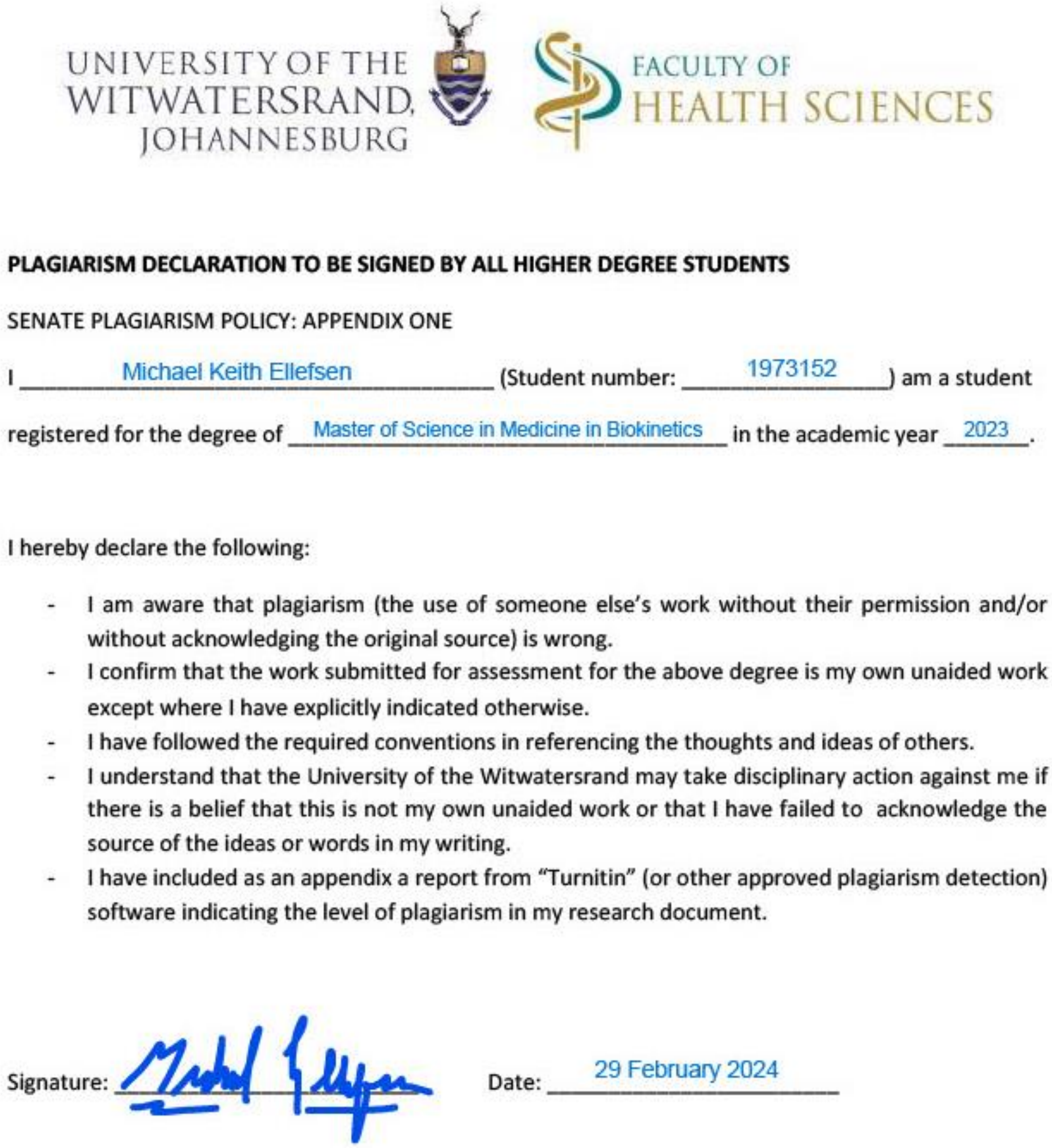
(On behalf of the FGSC)

____________________ ____________________ ____________________

(Full name(s) and Surname) (Sign) (Date)

APPENDIX M

Plagiarism declaration to be signed by all higher degree students



UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

FACULTY OF HEALTH SCIENCES

PLAGIARISM DECLARATION TO BE SIGNED BY ALL HIGHER DEGREE STUDENTS

SENATE PLAGIARISM POLICY: APPENDIX ONE

I Michael Keith Ellefsen (Student number: 1973152) am a student registered for the degree of Master of Science in Medicine in Biokinetics in the academic year 2023.

I hereby declare the following:

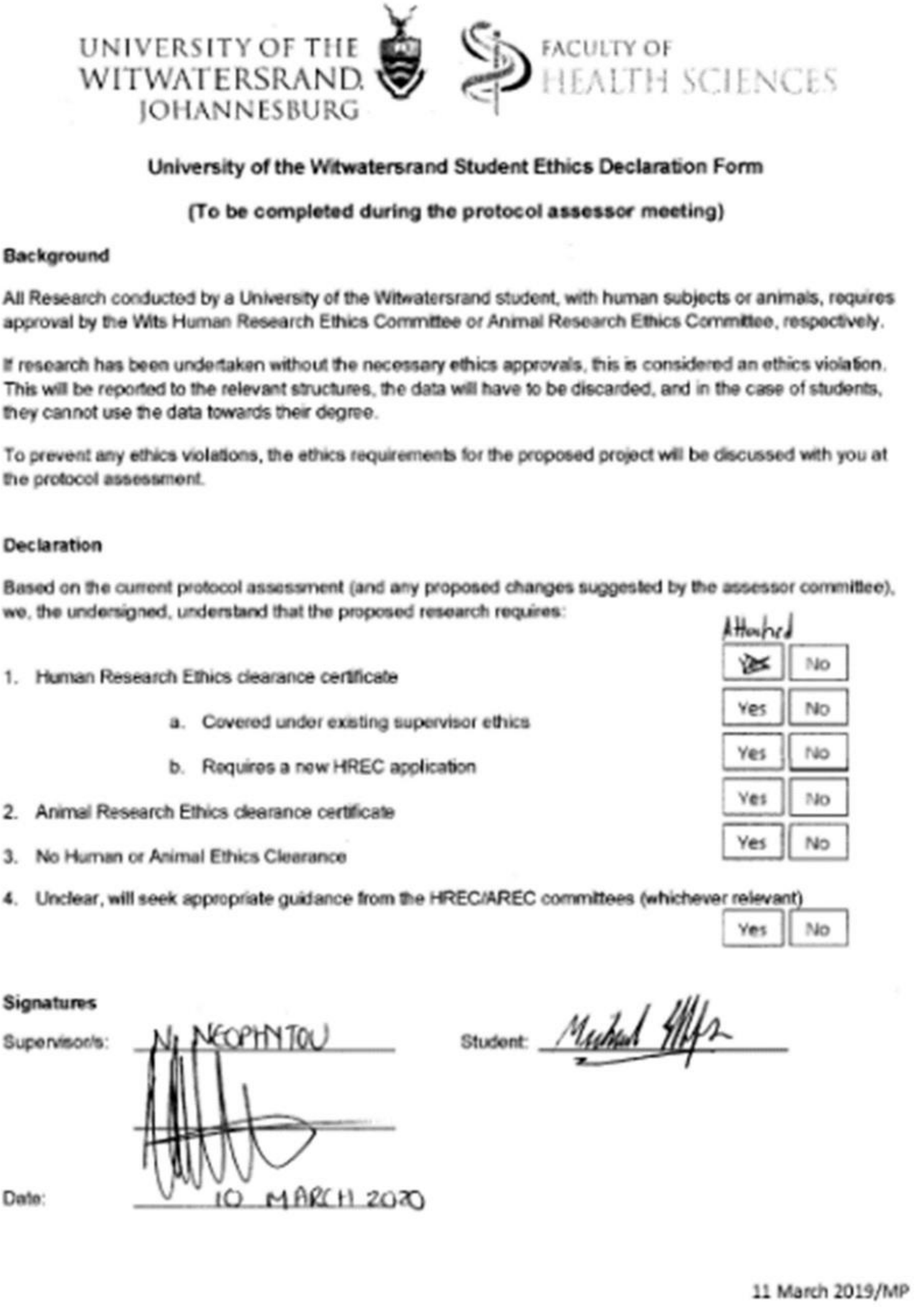
- I am aware that plagiarism (the use of someone else's work without their permission and/or without acknowledging the original source) is wrong.
- I confirm that the work submitted for assessment for the above degree is my own unaided work except where I have explicitly indicated otherwise.
- I have followed the required conventions in referencing the thoughts and ideas of others.
- I understand that the University of the Witwatersrand may take disciplinary action against me if there is a belief that this is not my own unaided work or that I have failed to acknowledge the source of the ideas or words in my writing.
- I have included as an appendix a report from "Turnitin" (or other approved plagiarism detection) software indicating the level of plagiarism in my research document.

Signature:

Date: 29 February 2024

APPENDIX N

Student ethics declaration form



UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG
FACULTY OF HEALTH SCIENCES

University of the Witwatersrand Student Ethics Declaration Form

(To be completed during the protocol assessor meeting)

Background

All Research conducted by a University of the Witwatersrand student, with human subjects or animals, requires approval by the Wits Human Research Ethics Committee or Animal Research Ethics Committee, respectively.

If research has been undertaken without the necessary ethics approvals, this is considered an ethics violation. This will be reported to the relevant structures, the data will have to be discarded, and in the case of students, they cannot use the data towards their degree.

To prevent any ethics violations, the ethics requirements for the proposed project will be discussed with you at the protocol assessment.

Declaration

Based on the current protocol assessment (and any proposed changes suggested by the assessor committee), we, the undersigned, understand that the proposed research requires:

1. Human Research Ethics clearance certificate — Attached [✓ Yes] No
    a. Covered under existing supervisor ethics — Yes No
    b. Requires a new HREC application — Yes No
2. Animal Research Ethics clearance certificate — Yes No
3. No Human or Animal Ethics Clearance — Yes No
4. Unclear, will seek appropriate guidance from the HREC/AREC committees (whichever relevant) — Yes No

Signatures

Supervisor/s: N. NEOPHYTOU

Student: Michael

Date: 10 MARCH 2020

11 March 2019/MP

APPENDIX O

Consent to use photographs

Consent of Lisa Ellefsen

I, Lisa Ellefsen, grant permission for Michael Ellefsen to use and reproduce my photographs for the study: ““The acute effect of static stretching versus dynamic neural mobilisation exercise on muscular strength, power and jump power in martial artists”.

Lisa Ellefsen

Lisa Ellefsen

20 February 2024

Date

Consent of Michael Ellefsen

I, Michael Ellefsen, freely consent to the use and reproduction of my photographs for the study “The acute effect of static stretching versus dynamic neural mobilisation exercise on muscular strength, power and jump power in martial artists”.

Michael Ellefsen

Michael Ellefsen

20 February 2024

Date

APPENDIX P

Example participant feedback report

Notes on optional feedback reports and materials

- An automatic report generator was created in Microsoft excel.
- Formulas were used to immediately compare participant results to gender-based normative values in the sheet. Formulas interpreted participant results using VLOOKUP tables and paragraphs text with individualised feedback was constructed using decision trees.
- Normative values were initially taken from the literature. A concurrent database was set up with automatically updating percentile statistics. As data became available these were used to provide feedback to participants based on study findings.
- Extra information was added on exercise, isokinetics and training for the participants convenience.

Michael Ellefsen Biokineticist

BCom (Sport Management), BA (Hons) (Biokinetics), EIM (ACSM)

Tel:	084 995 0005
Mail:	michael@ellefsen.za.net
Instagram:	https://www.instagram.com/me.biokinetics/
Facebook:	https://www.facebook.com/ME.Biokinetics/

Research Project	"The acute effect of dynamic neural mobilization exercise versus static stretching on muscular strength and power in martial artists"
First name	Example
Last name	Example
Date	Example

Dear
Example,

Thank you for participating in this Biokinetics Research at the University of Witwatersrand. You have made a great contribution to the scientific understanding of exercise. This information will be very useful to coaches, trainers, biokineticists and physical therapists in the future who use this information to make decisions on how to best train their clients.

Please find attached the results from your baseline assessment. This information should be useful for you to better understand your own bodies current abilities and help you to consider how you may go about training.

Best regards,

Michael
Ellefsen
Registered Biokineticist
Accredited Anthropometrist
Head Researcher: Wits Martial Arts
Research

Body Composition

Body composition testing measures your body fat, height, and weight to give you an idea where you carry body fat, whether you are lean or have extra body fat and to estimate how much lean mass (e.g. Muscle and bone) you have.

Upper body	3.75	mm
Middle body	6.2	mm
Lower body	9.7	mm
Body fat % average score	4.8	%
Unhealthy body fat % range	3.00	%
Lean mass	64.7	Kg
Standing height	174.5	cm
Body mass	68	Kg
Body Mass Index	22.3	Kg/m.^{2}

Feedback

Your body fat % was estimated to be 4.8 %, which is in the very lean category for people your gender and age. The unhealthy body fat percentage for your gender is 3 %. This means that your lean mass (including muscle, bone and water is 64.7 Kgs. The BMI, which is a general indicator of how heavy you are suggests that you are in the average weight category. Weight status should always be seen as a motivator. Let the scores of today inspire you for the future.

Fusion Jump Test

Jump testing is a good test for assessing low body power. Low body power is useful for many activities, like kicking, booting, grabbing with the legs, and leaping. High low body power helps to differentiate high performing athletes, with more advanced athletes receiving higher scores.

Jump height	48.67	cm
Jump Power	3979.7	Watts
Power to Weight Ratio	58.52	Watts/kg
Maximum Concentric Impulse	210.13	N/sec/kg

Feedback

Jump height tells you about power but does not consider the height and weight of a person. You jump height was 48.67 cm, which is a high score. Well done on the high score! Your score can be improved further through specific leg power training, such as performing weighted barbell power moves.

Jump power tells you how many Watts of power you expressed with your legs. This score is useful because it helps you understand how much force you produce compared to other people. You scored 3979.7 watts, which is high. Power is improved through specific leg power training, involving a combination of speed and resistance.

The Power to Weight ratio explains how much power you produce for your body size. This number allows tells you how efficiently you produce power. Scores are made better by better force production (ability and technique) and made worse by a heavier body weight. Your ratio is 58.52 Watts/kg, which is in the Optimal. category.

Maximum Concentric Impulse indicates the directedness of your jump. It gives you an idea of your jumping efficiency and ability. Your score was 210.13 which is in the high category.

Isokinetics

Isokinetic tests are a comprehensive way to measure your performance. In the test you exercise against a computer-controlled system, which measures the forces you produce. Iso means "same" and "kinetic" means movement. These tests are always performed at a controlled speed so that your muscle function can be measured in a controlled way. Slow speeds give better information about strength, while high speeds give more information about power.

Muscle imbalances

Muscle imbalances can decrease your performance, and influence injury risk. Certain muscles. Identifying muscle imbalances can be important for your performance. You can address muscle imbalances by purposefully training the weak side.

	Quadriceps		Hamstrings		Hamstring to quadriceps ratio	
Speed	Imbalance	Class	Imbalance	Class	Score	Class
Slow	-4.9	small	24.1	medium	D: 47.9	Low
Medium	1.5	small	12.3	small	ND: 34.6	Low
Fast	12.8	small	5.0	small		
Feedback						

You have some small muscle imbalances. These likely will not affect your injury risk can be addressed if you choose. You have some medium muscle imbalances. Medium imbalances can increase your injury risk. It is advisable to address them with strength training. The hamstring quadriceps ratio is low, meaning that the quadriceps are overpowering the hamstrings. The hamstrings are usually 60% of the strength of the quadriceps. You can improve the ratio by strengthening the hamstrings

* D: Dominant leg; ND: Non-Dominant leg. Negative scores indicate the dominant leg is weaker.

Torque: Body Weight Ratio

Peak torque/ body weight is your strength to weight ratio (also called your relative strength value). It allows you to compare how powerful you are to other people and tells you how powerful you are for your body weight. The power to weight is important for performance with higher scores associated with higher levels of sports participation.

	Dominant leg	**Current Level**	**Next Target**	**Non-Dominant Leg**	**Current level**	**Next Target**
Quads	320.7	Elite	360	336.3	Elite	360
Hamstrings	153.5	National	160	116.5	Recreational	140

Feedback

Your quadriceps perform at different competitive levels. Consider performing more training on the weaker side to increase its strength to balance out your performance. Strength training usually involves performing 3 to 5 sets of high intensity resistance exercise (8-12 repetitions until reaching fatigue with a rest period between sets of 2 to 3 minutes). Performing additional sets on the weaker side may help you achieve your goals.

Your hamstrings perform at different competitive levels. Consider performing additional strength training on the weaker side to balance out your categories before moving on. Exercises such as lunges, hamstring curls, stability ball rollouts, stability ball pelvic raises or deadlift may be useful.

Fatigue Index

Fatigue Index tells you how much your maximum strength decreased throughout your exercise.

Quadriceps

Speed	**Dominant leg**	**Current Level**	**Next Target**	**Non-Dominant Leg**	**Current level**	**Next Target**
Slow	-16.7	Positive	Retest	23.4	low	19.25
Medium	23.8	average	18	23.8	good	6.4
Fast	38.4	average	31.6	38.4	average	24.9
Hamstrings						
Slow	15.2	v.good	Optimal	16.1	v.good	Optimal
Medium	17.9	good	10.3	29.2	average	17.2
Fast	16.1	v.good	Optimal	25.2	good	9.5

Feedback

Some of your quadriceps have a low level of fatigue, consider performing endurance training to improve your scores. You can perform exercises such as leg extensions, Bulgarian split squat, weighted step ups and squats to train the quadriceps. Some of your quadriceps have a good level of fatigue resistance. Consider focusing training on other areas. Some of your hamstrings have a good level of fatigue resistance. Consider focusing training on other areas.

Average power

Average power indicates how powerful you are. Power is about how much strength you can produce in a short time. Power scores are always higher with faster speeds. Power is important for generating "hard hitting" kicks, pulling and pushing an opponent. Power is trained using "power training" techniques.

Quadriceps

Speed	**Dominant leg**	**Current Level**	**Next Target**	**Non-Dominant Leg**	**Current level**	**Next Target**
Slow	140.5	low	150.5	155.7	Average	162.1
Medium	319.6	Average	320.1	282.2	Average	313.3
Fast	348.3	Average	349.7	269.3	low	280.9

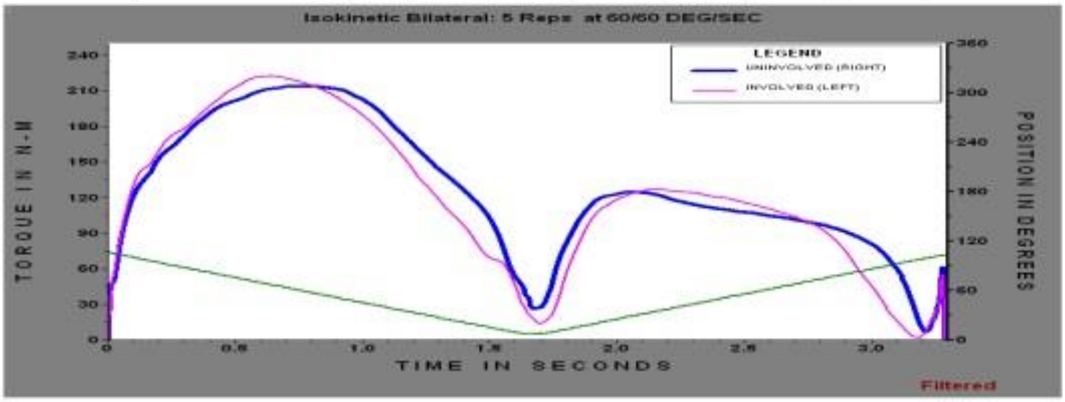
Hamstrings						
Slow	75.8	low	84.7	57.8	v. low	62.6
Medium	121	v. low	135.1	104	v. low	124.1
Fast	152.2	Average	181.9	91.9	v. low	123.5

Feedback
Your quadriceps scores Low in power. Consider doing power training by working on using speed with resistance. The hamstrings showed weakness in some categories consider, doing power exercises such as hamstring curls or pelvic lift variations to improve your performance. Some approximate goals have been provided to give you some guidance in reaching the next level of performance.

Comprehensive Evaluation

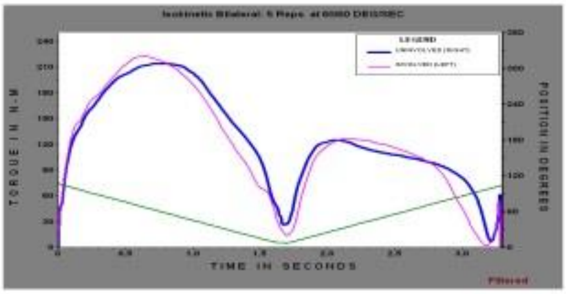
Name:	[redacted]	Session:	[redacted]	Windowing:	**None**
ID:	[redacted]	Involved:	**None**	Protocol:	**Isokinetic Bilateral**
Birth Date:	[redacted]	Clinician:		Pattern:	**Extension/Flexion**
Ht:	**173**	Referral:		Mode:	**Isokinetic**
Wt:	**80.0**	Joint:	**Knee**	Contraction:	**CON/CON**
Gender:	**Male**	Diagnosis:		GET:	**18 N-M at 29 Degrees**

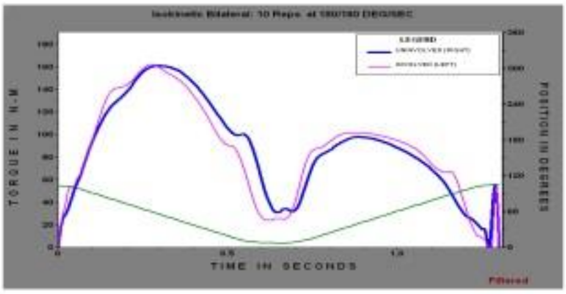
		EXTENSION 60 DEG/SEC			FLEXION 60 DEG/SEC		
# OF REPS: Right 5		UNINVOLVED	INVOLVED	DEFICIT	UNINVOLVED	INVOLVED	DEFICIT
# OF REPS: Left 5		RIGHT	LEFT		RIGHT	LEFT	
PEAK TORQUE	N-M	214.0	222.3	-3.9	124.6	126.9	-1.8
PEAK TQ/BW	%	267.8	278.2		156.0	158.8	
TIME TO PK TQ	MSEC	800.0	580.0		370.0	420.0	
ANGLE OF PK TQ	DEG	58.0	64.0		29.0	37.0	
TORQ @ 30.0 DEG	N-M	153.8	130.0	15.5	124.6	119.7	3.9
TORQ @ 0.18 SEC	N-M	146.0	158.2	-8.3	109.6	99.7	9.0
COEFF. OF VAR.	%	4.8	2.7		1.6	2.9	
MAX REP TOT WORK	J	284.8	247.5	13.1	163.1	141.3	13.4
MAX WORK REP #	#	1	3		2	1	
WRK/BODYWEIGHT	%	356.4	309.7		204.1	176.8	
TOTAL WORK	J	1320.4	1197.9	9.3	792.9	657.1	17.1
WORK FIRST THIRD	J	498.0	437.2		288.6	247.1	
WORK LAST THIRD	J	399.6	359.5		232.6	199.3	
WORK FATIGUE	%	19.7	17.8		19.4	19.4	
AVG. POWER	WATTS	155.2	159.3	-2.7	93.7	91.8	2.1
ACCELERATION TIME	MSEC	30.0	30.0		30.0	40.0	
DECELERATION TIME	MSEC	110.0	140.0		50.0	50.0	
ROM	DEG	98.7	86.3		98.7	86.3	
AVG PEAK TQ	N-M	200.6	213.6		122.9	122.5	
AGON/ANTAG RATIO	%	58.2	57.1	G: 61.0			



Graphical Evaluation

Name:	[redacted]	Session:	[redacted]	Windowing:	**None**
ID:	[redacted]	Involved:	**None**	Protocol:	**Isokinetic Bilateral**
Birth Date:	[redacted]	Clinician:		Pattern:	**Extension/Flexion**
Ht:	**173**	Referral:		Mode:	**Isokinetic**
Wt:	**80.0**	Joint:	**Knee**	Contraction:	**CON/CON**
Gender:	**Male**	Diagnosis:		GET:	**18 N-M at 29 Degrees**

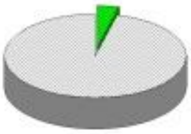




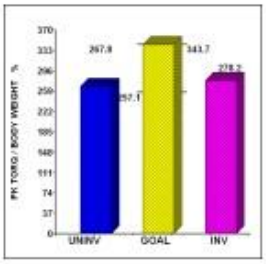
EXTENSION

Stronger

3.9 %



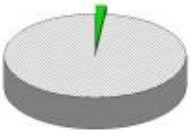
60 DEG/SEC



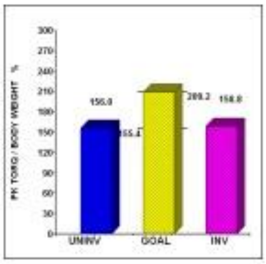
FLEXION

Stronger

1.8 %



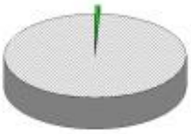
60 DEG/SEC



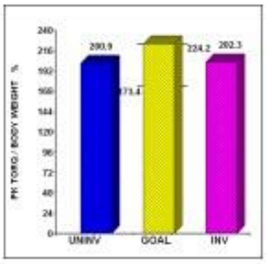
EXTENSION

Stronger

0.7 %



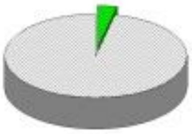
180 DEG/SEC



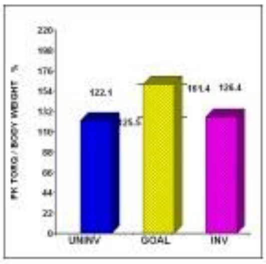
FLEXION

Stronger

3.5 %



180 DEG/SEC

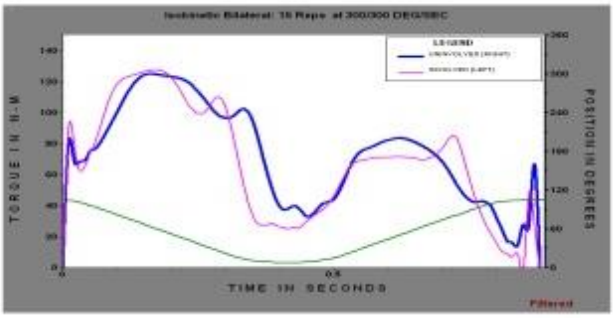


Comments:

EAK TORQUE:	Highest muscular force output at any moment during a repetition. Indicative of a muscle's strength capabilities.
EAK TQ/BW :	Represented as a percentage normalized to bodyweight and compared to an established goal
EFICITS:	1 to 10% No significant difference between extremities. 11 to 25% Rehabilitation recommended to improve muscle performance balance. > 25% Significant Functional Impairment (-) Negative deficit indicates involved extremity performed better than uninvolved

Graphical Evaluation

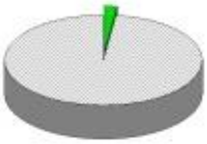
Name:	[redacted]	Session:	[redacted]	Windowing:	**None**
ID:	[redacted]	Involved:	**None**	Protocol:	**Isokinetic Bilateral**
Birth Date:	[redacted]	Clinician:		Pattern:	**Extension/Flexion**
Ht:	**173**	Referral:		Mode:	**Isokinetic**
Wt:	**80.0**	Joint:	**Knee**	Contraction:	**CON/CON**
Gender:	**Male**	Diagnosis:		GET:	**18 N-M at 29 Degrees**



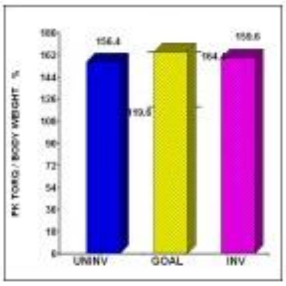
EXTENSION

Stronger

2.1 %



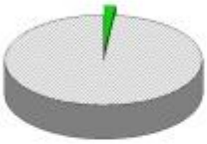
300 DEG/SEC



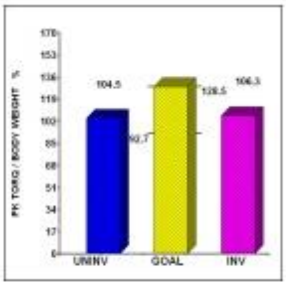
FLEXION

Stronger

1.8 %



300 DEG/SEC



Comments:

AK TORQUE: Highest muscular force output at any moment during a repetition. Indicative of a muscle's strength capabilities.
AK TQ/BW : Represented as a percentage normalized to bodyweight and compared to an established goal
FICITS: 1 to 10% No significant difference between extremities.
11 to 25% Rehabilitation recommended to improve muscle performance balance.
> 25% Significant Functional Impairment
(-) Negative deficit indicates involved extremity performed better than uninvolved

Exercise Guide

For training based on your isokinetic test

Goal focused exercise

This document explains basic exercise techniques and basic training method. If you are training towards a certain goal, such as strengthening the look at the strength training advice in the first section then choose some exercises you can do from the exercise techniques section for the specific muscles you are aiming to train. Exercise is best done with goals in mind. Always start with a small goal then progress to bigger ones to build success upon success.

Scientific training method

A training method is a systematic approach to exercising in the long term. Exercise affects you differently over days, weeks, months, and years so you should plan training systematically to make sure you progress at a good pace. The body continuously tries to adapt to training and as it does this your body may stop receiving results. Be conscious about the training principles below when thinking about your exercise.

Principles to guide training[1]

Specific	Training a certain muscle gives you a certain benefit. Doing heavy training will make you stronger, but not more enduring. Doing slow training will improve strength but not power. Training quadriceps (front of thigh) will not usually improve hamstrings (back of thigh).
Results can reverse	When you exercise the body gets better at exercise over time. When you don't exercise the body gets better at not exercising over time. The results you gain can also be lost without maintenance.
Variety	The body gets used to a particular workout after doing that same workout after about three times. Vary your workouts, by working harder or easier on certain days or doing different exercises to keep your results coming.
Progression	As you get stronger or more powerful you need to progress. Making it too difficult can lead to injury. Not progressing can lead to boredom.
Overload	To get the body to adapt to be stronger, more enduring, or more powerful you need to do more than you normally do. Usually working at a 7/10 intensity is what is required.

Reference: [1]Plowman, S & Smith, D. Exercise physiology: for health, fitness, and performance (4th Edition). LWW: Lippincott Williams and Wilkins.

Training muscle strength, power, or endurance[2]

Ability	**Description**	**How to**
Strength	Strength training makes you stronger. You produce more force, pushing or	8-12 repetitions till fatigue; 3-5 sets; 2-3 minutes rest between each set. 2-3X per

	pulling much harder. Strength usually happens slowly.	week. *Advanced athletes may use higher intensities.
Power	Power (or explosiveness) lets you use more force at speed.	15-20 repetitions at high speed till losing power; 3-5 sets; rest 2-3 minutes rest between each set. 2-3X per week.
Endurance	As you train you lose strength to fatigue. Endurance lets people loose less and recover faster.	15-20 repetitions at medium speed till fatigue; 3-5 sets; rest: 30 seconds between each set. 2-3X per week.

Repetition: Doing one complete movement of an exercise (e.g. a squat). **Set:** A series of exercise (e.g. 8-12 squats)

Reference: Hagg, G. and Triplett, N. (2021). Essentials of strength training and conditioning (4th Edition). Human Kinetics: Champaign, IL.

Training Progression

As you exercise you get stronger. When you get stronger you will want to make the exercises harder if you want to get further results. On average people train certain abilities for 3-5 weeks each. Traditionally people train 3-5 weeks of endurance, then 3-5 weeks of strength and then 3-5 weeks of power. Sequencing your training is important because endurance exercises usually use the lightest resistance and has the lowest risk of injury. Strength and power training are both more intense incorporating speed and high resistance. You should be well adjusted to a certain intensity before moving on to the next one. If adding extra resistance people usually increase the weight, when they feel they can comfortably 2-3 extra repetitions more when they finish their set (e.g. I aim for 15 lunges, but when I reach 15, I feel I can still do more. I would add some extra weight so that I can train at a harder level and only do the 15 I aimed for. Advanced athletes often use a progression sequence involving: Getting ready (or anatomical adjustment), hypertrophy (growing muscles larger), strength training and finally a last stage appropriate for their sport, such as maximum power (Olympic weightlifting), maximum endurance, (marathon), maximum hypertrophy (bodybuilding), maximum strength (strongman), or power endurance (martial arts).

Training Power Capacity

Many martial artists aim to improve their power. Power is the ability to generate high forces over a short time. A powerful punch or kick both moves quickly and hits hard. Powerful techniques come from a combination of technique (generating power from movements) and your ability to generate power with muscles. You can achieve better levels of power in a kick or punch by doing power training using martial arts techniques (like punching or kicking drills), plyometric or jumping training (e.g. skipping, vertical jumping or leaping exercises) or power training using resistance exercises (e.g. doing movements like the overhead squat press with dumbbells or barbells).

Training to Sustain Power

Power endurance is the ability to maintain high levels of power over time. Power training is “anaerobic”, meaning that during high intensity power exercise, the body does not mainly rely on oxygen to produce energy. Because the intensity is so high, the body focuses on producing large amounts of power without oxygen (anaerobically). During this process the body produces lactic acid. Lactic acid is generated for high intensity exercise lasting between 10 seconds and 120 seconds. The higher the intensity the more lactic acid is generated. Eventually when the lactic acid levels are high enough the muscles cease to function properly, and fatigue will cause you to stop moving (or sparring!). Special training called Lactic Capacity Training allows you to tolerate higher levels of lactic acid before having to stop moving. This training causes your muscles to develop special chemicals called “Lactic Shuttles” which clear away lactic acid and prevent it from building up to intolerable levels. All lactic acid is normally removed within 80 seconds of stopping exercise, despite common myths which state that is lasts into the next day. Lactic Threshold Training is another important type of training, which allows you to train at a higher level, before beginning to generate large amounts of lactic acid (e.g. spar harder before reaching the “red zone”, which can only be tolerated for so long). The table below gives some basic guidelines on training for lactic capacity and lactic threshold.

Training Power Endurance[1]

<table>
<tr><th></th><th>Duration of Reps</th><th># of Reps</th><th>Work to rest Ratio</th><th>Intensity</th></tr>
<tr><td>Lactic Capacity Training</td><td>20-60 seconds</td><td>2-10</td><td>At least 1:4. At most 1:24.</td><td>85-95% of maximum effort[1]</td></tr>
<tr><td>Lactic Threshold Training</td><td>1-10 minutes</td><td>3-40</td><td>At least 1:0.3. At most 1:1:</td><td>85-95% of maximum HR.</td></tr>
<tr><td colspan="5">Example [adapted from 1]</td></tr>
<tr><td colspan="5">A long-distance martial artist would like to improve endurance for a 3-minute match.
They could add the following training drill to their program to improve lactic capacity:
Lactic Capacity Set (1min work, 4 mins active rest)
High speed kicks to a bag for 30 seconds (aim for 85% intensity “Feels very, very hard/fast”)
○ 120 seconds of rest (1:4 rest ratio)
○ High speed punches to a bag 30 seconds
○ 120 seconds of rest (1:4 rest ratio)
Since this set contains 2 bursts/ repetitions of high intensity work and the # of reps target is 2-10. They could at least perform the sequence 1X or else do it 5X (for 10 reps).</td></tr>
</table>

On an alternative day they could add the following drill to increase their lactic threshold.

Lactic threshold set[3] (4 min work; 2 mins active rest)

- 1 min Skipping at 85% max HR (feels: “hard, but not all out”).
- 30 seconds shadow boxing (sparring).
- 30 seconds high intensity kicks
- 1 minute jumping jacks.
- 30 seconds power push ups/ half-push ups.
- 30 seconds burpees

2 mins active recovery light technical drills.

Reference

[1] Adapted from: Bompa, O & Buzzichelli, C. (2015). Periodisation training for sports (3rd Edition). Human Kinetics, Champaign, IL.

[1] Lactic Capacity training is very high intensity and non-sustainable for a long time. 85% of maximum effort is much higher than 85% of maximum heart rate. 85% of maximum heart rate is a high, yet sustainable heart rate, especially for trained athletes.

[2] Exercises like kata, shadow boxing or light workout can be added here as part of active recovery.

[3] This Lactic Threshold Training has been designed in the format of a High Intensity Interval Training (HITT) workout. Other formats like sparring, cardio (cycling, jogging, or skipping) or weightlifting can also be used.

Exercise Technique

Exercise techniques are ways of loading the muscles. During exercise you can expect muscle burn, tiredness, and muscle shaking, but you should never experience pain, which is a sign that you may be causing injury, overdoing it, or performing the technique wrong. Some techniques are more difficult to do correctly, while others are simpler. The difficulty of most techniques can be changed by adding or removing weights. This section describes several common exercises, which vary from bodyweight exercises requiring no or limited equipment and gymnasium exercises which require machines or weights.

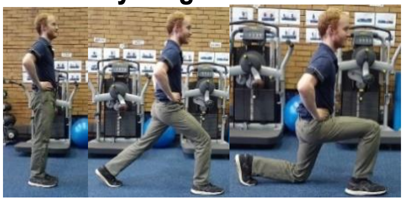
Reference:

[1] Adapted from: American College of Sports Medicine (2021). ACSM’s Guideline for Exercise Testing and Prescription. Human Kinetics, Champaign, IL.

Hamstrings

The hamstring are the muscles at the back of the thighs. They work whenever the leg is behind you (such as pushing you forward during funning, lunging, grabbing something with the legs, kicking behind you or leaping forward.

Picture	Instructions	Difficulty
Pelvic lift 	Lie face up. Bend the knees to 90º. Lift the hips off the floor until they are in a straight line with the knees and the shoulders. Return to the floor.	easy
Chair pelvic lift 	Lie face up. Place the feet on a chair with knees bent to 90º. Lift the hips off the floor until they are in a straight line with the knees and shoulders. Return to the floor and repeat.	medium
Single pelvic lift 	Lie face up. Bend one knee to 90º and straighten the other. Lift the hips of the floor, keeping the pelvis level, until the hips are in a straight line with the bent knee and the shoulders. Keep the straight leg in line with the opposite knee. Holding it higher is usually easier than lower.	medium
Ball pelvic lift 	Lie face up. Bend the knees to 90º and place the feet on a stability ball. Keep the feet wider for easier stability or narrower for more difficulty. Lift the hips off the floor with control until the knees are in a straight line with the knees and shoulders. Return to the floor and aim to keep the knees bent at 90º throughout.	hard

		
Ball Rollout 	Lie face up. Place feet on stability ball. Wide placement is easier allowing better stability. Lift hips till almost in a straight line with shoulders and knees. Straighten knees rolling the ball out, keeping hips at same level. Bend knees to roll ball back in and repeat.	hard
High pelvic lift 	Lie face up. Place the feet on a high surface with knees bent to 90º. Lift the hips off the floor until they are in a straight line with the knees and shoulders. Return to the floor and repeat.	medium
Stationary lunge 	Step far forward so that when the front knee is bent 90º, the knee is over the heel. Lower the body towards the ground by bending the knees. Stop just before the back knee touches the ground. Then stand and repeat. Aim to keep both feet facing forward.	easy
Barbell lunge 	Same as above but with a weighted bag, barbell, or kettlebells for extra resistance.	medium
Forward stepping lunge	Step forward without letting the foot fall to slap the floor and enter a lunge. Then step forward to lunge on the alternate side.	medium
Backward stepping lunge	Step backward gently finding the ground with the foot, without impacting the ground too hard. Then perform a lunge before stepping back to lunge on the opposite side.	medium
Forward-Back Combination	From lunge, step forward, then back with control and immediately repeat.	medium
Hamstring curl	Sit on the hamstring curl machine. Load the appropriate amount of weight. Begin with the leg just less than straight avoiding "locking out". Pull the leg into a curl then return to an almost straight position.	medium

		
Back Bridge 	Lie face up on the ground. Lift the body up onto the heels and the elbows. The difficulty is in keeping the hips up.	medium
Single back bridge 	Lie face up. Lift the body up onto the heels and the elbows. Keep the hips up. Lift one leg slightly off the floor. To make this easier, keep the legs wider. Keep breathing.	hard
High single back bridge 	Lie face up. Place the heels onto a chair or bench. Lift the body onto the elbows and get the hips in about a straight line with the knees and shoulders. Lift one leg slightly off the bench and hold. Keep breathing.	hard

Quadriceps

The quadriceps are the large muscles at the front of the thighs. They push the body upwards (such as getting out of a chair or climbing a hill), backwards (such as retreating or back stepping) and kick the leg out (such as doing a front kick or booting). They are very important for overall health and should be kept strong throughout life.

Picture	Instructions	Difficulty
Weighted squat 	Stand facing toward the bar if using a squat rack. Step under the bar and push the shoulders back. Place the bar where comfortable on the shoulders and grip the bar with the hands at either side at a comfortable width. Push the elbows slightly back. Squat down by bending the knees pushing the hips backward, rather than kneeling forward at the knees. The knees generally should not pass the toes. Feet are about hip, or shoulder width apart and generally pointed slightly outwards. Lower till the thighs are just above parallel to the floor then return to standing.	depends on resistance

Knee extension 	Sit on the knee extension machine. Adjust the seat so that the knee cushion rests comfortable below the knee level. Adjust the seat so that your knees are comfortably positioned. Adjust the ankle cushion so that the lower leg is firmly supported between the ankle and knee cushions. From a slightly bent position, curl the knees until the knees are bent to at least 90º.	depends on resistance
Leg press 	Sit on the machine. Adjust the seat forward/back until the knees are bent at just above 90º. Adjust the incline of the seat so that the back rests at about 45º to the thighs. In the close position, the knees should be over the midfoot or the heel. Press with the feet so the body pushes away from the plate. Press until the knee is almost straight, but not "locked out" and then return with control.	depends on resistance
Split squat 	Place the back foot on a chair or bench. Step forward far forward so that when bent to 90º the knee remains over the heel or midfoot and does not move forward towards the toes. Keep the hands out to the side for balance if needed. Lift and lower in a lunge motion.	medium
Split squat with balance pole 	Place the back foot on a chair or bench. Step forward far forward so that when bent to 90º the knee remains over the heel or midfoot and does not move forward towards the toes. Keep the hands out to the side for balance if needed. Use a balance pole for support but avoid pushing onto the pole for assistance in standing up.	medium
Single leg squat 	Stand in front of a chair. Adjust the difficulty by changing the height of the chair. Higher chairs are easier than lower. A balance pole is usually needed in most people. Slowly sit back to the chair without collapsing. The knee should not move past the toes. Standing up is more difficult than sitting down so adjust the difficulty accordingly.	medium
Step up 	Stand facing a step. The higher the step the more difficult the exercise. Step forward so that the knee is over the midfoot or the heel or the forward leg. Step upward without letting the knee move forward over the toes. Then return the body to the floor by stepping back, keeping the knee from leaning forward past the toes. Use extra weight to change the resistance.	depends on resistance

Vastus Medialis (lower quad)

The vastus medalis is often called the “teardrop” muscle. It is a muscle on the lower inner part of the front of the thigh. It is important for knee stability, because it attaches to the inner ligaments of the knee joint, pulling them stiff and helping to protect the knee joint from injuries, which can happen when the knee is overly loose.

Static Vastus Medius Activation 	This is a very basic exercise designed for beginners. It does grow the teardrop muscle bigger if done every second day for about 6 weeks. Sit with the legs straight in front of you and a pillow or rolled towel under the knee. Without straightening the knee consciously contract the vastus medialis muscles for 10 seconds. Repeat until you start feeling fatigue.	very easy
	Lie face up. Place a pillow or rolled towel under the knee with the ankle on the floor. Straighten the leg by squeezing the knee down into the pillow. Hold for 10 seconds. Repeat until the muscles begin to feel fatigue.	very easy
60° Static Semi-Squat with Adduction 	Squat down till your knees are bent to 45 degrees and then a little further. Holding the squat in this position trains the Quadriceps muscles strongly. If you add a resistance band or squeeze a ball between the knees you can target the Vastus Medius muscle more allowing you to get extra teardrop training. Hold for 60 seconds.	medium
Static leg lift 	Stand against a wall or support. Place one leg slightly forward and keep it straight. Lift the straight leg upward until it reaches a difficult height. Turn the foot slightly outward and lift it very slightly higher to reach “Difficult” resistance. Hold position.	medium
Wall sit 	Sit against the wall with knees bent to 90° of above. Hold position while breathing normally.	easy

Single leg wall sit 	Sit against a wall with knees bent to 90° or above. Lift one foot slightly off the ground. Hold position while breathing normally.	medium
Low seat cycling 	Adjust the bike seat so the seat is lower than normal. Line the seat up with 10-20cm lower than the hip while standing so that the thigh reaches a parallel to the floor position while cycling. The greater knee bend will help train the low quad muscles. Also setting the bike seat back or leaning forward into racing posture will help.	medium

Knee Stability

Knee stability training is all about the knees "Wobbling" when you are trying to exercise. When the knees bend, they can be unstable. With good strength and skill, you can have "good dynamic control" of your knees while exercising, allowing you to protect your knees during movement. Dynamic knee stability happens when your knee is bent, because when it is straight the ligaments and bones hold the knee joint together. Improving knee stability involves a combination of strengthening muscles like the hamstring and vastus medialis and then doing stability or "neuromuscular" exercises which usually involve "balancing" type exercises, but with the knees bent to the muscles can be involved.

Single leg stand-up 	This exercise is great for strengthening the quadriceps, but also involves a lot of knee stability. Sit on a chair and using on leg, stand up. You can also sit down with one leg. As you stand you will be tempted to shoot up from the chair or fall down onto the chair. Rather practice stability by standing in a slow controlled way and also sitting back down. Prevent your knee from collapsing towards the middle or the outside and prevent the hips from swaying out to the side. With control and stability stand and sit down.	medium
Unstable Single leg standing 	Stand on an unstable surface like a foam pad, pillow, or wobble board. Hold position for 60 seconds without wobbling and loosing stability too much. To increase difficulty bent the supporting knee.	medium

Unstable Forward taps 	Start standing on an unstable foam mat, wobble board, hedgehog, or pillow. Squat until your knee is bent 30 to 60 degrees. Reach the foot and tap the ground forward, without letting the supporting leg move. Keep it stable.	medium
Unstable Backward taps 	Start standing on an unstable foam mat, wobble board, hedgehog, or pillow. Squat until your knee is bent 30 to 60 degrees. Reach the foot and tap the ground behind you, without letting the supporting leg move. Keep it stable.	medium
Unstable Side taps 	Start standing on an unstable foam mat, wobble board, hedgehog, or pillow. Squat until your knee is bent 30 to 60 degrees. Reach the foot and tap the ground behind you, without letting the supporting leg move. Keep it stable.	medium
Adding more instability **Hedgehogs**  **Half (BOSU) Ball**  **Wobble boards** 	Adding even more instability to the surface you train on increases the difficulty of the exercise. Wobble board training is particularly effective to improve stability.	Medium

General exercise & health tips

Keep your motivation strong by building training into habits. At least once a week do an activity with other people (like martial arts, walking, running, biking, or other sports. Use habits as anchors to keep you grounded during tough work-life balance times. Achieve small goals and to prepare for achieving larger ones in the future. For health do 150 minutes of physical activity per week.[2] Aim for moderate intensity exercise or vigorous if you can manage it. Resistance training and flexibility exercise should be done 2X per week for adults. After 50 years if age, make sure you are doing coordination exercises and learning NEW skills, such as martial arts or dancing. If there are any aches or pains check in with your doctor or Health care provider. Exercise to keep yourself young and add more life to your years. Remember that people behave in groups and visibly looking after yourself leads other people to do the same. Changing your health can have a profound and positive impact on yourself and the people around you.

Training with aches, pains, and injuries

Aches and pains during exercise are abnormal signs. If you experience any symptoms with exercise such as pain, please seek advice and care from your healthcare professional, such as a biokineticist, physical therapist or general practitioner. This exercises in this document are general fitness advice, please consult your healthcare professional for individualized treatments and health advice.

References:

[1] Adapted from: Bompa, O & Buzzichelli, C. (2015). Periodisation training for sports (3rd Edition). Human Kinetics, Champaign, IL.

[2] Adapted from: American College of Sports Medicine (2021). ACSM’s Guideline for Exercise Testing and Prescription. Human Kinetics, Champaign, IL.

Self-Testing Guide

Basic tests you can use to monitor your performance.

Easy self-fitness testing

Introduction

Fitness testing doesn't always need to involve fancy machines and expensive equipment. While these tests provide a great deal of useful information, they can be expensive and hard to access (e.g. coming through to an exercise science laboratory). There are certain exercise tests which you can perform at home or at the gymnasium which are basic and will give you information to guide your progress.[1]

1. Explosive Power Testing

The **Counter Movement Jump test** which you performed at the laboratory is a great test for your Peak Power Output, however it requires technology to give you measurements. The **Vertical Jump test** is a simple test for explosive power which you can do at home. It is different from the Counter Movement Jump test, because it involves swinging the arms, but is still a simple way to measure lower body power.[1]

Instructions:[1]

a) Place a measuring tape on a wall.
b) Stand with the wall and tape to your side.
c) Reach your hand up and touch the wall. Note the height.
d) Swing hands down, bend the knees and jump as high as possible.
e) Tap the measuring tape. Note the height.
f) Subtract the first score from the second score.
g) Try 3 to 5 jumps and keep your maximum score.

Extra tips:[1]

a) A partner can assist you in your test. You can ask someone to watch the height of the wall tap so the jumper can focus on jumping.
b) If working by yourself, some prefer to rub some chalk dust on the index finger. This will leave a mark on the wall that you can review afterwards.
c) Once you have a jump height you have the option of calculating a Jump Power score using the following formula: POWER= (60.7xjump height (cm)) + (45.3x body weight (kg)) – 2055.
d) For further information visit: https://www.topendsports.com/testing/tests/vertjump.htm

Compare your scores to the averages:

Rating	Males (cm)	Females (cm)
Excellent	>70	>60
Very good	61-70	51-60
Above average	51-60	41-50
Average	41-50	31-40
Below average	31-40	21-30
Poor	21-30	11-20
Very Poor	<21	<11

Adapted from: https://www.topendsports.com/testing/norms/vertical-jump.htm[1]

[1] **Reference: Vertical jump height norms. (2012). Topend Sport. Available at:** https://www.topendsports.com/testing/norms/vertical-jump.htm. Accessed 05 Nov 2019.

2. Multiple Repetition Maximum Strength testing

Hamstring Curl Test

Leg Extension Test

Isotonic Multiple Maximum Strength testing is a basic type of strength testing, which can be done at the gymnasium using resistance exercise machines. Since this testing involves pushing heavy weights a few safety fundamentals are essential. Technique must be correct. A proper warm-up should be included. In beginners the weight is not increased excessively.[1]

Instructions:

This test ends when you can only perform 8 repetitions of exercise. This procedure can be used for most exercises; however, this explanation specifically focuses on Leg Extension and Hamstring Curl Machine exercises.[1]

The resistance is slowly and incrementally increased. Each time you increase the resistance, you try to perform 8 repetitions. If you reach 8 repetitions and feel you could not perform another repetition, the test is over. For safety, beginners should not aim for less repetitions than 8 and also should only perform testing using exercise machines. If uncomfortable a qualified trainer can assist, else a friend can spot your exercise.[1]

Steps in 1 Repetition Max:[1]

a) Warm-up doing at least 10 body weight squats or leg extensions with a light (5/10 Effort) resistance.
b) Based on how difficult the exercise felt increase the weight 5% or 10% and try performing 12 good quality repetitions without stopping. Rest for 2 minutes.
c) If you performed the previous set completely, increase the weight again and then attempt 10 repetitions. Rest for 2 minutes.
d) If you performed the previous set completely, increase the weight again and then attempt 8 repetitions. Rest for 2 minutes.
e) You have 2 more attempts to increase sequence increasing weight and rest before the test ends. After performing multiple sets, you will fatigue and will need to test again another day.
f) Use the following online calculator to measure your "Maximum Strength or 1RepMax: https://strengthlevel.com/one-rep-max-calculator. Alternatively use the formula: (Resistance used for 8 reps (kgs)/80*)100

[1]: Reference: 1-RM Tests (repetition maximum tests). Topend Sports. https://www.topendsports.com/testing/tests/1rm.htm#:~:text=After%20a%20warm%20up%2C%20choose,maximum%20weight%20lifted%20is%20recorded. Accessed 05 Dec 2019

Extra tips:[1]

a) For further instructions, please visit: https://www.topendsports.com/testing/tests/1rm.htm
b) Beginners should not attempt a "1 Rep Maximum" test without supervision for safety reasons.

Compare your scores to the averages:[1]

a) Specific averages for your body weight and gender are available at the following web address:
    a. Leg Extension Machine exercise: https://strengthlevel.com/strength-standards/leg-extension/kg
    b. Leg Flexion Machine exercise: https://strengthlevel.com/strength-standards/seated-leg-curl

Many different fitness tests are available for assessing your fitness. I would recommend looking into fitness further. If you would like more information, please see the following web address: https://www.topendsports.com/ [1]

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[1]: Reference: 1-RM Tests (repetition maximum tests). Topend Sports. https://www.topendsports.com/testing/tests/1rm.htm#:~:text=After%20a%20warm%20up%2C%20choose,maximum%20weight%20lifted%20is%20recorded. Accessed 05 Dec 2019

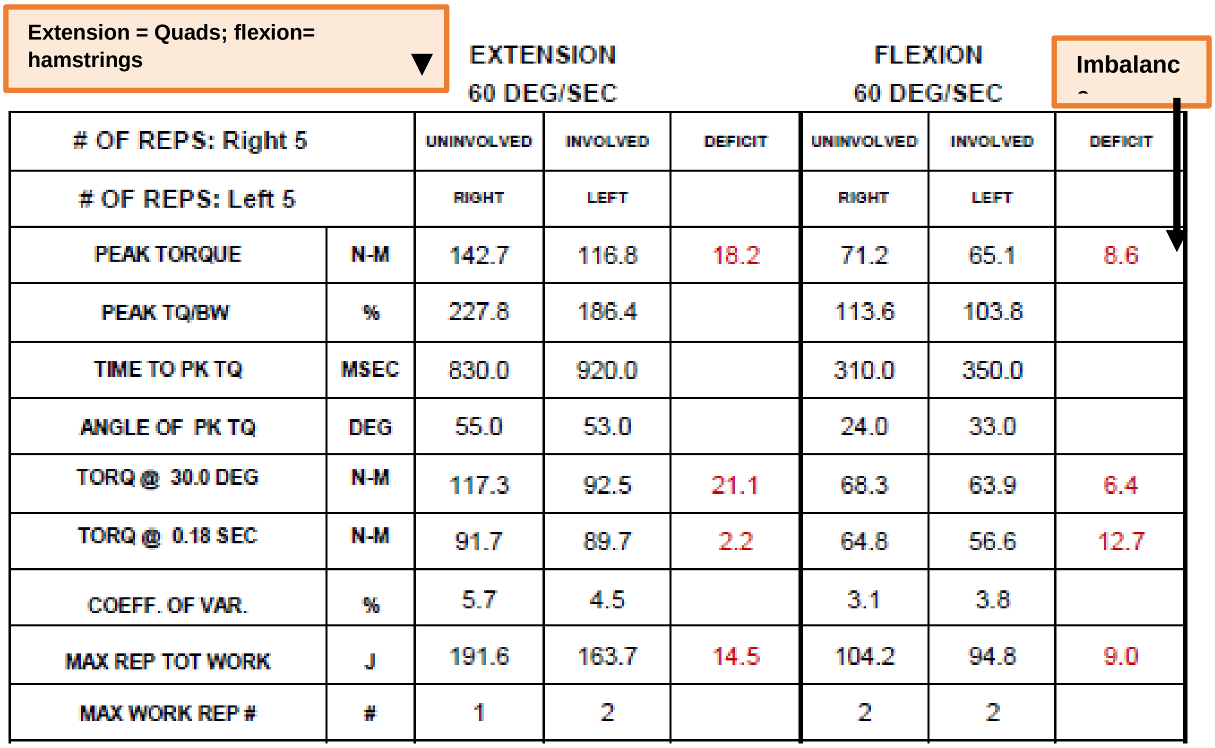
Reading

the

Isokinetic Report

Reading your ISOKINETIC (Iso) report

A comprehensive isokinetic report includes a lot of information. This document explains all the variables so you can get a better understanding of what the test is telling you about your fitness and performance. First it explains the numbers presented on the report and then it explains the isokinetic curve at the bottom report page.



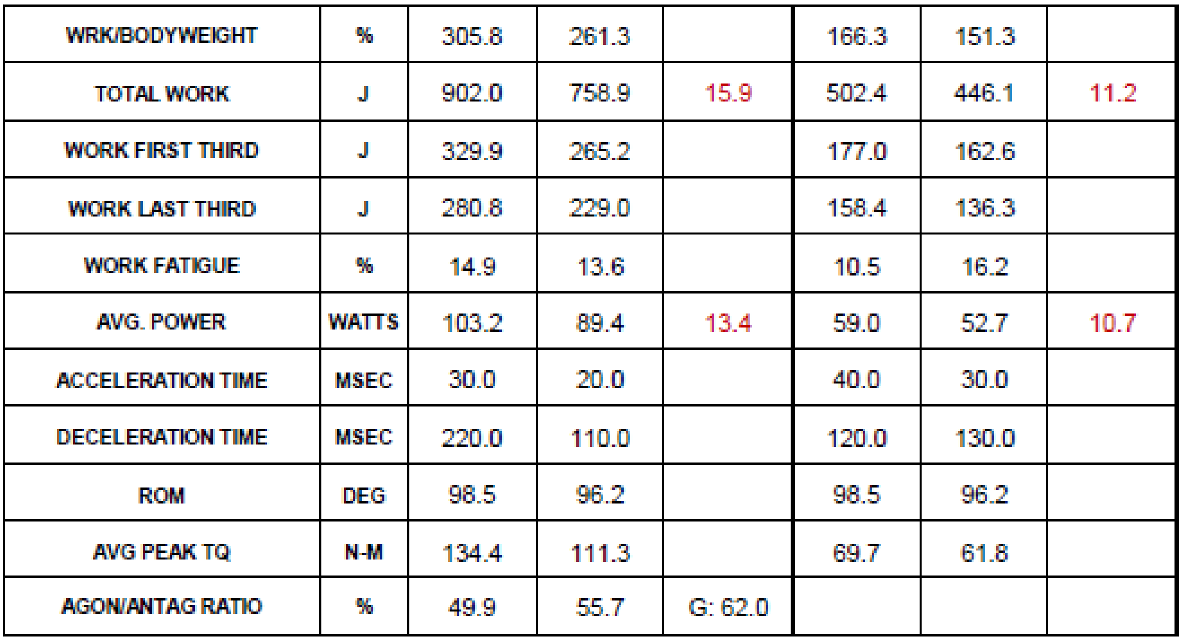
Extension = Quads; flexion= hamstrings

Imbalanc

		EXTENSION 60 DEG/SEC			FLEXION 60 DEG/SEC		
# OF REPS: Right 5		UNINVOLVED	INVOLVED	DEFICIT	UNINVOLVED	INVOLVED	DEFICIT
# OF REPS: Left 5		RIGHT	LEFT		RIGHT	LEFT	
PEAK TORQUE	N-M	142.7	116.8	18.2	71.2	65.1	8.6
PEAK TQ/BW	%	227.8	186.4		113.6	103.8	
TIME TO PK TQ	MSEC	830.0	920.0		310.0	350.0	
ANGLE OF PK TQ	DEG	55.0	53.0		24.0	33.0	
TORQ @ 30.0 DEG	N-M	117.3	92.5	21.1	68.3	63.9	6.4
TORQ @ 0.18 SEC	N-M	91.7	89.7	2.2	64.8	56.6	12.7
COEFF. OF VAR.	%	5.7	4.5		3.1	3.8	
MAX REP TOT WORK	J	191.6	163.7	14.5	104.2	94.8	9.0
MAX WORK REP #	#	1	2		2	2	

Variable	**Explanation**
Peak torque	The absolute maximum force/ strength you produced.
Peak Torque/BW	The strength compared to body weight, the strength: bodyweight ratio or how strong you are for your build.
Time to Peak Torque	Indicates how quickly you ramp up to max force or the explosiveness at this speed. Fast scores mean more force earlier in the movement.
Angle of PK TQ (Peak Torque)	The knee bend angle at which the muscles are strongest. Fighters who spend time with the knees bent for example would like to be strong in that position (e.g. Grapplers). 90° indicates a 90° bend in the knee.

Torque @ 30°	The knee joint “unlocks” at a slight bend or 30°. This score tells you about the stability of your knee. If you score low knee stabilization training is usually recommended. Looseness of the knee joint could lead to injury if the knee joint is cranked.
Torque @ 0.18 sec	This score is called the Time Rate of Tension Development. This can be considered how explosively you can produce force. Explosive force is important for powerful movement like kicks, but also most force (usually 80%) should be produced within a short time to support the body, e.g. after a kick or running stride.
Coeff. Of Var.	Indicates how well the movements were performed.
Max Rep Tot Work	This score helps indicate how well the knee functions. This score is often used in knee rehabilitation. It tells you how well the knee muscles activate and produce forces when working at their most (the rep where you did the most work.
Max Work Rep #	This is the repetition where you worked the most. You should work the most in the beginning of the set. Working in the first rep is difficult to achieve, working in the last reps indicates you need to work on initiating movement more.



WRK/BODYWEIGHT	%	305.8	261.3		166.3	151.3	
TOTAL WORK	J	902.0	758.9	15.9	502.4	446.1	11.2
WORK FIRST THIRD	J	329.9	265.2		177.0	162.6	
WORK LAST THIRD	J	280.8	229.0		158.4	136.3	
WORK FATIGUE	%	14.9	13.6		10.5	16.2	
AVG. POWER	WATTS	103.2	89.4	13.4	59.0	52.7	10.7
ACCELERATION TIME	MSEC	30.0	20.0		40.0	30.0	
DECELERATION TIME	MSEC	220.0	110.0		120.0	130.0	
ROM	DEG	98.5	96.2		98.5	96.2	
AVG PEAK TQ	N-M	134.4	111.3		69.7	61.8	
AGON/ANTAG RATIO	%	49.9	55.7	G: 62.0			

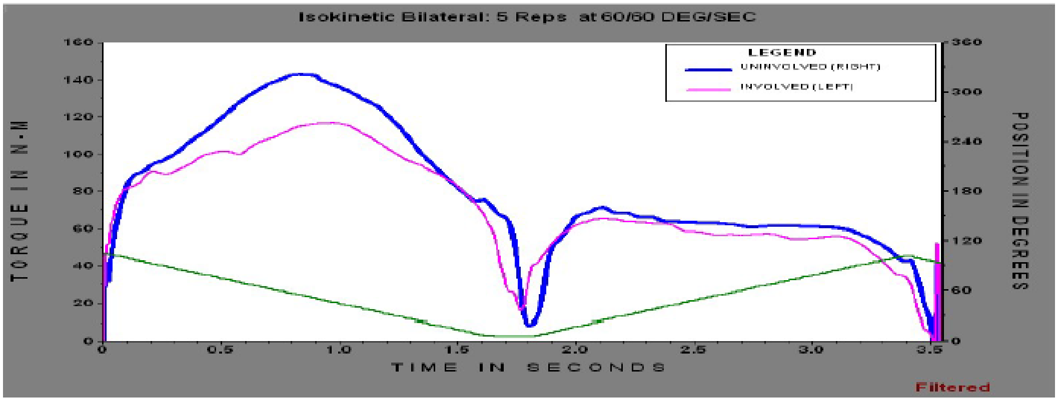
Variable	**Explanation**
WRK/ Bodyweight	The work to bodyweight ratio tells you efficiently you function. High scores mean that you produce a high force level and sustain is throughout the repetition. The amount of force produced for your body weight would also be good.
Total work	This is how much work you did throughout the entire set. Low scores may mean that one leg was consistently weaker, fatigued more or worked in a very different range compared to the opposite side.
Work First Third	This indicates how hard you exercised in the beginning of the set. You should score higher in this than in the last third of the set.
Work Last Third	This indicates how hard you exercised during the end of the set. You should score lower in this than in the first third of the set.
Work fatigue	How your work dropped off over time. This shows how you fatigued over the course of the set. People who fatigue more lose the ability to push out strong repetitions later in the set.
Average Power	How explosive the movements were. Power is important in producing movements with both high speed and high force. After injury the recovery of power may be a priority.
Acceleration time	The time it takes to reach the test speed from standstill. This indicates how well the nerves activate the muscle to cause movement.
Deceleration time	The time it takes to stop from moving at the test speed. This indicates how well the nerves cause a “braking” action from other muscles to cause movement to slow down.
ROM	The range of motion you used during the exercise.
Average Peak TQ	The average of the maximum strength scores demonstrated throughout the test. This can indicate how much your maximum strength dropped off during the exercise session. Scores close to the Peak Torque score indicate that your maximum force remained relatively unchanged with this level of fatigue.
Agonist/ Antagonist Ratio	The hamstrings are normally have about 60% of the strength of the quadriceps muscles. The hamstrings often need to work like “brakes” for the quadriceps muscles and slow the lower leg down as it swings forward with movements. If the hamstrings are much weaker, they may be overpowered by the quadriceps, and this increases risk of injury.

Notes

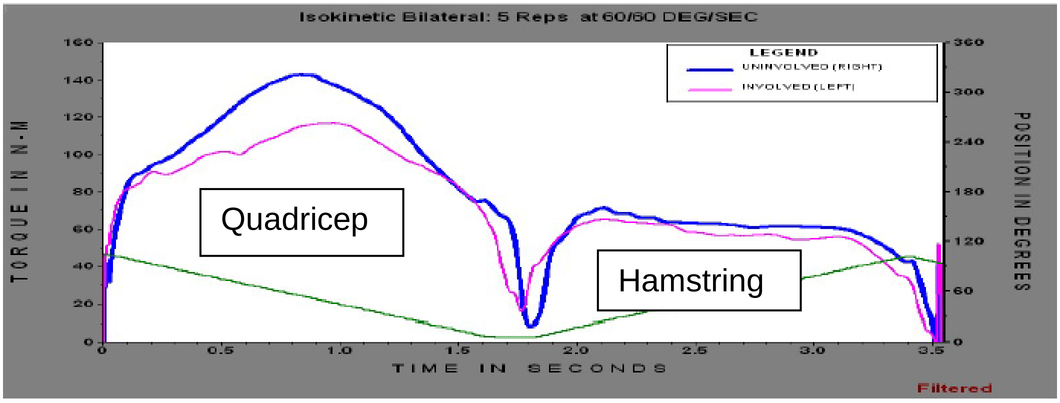
Please use this space to take notes, write down reflections or ideas.

Reading your Isokinetic curve

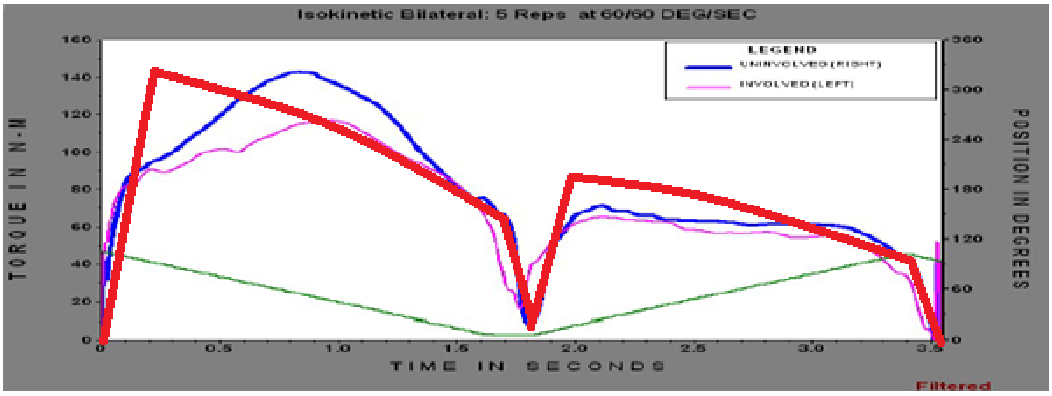
The curve can tell you a lot about how you develop strength and how your muscles function.



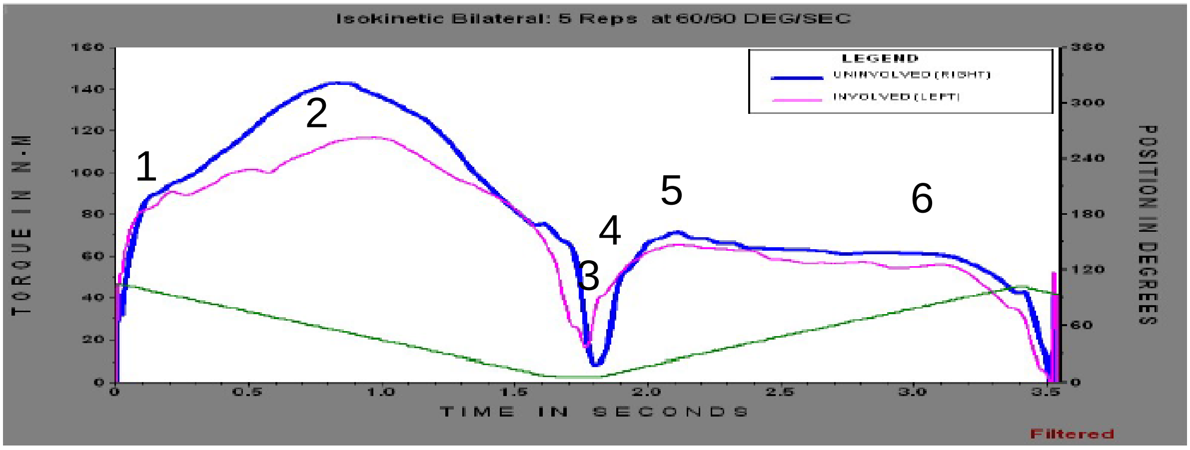
The first "mountain" shows how you produced force from the quadriceps muscles at the front of the thigh. The second "mountain" shows how you produced force from the hamstring muscles at the back of the thigh.



Shown in red here is an idealised version of this graph in a well-trained athlete. The "Mountain" begins with a steep uphill, which means the athlete quickly developed their maximum force. The force slowly drops as the muscle shortens and the leg straightens out. When the leg hits the target at the end of the movement, the muscle shuts down and the opposite muscle the hamstring quickly activates, reaches its maximum force, and then shortens while the leg is pulled until it hits the "stop" or target at the end of the range.



Example: Reading an isokinetic graph



Quadriceps

1. The **slope up the mountain (quadriceps)** is gradual, suggesting that it takes some time to reach maximum force. In a trained athlete the slope would be steep, suggesting that they reach maximum force quickly and explosively.
2. **The peak:** There is a gap between the Blue (right leg) force and the pink (Left leg) force, indicating that there is a strength imbalance between the two legs. The pink (left) is weaker when it needs to produce maximum force.
3. **The valley** between the mountains deep and narrow, suggesting that the quads turn off efficiently and the hamstrings turn on efficiently, as they should.

Hamstrings

4. The **slope** is steep, suggesting the rate of force development is good and there is a good explosiveness as the muscles activate.
5. The **peak** is not clearly very high, suggesting the hamstrings may be more untrained or weak, as there is not a lot of force being produced. There is a very small gap between the blue and pink lines, suggesting a very small muscle imbalance with the right being slightly stronger.
6. There **downslope** is fairly flat, indicating the hamstrings did not lose much force as they shortened. This is quite normal for hamstrings. Seeing a sharp downslope would suggest more fatigue.