

Running head: PNF STRETCHING

Comparing the effects of two proprioceptive neuromuscular facilitation stretching techniques and static stretching on active knee extension range of motion and vertical jump performance

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ABSTRACT

Proprioceptive neuromuscular facilitation (PNF) stretching has often been identified as an effective stretching technique for improving range of motion (ROM) prior to exercise. The two PNF stretching techniques that are most commonly performed are autogenic inhibition and reciprocal inhibition stretching. These techniques increase ROM by applying resistance to either agonist (i.e. autogenic) or antagonist (i.e. reciprocal) muscle groups to reduce reflex activity. Variability in PNF stretching procedures, however, cause difficulty comparing studies and translating findings to clinical practice. Limited research has also been performed on the effects of PNF stretching on athletic performance. The present study compared the effects of static, autogenic inhibition, and reciprocal inhibition stretching on knee extension ROM and vertical jump performance. Thirty healthy participants (16 male and 14 female) performed an Active Knee Extension test and a Vertical Jump test after 4 counter balanced stretching conditions. The stretching conditions consisted of no stretching (control), static stretching, autogenic inhibition stretching, and reciprocal inhibition stretching. A one-way analysis of variance (ANOVA) with repeated measures and the Bonferonni post hoc test identified static stretching, autogenic inhibition stretching, and reciprocal inhibition stretching significantly increased knee extension ROM by means of 7.8, 8.1, and 9.4 degrees, respectively when compared to no stretching ($p < .001$). No significant differences were identified between the ROM increases associated with each technique ($p > 0.05$). Pairwise comparisons also identified no significant differences in vertical jump height (cm) before or after the use of static, autogenic inhibition, or reciprocal inhibition stretching ($p > 0.05$). The present study was the first to compare these stretching techniques using recommended pre-activity procedures. The results of this study

identified all three stretching techniques as effective techniques for improving ROM prior to exercise without decreasing vertical jump performance.

Keywords: Proprioceptive Neuromuscular Facilitation, Stretching, Range of Motion, Vertical Jump, Autogenic Inhibition, Reciprocal Inhibition

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CHAPTER 1

Introduction

Proprioceptive neuromuscular facilitation (PNF) is a blanket term describing a variety of protocols that target many aspects of muscle training while improving mobilization, coordination, and stability (Westerwater-Wood, Adams, & Kerry, 2010). These techniques are performed in clinical and athletic contexts to increase joint range of motion (ROM) and improve performance (Hindle, Whitcomb, Briggs, & Hong, 2012). In comparison to static and dynamic stretching, PNF stretching has been identified as an alternative stretching technique for effectively improving short-term active and passive ROM (Sharman, Cresswell, & Riek, 2006). The mechanisms supporting the effectiveness of PNF stretching to increase ROM are attributed to the presence of autogenic and reciprocal inhibition.

Autogenic inhibition occurs when resistance is applied to the targeted muscle, thereby causing inhibited muscular activity within the same muscle once the contraction is stopped (Khamwong et al., 2011). The stretching technique in which resistance is applied to the opposing muscle is supported by the theory of reciprocal inhibition. Reciprocal inhibition occurs when resistance is applied to the muscle opposite to the muscle of interest, thereby inducing inhibition within the targeted muscle (Hindle et al., 2012).

Autogenic inhibition and reciprocal inhibition are the mechanisms involved in PNF stretching which act to reduce tonic reflex activity by inhibiting motor neuron pools following contraction (Guissard & Duchateau, 2006; Yuktasir & Kaya, 2009). When a muscle is stretched, muscle spindles detect change in muscle length, activating a stretch reflex (Fahey et al., 2013). The stretch reflex is a natural defense mechanism causing the muscle to contract, thereby resisting the stretch to avoid injury (Yuktasir & Kaya, 2009). By applying resistance prior to stretch the tonic reflex is reduced, allowing the target muscle to be brought into an increased

length without the nervous system causing the muscle to contract and resist the stretch. Through the inhibited reflex activity, the joint is thereby able to be passively brought into increased ROM. The presence of autogenic inhibition or reciprocal inhibition, differs based on the specific PNF stretching technique performed.

Proprioceptive neuromuscular facilitation stretching is performed by first identifying the muscle of interest and opposing muscle group, and then holding the joint at the end ROM following the application of appropriate resistance. The primary difference between PNF stretching techniques is based on the muscle to which resistance is placed. Resistance can be placed on either the targeted, or opposing muscle to reduce the targeted muscle's resistance to stretch. The stretching technique in which resistance is applied directly to the muscle of interest is supported by the theory of autogenic inhibition (Rowlands et al., 2003). Once resistance is applied to the muscle, the joint is then passively moved and held in the new available range.

Literature associated with PNF stretching includes a large degree of variability related to terminology and procedural definitions. Within the two PNF stretching techniques, procedural variation occurs with respect to the placement (agonist or antagonist muscle), duration, and amount of force applied to the muscle. As a result, terms are often used interchangeably to describe altered procedures (Sharman et al., 2006). Variability among terminology and procedure is problematic as it results in difficulty analyzing, comparing, and translating results to a clinical setting. Due to the presence of confusion associated with terminology and procedures, the following study will use the terms autogenic inhibition and reciprocal inhibition to describe the procedures in which these mechanisms support.

In addition to the confusion associated with PNF stretching terminology and procedures, the extent to which PNF stretching improves ROM has been questioned. Puentedura et al. (2011)

and Yuktasir and Kaya (2009) found similar improvements in knee extension ROM when comparing autogenic inhibition stretching with static stretching. Since ROM improvements were similar between stretching techniques, it was argued that static stretching was the preferable technique to increase ROM for two main reasons; there is a reduced need for advanced skill while applying static stretching and this technique does not require the participation of a partner to apply a resistive force. Contrary findings were reported by Miyahara et al. (2013) when the effects of autogenic inhibition stretching on hip flexion ROM was compared to static stretching. After applying maximal resistance directly to the hamstring muscles during autogenic inhibition stretching, hip flexion ROM was significantly increased compared to the increases associated with static stretching technique. Future research to address the amount of procedural variability within each study is needed to fully understand the effects of PNF stretching procedures on ROM.

Although Miyaraha et al. (2013), Puentedura et al. (2011), and Yuktasir and Kaya (2009) each targeted the hamstrings with an autogenic inhibition stretching technique, the amount and duration of resistance was different in each study. Different applications of resistance within PNF stretching is problematic as it may alter the extent to which autogenic or reciprocal inhibition can occur, thereby influencing the ROM. Conflicting results between studies could, therefore, be reasoned to be due to the altered procedures used. As a result, the procedural variability within the resistance phase of PNF stretching poses a major concern as it creates difficulty comparing studies and translating stretching procedures to a clinical setting. As a result, a gap in the literature is present identifying recommended PNF stretching procedures, which may cause difficulty prescribing this technique prior to exercise.

Despite the inconsistent procedures used between studies, PNF stretching is often recommended to be performed prior to exercise to increase ROM and reduce the risk for muscular injuries (Behm, Blazevich, Kay, & McHugh, 2013; Miyahara et al., 2013). The effect of PNF stretching on performance, however, remains largely under researched. Among the limited studies examining the effect of PNF stretching on athletic performance, procedural variation also occurs with respect to the duration and amount of force applied during the resistance phase of the PNF technique. As a result, the effects of PNF stretching on athletic performance is relatively unknown and a comparison between autogenic and reciprocal inhibition techniques is absent.

Purpose

The purpose of this study will be to compare the effects of static stretching, autogenic inhibition, and reciprocal inhibition techniques on active knee extension ROM and vertical jump performance.

Significance of Study

Prior to athletic performance, static or PNF stretching has been recommended to increase ROM towards improving athletic performance while reducing the risk of injury (Miyahara et al., 2013; Safran et al., 1988; Worrell et al., 1994) Including PNF stretching prior to athletic activity is problematic due to procedural inconsistency within the literature and the lack of research identifying the effect of PNF stretching on athletic performance. Additionally, PNF stretching techniques specific to autogenic and reciprocal inhibition have yet to be compared using recommended procedures. The following study will aim to provide clarity for recommended PNF stretching procedures to allow for easier implementation when prescribing this stretching technique. This study will also be first among the literature to compare the effects of both

autogenic and reciprocal inhibition stretching techniques on ROM and vertical jump performance using recommended pre-activity procedures.

Hamstring muscular strains are the most common injury in activities involving sprinting or jumping (Petersen & Holmich, 2005). The risk for muscular injury, however, has been found to reduce significantly when ROM of the associated joint is increased prior to athletic performance (Safran et al., 1988; Weppeler & Magnusson, 2010). This is due to the increased ability of connective tissue and muscle to absorb force and avoid muscular strain when ROM is improved (Worrell & Perrin, 1992). The importance for stretching the hamstring muscles prior to performance is thereby highly emphasized. As a result, the following study will target the hamstring muscles prior to completing a vertical jump to identify the effects of PNF stretching before exercise.

In an athletic context, coaches and athletes utilize vertical jump tests as a measurement of muscle power and to identify the effectiveness of training programs (McLellan, Lovell, & Gass, 2011). To perform a maximal vertical jump, multiple components are coordinated such as muscular strength, rate of force development, and multi-segment coordination (Dowling & Vamos, 1993). As a result, vertical jump performance has been strongly correlated with athletic performance in sports such as American football, diving, weightlifting, and sprinting (Carlock et al., 2004; Leard et al., 2007).

CHAPTER 2

Review of Literature

Proprioceptive neuromuscular facilitation stretching is performed in an athletic environment to improve both active and passive ROM (Hindle et al., 2012). Proprioceptive neuromuscular facilitation stretching is performed by applying resistance to either a targeted muscle group, or the antagonist muscle group. As such, techniques associated with PNF stretching contain procedural variability based on the placement, duration, and amount of force applied during the resistance phase of the stretch (Feland & Marin, 2004).

The amount of procedural variability identified within the stretching protocols is problematic as altered procedures are often used in studies attempting to identify the effects of PNF stretching on ROM and athletic performance. The effects of PNF stretching on ROM has varying results which may be due to the variability in procedures included in the studies (Feland, Myrer, & Merrill, 2001; Puentedura et al., 2011).

Gaining ROM by performing stretching techniques before exercise has been proposed to prevent injuries, muscle imbalances, and potentially improve muscular function and sport performance (Wanderley et al., 2018). Although PNF stretching is recommended as an option to increase ROM prior to exercise, the effects of PNF stretching on athletic performance has been under researched. In addition to the minimal research available, procedural variability causes difficulty comparing studies and translating findings to a clinical setting. The literature examining the mechanisms supporting the use of static and PNF stretching to improve ROM, the correct implementation of each stretching technique, and prior literature identifying the effects of PNF stretching on ROM and athletic performance will be highlighted.

Underlying Physiology of Proprioceptive Neuromuscular Facilitation

To identify how each stretching technique improves ROM, it is important to first identify the factors responsible for ROM. The constructs affecting ROM of a joint includes the associated structures, muscle elasticity and length, and neurological components (Insel, Roth, Irwin, & Burke, 2012). Decreased ROM of a joint is commonly attributed to abnormal shortness of muscles and tendons that cross the joint (Threlkheld, 1992). When a muscle is placed in a shortened position for a prolonged period, collagen bundles *crimp* because of the increased slack within the muscle. The term *crimp* refers to the layout of collagen in which fibres run parallel while frequently changing direction in a wave-like pattern. Initially, when a joint is placed on stretch, the force of stretch is resisted by the unbending of rope-like collagen fibres (Thomopoulos & Genin, 2012).

Although mechanical changes in collagen alignment occur slowly over a prolonged stretch, increases in ROM are found immediately after stretching. Temporary increases in joint ROM can be attributed to *creep* of muscle fibres. The term *creep* identifies the ability of a constant force to gradually increase the length of the musculotendinous unit due to viscoelastic properties present (Sharman et al., 2006; Thomopoulos & Genin, 2012). When a muscle is stretched, wavelike elastin fibres straighten to increase in length. Upon completion of the stretch, the elastin fibres shorten back to the initial state. Muscle fibres also *creep* when sustained tension is present to temporarily increase muscle length. The applied force allows for a temporary straightening of crimped collagen fibres, thereby increasing the muscular length. This phenomenon is temporary due to a viscoelastic response which gradually returns the muscle to a shortened position. If muscle fibres are constantly increased through flexibility training, then long-term changes will occur due to changes in collagen fibres creating plastic elongation.

Despite the need for a prolonged stretching regiment to cause lasting improvements in muscular flexibility, ROM immediately increases after stretching. Although the elasticity of muscle plays a role, the nervous system can also be modified by altering the joint's ability to resist stretch. When a muscle is stretched, muscle spindles detect the amount and rate of change in which a muscle is lengthened (Fahey et al., 2013). This detection of stretch stimulates a defense mechanism causing the muscle to contract to resist the stretch (Yuktasir & Kaya, 2009). This reflex causing resistance to stretch can be altered by inhibiting electrical neuromuscular activity, restricting the protective reflex against the stretch. The following will explain in detail the approaches used by static stretching and PNF stretching techniques to temporarily improve ROM through the ability to manually stretch the muscle, or alter nervous system activity.

Autogenic Inhibition. As previously stated, determining the agonist and antagonist muscle groups responsible for the desired movement is a crucial step before performing PNF stretching. This is due to the alternate procedure associated with the placement of resistance. During the autogenic inhibition technique, resistance is applied directly to the muscle of interest. Through applying resistance to the targeted muscle directly, autogenic inhibition has been highly speculated as the physiological rationale for increasing joint ROM (Rowlands et al., 2003). Autogenic inhibition refers to the presence of lowered excitation within a contracting muscle due to the presence of an inhibitory interneuron from the Golgi tendon organ (Sharman et al., 2006). These interneurons are activated within the spinal cord propagating an inhibitory stimulus on the alpha motor neuron, decreasing the efferent motor drive within the muscle, as well as the excitability of the same muscle (Hindle et al., 2012). The inhibition of the alpha motor neuron promotes relaxation, causing an increased ability to elongate muscle fibres with decreasing resistance to stretch (Khamwong et al., 2011). This theory can be applied to the autogenic

inhibition PNF stretching technique as the muscle targeted for inhibition, is the same muscle in which resistance is applied.

An example of PNF stretching is illustrated in Figure 1 as the hamstring muscles are targeted to utilize an autogenic inhibition approach. To perform autogenic inhibition stretching, the participant isometrically contracts the hamstring muscles as the examiner applies resistance to resist knee flexion. After the examiner releases the resistance, the joint may be passively moved into increased knee extension ROM due to the inhibitory stimulus and decreased ability of the hamstrings to resist the stretch.



Figure 1. Autogenic inhibition stretching technique.

Reciprocal Inhibition. The reciprocal inhibition PNF stretching technique is performed by the examiner applying resistance to the antagonistic muscle to the targeted muscle. Applying resistance to the antagonist uses the theory of reciprocal inhibition to cause relaxation of the

targeted muscle group (Hindle et al., 2012). Reciprocal inhibition is induced when the opposing muscle is voluntarily isometrically contracted decreasing the neural activity in the target muscle (Sharman et al., 2006). Evidence of this theory was identified in a study by Rowlands et al. (2003) that found decreased neural activity in the biceps femoris muscle after the application of this PNF stretching technique. Relaxation in the antagonist muscle is reasoned to be a result of the nervous system attempting to maximize force by the agonist muscle without counteracting resistance produced by the antagonist muscle (Hindle et al., 2012; Sharman et al., 2012).

Increased inhibition is the result of proprioceptive constructs in the target muscle causing decreased neural activity (Rowlands et al., 2003). Therefore, the reciprocal inhibition stretching technique causes inhibitory interneurons within the antagonistic muscle to reduce neural activity in the targeted muscle (Davis et al., 2005). This results in decreased muscular activity and inhibition to resist the stretch of the targeted muscle. Therefore, the joint can be brought passively into a newly obtained ROM. An example of the reciprocal inhibition stretching technique is illustrated in Figure 2 as the hamstring muscles are targeted by resisting the quadriceps femoris muscles.



Figure 2. Reciprocal inhibition stretching technique for the hamstring muscle group.

Although the presence of autogenic or reciprocal inhibition is known to occur during PNF stretching, the associated increases of ROM have been speculated to be due to additional neurologic adaptations (Sharman et al., 2006). To fully explain ROM increases after PNF stretching, further research is needed to explore the presence of additional theoretical mechanisms contributing to the length tension changes in the tissue.

Stress Relaxation Theory. The Stress Relaxation Theory indicates that when the musculotendinous unit is held in a lengthened position, then the tension to resist the stretch will decline in a nonlinear fashion (Magnusson, 1998; Sharman et al., 2006). The Stress Relaxation Theory identifies the alteration of mechanical properties within the musculotendinous unit, allowing the joint to adapt to the tension applied by the stretch. This affects the viscoelastic aspect of the muscle tissue, resulting in decreased muscle stiffness (Khamwong et al., 2011). The decreased muscle stiffness occurs due to actin and myosin bonds being broken, reducing stiffness and resistance to stretch within the muscle (Khamwong et al., 2011). Once the actin and myosin bonds are broken, the viscous properties of the musculotendinous unit lose its ability to resist stretch and elongates over time (Sharman et al., 2006). This results in an increased length of the musculotendinous unit, improving ROM. This is found to be a protective mechanism for the body as it allows the muscle to prevent muscular strains or tears because of the stretch (Hindle et al., 2012). It is important to note, however, that improvements are temporary because of *creep* in the tissues in which the muscle returns to a slightly lengthened position compared to the baseline resting length. To achieve greater changes in range, the viscoelastic components of muscle require a prolonged stretch duration to achieve a permanent change (Depino, Webright, & Arnold, 2000).

The Stress Relaxation Theory occurs in static, autogenic inhibition, and reciprocal inhibition stretching techniques when the joint is held in an increased ROM. Evidence has shown that a stretch must be held for at least 15-30 seconds for adaptation to begin in an increased ROM (Magnusson, 1998). As a result of stretch, the muscle tension against the stretch will decrease over time. Due to the viscoelastic properties of the musculotendinous unit, however, increases in ROM after a single 30 second static stretch or autogenic inhibition stretch is known to return to baseline within 3 to 10 minutes (Depino et al., 2005; Ryan et al., 2008; Spernoga, Uhl, Arnold, & Gansneder, 2001). Therefore, extensive programs that focus on stretching muscles are needed to create lasting increases in ROM.

During both PNF stretching protocols, inhibitory interneurons stimulate the targeted, or antagonistic, muscle group allowing the passive properties of the musculotendinous unit of the target muscle to be stretched (Hindle et al., 2012). It is important to note the newly acquired ROM is only held in position as an additional stretch may stimulate a stretch reflex (Ryan, Walter, & Stout, 2009).

Gate Control Theory. The Gate Control Theory (Melzack & Wall, 1967) suggests that two different stimuli activate respective receptors simultaneously. The increase in ROM resulting from PNF stretching was initially hypothesized to be due to lowered pain inhibitory systems that were stimulated because of the technique's resistance. This theory proposed that both pain and pressure stimuli have afferent nerve fibres connected to the same interneurons within the spinal column. During PNF stretching, the Gate Control Theory suggests that the pressure signals are received before the pain impulses. As a result, an increased stretch could be placed before the perception of pain to cause a counteracting reflex.

This theory has since been discounted as an oversimplifying pain description, however, a

distraction of pain may be evident as an additional explanation for the effectiveness of PNF stretching to improve ROM (Magnusson, 1998; Sharman et al., 2006; Weppeler & Magnusson, 2010). It is important to note that the depressed stretch reflex resulting from the distraction from pain fades within 5 seconds, so the joint should be brought into the newly available ROM immediately following resistance. More research is needed to evaluate the mechanism by which pain distraction theories affect changes in the ROM.

Implementation of Proprioceptive Neuromuscular Facilitation Stretching

To appropriately and effectively perform autogenic or reciprocal inhibition techniques, it is important to understand the optimal force and duration of resistance needed to increase ROM. Maddigan et al. (2012) reported similar findings between the use of isometric, concentric, and eccentric contractions. The use of an isometric contraction, however, appears most frequently described in the literature related to the use of PNF stretching techniques.

Although a maximum contraction was first thought to be optimal when performing PNF stretching techniques (Hindle et al., 2012; Sharman et al., 2006), it has since been identified that a submaximal force relative to each participant should be performed (Woods et al., 2007). This inference is consistent with Felan and Marin (2004) in which PNF stretching using 20-60% of the individual's maximal contraction resulted in similar benefits in hamstring flexibility. This study identified similar improvements regardless of the contraction intensity. The effect of different types of muscular contractions on muscular activity, however, has yet to be determined. Submaximal resistance may be optimal due to the risk of injury and potential for increasing muscular activity with a maximal contraction. These harmful effects and risks of injury can be attributed to exercise induced muscle soreness or muscle strain which could occur after a forceful contraction (Feland & Marin, 2004).

Within the resistance phase of PNF stretching techniques, the duration in which resistance is applied varies between 3-10 seconds. Cornelius and Rauschuber (1987), however, compared the effects of 6 seconds and 10 seconds of contractions during the resistance phase of reciprocal inhibition stretching and reported no differences in hip flexion ROM. Since similar increases in ROM were found between durations, a 6 second resistance phase is recommended for time efficiency and to avoid the possibility of muscular fatigue.

Variability in Terminology

Proprioceptive neuromuscular facilitation stretching is often used as a blanket term to describe either autogenic inhibition or reciprocal inhibition techniques. Although PNF stretching encompasses two main approaches to improving ROM, there is a common misconception found in the literature with respect to the terminology used to identify the associated technique. Terms used to describe PNF stretching techniques are based on the order in which resistance and stretching phases are performed. The most common terms used to describe PNF stretching techniques includes: contract-relax, hold-relax, agonist-contract-relax, contract-relax-agonist-contract, and slow-reversal-hold-relax (Cornelius & Rauschuber, 1967; Feland & Marin, 2004; Sharman et al., 2006). These terms have caused confusion among clinicians and researchers as certain terms are often used synonymously to identify different procedures. For example, the terms contract-relax and hold-relax, are often used interchangeably to identify the PNF stretching technique using an autogenic inhibition approach (Feland et al., 2004; Osternig et al., 1990). The term contract-relax, however, can also be identified in studies utilizing a reciprocal inhibition technique (Feland et al., 2001).

In addition to variability in terminology used to describe PNF techniques, PNF stretching is also used as a general term without additional details and further explanation of the technique

used in the study. This is evident in various studies as the muscles in which the resistance is applied is often not clearly identified (Barroso, Tricoli, Dos Santos Gill, Ugrinowitsch, & Roschel, 2012; Bradley, Olsen, & Portas, 2007; Nelson, Chambers, McGown, & Penrose, 1986). Unclear descriptions respective to the placement of resistance causes difficulty in determining the specific PNF technique used in each study. The variability associated with terminology and procedures is also highly problematic as it causes difficulty analyzing results, comparing between studies, and translating findings to a clinical setting. Despite the varying terminology used to identify PNF stretching procedures, the following will assess the available literature comparing the effects of autogenic and reciprocal inhibition stretching with the traditionally used static stretching technique.

Effect of Stretching on Range of Motion

Prior to athletic performance, static or PNF stretching is often performed as part of a warm-up procedure to increase ROM. Optimizing ROM as part of a warm-up is particularly important to enhance the ability of the musculotendinous unit to adapt to imposed stresses, reducing the risk of muscular injury (Safran et al., 1988; Wepler & Magnusson, 2010; Worrell & Perrin, 1992).

Hamstring muscle strains are most prevalent in sports associated with jumping and sprinting, with a high rate of re-injury (Petersen & Holmich, 2014). The cause of hamstring strains is most often due to the hamstring muscles contracting eccentrically to decelerate knee extension before rapidly contracting concentrically to become an active extensor of the hip joint. As a result, the hamstring muscles may contract during knee extension causing muscular strain due to the conflicting movements.

Due to the importance associated with stretching the hamstring muscles to reduce the risk of injury, most literature examining the effect of PNF stretching on ROM includes the hamstrings as the target muscle for the procedures. Since autogenic inhibition and reciprocal inhibition techniques have yet to be compared, the following will identify existing literature associated with each procedure and the associated stretching technique that was compared.

Autogenic Inhibition Effect on Range of Motion. The autogenic inhibition technique has been identified as an effective and safe way to improve knee extension ROM. Yuktasir and Kaya (2009) compared the effects of autogenic inhibition and static stretching on active knee extension ROM. The autogenic inhibition technique was applied using submaximal resistance for 5 seconds. Significant increases were identified after both static and autogenic inhibition stretching by means of 15.4 and 19.22 degrees, respectively. No significant difference, however, was evident between the two different stretching protocols. Similar results were identified by Puentedura et al. (2011) who applied a longer duration of submaximal resistance (10 seconds) to increase knee extension ROM in comparison to static stretching. Although both static stretching and autogenic inhibition stretching techniques resulted in increased knee extension, there was no significant difference between the techniques as each increased knee extension ROM by 9.1 and 8.9 degrees, respectively. Due to the similar findings and increased ROM in both studies, the use of static stretching prior to exercise due to the simplicity of the procedure without the associated procedural confusion with a PNF stretching approach was recommended.

Contrary findings were reported by Miyahara et al. (2013) who compared the effects of static stretching and autogenic inhibition stretching on hip flexion ROM using a Straight Leg Raise Test. Like the previously mentioned studies, resistance was applied to promote relaxation in the hamstring muscles prior to ROM measurement. Maximal resistance, however, was applied

for 6 seconds prior to being stretched. The two stretching techniques did not provide similar increases in hip flexion ROM after autogenic inhibition stretching compared to static stretching. This was evident as autogenic inhibition improved hip flexion by 12 degrees, whereas static stretching only increased hip flexion by 4 degrees. These results disputed the preference of static stretching over PNF stretching reported previously, as the autogenic inhibition technique resulted in increased hip flexion ROM.

Reciprocal Inhibition Stretching Effect on Range of Motion. Despite autogenic inhibition stretching being the technique most prevalently cited in the literature, research exists identifying the effects of the reciprocal inhibition techniques on ROM. Osternig, Robertson, Troxel, and Hansen (1990) compared both PNF stretching techniques with an aim of improving knee extension ROM. It was found that the reciprocal inhibition technique provided 9-13% increases in knee extension ROM than the autogenic inhibition technique. These findings are significant because it identifies the importance of comparing autogenic and reciprocal inhibition stretching. Since each stretching technique uses an altered approach to reduce muscular activity, the effectiveness of each technique to increase ROM may also be different.

Although Osternig et al. (1990) identified a difference in knee extension ROM between the two different PNF stretching techniques, procedural variability was present between the two techniques. While both PNF stretching techniques included a maximal hamstring muscle contraction for 5 seconds, the types of contractions were different for each technique. The autogenic inhibition technique consisted of an isometric contraction resisted by the researcher. During reciprocal inhibition approach, however, the participant performed a maximal concentric contraction to extend the knee without any resistance applied from a researcher. The procedure also differed following the application of the resistance. For the autogenic inhibition technique,

the joint was brought into a newly acquired ROM for 5 seconds. For the reciprocal inhibition technique, however, any further procedures following the application of resistance was not indicated. The use of altered techniques and lack of description makes it difficult to compare the methodologies to identify potential differences in the effects of each on ROM. Future research is warranted to compare the effects of autogenic and reciprocal inhibition stretching techniques using similar amounts of resistance and stretching phases.

Pre-activity Stretching and Athletic Performance

Stretching to increase ROM prior to exercise is recommended to improve performance and reduce the risk of injury (Bradley et al., 2007; Weppeler & Magnusson, 2010). Static stretching, however, has been speculated as detrimental to maximal performance measures such as sprinting, vertical jumping, and peak cycling power (Behm et al., 2016). This is reasoned to be due to the neural inhibition and muscle soreness associated with this mechanism of stretch when applied prior to exercise (Young, Ballarat, & Behm, 2002). As a result, many athletes have avoided stretching prior to exercise. This has since been disputed as static stretching has been identified detrimental to these maximal performance measures only when the stretch is held for longer than 60 seconds (Behm & Chaouachi, 2011). Since both autogenic and reciprocal inhibition techniques include a passive stretching phase to bring the joint into an increased ROM, it is speculated that the use of these techniques prior to exercise may also induce changes in performance.

Although limited research exists, the effects of autogenic inhibition on vertical jumping ability has been analyzed. Yuktasir and Kaya (2009) compared the effects of static stretching with autogenic inhibition stretching on drop jump performance. The Drop Jump Test was performed by the participant dropping from a 60 cm height and landing on a contact mat prior to

jumping upward as high as possible. The contact mat was used to measure flight time between the initial drop and the landing after the vertical jump. Flight time was then used to calculate jump height (cm). Since autogenic inhibition and static stretching has been speculated to reduce peak force, rate of force production, and power output (Bradley et al., 2007; Young, Ballarat, & Behm, 2002) both stretching techniques were compared over a 6-week period to assess the long-term effect on counter movement jump performance. Drop jump performance, however, was consistent between each stretching technique compared to a control group with no changes evident in jump height.

Christensen and Nordstrom (2008) supported these findings using a Just Jump[®] system to measure vertical jump height during a counter movement vertical jump. This protocol measured vertical jump height using flight time like the Drop Jump Test, although an initial drop from a determined height was not performed. Vertical jump height was measured after no stretching, dynamic stretching, and autogenic inhibition stretching. No differences were reported between the groups as mean jump height in each group were 60.2, 60.3, and 60.2 cm, respectively.

Bradley et al. (2007) offered conflicting results to the previous studies by comparing vertical jump height before and after PNF stretching. After the PNF stretch was performed, jump height significantly decreased by a mean of 5.1%. This study measured vertical jump height using both counter movement, and static vertical jump procedures. The method for measuring vertical jump height during both types of jumps, however, was not specified. Also, the PNF stretching technique and associated muscle groups were not identified in the study. Additionally, although PNF stretching was reported detrimental to performance, the study failed to include the average jump height performed pre- and post-intervention. The lack of detailed stretching procedures and specific mean ROM measurements create difficulty comparing results to other

studies and identifying clinical significance. Nonetheless, Bradley et al. (2007) identified potential negative effects on vertical jump height because of PNF stretching, which warrants further examination.

Despite the confusion among procedures and conflicting results about the effects of PNF stretching on ROM, this technique is still identified as a method to increase ROM prior to exercise (Safran et al., 1988; Worrell et al., 1992). The effects of autogenic inhibition stretching on athletic performance, however, has been under researched while reciprocal inhibition stretching has yet to be examined. The purpose of the following study will, therefore, be to compare the effects of static, autogenic inhibition, and reciprocal inhibition stretching techniques on knee extension ROM and vertical jump performance.

Hypotheses

1. Based on Puentedura et al. (2011) and Yuktasir and Kaya (2009) it is hypothesized that autogenic and reciprocal inhibition stretching techniques will provide similar increases to knee extension ROM, although both techniques will result in increased ROM that is superior to the static stretching technique. This hypothesis is reasoned due to the ability of the PNF stretching technique to alter neural activity, reducing a resistance to stretch and potentially increasing stretch tolerance (Magnusson, 1998; Sharman et al., 2006; Weppeler & Magnusson, 2010).
2. Based on Christensen and Nordstrom (2008) and Yuktasir and Kaya (2009), it is hypothesized that all three stretching techniques will result in no change in vertical jump height. This is reasoned to be consistent with previous studies identifying minimal differences in athletic performance after static and autogenic inhibition stretching were implemented.

CHAPTER 3

Methodology

Participants

Convenience sampling was used to recruit volunteers from a healthy population (see Table 1). The study examined 30 participants (16 males and 14 females) between the ages of 18 and 30 years (mean age 23 ± 1.64 years). Participants were included if they performed the recommended 150 minutes of moderate- to high-intensity physical activity per week according to the Canadian Society of Exercise Physiology (CSEP) guidelines (2013). This guideline was chosen to screen for participants that would have a moderate degree of fitness to mitigate the risk of injury when performing a maximal exertion vertical jumping task. Exclusion criteria included any individual experiencing injuries or exercise restrictions related to stretching, jumping, or vertical reaching. Exercise restrictions included muscular strains and sprains, fractures, neurologic complications, or other injuries related to the knee, hip, or shoulders. Since normal knee extension ROM is 15 degrees of hyperextension (Shelbourne, Biggs, & Gray, 2007), any individual that obtained 0 degrees of knee extension during the initial Active Knee Extension Test was excluded from the study. This was to avoid stretching the joint into a hyperextended position which may have caused injury.

Table 1: Participants Demographics

Statistic	Mean	Standard Deviation
Age	23.27	1.64
Body Mass Index	24.59	3.13

Instrumentation

Metriks™ Digital Inclinometer. The Metriks™ Digital Inclinometer was used in this study to measure active knee ROM in degrees. This tool was identified as a valid device used for the measurement of knee extension with high intraclass correlation coefficients for both inter-examiner and intra-examiner reliability when compared to a goniometer (Brosseau et al., 2001; Santos et al., 2012).



Figure 3. Metriks™ Digital Inclinometer. Retrieved from http://metriks.ca/?attachment_id=634

Vertec™. The Vertec™ device is a tool comprised of plastic swivels arranged 0.0127 meters (1.27 cm) apart that is connected to a metal pole which was adjusted to the individual's standing reach height. This tool has been validated by Leard et al. (2007) by comparing vertical jump height to a criterion reference 3-camera motion analysis system which has been considered as the gold standard for measuring vertical jump height.



Figure 4. Vertec™. Retrieved from <https://www.sportsimports.com/shop/training-tools/training-vertec/jump-trainer/>

Baseline™ Electronic Push/Pull Dynamometer. The Baseline™ Electronic Push/Pull Dynamometer is a hand-held tool used to measure muscular strength (N) produced by a joint. Kelln, McKeon, Gontkof, and Hertel (2008) reported that the hand-held dynamometer had high inter- and intra-rater reliability for assessing lower limb strength in healthy subjects as long the participant did not overpower the tester. This was operationalized using three different testers during two different sessions with a healthy population. Arnold, Wakentin, Chilibeck, and Magnus (2010) identified the electronic hand-held dynamometer as a tool providing valid measurement of muscular strength for knee extension by comparing the tool with a Biodex System 3® isometric dynamometer.



Figure 5. Baseline™ Electronic Push/Pull Dynamometer. Retrieved from http://www.ptunited.com/measurement-dynamometers-and-accessories-c-87_93.html

Procedure

After obtaining ethical approval from the research ethics board of the academic institution and obtaining consent from the participant, each participant completed one testing session for a duration of 90 minutes. At the beginning of the session, each participant read and filled out an informed consent form (Appendix B) and Physical Activity Readiness Questionnaire for Everyone (PAR-Q+) form (Appendix C) to screen for any illnesses or contraindications concerning exercise (CSEP, 2013). Age, sex, height, and weight were then recorded. Leg dominance was also identified by asking the participant which leg he/she would use to kick a ball.

Each participant performed a 5 minute warm-up consisting of cycling on a stationary bicycle at a rate of 3-4 on the modified Rate of Perceived Exertion scale (Borg, 1982). Each session included four phases consisting of baseline ROM and vertical jump height measurements, followed by three separate stretching interventions (see Figure 6). Active knee extension ROM (degrees) and vertical jump height (cm) were measured a total of four times (at baseline without a stretching intervention, as well as immediately after each stretching

intervention was applied). Active knee extension ROM was measured using the Active Knee Extension Test, and vertical jump height was measured using the Static Vertical Jump Test. The three stretching techniques consisted of a static stretch, autogenic inhibition stretch, and reciprocal inhibition stretch. Stretching interventions were separated by a 10 minute rest period to ensure sufficient time for knee extension measurements to return to baseline. This time separation was deemed to be sufficient based on Depino et al. (2005) who reported that knee extension ROM returned to baseline 3 minutes after static stretching. Additionally, Ryan et al. (2008) identified that ROM measurements returned to baseline within 10 minutes when static stretching techniques were held for less than 2 minutes. The duration of 10 minutes is also supported by Spornoga, Uhl, Arnold, and Gansneder (2001) who reported that active knee extension ROM returned to baseline within 6 minutes after autogenic inhibition stretching was applied. The order in which each stretching intervention was performed was counterbalanced to ensure the absence of a learning effect.

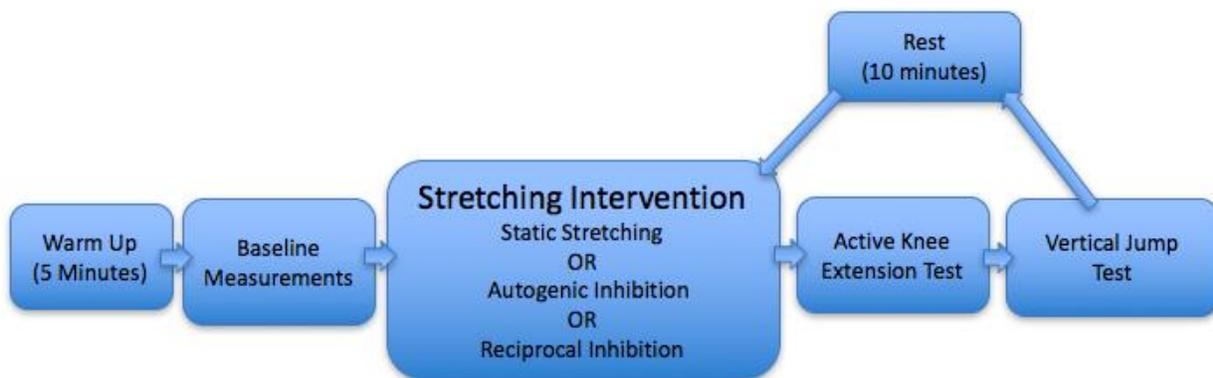


Figure 6. Session Overview. This figure identifies the order in which data collection was performed.

Active Knee Extension Test. Active knee extension ROM of the dominant leg was measured using an Active Knee Extension Test (see Figure 3). This test is consistent with methodologies used by Puente-dura et al. (2011) and Yuktasir and Kaya (2009). A point was first marked 10 cm distal to the tibial tuberosity on the anterior aspect of the tibia on the individual's dominant leg. The Active Knee Extension Test began with the participant lying in a supine position on a padded table. The participant's dominant leg was then held at 90 degrees of hip flexion and knee flexion. The student researcher held the hip at 90 degrees of flexion for each participant to ensure consistency. The participant was then instructed to extend the dominant knee as much as possible. Active knee extension was then measured by placing the inclinometer on the previously marked point on the tibia. It is important to note that during each Active Knee Extension Test or stretching technique, the limb not receiving a stretch/measurement remained at 90 degrees of knee flexion to eliminate stress on the neural tissue.



Figure 7. Active Knee Extension Test.

Static Vertical Jump Test. A Static Vertical Jump Test was performed using a modified CSEP vertical jump protocol. To begin the test, each participant was instructed to stand in an upright position with his/her feet shoulder width apart under the rungs of the Vertec™ device. The participant reached directly above his/her head displacing the highest available rung and then a standing reach height measurement (cm) was recorded. Before initiating the vertical jump, each participant entered a squatted position. The squatted position consisted of having the knees flexed to 90 degrees, arms placed at the participant's side, with his/her fingers pointing towards the ground. The squatted position was held for 3 seconds prior to the participant jumping vertically. The participant remained in a static position before jumping to eliminate the contributions of a counter movement which would include the stretch shortening cycle (Riggs & Sheppard, 2009). During the vertical jump, each participant was instructed to reach as high as possible to displace highest available rung with his/her dominant hand. During the baseline measurement test, the participant completed three practice trials to become familiarized with the test. Each vertical jump test, thereafter, consisted of three trials with a recovery time of 60 seconds in between each trial. The difference between the highest vertical jump trial and the initial standing reach height measurement was recorded. The arms also remained in a still position while perpendicular to the ground before the jump as the momentum of an arm swing has been reported to improve jumping performance by 10-15% (Baker, 1996).

Static Stretching. The static stretching procedure began with the participant lying in supine on a padded table. The participant then flexed both knees to 90 degrees. The limb receiving the stretch was then passively moved into 90 degrees of hip flexion while the knee was then passively extended. The passively extended knee was slowly brought to the initial point in which the participant indicated a stretching sensation without associated pain. The stretch was

applied for three repetitions of 30 seconds for each limb. This procedure is consistent with recommendations by Behm and Chaouachi (2011) for pre-activity stretching prior to exercise. Each repetition also alternated between limbs. Each stretching technique was applied to the non-dominant leg first before alternating legs after each repetition. This allowed an immediate measurement of knee extension ROM after the final stretch repetition was completed.

Autogenic Inhibition Stretching. The autogenic inhibition PNF stretching technique began with the participant lying in supine on a padded table. The first phase of the stretching technique was initiated by the student researcher passively flexing the participant's hip to 90 degrees, then passively extending the knee to the available end ROM position. The researcher then instructed the participant to maintain the current knee position by contracting the hamstring muscles while the researcher applied counteracting force to extend the knee. Normal muscular strength during a maximal contraction for the age group included in this study is 465 N for females, and 575 N for males (Bohannon, 1997). Because of the minimal amount of resistance required for an effective PNF stretching technique, only 10% of the normative data for females was applied for each repetition of PNF stretching (46 N). This amount of force is assumed to be submaximal due to the inclusion of healthy, physically active participants. The Baseline™ Electronic Push/Pull Dynamometer was used to ensure a consistent amount of resistance was applied for each repetition. Submaximal resistance was applied for 6 seconds for optimal, time-efficient results (Cornelius & Rauschuber, 1987). Following the application of the resistance, the participant was asked to relax the muscles and allow for the researcher to extend the knee to a new end-point. It is important to note that the muscle was not brought into stretch as this may initiate a stretch reflex. This position was held for 15 seconds and then brought back to a resting

position in which knees were flexed at 90 degrees with the participant's feet placed on the table. A total of three repetitions were performed, alternating legs for each repetition.

Reciprocal Inhibition Stretching. The reciprocal inhibition PNF stretching technique followed similar procedures that were described for the autogenic inhibition stretching technique. The reciprocal inhibition stretching technique only differed due to the altered placement of resistance. The researcher attempted to push the knee into flexion while the participant resisted this movement by isometrically contracting the quadriceps femoris muscle group. The duration and the amount of force remained consistent with the procedures identified for the autogenic inhibition stretching technique.

The three stretching techniques were applied to both the dominant and non-dominant legs as each leg would contribute to the performance of a vertical jump task. The student researcher was responsible for the application of each stretching technique and the completion of the ROM and vertical jump height measurements to ensure consistency. Data collected and used for analysis included the difference between baseline and post-stretching intervention measurements of knee extension ROM (degrees) and vertical jump height (cm).

Research Design

The design of the study was a randomized cross-over counterbalanced study as one group of participants experienced four conditions consisting of no treatment, static stretching, autogenic inhibition stretching, and reciprocal inhibition stretching techniques. The order in which the conditions were applied was counterbalanced to ensure an order effect was absent specific to knee extension ROM and vertical jump measurements.

Data Analysis

One independent variable was present in this study with three levels (autogenic inhibition, reciprocal inhibition, and static stretching techniques). The dependent variables included active knee extension ROM (degrees) and vertical jump height (cm). The data was analyzed first using descriptive statistics in association with the dependent variables included in the study. Therefore, the mean and standard deviation were calculated and analyzed for knee extension ROM (degrees) of the dominant leg and maximal vertical jump height (cm). To answer the research questions pertaining to the effects of autogenic inhibition, reciprocal inhibition, and static stretching techniques on ROM and vertical jump performance, a one-way ANOVA with repeated measures and Bonferroni's post hoc analysis was performed considering the independent variable separately for each dependent variable.

CHAPTER 4

Results

A one-way repeated measures ANOVA was conducted to compare the effects of autogenic inhibition, reciprocal inhibition, and static stretching on active knee extension ROM as measured in degrees. Mauchly's Test of Sphericity indicated that the assumption of sphericity was not violated $\chi^2(5) = 9.108, p = .105$. As a result, each stretching technique elicited statistically significant changes in active knee extension ROM compared to the initial ROM measurement, $F(3,87) = 60.521, p < .001$. Pairwise comparisons using the Bonferonni post hoc test (Table 1) was used to compare the effects of each stretching condition on active knee extension ROM. Static stretching (M=71.43 degrees, SD=12.77), autogenic inhibition stretching (M=71.73 degrees, SD=11.92), and reciprocal inhibition stretching (M=73.08 degrees, SD=12.22), significantly increased knee extension ROM when compared to the no stretching technique (M= 63.63 degrees, SD = 13.93) ($p < .001$). There was no significant difference in knee extension improvement between the three stretching techniques (see Table 2).

Table 2: Range of Motion Pairwise Comparisons

Stretching Intervention		Mean Difference (Degrees)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
No Stretching	SS	-7.797*	.825	.000	-10.133	-5.460
	AI	-8.103*	.843	.000	-10.492	-5.715
	RI	-9.453*	.972	.000	-12.206	-6.701
Static Stretch	NR	7.797*	.825	.000	5.460	10.133
	AI	-.307	.667	1.000	-2.195	1.581
	RI	-1.657	.703	.152	-3.646	.333
Autogenic Inhibition	NR	8.103*	.843	.000	5.715	10.492
	SS	.307	.667	1.000	-1.581	2.195
	RI	-1.350	.606	.204	-3.067	.367
Reciprocal Inhibition	NR	9.453*	.972	.000	6.701	12.206
	SS	1.657	.703	.152	-.333	3.646
	AI	1.350	.606	.204	-.367	3.067

Note.

NR is no stretching intervention

SS is static stretching

AI is autogenic inhibition stretching

RI is reciprocal inhibition stretching

* identifies a significant difference in knee extension ROM (degrees)

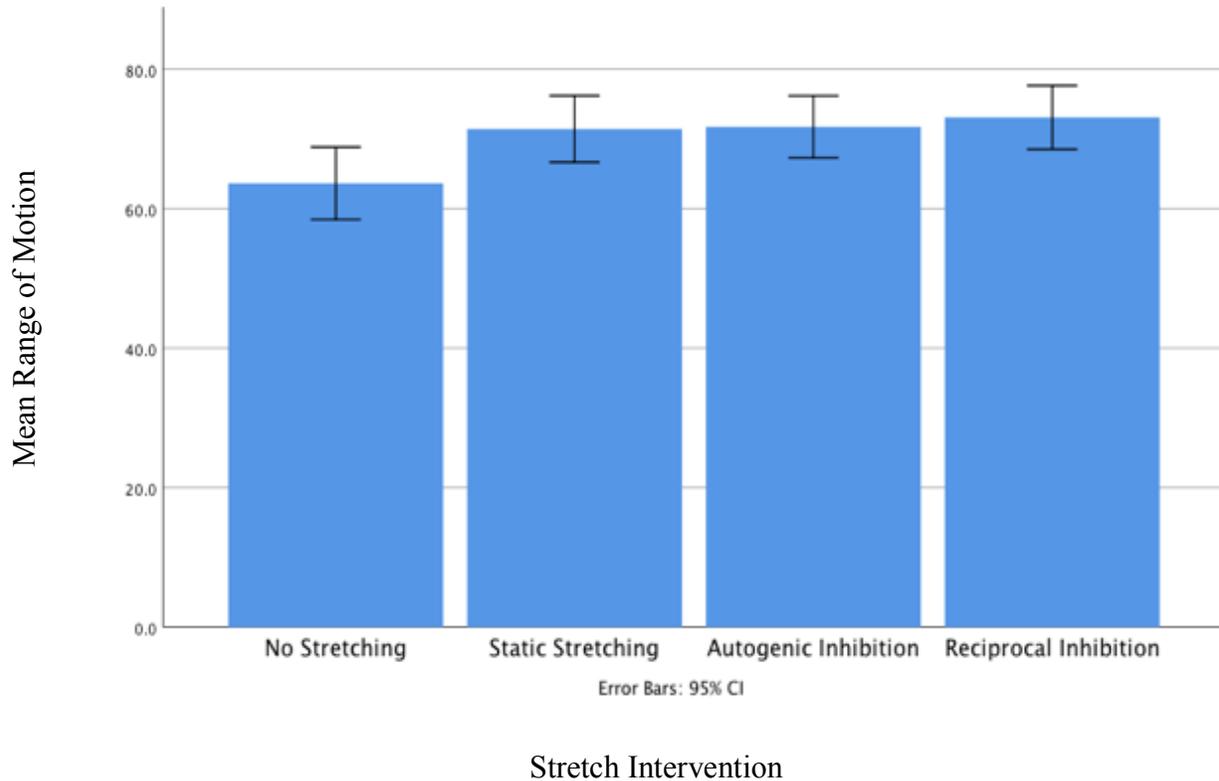


Figure 8. Mean Knee Extension Range of Motion. This figure identifies a significant increase in mean active knee extension ROM (degrees) after each stretching technique compared to no stretching.

Vertical Jump Performance

A one-way repeated measures ANOVA was conducted to compare the effects of autogenic inhibition, reciprocal inhibition, and static stretching on vertical jump height.

Mauchly's Test of Sphericity indicated that the assumption of sphericity was not violated $\chi^2(5) = 5.79, p = .327$. As a result, a statistically significant change in vertical jump height was evident after the initial measurement with no stretching technique intervention, $F(3,87) = 3.85, p < .05$.

Pairwise comparisons using the Bonferonni post hoc test (Table 2) was used to compare the effects of each stretching condition on vertical jump height. Compared to the no stretching

intervention (M=46.06 cm, SD=11.73), static stretching (M=46.14 cm, SD=11.5), autogenic inhibition (M=46.06 cm, SD=11.45), and reciprocal inhibition (M=45.8 cm, SD=11.05) each resulted in no significant differences in mean vertical jump height. Based on these results, no significant difference in vertical jump height (cm) was identified after the use of autogenic inhibition, reciprocal inhibition, or static stretching (see Table 3).

Table 3: Vertical Jump Height Pairwise Comparisons

Stretching Intervention		Mean Difference (cm)	Std. Error	Significance	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
1. No Stretching	SS	.550	.284	.372	-.253	1.353
	AI	.635	.249	.098	-.071	1.341
	RI	.889	.317	.054	-.009	1.787
2. Static Stretch	NR	-.550	.284	.372	-1.353	.253
	AI	.085	.235	1.000	-.582	.751
	RI	.339	.292	1.000	-.487	1.164
3. Autogenic Inhibition	NR	-.635	.249	.098	-1.341	.071
	SS	-.085	.235	1.000	-.751	.582
	RI	.254	.231	1.000	-.400	.908
4. Reciprocal Inhibition	NR	-.889	.317	.054	-1.787	.009
	SS	-.339	.292	1.000	-1.164	.487
	AI	-.254	.231	1.000	-.908	.400

Note.

NR is no stretching intervention

SS is static stretching

AI is autogenic inhibition stretching

RI is reciprocal inhibition stretching

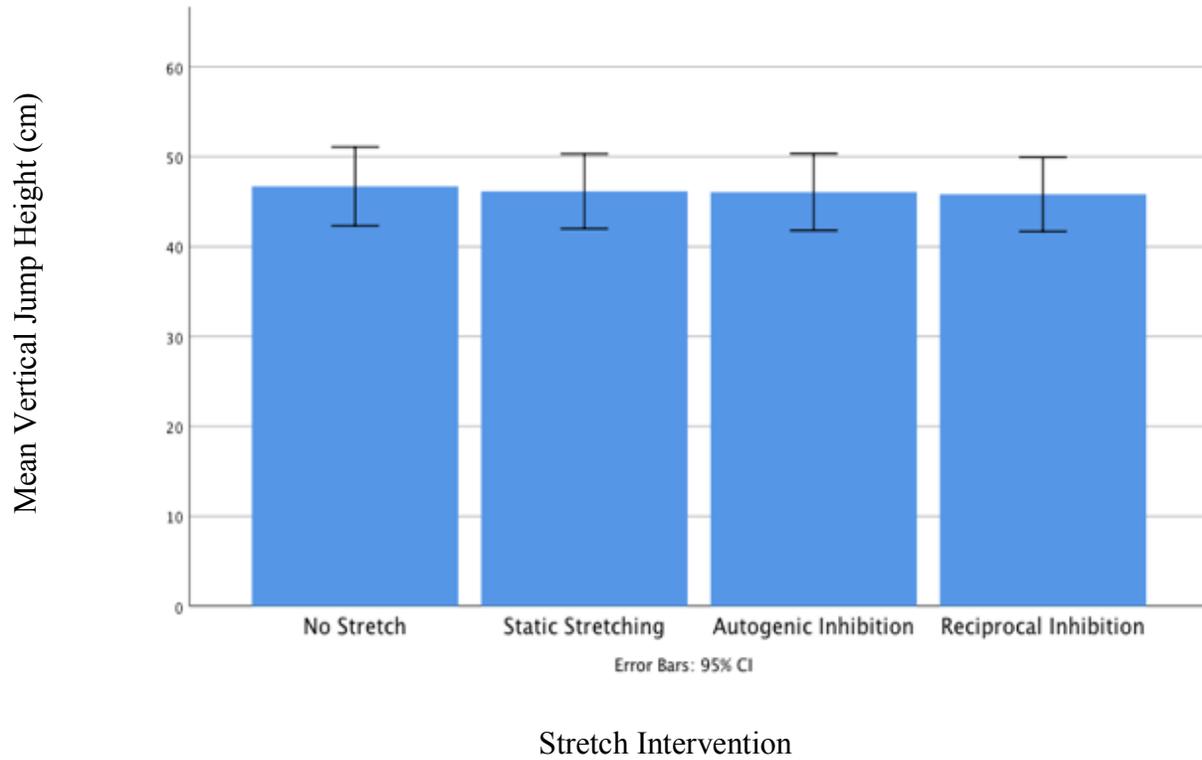


Figure 9. Mean Vertical Jump Height. This figure illustrates no significant differences in mean vertical jump height measurements (cm) after each stretching condition compared to no stretching.

CHAPTER 5

Discussion

This study was designed to assess and compare the effects of static, autogenic inhibition, and reciprocal inhibition stretching on active knee extension ROM and vertical jump height. The main results identified that each stretching technique significantly increased active knee extension ROM compared to the baseline measurements. The amount in which ROM increased, however, remained consistent regardless of which stretching technique was performed. No significance change was found in vertical jump height measurements irrespective of the stretching technique applied.

Range of Motion

Prior to this study, a clear understanding of the effectiveness of PNF stretching to increase ROM in comparison to static stretching was yet to be determined. A main reason for the lack of understanding could be attributed to procedural variability within PNF stretching in previous studies (Miyahara et al., 2013, Puendentura et al., 2007, Yuktasir and Kaya, 2009). Although previous studies have examined the effects of autogenic inhibition stretching techniques on knee extension ROM with other stretching techniques, different resistance phases have been utilized. Additionally, limited research exists comparing the effects of reciprocal inhibition stretching on ROM prior to exercise. By utilizing recommended pre-exercise stretching protocols specific to autogenic and reciprocal inhibition stretching techniques, the present study aimed to examine the effects of different PNF stretching techniques and static stretching and compare their effectiveness with no stretching prior to exercise.

Consistent with previous studies, autogenic inhibition stretching remained an effective method for improving knee extension ROM compared to the no stretching intervention

(Puentedura et al., 2011; Wallin et al., 1985; Yuktasir & Kaya, 2009). The increase in knee extension ROM because of this technique was speculated to be mainly due to autogenic inhibition. Based on this theory, it is assumed that when resistance was applied to the hamstring muscle group, lowered excitability of the alpha motor neuron pool was created. Since muscular activity within the hamstring muscles was lowered, knee extension was then able to be passively moved and held in an increased ROM without a counteracting stretch reflex (Guissard & Duchateau, 2006; Sharman et al., 2006).

Previous research has compared the increases in ROM associated with autogenic inhibition and static stretching. Yuktasir and Kaya (2009) reported no difference between stretching techniques which was supported further by Puentedura et al. (2011). These findings remained consistent in the present study as only a difference of 0.3 degrees of knee extension was evident between the two stretching techniques. Since each technique resulted in similar increases of knee extension ROM, it was speculated that each technique may have reduced the excitability of the of alpha motor neuron pool to avoid a stretch reflex to the same extent (Nakimura, Ikezoe, Takeno, & Ichihashi, 2010). Reduced excitability occurring after both static stretching and autogenic inhibition stretching could be a reason for the similar increases of knee extension ROM.

Contrary findings to the present study were identified by Miyahara et al. (2013), as the autogenic inhibition stretching technique provided significant increases in hip flexion ROM compared to the static stretching technique. Since the hamstring muscles were targeted similar to previous studies measuring knee extension ROM, future research is warranted to determine the effectiveness of autogenic inhibition stretching for specific joints and muscles. Another reason for the contrary findings may be due to the different movements that were resisted to target the

hamstrings. The present study targeted the hamstring muscles by resisting knee flexion, whereas Miyahara et al. (2013) targeted the hamstring muscles by resisting hip extension. Since the hamstring muscle is a two joint-muscle, the differences in results between the two studies could be due to resisting movement at the knee instead of the hip.

It should also be noted that Miyahara et al. (2013) utilized maximal resistance with the autogenic inhibition technique, which may be contraindicated prior to exercise. Avoiding a maximal contraction during PNF stretching prior to exercise is recommended particularly due to the potential for a higher level of muscular activity immediately after contraction, the risk of injury, and possible fatigue following maximal contractions (Feland & Marin, 2004). Although Miyahara et al. (2013) identified further increases in hip flexion ROM after PNF stretching using maximal resistance, a submaximal resistance was utilized in the present study due to its recommendation prior to exercise.

Among PNF stretching procedures, limited research exists examining the effects of reciprocal inhibition on ROM. As identified in Table 2, reciprocal inhibition stretching significantly increased knee extension ROM by 9.4 degrees compared to baseline measures. Despite limited research analyzing this type of PNF stretching technique, the immediate increase in knee extension ROM was expected due to the theory of reciprocal inhibition. This theory speculates that once resistance was applied to knee extension, proprioceptive constructs decreased nervous system activity within the opposing muscle group (hamstrings) to allow for the quadriceps contraction to occur (Davis et al., 2005; Rowlands et al., 2003; Sharman et al., 2006). Since nervous system activity was lowered in the hamstring muscles, knee extension was then able to be passively moved and held in an increased ROM without a counteracting stretch reflex (Guissard & Duchateau, 2006; Sharman et al., 2006).

When comparing increases in knee extension ROM between the three stretching techniques, it was evident that all three techniques produced similar results. Although reciprocal inhibition produced the highest mean increase in knee extension ROM (9.45 degrees) compared to static stretching (7.8 degrees) and autogenic inhibition stretching (8.1 degrees), the differences were not statistically significant. To date, only one study has compared the effects of these three stretching techniques on ROM with contrary results. Osternig et al. (1990) identified conflicting results as reciprocal inhibition stretching increased knee extension ROM by 9-13% more than both static and autogenic inhibition stretching. Conflicting results may be attributed to the variability between both PNF stretching procedures utilized in the study. During the resistance phase of autogenic inhibition stretching, the researchers resisted a maximal isometric contraction of the hamstrings muscle group. An altered application of resistance was performed during reciprocal inhibition stretching as the participant performed a maximal concentric contraction to extend the knee, without any resistance placed by a researcher. After applying resistance during the autogenic inhibition stretching technique, the increased range was held for 5 seconds. No description of further procedures however, was identified after the resistance phase of the reciprocal inhibition technique. As a result, the conflicting results may be due to the inconsistent procedures used by Osternig et al. (1990). The present study is, therefore, the first to utilize and compare consistent, recommended pre-activity procedures for autogenic and reciprocal inhibition stretching.

Prior to athletic performance, stretching is highly recommended to be performed as a part of a warm-up to increase ROM and reduce the risk of muscular injury (Miyahara et al., 2013; Safran et al., 1988; Worrell et al., 1994). Stretching of the hamstring muscles is particularly important because of high incidence of hamstring muscular strains in sports associated with

jumping (Petersen & Holmich, 2014). As highlighted in Table 2, static, autogenic inhibition, and reciprocal inhibition stretching significantly increased knee extension ROM compared to no stretching. The risk for muscular injury is speculated to be reduced by stretching as part of a warm up. This is reasoned to be due to an enhanced ability of the musculotendinous unit to adapt to imposed stresses after the muscle has been stretched (Safran et al., 1988; Weppeler & Magnusson, 2010; Worrell & Perrin, 1992).

Based on the results of this study, all three stretching techniques can be performed as effective options for increasing ROM prior to athletic performance. Static stretching, however, may be recommended as the preferred stretching technique due to the similar increases in knee extension ROM. This recommendation is similar to studies by Puentedura et al. (2011) and Yuktasir and Kaya (2009) due to the complexity and technique associated with PNF stretching procedures. Static stretching may also be recommended as PNF stretching often requires the assistance of a partner during the resistance phase of the stretch. As a result, static stretching is easier and more convenient to be performed compared to PNF stretching.

Vertical Jump Height

As part of a warm-up routine, stretching is traditionally performed to increase ROM, reduce the risk of injury, and promote better performance (Bradley et al., 2007; Weppeler & Magnusson, 2010). Stretching is particularly emphasized prior to sports involving jumping because hamstring muscular injuries commonly occur as a result of this athletic movement (Petersen & Holmich, 2005). Among stretching techniques, static stretching is known to cause potential decreases in vertical jump performance when repetitions are held for 60 seconds or longer (Behm & Chaouachi, 2011). One reason for decreased performance may be because of neural inhibition which may affect muscular activation during performance (Young & Behm,

2003). Furthermore, possible performance decreases may be a result of decreased musculotendinous stiffness, which has been found to reduce the speed of force transmission, limiting force production (Bradley et al., 2007; Young, Ballarat, & Behm, 2002). Limited research, however, exists identifying the effects of PNF stretching techniques on vertical jump performance.

Vertical jump height remained consistent after static, autogenic inhibition, and reciprocal inhibition stretching compared to no stretching (see Table 3). These results support Christensen and Nordstrom (2008) who identified no difference in vertical jump height before or after performing autogenic inhibition stretching. Similarly, Yuktasir and Kaya (2009) also identified no difference in vertical jump height before or after an autogenic inhibition stretching technique was performed. Since vertical jump height remained consistent despite the presence or absence of static or PNF stretching techniques, it is assumed that neural inhibition and decreased musculotendinous stiffness returned to baseline prior to the completing the vertical jump test. More research, however, is needed to examine these mechanisms more directly. As a result, it was identified that either PNF stretching technique may be utilized as part of a warm-up, without hindering vertical jump performance.

Bradley et al. (2007) compared the effects of static and PNF stretching on vertical jump performance. Among the three stretching procedures, PNF stretching was recorded as the only technique detrimental to performance. After PNF stretching was performed, vertical jump decreased by approximately 5% compared to static and ballistic stretching. Since PNF stretching contains an additional resistance component to alter neural activity, these findings were reasoned to be due PNF stretching's ability to decrease neural activity and decrease musculotendinous stiffness more than that of static stretching.

The conflicting results identified by Bradley et al. (2007) may be due to two main reasons. First, different methods were utilized to measure jump height in each study. Although Bradley et al. (2007) measured jump height (cm), it was not clear how jump height was measured or defined. Contrasting studies by Christensen and Nordstrom (2008) and Yuktasir & Kaya (2009) utilized a Just Jump system[®] and drop jump procedure, respectively. Both studies identified no significant effects on vertical jump height after autogenic inhibition stretching techniques were performed. Insufficient detail was also provided by Bradley et al. (2007) as specific vertical jump height associated with each stretching technique were not reported. Consequently, it is difficult to compare the results of Bradley et al. (2007) to other studies particularly as the methodological approach for measuring jump height, as well as reported findings, were not apparent.

Additionally, the intensity of contraction used during the resistance phase of each study may explain the difference in vertical jump findings. The present study utilized submaximal resistance similar to Christensen and Nordstrom (2008) and Yuktasir and Kaya (2009) and identified no differences in vertical jump height before or after stretching. These findings contradict Bradley et al. (2007) who utilized a maximal contraction during the resistance phase of PNF stretching. Since the PNF stretching procedures that included maximal resistance negatively affected vertical jump performance, the effect of PNF stretching on performance may be dependent on the intensity of contraction performed during resistance. Submaximal resistance may be optimal due to the lasting effects on nervous system activity which could negatively impact vertical jump performance. Furthermore, the use of maximal contractions prior to performance poses a risk for induced muscle soreness or muscular strain and should be avoided (Feland & Marin, 2004).

Our study was the first to compare the effects of static, autogenic inhibition, and reciprocal inhibition stretching on vertical jump performance using recommended pre-activity procedures. Despite the potential for static and PNF stretching to decrease performance, the results of this study identified no differences in vertical jump height before or after stretching was performed (see Table 2). The results of this study indicate that both static and PNF stretching, using recommended pre-activity procedures, offer effective options for improving ROM as part of a warm up without affecting vertical jump performance.

Limitations

To date, this study was the first to examine and compare the PNF stretching procedures using recommended pre-activity procedures. Since convenience sampling of a normal population was used in this study, a limitation may reside in the varying fitness levels and experience associated with stretching and vertical jumping. Varying fitness levels may have affected results as a degree of fatigue may have reduced jump height during the final trials. Participants with limited experience vertically jumping may have also experienced a learning effect. If a learning effect was present, vertical jump heights may have increased as the trials progressed. Similarly, this study did not limit exercise or flexibility training prior to participating in the study. A limitation could be present based on activities performed prior to testing. If a participant performed stretching exercises prior to the testing session, then the initial baseline ROM measurements may have been increased. As a result, the stretching techniques performed thereafter would have had a limited effect. The way in which ROM was measured could also be a limitation. During the Active Knee Extension Test, the participant's hip was brought into 90 degrees of hip flexion and held in this position by the researcher. A limitation may, therefore, be present as a specialized device was not used to ensure 90 degrees of hip flexion was maintained

during knee extension. If the participant compensated their posture and extended at the hip during the Active Knee Extension Test, then increased knee extension ROM measurements may have been collected. After each repetition of PNF stretching, the knee was brought back to 90 degrees of flexion and the leg was lowered to the mat prior to the next repetition. A limitation is present as further increases in knee extension ROM may have occurred if resistance was applied immediately following the first repetition, while in the newly acquired ROM.

Delimitations

This study was designed to simulate a general warm-up prior to physical activity involving jumping. Participants in this study were delimited to a normal population consisting of healthy males and females who were moderately active to avoid the risk of injury. The present study targeted the hamstrings muscle group and was delimited to the use of two PNF stretching techniques and static stretching. Therefore, the results in the present study cannot be generalized to additional muscle groups or joints. A static vertical jump was performed in this study to directly compare the effects of static, autogenic inhibition, and reciprocal inhibition stretching techniques on a maximal athletic performance measure (Yuktasir & Kaya, 2009). This performance measure has been strongly correlated to sports such as American football, diving, weightlifting, and sprinting (Carlock et al., 2004; Leard et al., 2007).

CHAPTER 6

Conclusion

Our study was the first to examine and compare the effects of static, autogenic inhibition, and reciprocal inhibition stretching techniques using recommended pre-activity procedures. The results of this study identified static, autogenic inhibition, and reciprocal inhibition stretching as effective mechanisms for significantly improving ROM, without decreasing vertical jump height. Both autogenic inhibition and reciprocal inhibition stretching techniques are effective options to be utilized as part of a standard warm-up routine prior to exercise. Since the use of PNF stretching encompasses a more complex procedure, the use of static stretching could be recommended to avoid injury and ensure optimal performance in a timely manner.

Future Research

This study utilized PNF stretching to target the hamstring muscle and increase knee extension ROM. Since the hamstring muscles affect movement at both the hip and the knee, future research may be warranted to identify the effects of this stretching technique on hip flexion as well as knee extension. Future research is also needed to identify the effects of this stretching technique on different joints and performance measures. Further investigation of physiological explanations for the increased ROM associated with PNF stretching techniques is also needed.

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Appendix A
Recruitment Poster



PARTICIPANTS WANTED FOR RESEARCH:
Comparing the effects of two proprioceptive neuromuscular facilitation stretching techniques and static stretching on active knee extension range of motion and vertical jump performance.

Conducted by:
 Nick Vaillant
 School of Kinesiology
 Lakehead University

You are eligible to participate if...

- You are healthy between the ages of 18 – 30 years
- You perform 150 minutes of moderate to high intensity exercise per week

The Study will include:

- One session of approximately 1 hour and 30 minutes
- 4 Knee Extension Range of Motion tests
- 4 Vertical Jump Tests
- 3 Stretching Techniques: Static Stretching, Autogenic Inhibition Stretching, and Reciprocal Inhibition Stretching



You are NOT eligible if...

- You have injuries relating to jumping, stretching, or reaching
- You have an illness or condition where maximal physical exertion should be avoided

If you are interested in volunteering or would like more information email:

Nick Vaillant
nvaillan@lakeheadu.ca
 OR
 Supervisor Dr. Ian Newhouse
ian.newhouse@lakeheadu.ca

This study has been approved by the Lakehead University Research Ethics Board

Appendix B
Information Letter



School of Kinesiology
t: (807) 343-8544
f: (807) 343-8944

Dear Potential Participant,

Thank you for having an interest in the study titled "Comparing the effects of static stretching and two proprioceptive neuromuscular facilitation techniques on range of motion and vertical jump performance." Lakehead University graduate student Nicholas Vaillant will be in charge of the study under the supervision of Dr. Ian Newhouse. The purpose of this study is to compare the effects of static stretching, autogenic inhibition, and reciprocal inhibition techniques on active knee extension ROM and vertical jump performance. Static stretching involves a joint being brought and held at the end range of motion. Autogenic and reciprocal inhibition stretching are performed by applying a small amount of force to the joint before being brought into the end range of motion. This study will compare the three techniques because of the benefits associated with discovering which stretching technique should be performed before exercise. If you chose to be a part of the following study, you may benefit by being exposed to the how to properly perform each stretching exercise, as well as the vertical jump test.

The reason why we would like you to be in the study is because you are healthy, able to complete a vertical jump, and between the ages of 18 and 30. You are a volunteer and you may quit the study at any given time. You are also free to decline to answer any questions we ask or refuse to partake in laboratory testing without consequence.

The study will consist of one testing session for a total duration of approximately 1.5 hours. The testing procedures will begin with you performing a brief warm-up, followed by a knee extension range of motion measurement and a vertical jump test. The knee extension range of motion measurement will begin with you laying on your back and lifting your knee towards your chest. The research will assist you in maintaining this position while you extend your knee as far as possible. The vertical jump test will begin with you holding a squat position for 3 seconds with your arms by your side. You will then jump as high as possible pushing the highest swivel on the Vertec™ device. Both the distance in which you can extend your knee and the vertical jump height will be used as numerical data in the study. After these measurements are taken, the researcher Nicholas Vaillant will assist you in performing the 3 previously discussed stretching techniques to the hamstring muscles. Each stretching technique will be performed in a random order, with knee range of motion and vertical jump height measurements occurring after each stretching technique is performed.

Although safety is our primary concern, there are possible risk factors in the study. Injuries such as muscular strains or cardiovascular complications may arise as you try to jump as high as possible. These potential injuries or complications however have been reduced because of the inclusion of a warm-up at the beginning of the study.

Upon completion of the study, the results may be published and/or presented orally at a future conference. To ensure confidentiality and anonymity, no names will be entered into the data or published results or oral presentations will not indicate individual participants. The data gained from the study will remain with the researchers involved with all forms of confidentiality enforced. Upon request, we can provide you a copy of your individual results as well as the published results. Following the retrieval of information, data will be stored on a document enclosed in a password protected external hard drive. Any hard copy data sheets will be kept in a locked filing cabinet in the office of Dr. Newhouse at Lakehead University. These data sheets will be accessible by the researcher and supervisor for a minimum of 5 years.

If you wish to be in the research study “Comparing the effects of static stretching and two proprioceptive neuromuscular facilitation techniques on range of motion and vertical jump performance,” please complete and return the informed consent form and PAR-Q form to the researcher. The following research project has been reviewed and has received ethics clearance through a Lakehead University Research Ethics Committee and if you have any concerns or questions or require further information about the study, be sure to contact one of the researchers at the e-mail addresses listed below. Your participation is greatly appreciated. Thank you for your consideration!

Sincerely,

Nicholas Vaillant

Researcher

nvaillant@lakeheadu.ca

Dr. Ian Newhouse

Research Supervisor

ian.newhouse@lakeheadu.ca

Appendix C
Consent Form



School of Kinesiology
t: (807) 343-8544
f: (807) 343-8944

I _____ agree to take part in the study titled

(Print Full Name)

“Comparing the effects of static stretching and two proprioceptive neuromuscular facilitation techniques on range of motion and vertical jump performance.” I understand this study will include four separate knee extension and vertical jump tests and graduate student Nicholas Vaillant will lead the study under the supervision of Dr. Ian Newhouse.

I have read and understood the information letter. I understand the potential risks of muscular strain that may occur as a result of jumping as high as possible during the vertical jump test. I also understand that I may benefit from the study by learning how to properly use each of the three stretches.

I understand that taking part in this study is completely voluntary and that I have the right to stop taking part at any time during the study. I also understand that all personal information that I may provide will remain confidential as only the researcher Nicholas Vaillant and supervisor Dr. Newhouse will have access to this data for a minimum of 5 years.

This study has been approved by the Lakehead University Research Ethics Board. If you have any questions related to the ethics of the research and would like to speak to someone outside of the research team please contact Sue Wright at the Research Ethics Board at 807-343-8283 or research@lakeheadu.ca.

I also understand I can access my personal data and the final report by contacting the researchers through email upon the completion of the study.

Signature of Participant

Date (DD/MM/YYYY)

Signature of Witness

Date (DD/MM/YYYY)

Appendix D

Physical Activity Readiness Questionnaire for Everyone.

Physical Activity Readiness Questionnaire for Everyone.

CSEP approved Sept 12 2011 version

PAR-Q+

The Physical Activity Readiness Questionnaire for Everyone

Regular physical activity is fun and healthy, and more people should become more physically active every day of the week. Being more physically active is very safe for MOST people. This questionnaire will tell you whether it is necessary for you to seek further advice from your doctor OR a qualified exercise professional before becoming more physically active.

SECTION 1 - GENERAL HEALTH

Please read the 7 questions below carefully and answer each one honestly: check YES or NO.		YES	NO
1.	Has your doctor ever said that you have a heart condition OR high blood pressure?	<input type="checkbox"/>	<input type="checkbox"/>
2.	Do you feel pain in your chest at rest, during your daily activities of living, OR when you do physical activity?	<input type="checkbox"/>	<input type="checkbox"/>
3.	Do you lose balance because of dizziness OR have you lost consciousness in the last 12 months? Please answer NO if your dizziness was associated with over-breathing (including during vigorous exercise).	<input type="checkbox"/>	<input type="checkbox"/>
4.	Have you ever been diagnosed with another chronic medical condition (other than heart disease or high blood pressure)?	<input type="checkbox"/>	<input type="checkbox"/>
5.	Are you currently taking prescribed medications for a chronic medical condition?	<input type="checkbox"/>	<input type="checkbox"/>
6.	Do you have a bone or joint problem that could be made worse by becoming more physically active? Please answer NO if you had a joint problem in the past, but it does not limit your current ability to be physically active. For example, knee, ankle, shoulder or other.	<input type="checkbox"/>	<input type="checkbox"/>
7.	Has your doctor ever said that you should only do medically supervised physical activity?	<input type="checkbox"/>	<input type="checkbox"/>

If you answered NO to all of the questions above, you are cleared for physical activity.



Go to Section 3 to sign the form. You do not need to complete Section 2.

- › Start becoming much more physically active – start slowly and build up gradually.
- › Follow the Canadian Physical Activity Guidelines for your age (www.csep.ca/guidelines).
- › You may take part in a health and fitness appraisal.
- › If you have any further questions, contact a qualified exercise professional such as a CSEP Certified Exercise Physiologist® (CSEP-CEP) or CSEP Certified Personal Trainer® (CSEP-CPT).
- › If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.



If you answered YES to one or more of the questions above, please GO TO SECTION 2.



Delay becoming more active if:

- › You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
- › You are pregnant – talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
- › Your health changes – please answer the questions on Section 2 of this document and/or talk to your doctor or qualified exercise professional (CSEP-CEP or CSEP-CPT) before continuing with any physical activity programme.

SECTION 2 - CHRONIC MEDICAL CONDITIONS

Please read the questions below carefully and answer each one honestly: check YES or NO.		YES	NO
1.	Do you have Arthritis, Osteoporosis, or Back Problems?	<input type="checkbox"/> If yes, answer questions 1a-1c	<input type="checkbox"/> If no, go to question 2
1a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	<input type="checkbox"/>	<input type="checkbox"/>
1b.	Do you have joint problems causing pain, a recent fracture or fracture caused by osteoporosis or cancer, displaced vertebra (e.g., spondylolisthesis), and/or spondylolysis/pars defect (a crack in the bony ring on the back of the spinal column)?	<input type="checkbox"/>	<input type="checkbox"/>
1c.	Have you had steroid injections or taken steroid tablets regularly for more than 3 months?	<input type="checkbox"/>	<input type="checkbox"/>
2.	Do you have Cancer of any kind?	<input type="checkbox"/> If yes, answer questions 2a-2b	<input type="checkbox"/> If no, go to question 3
2a.	Does your cancer diagnosis include any of the following types: lung/bronchogenic, multiple myeloma (cancer of plasma cells), head, and neck?	<input type="checkbox"/>	<input type="checkbox"/>
2b.	Are you currently receiving cancer therapy (such as chemotherapy or radiotherapy)?	<input type="checkbox"/>	<input type="checkbox"/>
3.	Do you have Heart Disease or Cardiovascular Disease? This includes Coronary Artery Disease, High Blood Pressure, Heart Failure, Diagnosed Abnormality of Heart Rhythm	<input type="checkbox"/> If yes, answer questions 3a-3e	<input type="checkbox"/> If no, go to question 4
3a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	<input type="checkbox"/>	<input type="checkbox"/>
3b.	Do you have an irregular heart beat that requires medical management? (e.g. atrial brillation, premature ventricular contraction)	<input type="checkbox"/>	<input type="checkbox"/>
3c.	Do you have chronic heart failure?	<input type="checkbox"/>	<input type="checkbox"/>
3d.	Do you have a resting blood pressure equal to or greater than 160/90 mmHg with or without medication? (Answer YES if you do not know your resting blood pressure)	<input type="checkbox"/>	<input type="checkbox"/>
3e.	Do you have diagnosed coronary artery (cardiovascular) disease and have not participated in regular physical activity in the last 2 months?	<input type="checkbox"/>	<input type="checkbox"/>
4.	Do you have any Metabolic Conditions? This includes Type 1 Diabetes, Type 2 Diabetes, Pre-Diabetes	<input type="checkbox"/> If yes, answer questions 4a-4c	<input type="checkbox"/> If no, go to question 5
4a.	Is your blood sugar often above 13.0 mmol/L? (Answer YES if you are not sure)	<input type="checkbox"/>	<input type="checkbox"/>
4b.	Do you have any signs or symptoms of diabetes complications such as heart or vascular disease and/or complications affecting your eyes, kidneys, and the sensation in your toes and feet?	<input type="checkbox"/>	<input type="checkbox"/>
4c.	Do you have other metabolic conditions (such as thyroid disorders, pregnancy-related diabetes, chronic kidney disease, liver problems)?	<input type="checkbox"/>	<input type="checkbox"/>
5.	Do you have any Mental Health Problems or Learning Difficulties? This includes Alzheimer's, Dementia, Depression, Anxiety Disorder, Eating Disorder, Psychotic Disorder, Intellectual Disability, Down Syndrome)	<input type="checkbox"/> If yes, answer questions 5a-5b	<input type="checkbox"/> If no, go to question 6
5a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	<input type="checkbox"/>	<input type="checkbox"/>
5b.	Do you also have back problems affecting nerves or muscles?	<input type="checkbox"/>	<input type="checkbox"/>

Please read the questions below carefully and answer each one honestly: check YES or NO.		YES	NO
6.	Do you have a Respiratory Disease? This includes Chronic Obstructive Pulmonary Disease, Asthma, Pulmonary High Blood Pressure	<input type="checkbox"/> If yes, answer questions 6a-6d	<input type="checkbox"/> If no, go to question 7
6a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	<input type="checkbox"/>	<input type="checkbox"/>
6b.	Has your doctor ever said your blood oxygen level is low at rest or during exercise and/or that you require supplemental oxygen therapy?	<input type="checkbox"/>	<input type="checkbox"/>
6c.	If asthmatic, do you currently have symptoms of chest tightness, wheezing, laboured breathing, consistent cough (more than 2 days/week), or have you used your rescue medication more than twice in the last week?	<input type="checkbox"/>	<input type="checkbox"/>
6d.	Has your doctor ever said you have high blood pressure in the blood vessels of your lungs?	<input type="checkbox"/>	<input type="checkbox"/>
7.	Do you have a Spinal Cord Injury? This includes Tetraplegia and Paraplegia	<input type="checkbox"/> If yes, answer questions 7a-7c	<input type="checkbox"/> If no, go to question 8
7a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	<input type="checkbox"/>	<input type="checkbox"/>
7b.	Do you commonly exhibit low resting blood pressure significant enough to cause dizziness, light-headedness, and/or fainting?	<input type="checkbox"/>	<input type="checkbox"/>
7c.	Has your physician indicated that you exhibit sudden bouts of high blood pressure (known as Autonomic Dysreflexia)?	<input type="checkbox"/>	<input type="checkbox"/>
8.	Have you had a Stroke? This includes Transient Ischemic Attack (TIA) or Cerebrovascular Event	<input type="checkbox"/> If yes, answer questions 8a-c	<input type="checkbox"/> If no, go to question 9
8a.	Do you have difficulty controlling your condition with medications or other physician-prescribed therapies? (Answer NO if you are not currently taking medications or other treatments)	<input type="checkbox"/>	<input type="checkbox"/>
8b.	Do you have any impairment in walking or mobility?	<input type="checkbox"/>	<input type="checkbox"/>
8c.	Have you experienced a stroke or impairment in nerves or muscles in the past 6 months?	<input type="checkbox"/>	<input type="checkbox"/>
9.	Do you have any other medical condition not listed above or do you live with two chronic conditions?	<input type="checkbox"/> If yes, answer questions 9a-c	<input type="checkbox"/> If no, read the advice on page 4
9a.	Have you experienced a blackout, fainted, or lost consciousness as a result of a head injury within the last 12 months OR have you had a diagnosed concussion within the last 12 months?	<input type="checkbox"/>	<input type="checkbox"/>
9b.	Do you have a medical condition that is not listed (such as epilepsy, neurological conditions, kidney problems)?	<input type="checkbox"/>	<input type="checkbox"/>
9c.	Do you currently live with two chronic conditions?	<input type="checkbox"/>	<input type="checkbox"/>

Please proceed to Page 4 for recommendations for your current medical condition and sign this document.

PAR-Q+



If you answered NO to all of the follow-up questions about your medical condition, you are ready to become more physically active:

- › It is advised that you consult a qualified exercise professional (e.g., a CSEP-CEP or CSEP-CPT) to help you develop a safe and effective physical activity plan to meet your health needs.
- › You are encouraged to start slowly and build up gradually – 20-60 min. of low- to moderate-intensity exercise, 3-5 days per week including aerobic and muscle strengthening exercises.
- › As you progress, you should aim to accumulate 150 minutes or more of moderate-intensity physical activity per week.
- › If you are over the age of 45 yrs. and NOT accustomed to regular vigorous physical activity, please consult a qualified exercise professional (CSEP-CEP) before engaging in maximal effort exercise.



If you answered YES to one or more of the follow-up questions about your medical condition:

- › You should seek further information from a licensed health care professional before becoming more physically active or engaging in a fitness appraisal and/or visit a or qualified exercise professional (CSEP-CEP) for further information.



Delay becoming more active if:

- › You are not feeling well because of a temporary illness such as a cold or fever – wait until you feel better
- › You are pregnant - talk to your health care practitioner, your physician, a qualified exercise professional, and/or complete the PARmed-X for Pregnancy before becoming more physically active OR
- › Your health changes - please talk to your doctor or qualified exercise professional (CSEP-CEP) before continuing with any physical activity programme.

SECTION 3 - DECLARATION

- › You are encouraged to photocopy the PAR-Q+. You must use the entire questionnaire and NO changes are permitted.
- › The Canadian Society for Exercise Physiology, the PAR-Q+ Collaboration, and their agents assume no liability for persons who undertake physical activity. If in doubt after completing the questionnaire, consult your doctor prior to physical activity.
- › If you are less than the legal age required for consent or require the assent of a care provider, your parent, guardian or care provider must also sign this form.
- › Please read and sign the declaration below:

I, the undersigned, have read, understood to my full satisfaction and completed this questionnaire. I acknowledge that this physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if my condition changes. I also acknowledge that a Trustee (such as my employer, community/fitness centre, health care provider, or other designate) may retain a copy of this form for their records. In these instances, the Trustee will be required to adhere to local, national, and international guidelines regarding the storage of personal health information ensuring that they maintain the privacy of the information and do not misuse or wrongfully disclose such information.

NAME _____ DATE _____

SIGNATURE _____ WITNESS _____

SIGNATURE OF PARENT/GUARDIAN/CARE PROVIDER _____

**For more information, please contact:
Canadian Society for Exercise Physiology
www.csep.ca**

KEY REFERENCES

1. Jamnik VJ, Warburton DER, Makarski J, McKenzie DC, Shephard RJ, Stone J, and Gledhill N. Enhancing the effectiveness of clearance for physical activity participation; background and overall process. APNM 36(S1):S3-S13, 2011.
2. Warburton DER, Gledhill N, Jamnik VK, Bredin SSD, McKenzie DC, Stone J, Charlesworth S, and Shephard RJ. Evidence-based risk assessment and recommendations for physical activity clearance; Consensus Document. APNM 36(S1):S266-s298, 2011.

The PAR-Q+ was created using the evidence-based AGREE process (1) by the PAR-Q+Collaboration chaired by Dr. Darren E. R. Warburton with Dr. Norman Gledhill, Dr. Veronica Jamnik, and Dr. Donald C. McKenzie (2). Production of this document has been made possible through financial contributions from the Public Health Agency of Canada and the BC Ministry of Health Services. The views expressed herein do not necessarily represent the views of the Public Health Agency of Canada or BC Ministry of Health Services.