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The Effects of Two Different Post-Exercise Stretching Modalities on Delayed Onset Muscular Soreness in Adults

Ryan P. McGrath

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THE EFFECTS OF TWO DIFFERENT POST-EXERCISE STRETCHING MODALITIES ON
DELAYED ONSET MUSCULAR SORENESS IN ADULTS

by

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Bachelor of Arts, Jamestown College, 2007

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Submitted to the Graduate Faculty

of the

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in partial fulfillment of the requirements

for the degree of

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This thesis, submitted by Ryan P. McGrath in partial fulfillment of the requirements for the Degree of Master of Science from the University of North Dakota, has been read by the Faculty Advisory Committee under whom the work has been done and is hereby approved.

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Title The Effects of Two Different Post-Exercise Stretching Modalities on
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ABSTRACT

Until recently, research suggested that post-exercise stretching may reduce delayed onset muscle soreness (DOMS) in those who exercise; however, newer research indicates that stretching has no effect on DOMS. However, it appears that the effect of proprioceptive neuromuscular facilitation (PNF) stretching on preventing DOMS has not been adequately studied. The primary purpose of the study was to research the effect of PNF stretching on DOMS. The secondary purpose was to evaluate if one's level of flexibility had a correlation with high levels of DOMS. The study was a posttest-only control group design. Participants were randomly assigned into a stretching group (PNF, static, control) after performing a DOMS inducing exercise. Participants then rated their soreness level on a pain scale (range 1-6) 24 and 48 (plus or minus 2 hours) hours after the DOMS inducing exercise. Flexibility also was measured to see if the participants muscle range was correlated to DOMS. The main result showed that there was no difference between PNF stretching and reduced pain scores. Other results showed that there was a correlation between the 48 hour post-exercise pain score and pre-post flexibility change in the PNF stretch group ($p < .01$), a correlation between the 48 hour post-exercise pain score and pre-exercise stretch score overall ($p < .05$), and a correlation between the 48 hour post-exercise pain score and the post-exercise stretch score overall ($p < .05$). The results suggest that PNF stretches may have possibly placed a load on an already damaged muscle causing more strain on the trained muscle. Suggestions for future research include a prolonged study similar to this, assess ones DOMS level by

using biochemical markers, or use of vibration platform training with a stretching protocol.

CHAPTER I

INTRODUCTION

There is often nothing more satisfying for those who exercise than completing a hard, intense workout; however, there may be nothing more annoying than the pain and stiffness that may follow the workout. It is believed by some that stretching after exercising will reduce the amount of soreness they may feel (Bobbert, Hollander, & Huijing (1986). There are many different types of stretches that individuals may perform to try to reduce muscle soreness.

Flexibility is one of the five major components of health-related fitness (Corbin & Lindsey, 2005). Stretching is often the most neglected component of exercise (Hedrick, 1993). Proposed benefits of stretching include increasing muscular performance and an increased range of motion, reduction of injury, and stretching of tendons (Pollock et al., 1998). Although these are great reasons for individuals to stretch, those who exercise often neglect flexibility and stretching. It may be that some people may not stretch because they believe that stretching is too time consuming and pointless (Hedrick, 1993). Others do not like the pulling and discomfort that occurs during stretching. In addition, stretching/flexibility are often not associated with exercise goals of most people (Hedrick, 1993).

It has been suggested that a general stretching program that exercises the major muscle/tendon groups should be developed using different types of stretching (Pollock et al., 1998). Generally, there are three major types of stretches: static, ballistic, and proprioceptive neuromuscular facilitation (PNF) (Pollock et al., 1998). All three types of stretches may be done actively (stretch agonist muscle with the antagonist muscle) or passively (assistance from other non-antagonist muscles, an assistant, or from an apparatus). PNF stretching is defined as alternating isometric contraction combined with passive stretching through a selected series of motions (McAtee, 2007). The key point when performing PNF stretching is to pre-contract the muscle being stretched. An example of PNF stretching may include an individual holding another person's leg perpendicular to the ground at which point he/she contacts the muscle for a short period of time.

Ballistic stretching involves repetitive bouncing motions where the muscle is rapidly stretched and immediately relaxed. It is important to know that ballistic stretching uses momentum to produce the stretch. There is concern that when one performs ballistic stretching, it may overstrain the muscle resulting in injury (Corbin & Lindsey, 2005). Due to the possible muscular damage involved with ballistic stretching, some may not recommend that one performs ballistic stretching unless ballistic stretching is specific to the individuals exercise regimen (Corbin & Lindsey, 2005).

Static stretches are done actively and passively. It is important to know that static stretches should be held for ten to thirty seconds (Pollock et al., 1998). About four repetitions per muscle group should be completed for a minimum of two to three days per

week for static stretching (Pollock et al., 1998). Although this is a recommended amount, individuals may not do what is recommended in order to suit their individual needs.

Pollock et al. (1998) suggested that it is not in the best interest for individuals to neglect stretching because doing so may be harmful to their bodies. The positive effects of stretching significantly outweigh the negative (Hume, Cheung, Maxwell, & Weerapong, 2004). Flexibility is an important aspect of health related fitness, and stretching is often necessary to obtain flexibility. Regular stretching has traditionally been recommended for several reasons because it is an important component in sport, health, and fitness (Corbin & Lindsay, 2005).

Soreness after exercise is characterized into two different categories: acute muscle soreness and delayed onset muscular soreness (DOMS) (Kent, 1998). Acute muscle soreness is soreness that occurs immediately after or during training. This soreness is typically due to poor blood flow to the trained area or local swelling/edema. Soreness felt by muscles hours/days after exercise is a phenomenon called DOMS. According to the Oxford Dictionary of Sports Science and Medicine, DOMS is muscular discomfort that develops one or two days after exercise has stopped. DOMS is generally considered to be an adult phenomenon, but some children also exhibit DOMS too (Plowman & Smith, 2003). Muscle soreness is a very common problem that affects the physical and psychological performance of athletes and those who exercise (Bobbert, Hollander, and Huijing, 1986).

An individual can experience DOMS as a result of doing many different exercises: when the individual exercises at a much higher intensity than normally

accustomed to, when a person exercises for a much longer duration than normally accustomed to, and when the type of specific muscle contraction is considerably different than accustomed to (e.g., concentric and eccentric) is when a person is likely to experience DOMS (McArdle, Katch, & Katch, 2007). Activities that include eccentric contractions are most likely to induce DOMS (e.g., negative/eccentric bench press; Hakkenin et al., 1998). Furthermore, eccentric strength training is believed to be a very efficient way to strengthen one's muscles quickly (Higbie, Cureton, Warren, & Prior, 1996). Treatment of DOMS consists of rest and use of anti-inflammatory drugs, such as aspirin (Rahnama, Rahmani-Nia, & Ebrahim, 2005). Recommendations for reducing DOMS have included reducing eccentric contractions, training at a lower intensity, and performing post-training routines that include stretching (Kent, 1998).

DOMS is of concern to exercise experts because it affects athletic performance and exercise participation (Plowman & Smith, 2003). The cause of DOMS has drawn significant research attention because of its importance. Two of the primary theories of DOMS are the mechanical trauma theory and the local ischemic theory (Plowman & Smith, 2003). These theories are not identical; however, they share many similarities.

The mechanical trauma theory was conceptualized by Armstrong, Laughlin, Rome, and Taylor in 1983. This theory proposes to describe the mechanisms responsible for DOMS (Plowman & Smith, 2003). This theory developed from a study of several laboratory rats that were tested running on incline and decline treadmills (Armstrong et al., 1983). The treadmills were set to various speeds and slopes. VO₂ levels and blood lactate measurements showed that metabolism during and post-exercise was higher in the rats who ran uphill. Those rats had to use more energy to run at an incline and their

muscles became damaged. This muscle damage also resulted in measurements of DOMS. Plowman and Smith (2003) give a definitive physiological description of the mechanical trauma theory.

Plowman and Smith (2003) commented:

The mechanical trauma model suggests that the mechanical forces in the contractile or elastic tissue result in structural damage to the muscle fibers.

Damage to the sarcolemma of the cell leads to disruption in calcium homeostasis, which results in death of the tissue. The presence of cellular debris and immune cells leads to swelling and inflammation, which is responsible for the sensation of DOMS (Plowman & Smith, 2003, p.535).

The local ischemic theory was developed by Devries and Housh (1995). They suggested that exercise causes edema in the muscle tissue, which then increases the pressure in the muscle tissue. Due to the increase in muscle tissue pressure, blood flow is reduced to the muscle which causes pain and muscle constriction. The muscle constriction then becomes the primary factor of DOMS. The local ischemic theory was conceptualized by Devries and Housh (1995) who measured thresholds of neuromuscular fatigue in the muscles of the rectus femoris. Through the use of electromyographic fatigue threshold, it was discovered that the superficial muscles of the rectus femoris experienced more fatigue during exercise than the deep muscles (Deveries & Haush, 1995).

It is possible that both theories are valid (Plowman & Smith, 2003). The local ischemic theory explains that overtraining involving long duration and vigorous intensity

activities leads to DOMS. The mechanical trauma model explains that DOMS takes place after activities that place significant automatic force on the muscle; specifically, eccentric contractions. Much of the research that supports the mechanical trauma theory has used eccentric exercise as a means of inducing DOMS. DOMS is produced by microscopic tears in the muscle (McArdle, Katch, & Katch, 2007). These tears release intracellular substances that induce the inflammatory response. The local ischemic theory and the mechanical trauma theory both achieve DOMS this way; however, the theories use different exercise methods to achieve the (proposed) tears that result in DOMS.

One of the more popular concepts regarding DOMS is that it is caused by accumulation of lactic acid (Edington & Edgerton, 1976). Research such as the mechanical trauma theory and the local ischemic theory, however, fail to support that lactic acid accumulation is the cause of DOMS (Cheung, K., Hume, P., & Maxwell, L., 2003). More specifically, those who suffer from McArdle's syndrome and do not produce lactic acid suffer from DOMS too (Plowman & Smith, 2003). McArdle's syndrome is a rapid onset of muscle fatigue, pain, and cramping during moderate and vigorous exercise (Lewis, Haller, Cook, & Nunnally, 1985). This is from the inability to breakdown glucose, which is a very important source of energy stored in the muscle. Also, lactic acid has a half-life of 15-25 minutes and is removed from the muscle in about an hour. Due to the removal of lactic acid from the muscle, lactic acid cannot cause DOMS (Lewis, Haller, Cook, & Nunnally, 1985).

Researchers have investigated whether stretching muscles post-exercise reduces levels of DOMS (Hebert & de Noronha, 2009). At rest, muscle tissue damaged during exercise repairs itself and becomes stronger through hypertrophy in order to adapt to the

workload and contractile forces being placed on the body. (Brooks, Fahey, & Baldwin, 2005). It has been suggested that stretching can accelerate recovery of the muscles, which will reduce levels of DOMS (Bobbert, Hollander, & Huijing, 1986).

The idea that stretching can reduce levels of DOMS is controversial. Some suggest that stretching can prevent DOMS after training (Bobbert, Hollander, & Huijing, 1986); others hypothesize that stretching has little effect on the prevention of DOMS (Wessei & Wan, 1994) based on anecdotal rather than scientific evidence (ACSM, 2000).

Performing regular stretching exercises can greatly increase flexibility of the area being stretched (Smith & Fryer, 2008). Doing a stretching routine post-exercise could be beneficial because it supports the local ischemic theory (Resiman, Walsh, & Proske, 2005). Furthermore, stretching the muscle will lengthen it resulting in a speedy recovery time (Bobbert et al., 1986). Regardless of the theory of DOMS causation, different stretching techniques may have a role in reducing DOMS.

Specific Studies on the Effect of Stretching on DOMS

There is a substantial amount of research about the effect of stretching and DOMS. Traditionally, DOMS is measured by overtraining the muscle and having the participants rank their level of soreness after a period of time. As shown in Table 1 most of this research has included testing the effect of different types of stretches on DOMS. All of the studies in Table 1 involve the participants of each study engaging in static stretching and all of the studies are testing stretching as a mechanism to relief DOMS. Furthermore, the studies in Table 1 use a stretch protocol before or after training in efforts to relief DOMS. Results are mixed.

Table 1: Literature review for the effect of different types of stretching on DOMS

Authors & year	Types of stretching	DOMS related variables	Procedure	Results
Bobbert, Hollander, & Huijing (1986)	Static-active	Amount of DOMS in trained area	Participants over trained the gastrocnemius muscle. They then used static-active stretches on one leg while the other leg was the control. Participants then rated their level of DOMS on each leg.	The experimental leg showed lower levels of DOMS compared to the control leg (positive effects).
Smith et al. (1993)	Ballistic and Static-active	Amount of DOMS on areas stretched	Participants were randomly divided into two groups and performed three identical sets of 17 stretches in various areas of the body. Those who static stretched held their stretch for 60 seconds. The ballistic performed their stretch for 60 bounces per minute. Participants then rated their soreness level on a ten point scale before the stretching routine, 24, 48, 72, 96, and 120 hours after the stretching routine. Participants just did the prescribed stretches, no other exercise.	Those who performed static-active stretches had higher levels of participants suffering from DOMS compared to the ballistic stretching groups. The highest amount of DOMS occurred after 24 hours (positive effects).
Wessel & Wan (1994)	Static-active	Amount of DOMS in trained area post-exercise	Soreness in knee flexor muscle was induced with concentric or eccentric contractions. Knee flexor muscles of experimental leg were stretched before exercise in experiment 1 and after exercise in experiment 2. Ten stretches were performed, each of 60 seconds duration. Muscle soreness measured 12, 24, 36, 48, 60, and 72 hours after exercise on a 100 point scale.	The stretching routine performed before or after eccentric exercise did not reduce DOMS (negative effects).
Lund, Vestergaard-Poulsen, & Kanstrup (1998)	Static-passive	Amount of DOMS felt by the participants	In the first experiment, participants performed eccentric strenuous exercise with the right quadriceps until exhaustion with no stretching. In the second experiment, participants again performed eccentric strenuous exercise on the right quadriceps until exhaustion. Following the exercise, participants participated in the stretches for 30 seconds, with a 30 second pause between sets, for 3 sets.	Static-passive stretching did not have any significant influence on reducing DOMS in the participants (negative effects).
Resiman et al. (2005)	Static-passive	Amount of DOMS felt by the participants	Participants performed static-passive stretches on one arm prior to eccentric exercise. The other arm was the control. Participants then performed elbow flexors until extreme fatigue. Participants rated DOMS and arm posture was measured.	Pre-exercise stretching may reduce DOMS and improve posture of trained/stretched area of the body (positive effects).
High, Howley, & Frands (1989)	Static stretching and/or warm-up	Amount of DOMS felt by the participants	Soreness in leg muscles induced with step test. Before exercise, the stretching group performed 2 quadriceps stretches each for 60 seconds. The warm-up group performed an active warm-up. Then both groups did both stretching and warm-up. The control group did nothing. Muscle soreness was measured 24 hours after the step test on 0-6 point scale.	Static stretching and/or warm-up did not prevent DOMS (negative effects).
Sady, Wortman, & Blanke (1982)	Ballistic and static-active	Amount of flexibility achieved by the participants. A flexible muscle may reduce DOMS.	Participants were divided into 4 different groups: control, static-active, ballistic and PNF. Baseline measurements were obtained on 2 separate days prior to and following a 3-day per week, 6-week flexibility training program. The amount of flexibility was measured by each group over time.	PNF stretching may be the preferred stretching technique for improving flexibility. This may indicate that because PNF stretching increases flexibility, it is likely PNF stretching may lower DOMS when compared to the other types of stretches done in the study.

Perusal of Table 1 reveals three studies which showed stretching reduced DOMS, while three other studies showed stretching did not reduce DOMS. In Table 1, all of the participants used a pain scale to rate their DOMS level. There are also mixed results about doing stretches before/after exercise or what type of stretches can reduce DOMS. One study measured flexibility (i.e. Sady et al, 1982) and was included in this section because it is believed by many that a flexible muscle recovers faster from training (e.g. Corbin & Lindsey, 2005). Smith et al. (1993) identified a possible variable that induces DOMS by stretching alone. The participants in that study may not have normally accustomed to doing an extensive stretching routine. Their flexibility level may have induced DOMS because they are not used to doing that type of muscle contraction for a long period of time.

Pain tolerance may play a role in participants too. Each person has a different pain tolerance; for this reason, the results in Table 1 may have been skewed. Gender, age, race, occupation, and many other variables may also influence pain. Typically, men tolerate more pain than women, Caucasians tolerate more pain than Orientals and African-Americans, pain tolerance decreases with age, and those exposed to daily pain have more tolerance than those who do not (Woodrow, Friedman, Siegelau, & Collen, 1972). Pain tolerance may differ from each participant.

Apart from or in addition to stretching, other methods of reducing DOMS have also been tested. Drugs, massage, muscle treatments, and many other tactics have been administered to participants to see if they reduce DOMS. The independent variables in Table 2 focus on non-stretch mechanisms that may reduce DOMS. All of the studies in Table 2 test DOMS felt by the participants. The independent variable(s) (DOMS reducing

mechanism) were introduced after the DOMS inducing exercise. The majority of the tested variables showed that DOMS was not eased by using a non-stretch mechanism.

This research is included because in most cases the interventions also included stretching.

Table 2: Literature review of stretching plus other methods of treating DOMS

Author & year	Independent variable	Dependent variable	Procedure	Results
Rodenburg, Steenbeck, & Schiereck (1994)	Stretching, warm-up and massage	Amount of DOMS felt by the participant	Participants were randomly divided into experimental and control groups. The experimental group did a combination of warm-up and stretching before eccentric exercise. The experimental group then received a massage after exercise. The control group just did the eccentric exercise. Participants then ranked their soreness on a scale.	A combination of warm-up and stretching before eccentric exercise and massage after exercise, was effective in reducing severity of DOMS
Gulick et al. (1996)	Anti-inflammatory drug, high velocity concentric muscle contractions on an upper extremity ergometer, ice massage, 10-minute static stretching, ointment, and a placebo.	Amount of DOMS felt by the participant following the training and independent variables	Participants were randomly assigned to a possible DOMS reducing variable. Participants then performed physical activity that would induce DOMS. The possible DOMS reducing variable was administered and DOMS level was rated by the participants afterward.	Only time was able to lower DOMS in participants.
Rahnama et al. (2005)	Warm-up stretching and ibuprofen	Amount of DOMS felt by the participant following training and independent variables.	Participants were divided into four random groups. The Solomon four group design was used. This consisted of warm-up stretches, ibuprofen, and a control. DOMS levels were then recorded. Participants then ranked their muscle soreness.	Doing a physical activity warm-up with or without ibuprofen prevented DOMS.
Zainuddin, Newton, Sacco, & Nosaka (2005)	Massage	Amount of DOMS felt by the participant following training and the independent variable.	Participants performed 10 sets of 6 maximal eccentric actions of the elbow flexors with each arm. One arm received 10 minutes of massage 3 hours after eccentric exercise; the other arm received no treatment. DOMS levels were shortly measured after the massage.	Massage was effective in alleviating DOMS by approximately 30% and reducing swelling, but it had no effect on muscle function.
Moraska (2007)	Massage	Amount of DOMS felt by the participant following training and the independent variable.	Participants were offered a 12-15 minute massage after running a race. Participants were randomly assigned to a student therapist with either 450, 700, or 950 hours of training in massage. A 10 point muscle soreness questionnaire was given to the participants before and after the massage, and 24 and 48 hours post-race.	The greater reduction in muscle soreness was achieved by therapists with 950 hours of training as opposed to those with 700 or 450 hours of massage training.

The findings in Table 2 are important to this study because they show that most other variables aside from stretching are not necessary for the participant when trying to

reduce DOMS. There are some data however that suggest gentle massage can reduce DOMS (Rodenburg et al., 1994). However, bias may have been introduced in the Moraska (2007) study because Moraska should not have advertised the level of training each masseuse had. Those participants who received massages from masseuses with the most training may have convinced themselves that their massages were more effective due to the higher level of masseuse training.

The results of the studies in Table 2 should be considered in DOMS research because if there is a variable that can prevent or reduce DOMS, stretching may become highly publicized as obsolete to DOMS prevention. Due to DOMS being developed from overtraining muscles (Kent, 1998), it is possible that stretching may cause DOMS because the load being placed on the muscles may be significant enough to fatigue muscles (Corbin & Lindsey, 2005). If a person does not stretch regularly, they are likely to get DOMS from doing an extensive stretching routine because they are not normally accustomed to that type of specific muscle contraction.

Stretching and Muscle Performance

The level of muscular performance is important to consider when assessing DOMS. Stretching and warming-up before exercise may result in muscles that are capable of exerting more force while less likely to become injured (Corbin & Lindsey, 2005). Again, all of the studies in Table 3 involve static stretching; however, the Worrell, Smith, and Winegardner (1994) study includes PNF and static stretching. The dependent variables in Table 3 test muscular efficiency through resistance training or VO₂ maximum testing. Participants in these studies used a stretch protocol before exercising.

The studies show that some stretching as part of warm-up may be beneficial to one's muscle output. Table 3 is devoted to how warm-up impacts muscular performance.

Table 3: Literature review of warming-up with stretches and muscle performance

Author & year	Independent variable	Dependent variable	Procedural	Results
Worrell, Smith, & Winegardner (1994)	PNF and static-active	The amount of muscular power achieved by the stretched area.	Participants were assigned stretches to the hamstring muscles. After the participants were stretched, participants were tested on hamstring strength at different degrees.	PNF stretching was slightly superior to static stretching in hamstring performance; however, both stretching categories are beneficial to hamstring performance.
Behm, Button, & Butt (2001)	Static-passive	The amount of muscular power achieved by the stretched area.	Participants were divided into two groups. The experimental group was tested before and 5-10 minutes following a 20 minute static stretching routine of the quadriceps. The control group did no stretching. Forces and twitches were measured with sophisticated equipment.	A regimen of prolonged, static-passive stretching can inhibit force of the knee extensors.
Gleim, Stachenfeld, & Nicholas (1990)	Overall flexibility though static-passive	VO2 maximum	Participants were put through a series of flexibility tests using static-passive stretches. They were then to complete a VO2 maximum or VO2 sub-maximum test on a treadmill.	Those who had more flexibility had a higher VO2 maximum than those who had lower flexibility.

These studies should be taken into account when future studies on DOMS are planned. Behm et al. (2001) showed that doing a vigorous static stretching routine pre-exercise can inhibit maximal muscle output. Maximal muscular power output should be desired by an individual performing exercise; thus, doing an extensive stretching routine before training significantly increases the chances of the participants not achieving maximal muscle output, especially when one is unaccustomed to doing so. Muscles may become fatigued from the stretching routine and/or muscle tension at the joints may not be adequate resulting in poor muscle output. The results in Table 3 show that having participants stretch vigorously prior to exercising is questionable. Moderate stretching and warming-up one's muscle temperature is a better alternative specifically because there will be some muscle tension at the joints which will help muscle output (Behm et al., 2001).

A review about the effects of stretching on athletic performance was conducted by Ian Shrier (2004). This review examined 72 articles that were related to the topic of the review. Shrier concluded that an acute bout of pre-exercise stretching does not improve force or jump height. Regular pre-exercise stretching improves force, jump height, and speed, although there is no evidence that improves running efficiency.

Stretching and Injury

When a person overtrains, sufficient rest time may not be allowed for the body to recover from the stress exercise brings. These exercised muscles are very fatigued and need to recover. Overtraining is defined as training at work level beyond physical tolerance limits so that the body is unable to recover completely during rest periods (Kent, 1998). A muscle that suffers from DOMS is more likely to become injured because the tissue is still damaged (Udani, Singh, Singh, & Sandoval, 2009). The independent variables in Table 4 examine if stretching reduces injury. Injury rates were recorded in each study; however, each study records their injury rates differently. For example, in the Ekstrand, Gillquist, and Liljedah (1983) study, injury rates are recorded by comparing a group that participated in a stretch intervention compared to a group that did not participate in the stretch intervention. This study differs from the Hartig and Henderson (1999) study. Here, the overall number of injuries was recorded. Results do show that stretching can be beneficial in reducing injury while training. Table 4 summarizes studies that evaluate stretching, DOMS, and injury together.

Table 4: Literature review of injury, stretching, and DOMS

Author & year	Independent variable	Dependent variable	Procedural	Results
Ekstrand, Gillquist, & Liljedah (1983)	Intervention on how to prevent injury	Amount of injuries between the two groups	Half of the teams received an intervention on how to prevent injury. The intervention included various topics including how stretching plays a role in injury prevention. The other group did not receive the intervention. Injury amount was then recorded between the two groups.	Seventy-five per cent fewer injuries in the intervention group occurred in comparison to the control group.
Hartig & Henderson (1999)	Stretching routine prior to physical training and hamstring flexibility	Number of injuries	Two different army companies going through basic training at the same time were used. Hamstring flexibility was checked at the beginning and at the end of the 13-week infantry basic training course. The control company proceeded through normal training. The intervention company followed the same program but added three hamstring stretches to the routine. Lower extremity over use injury rates were recorded.	Hamstring flexibility increased significantly in intervention group compared with the control group. The number of injuries was also significantly lower in the intervention group. Forty-three injuries occurred in the control group for an incidence rate of 29.1%, compared with the 25 injuries in the intervention group for an incidence rate of 17%.
Pope, Herbert, Kirwan, & Graham (2000)	Static stretching before exercise	injury levels on participants	1538 male army recruits were randomly assigned to stretching groups and control groups. Over the 12 weeks of training, both groups did an active warm-up. After the active warm-up one group performed a static stretching routine on the lower extremities and one did not.	There were 158 injuries in the stretch group and 175 in the control group. Static stretching before training did not lower injury.

The studies on injury prevention through stretching in Table 4 indicate that stretching may play a role in injury reduction. Stretching a muscle immediately following training may not immediately reduce DOMS; however, a continually stretched, flexible muscle is less likely to be injured and may suffer less DOMS.

Overall, the studies in table 4 showed that stretching can have an effect on DOMS, muscle efficiency and injury. Researchers have shown that pre-exercise or post-exercise stretching alone may or may not reduce DOMS (Bobbet et al., 1986; High et al., 1989; Lund et al., 1998; Resiman et al., 2005; Sady et al., 1982; Smith et al., 1993; Wessel & Wan, 1994;), studies that measure DOMS without a stretch protocol (Gulick et al., 1996; Moraska, 2007), that stretching before exercise may lower muscle efficiency (Behm, et al., 2001), and that stretching before and/or after reduces frequency of injury

(Edstrand et al., 1983; Hartig & Henderson, 1999). There is little research concerning PNF stretching. The majority of stretches that were administered to the participants was static-active/static-passive stretching.

Two recently published reviews concerning whether stretching after exercise has an influence on reducing DOMS report mixed results (Hebert & de Noronha, 2009; Hume et al., 2004). Hebert and de Noronha (2009) summarized 14 different studies and concluded that there is no need to further research the effects of stretching after exercise on DOMS due to the studies included in their review. They based their conclusions on the research that has shown that stretching has little or no effect of the reduction of DOMS. Another review as done by Hume et al. (2004) on treatment strategies affecting DOMS looking at 25 different studies showed that there was no research on the effects of other types of stretching (e.g. ballistic, PNF, and dynamic stretching) on muscle soreness and the severity of muscle damage (Hume et al., 2004). A person may be confident saying static stretching techniques have little effect on reducing DOMS; however, there is little research concerning PNF stretching and its capability of lowering DOMS. Also, there is little research that investigates if level of flexibility plays a factor on DOMS if a person stretches.

Summary

Since there is little research concerning the effects of PNF stretching or flexibility on DOMS, further study of the topic needs attention. The majority of stretches that were administered to the participants in the literature were static-active/static-passive stretching. This lack of research leads to the question, if a person is stretching to reduce DOMS, would PNF stretching be effective in lowering DOMS in individuals post-

exercise compared to static stretching or no stretching? Also, does a person's flexibility level indicate likelihood of DOMS after stretching? It is hypothesized that participants who engage in PNF stretching and those who have good flexibility will have a lower amount of DOMS. Participants who engage in static stretching post-exercise and those who are less flexible will have high levels of DOMS. The purpose of this study is to examine the premise that stretching, or at least some types of stretching, is effective in reducing soreness of muscles.

CHAPTER II

METHOD

This study investigated whether stretching after unaccustomed eccentric exercise could prevent delayed onset muscle soreness (DOMS). While previous research has shown little effect on post-exercise stretching on DOMS, the effects of PNF stretching on DOMS had not been tested. Therefore, this study was designed to specifically investigate whether post-exercise PNF stretching could limit or reduce DOMS.

Design

This study employed a posttest-only control group design (Campbell and Stanley, 1963) to study the effects of PNF, static, and no stretch (control group) on DOMS. In this randomized-groups design, the post-exercise participants were randomly assigned to one of three groups: PNF, static, or control. The dependent variable was the DOMS scores reported by each participant at 24 hours and 48 hours post-exercise (independent variables).

Participants

A convenience sample of 57 participants volunteered for this study. Participants were recruited as volunteers out of various physical education, exercise science, and wellness (PXW) classrooms. Participants were screened on age, history of injury, age, gender, level of training, level of performance, and size. Thomas, Nelson, and Silverman (2005) suggest using various inclusion and exclusion criteria because it helps target

participants that would best suit the study. Table 5 discusses the inclusion and exclusion criteria for participants who were involved in this study. The design of the study was a posttest-only control group design.

Table 5: Inclusion and exclusion criteria of participants

Participants	Inclusion Criteria	Exclusion Criteria	Why
Age	Must be 18 years of age or older	Below 18 years of age	Parental consent is not necessary because participants are adults.
Gender	Males or females	None	N/A
Level of Training	Preference will be given to those who are somewhat physically untrained	None	When a participant is untrained, they more likely to suffer from DOMS because they are not normally accustomed to exercising with high intensity
Level of Performance	Those who are able to complete all tasks that the study demands	Those who cannot complete all tasks that the study demands	Participants must complete all tasks or they would not valid participants
History of Injury	None	Those who have not been cleared by a doctor, therapist, or trainer to exercise area being tested	Having a prior catastrophic injury in the trained area may result in an increased risk of injury and/or may confuse pain in the previously injured area with DOMS
Par-Q	Answering "No" to all questions	Answering "Yes" to one or more of the questions	Answering "Yes" may result in a health complication of the participant, which would not make them eligible to participate in the study
Consent Form	Completing consent form	Not completing consent form	Participants who complete the consent form understand the study; understand their role in the study, and possible risks involved in the study

Those who were interested provided their name, e-mail, and phone number to the principal investigator after he explained the study. Those on the list were called by the researcher to set up a time for data collection. An exclusion and inclusion criterion was enforced at the beginning of the study.

Measures/Instrumentation

Muscle Soreness

DOMS was assessed using the High et al. (1989) soreness scale (see Appendix A) (High et al., 1989, p. 359). The scale was chosen because due to the simplicity of the questionnaire. The scale asks participants to rank their level of soreness in a 1-6 point scale ranging from “absence of soreness” to “most extreme pain possible from soreness” (High et al., 1989).

Hamstring and lower back flexibility were measured using a standard sit and reach measurement box because a sit and reach test is the most common way to assess one’s level of flexibility. Participants positioned themselves at the sit and reach box and reached forward and held the stretch while keeping their legs straight. Once they had reached forward as far as possible, the researcher recorded their score in centimeters.

Procedures

Screening and Preliminary Organization

Approval to conduct this study was granted by the IRB of the University of North Dakota (see Appendix D). After participant recruitment took place, specific times were arranged between each participant and the researcher to conduct the study so participant attendance was maximized. Participants then completed a standard consent form (see Appendix B). After completing the consent form, a PAR-Q was also given to participants

to assess their overall health (see Appendix C). If the participant passed the PAR-Q, they were then evaluated by the inclusion and exclusion criteria. Finally, the screened participant was given verbal information about the study at the Wellness Center before performing the study.

DOMS Inducing Exercise & Stretch Protocol

To prevent anticipation bias, the researcher did not identify what type of stretch the participant would be doing. For a warm-up, the participant did 5-10 minutes of easy jogging until they felt that they were ready to perform exercise. Participants then performed a sit and reach test and data were recorded.

The participant then performed his/her DOMS inducing exercise on the Leg Curl SP 5100 weight machine. Approximate number of repetitions was between eight and twelve. The participants concentrically contracted their hamstring muscles in a controlled movement and eccentrically contracted their muscles for 5 seconds per rep. The participant was asked to complete each exercise until they reached voluntary or muscular failure. Muscular failure is defined as when the participants are physically incapable of completing another repetition because their muscles are too fatigued. Voluntary failure is defined as when the participant feels that they are un-able or not willing to perform any more repetitions.

Group Allocation

Participants were randomly assigned to one of three groups: PNF stretch, static stretch, and control group. This was done by drawing a group allocation out of a hat before they participated in the study.

Stretch Protocols

After the DOMS-inducing leg curls, the participants were guided through the stretch protocols that they had been randomly assigned to. In the static group, participants sat on the floor with their legs apart. The participant then reached toward one foot with both hands while the researcher pushed on their back. When optimal stretch occurred, the stretch was held for ten seconds with four seconds rest for two sets on both legs.

The PNF stretch was performed on the hamstring. The participant was supine on the floor and the researcher elevated one leg on the researcher's shoulder while keeping the other leg straight. The leg was then further elevated while being kept straight and was contracted for five seconds, held for five seconds, and relaxed for four seconds. The participant did this two times with one leg and the same routine was performed on the other leg.

Those who were randomized to the control group performed no stretches. These participants were asked to relax for a moment. After the participant completed their stretches, another sit and reach test was conducted. The protocol for the post-exercise sit-and-reach test was the same as the earlier sit-and-reach test.

DOMS Questionnaire Administration

Participants were again reminded that they must complete the questionnaire within the time constraints. Specified time periods between 22-26 hours and 46-50 hours post-exercise. Exact time specifications were given to the participant to remind them when to record their responses. They were also told not to do any type of physical activity or stretches on the region of the body that had been trained (hamstrings). This may affect the level of DOMS. Participants then completed the pain questionnaire

approximately 24 hours (plus or minus two hours) post-exercise and another 48 hours (plus or minus two hours) post exercise via e-mail. When the participant completed the pain questionnaires, he/she had completed the study. Figure 1 illustrates the participant's involvement during their time at the UND Wellness Center.

Analysis

The main hypothesis in this study was that DOMS would be reduced by post-exercise stretching. This was tested using analysis of variance. Specifically, a 3x2 (treatment group x time) mixed ANOVA was computed with scores on the pain scale as the dependent variable. Where it was necessary, post hoc testing using the Holm-Sidak method was conducted.

The secondary hypothesis in this study is that flexibility was associated with levels of DOMS was tested using Pearson correlation analysis.

Figure 1: Flow Chart

CHAPTER III

RESULTS

This study investigated whether stretching after unaccustomed eccentric exercise could prevent delayed onset muscle soreness (DOMS). While previous research has shown little effect on post-exercise stretching on DOMS, a specific type of stretching (PNF) had not been tested. Therefore, this study was designed to specifically investigate whether post-exercise PNF stretching could limit or reduce DOMS.

The descriptive statistics of the individual groups, and the sample overall, are presented in Table 6 below:

Table 6: Descriptive Statistics

	Overall (N=57)		PNF (n=19)		Static (n=20)		Control (n=18)	
	<i>m</i>	<i>SD</i>	<i>m</i>	<i>SD</i>	<i>m</i>	<i>SD</i>	<i>m</i>	<i>SD</i>
Height (inches)	68.49	3.50	68.37	2.69	70.00	3.88	66.94	3.28
Weight (lbs.)	165.68	28.91	158.95	22.94	180.50	34.02	156.33	22.37
Pre-exercise stretch score (cm)	6.33	9.75	5.21	10.21	6.00	9.70	7.89	9.68
Post-exercise stretch score (cm)	7.91	9.71	6.26	10.26	8.50	9.74	9.00	9.41
24 hour post-exercise pain score	2.14	.93	2.2	.78	2.25	1.07	1.94	.93

Table 6 cont.

	Overall (N=57)		PNF (n=19)		Static (n=20)		Control (n=18)	
	<i>m</i>	<i>SD</i>	<i>m</i>	<i>SD</i>	<i>m</i>	<i>SD</i>	<i>m</i>	<i>SD</i>
48 hour post-exercise pain score	1.79	.99	1.63	1.01	2.00	1.07	1.72	.89
Pre-Post flexibility change (cm)	1.57	1.77	1.05	1.47	2.50	1.35	1.11	2.11
24 to 48 hour pain score change	.35	.89	.57	.90	.25	.96	.22	.80

The primary focus of this study was the issue of whether post-exercise PNF stretching could prevent DOMS compared to post-exercise static stretching, or to no stretching. A 3 x 2 (group x time) mixed ANOVA with pain measures taken at 24 and 48 hours post-exercise was used to test this hypothesis. The results of this analysis showed no main effect for stretching type ($F [2, 54] = .86, p = \text{NS}$), or interaction between group and time ($F [2, 54] = .93, p = \text{NS}$). However, there was an effect for time ($F [1, 54] = 8.67, p < .01$). Post hoc testing (Holm-Sidak method) showed that DOMS pain significantly decreased ($p < .05$) from 24 to 48 hours post-exercise for the PNF and control groups, but not for the static stretch group. This data set is presented in Figure 1.

Figure 2: Treatment Effects

(Correlations for each type of stretch are listed in tables 7-10).

Tables 7-10 examine the correlations between the variables tested in Table 7.

There was a strong correlation between the pre and post-exercise stretch scores and the 48 hour pain score. This may indicate that the participant's flexibility score may have an effect on their level of DOMS. In Table 8 (PNF group), a correlation between the participant's 48 hour pain score and the Pre-Post flexibility change is identified. Due the level of strain put on the muscles during a PNF stretch, a trained muscle may become more damaged after performing PNF stretching. This may especially be the case if an individual is not flexible or if the individual is not normally accustomed to PNF stretching.

Table 7: Overall Correlations (N=57)

	Pre-exercise stretch score	Post-exercise stretch Score	24 hour post-exercise pain score	48 hour post-exercise pain score	Pre-Post flexibility change	24 to 48 hour pain score change
Pre-exercise stretch score	-	$r=.98^{****}$	$r=.07$	$r=.29^*$	$r=-.11$	$r=-.24$
Post-exercise stretch score		-	$r=.07$	$r=.33^*$	$r=.06$	$r=-.29$
24 hour post-exercise pain score			-	$r=.57$	$r=.00$	$r=.40$
48 hour post-exercise pain score				-	$r=.20$	$r=-.51$
Pre-Post flexibility change					-	$r=-.23$
24 to 48 hour pain score change						-

Key

PC: Pearson Correlation

* $p<.05$

** $p<.01$

*** $p<.005$

**** $p<.001$

Table 8: PNF Group (n=19)

	Pre-exercise stretch score	Post – exercise stretch Score	24 hour post-exercise pain score	48 hour post-exercise pain score	Pre-Post flexibility change	24 to 48 hour pain score change
Pre-exercise stretch score	-	$r=.99****$	$r=.08$	$r=.25$	$r=-.04$	$r=-.21$
Post-exercise stretch score		-	$r=.13$	$r=.34$	$r=.10$	$r=-.27$
24 hour post-exercise pain score			-	$r=.52$	$r=.32$	$r=.28$
48 hour post-exercise pain score				-	$r=.61**$	$r=-.66$
Pre-Post flexibility change					-	$r=-.40$
24 to 48 hour pain score change						-

Key

PC: Pearson Correlation

* $p<.05$ ** $p<.01$ *** $p<.005$ **** $p<.001$

Table 9: Static Group (n=20)

	Pre-exercise stretch score	Post – exercise stretch Score	24 hour post-exercise pain score	48 hour post-exercise pain score	Pre-Post flexibility change	24 to 48 hour pain score change
Pre-exercise stretch score	-	r=.99****	r=.25	r=.38	r=-.04	r=-.14
Post-exercise stretch score		-	r=.17	r=.33	r=.09	r=-.18
24 hour post-exercise pain score			-	r=.59**	r=-.59**	r= .44
48 hour post-exercise pain score				-	r=-.32	r=-.45
Pre-Post flexibility change					-	r=-.30
24 to 48 hour pain score change						-

Key

PC: Pearson Correlation

*p<.05

**p<.01

***p<.005

****p<.001

Table 10: Control Group (n=18)

	Pre-exercise stretch score	Post – exercise stretch Score	24 hour post-exercise pain score	48 hour post-exercise pain score	Pre-Post flexibility change	24 to 48 hour pain score change
Pre-exercise stretch score	-	$r=.97^{****}$	$r=-.11$	$r=.24$	$r=-.23$	$r=-.40$
Post-exercise stretch score		-	$r=-.08$	$r=.29$	$r=-.01$	$R=-.41$
24 hour post-exercise pain score			-	$r=.61$	$r=.18$	$r=.48$
48 hour post-exercise pain score				-	$r=.20$	$r=-.39$
Pre-Post flexibility change					-	$r=-.01$
24 to 48 hour pain score change						-

Key

PC: Pearson Correlation

* $p<.05$

** $p<.01$

*** $p<.005$

**** $p<.001$

CHAPTER IV

DISCUSSION

Discussion of Results

The results of this study did not support the premise that either PNF or static stretching post exercise significantly reduces DOMS. Previous research indicates that there is no plausible evidence that any type of stretching reduces DOMS although PNF had not been specifically tested (Hebert & de Noronha, 2009).

The correlations in the data suggested the possibility that the contraction phase of the PNF stretch may have placed a load on the already fatigued muscle group. Due to this load, the trained muscle may have become more damaged. Muscle defense mechanisms (e.g. muscle spindle and/or golgi tendon apparatus) may have been depressed allowing strain of the muscle.

Although the exact cause of DOMS is unknown, it has been suggested that DOMS is caused by micro tears (damage) in the muscle from unaccustomed eccentric exercises. Stretching muscle tissue is not believed to accelerate recovery of damaged muscles. It is important to know that not everyone suffers from DOMS after exercising. Traditionally, those who are accustomed to doing specific related exercise are less likely to suffer from intense DOMS (McArdle, Katch, & Katch, 2007). Recommendations for avoiding DOMS include: concentric and isometric exercises, massage therapy, adapting the athlete to the DOMS inducing exercise, and rest (Hume, Cheung, Maxwell, &

Weerapong, 2004). During the 1960's and 1970's it was common to practice stretching before and/or after exercise to prevent soreness because during this period of time it was believed that DOMS was caused by spasms of the muscle. The spasms occurring in the muscle caused muscle contractions and muscle shortening. Stretching was taught to allow these muscles to elongate resulting in muscle elasticity (Udani, Singh, Singh, & Sandoval, 2009).

Discussion of findings in the context of previous related research

In the review of literature, PNF stretching had not been tested as a possible mechanism to reduce DOMS. The majority of studies in the review of literature primarily focused on static stretching and its role on reducing DOMS. This study is the first to test PNF stretching and its relationship to DOMS. Initial research on the topic suggested that those who participate in static stretching after training achieve low levels of DOMS (Bobert, Hollander, & Huijing, 1986); Wessel and Wan (1994) tested pre and post-exercise a series of static stretches after inducing DOMS on the quadriceps muscles. The stretching routine performed before and after eccentric exercise in this study did not reduce DOMS. Lund, Vestergaard-Poulsen, and Kanstrup (1998) also performed a DOMS inducing exercise on the quadriceps muscles followed by a static stretch routine. In this study, static stretching also did not have any significant influence on reducing DOMS in study participants.

Hebert and de Noronha (2009) suggested that stretching no longer needs to be researched because there is overwhelming evidence that pre- or post-exercise stretching static or ballistic stretching does not reduce DOMS. The results of this study appear to

concur with Hevert and de Noronha (2009); PNF stretching appears not to be beneficial to one trying to alleviate DOMS.

Study Limitations

Some limitations of this study should be noted. The first limitation would be the convenience sample that volunteered to participate. Participants were college students at the University of North Dakota and the majority of participants were relatively close in age. This sample is not necessarily an exact representation of people at different universities or with different age demographics. Another limitation of this study is the type of study design. A posttest-only control group design was used for practical reasons (e.g. mortality rates). Different study design types such as a cross-over or pretest-posttest control group design could be used to identify a longer time period participants are being tested. Another limitation involves the warm-up of the participants. Participants were allowed to choose how they warmed-up and for how long. Consistency lacks in this portion of the study. Participants should all do the same warm-up for the same period of time. Also, it may be suggested that participants perform a DOMS inducing exercise routine with more intensity. Performing 3 sets of seated leg curl may not be enough resistance training for one to achieve desired levels of DOMS.

Suggestions for Future Research

This study may be the first to evaluate the effects of post-exercise PNF stretching on DOMS. Therefore, further research can be conducted in this area. It is suggested that participants have a wider age and body composition. Testing PNF stretching and DOMS may also be tested by using a type of study design that includes a longer participation

time for the participants. Future research should keep consistency on how participants warm-up. Finally, because the data collected in this study are new, the study should be duplicated in order to confirm the results were not a fluke.

Conclusions

Coaches should show concern for their athletes when they are suffering from DOMS. Athletes often are not physiologically and psychologically performing at their highest level when they are suffering from DOMS (Behm, Button, & Butt, 2001). Also, DOMS may be an indication that the training load on an athlete/exerciser was excessive for a variety of reasons. An athlete is more likely to become injured when suffering from DOMS due to the muscle tissue damage (Ekstrand, Gillquist, & Liljedah, 1983). It has been proposed that repeating sub-maximal bouts of exercise is not as effective as progressive training; however, fitness level of the individual being trained should be used as an indicator of how much to push (Chen, Chen, Lin, Wu, & Nosaka, 2010). Coaches should consider using the FIT principle where progressively train their athletes and slowly increase the time of the activity, intensity of the activity, and duration of the activity in order to avoid DOMS.

Excessive static stretching should be avoided as a warm up (Corbin & Lindsay, 2005). The purpose of an active warm-up is to prevent injury, maintain current health status, enhance performance of the athlete(s), and to simulate competitive situations (Corbin & Lindsay, 2005). Warming-up also increases muscle temperature and body core temperature resulting in increased muscle elasticity, decreased tension at the joints, greater release of oxygen in the body, increased metabolic activity, increased nerve

conduction, increased thermoregulatory strain, increased oxygen consumption, increased blood flow with, and post activation muscle potential. Static stretching fails to increase the temperature of the muscle or the core temperature of the body. Stretching may increase muscle elasticity and tension at the joints; however, the increase in range of motion from stretching may decrease force production in the muscle due to the decrease tension in muscles. It is recommended that coaches prescribe activities for their athletes that are of low intensity and increase the temperature of the muscles. The athlete can then benefit from warming-up. Static and PNF stretching may be recommended to cool down because the muscles are often warm from performing activities. This allows the muscle to have higher elasticity resulting in a better stretch. Stretching may also help release heat within the muscles. The primary benefit of stretching is to increase the elasticity of muscles and tendons resulting in decreased likelihood of injury.

APPENDICES

Appendix A

Pain Scale

Directions: Select the number which best indicates your current level of soreness.

- 1 Complete absence of soreness
- 2 Moderate pain felt only when touched/slight persistent pain
- 3 Light pain when walking up or down stairs
- 4 Light pain when walking on a flat surface/painful
- 5 Moderate pain, stiffness or weakness when walking/very painful
- 6 Severe pain that limits your ability to move/unbearably painful

Appendix B

INFORMED CONSENT

TITLE: The Effects of Two Different Post-Exercise Stretching Modalities on Delayed Onset
Muscular Soreness in Adults

PROJECT DIRECTOR: Ryan McGrath
PHONE # 651-895-7570
DEPARTMENT: Physical Education, Exercise Science, and Wellness

STATEMENT OF RESEARCH

A person who is to participate in the research must give his or her informed consent to such participation. This consent must be based on an understanding of the nature and risks of the research. This document provides information that is important for this understanding. Research projects include only subjects who choose to take part. Please take your time in making your decision as to whether to participate. If you have questions at any time, please ask.

WHAT IS THE PURPOSE OF THIS STUDY?

You are invited to be in a research study about the effects of stretching on delayed onset muscular soreness (DOMS) because you fit the criteria for the study.

The purpose of this research study is to identify if some types of post-exercise stretching have the capability to reduce the typical delayed onset muscular soreness (DOMS) that occurs after unaccustomed resistance exercise. It is important to look at different ways to lower DOMS because, for some DOMS is a barrier to participation in healthful exercise.

HOW MANY PEOPLE WILL PARTICIPATE?

The goal is to recruit a total of 50-70 people. Students at the University of North Dakota and Jamestown College have been invited to participate.

HOW LONG WILL I BE IN THIS STUDY?

Your total participation in the study will last about 48 hours

University of North Dakota
Institutional Review Board

Approved on OCT 5 2009
Expires on OCT 4 2010

WHAT WILL HAPPEN DURING THIS STUDY?

The study will proceed as follows:

- After a brief explanation of the study you will be invited to complete this consent form and a Physical Activity Readiness Questionnaire (PAR-Q). The PAR-Q is a brief questionnaire that screens individuals for their readiness to exercise.
- If you agree to participate and are cleared by the PAR-Q, the next stage will be a brief 5-10 minute warm up consisting of simple calisthenics and jogging.
- Next will be a sit-and-reach stretch test which will measure the flexibility of the hamstring and lower back muscles.
- Following the sit-and-reach stretch test, you will be asked to do 3 sets of seated leg curl as follows: first set will use a nominal weight to familiarize you with the exercise, and enable judgment of subsequent resistance will be used. The second and third sets will utilize a resistance that should allow you to complete 8-15 repetitions. In each set you will be asked to lift the weight quickly but lower the weight more slowly over a 5-second time count.
- Immediately after the sit-and-reach you will either be guided through some stretching exercises, or be informed the physical part of the procedures is over. This will be predetermined randomly so that the researchers can see if stretching makes a difference to any post-exercise soreness that may occur.
- Finally, you will be given instructions on how to complete the brief muscle soreness questionnaire using the internet 24, and 48 hours after the exercises are completed.

WHAT ARE THE RISKS OF THE STUDY?

You may experience the typical soreness in the hamstring muscles that occurs after unaccustomed resistance exercise. This soreness typically lasts about 48 hours post-training. During exercise, you may experience slight discomfort from exercising. You may also experience cramping or muscle pulls in rare occurrences.

WHAT ARE THE BENEFITS OF THIS STUDY?

You may not benefit personally from being in this study. However, in the future, other people might benefit from this study because those who do exercise may use the principles in this study to reduce DOMS in their exercise routine.

WILL IT COST ME ANYTHING TO BE IN THIS STUDY?

You will not incur any costs for being in this research study.

University of North Dakota
Institutional Review Board

Approved on OCT 5 2009
Expires on OCT 4 2010

WILL I BE PAID FOR PARTICIPATING?

You will not be paid for being in this research study.

CONFIDENTIALITY

The data will be kept private to the extent permitted by law. In any report about this study that might be published, you will not be identified. Your study record may be reviewed by Government agencies, the University of North Dakota Institutional Review Board, Jamestown College Institutional Review Board, James Whitehead (advisor of researcher), Dennis Caine (Physical Education, Exercise Science, and Wellness department chair) or Ryan McGrath (principal investigator).

Any information that is obtained in this study and that can be identified with you will remain confidential and will be disclosed only with your permission or as required by law. Confidentiality will be maintained by means of keeping all consent forms and data in separate folders which will be locked in a file cabinet located in the Physical Education, Exercise Science, and Wellness (PXW) department at the University of North Dakota. You will be randomly assigned a number when you sign up for the study that will be kept confidential so the privacy of your name can be kept private. You and your data will be referred to as a number, not a name.

If we write a report or article about this study, we will describe the study results in a summarized manner so that you cannot be identified.

COMPENSATION FOR INJURY

In the event that this research activity results in an injury, treatment will be available including first aid, emergency treatment and follow-up care as needed. Payment for any such treatment is to be provided by you (you will be billed) or your third-party payer, if any (such as health insurance, Medicare, etc.) No funds have been set aside to compensate you in the event of injury. In addition, the study staff cannot be responsible if you knowingly and willingly disregard the directions they give you.

IS THIS STUDY VOLUNTARY?

Your participation is voluntary. You may choose not to participate or you may discontinue your participation at any time without penalty or loss of benefits to which you are otherwise entitled. Your decision whether or not to participate will not affect your current or future relations with the University of North Dakota or Jamestown College. You can decline this study at any time and you will not be contacted again about the study again.

If you decide to leave the study early, we ask that you notify the researcher via e-mail or phone.

University of North Dakota
Institutional Review Board

Approved on OCT 5 2009
Expires on OCT 4 2010

You will be informed by the research investigator of this study of any significant new findings that develop during the study which may influence your willingness to continue to participate in the study.

CONTACTS AND QUESTIONS?

The researcher conducting this study Ryan McGrath. You may ask any questions you have now. If you later have questions, concerns, or complaints about the research please contact Ryan McGrath at 651-895-7570 or by e-mail at ryan.mcgrath@und.nodak.edu anytime. James Whitehead (principal investigator's advisor) may be contacted by phone at 701-777-4347 or by e-mail at james.whitehead@und.nodak.edu.

If you have questions regarding your rights as a research subject, or if you have any concerns or complaints about the research, you may contact the University of North Dakota Institutional Review Board at (701) 777-4279 or the Jamestown College Institutional Review Board at (701) 252-3467 ext. 2582. Please call these numbers if you cannot reach research staff, or you wish to talk with someone else.

Your signature indicates that this research study has been explained to you, that your questions have been answered, and that you agree to take part in this study. You will receive a copy of this form.

Subjects Name: _____

Signature of Subject

Date

University of North Dakota
Institutional Review Board

Approved on OCT 5 2009
Expires on OCT 4 2010

Date _____

Subject Initials: _____

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	1. Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
☐	☐	2. Do you feel pain in your chest when you do physical activity?
☐	☐	3. In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4. Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
☐	☐	6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7. Do you know of <u>any other reason</u> why you should not do physical activity?

If
you
answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _____

SIGNATURE _____

SIGNATURE OF PARENT
or GUARDIAN (for participants under the age of majority) _____

DATE _____

WITNESS _____

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

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continued on other side...

PAR-Q & YOU

Physical Activity Readiness
Questionnaire - PAR-Q
(revised 2002)

CANADA'S Physical Activity Guide to Healthy Active Living

Physical activity improves health.

Every little bit counts, but more is even better - everyone can do it!

Get active your way - build physical activity into your daily life.

- at home
- at school
- at work
- at play
- on the way
- ...that's active living!

Choose a variety of activities from these three groups:

Endurance
• Walking
• Jogging
• Swimming
• Bicycling
• Aerobic dance
• Stair climbing
• Gardening
• Housework
• Skiing
• Snowshoeing
• Fishing
• Hunting
• Golfing
• Tennis
• Badminton
• Table tennis
• Bowling
• Billiards
• Darts
• Chess
• Backgammon
• Bridge
• Cards
• Video games
• Computer games
• Puzzles
• Rubik's cube
• Jigsaw puzzles
• Crossword puzzles
• Word searches
• Trivia
• Jeopardy
• Wheel of Fortune
• Jeopardy Jr.
• Wheel of Fortune Jr.
• Jeopardy Jr. Jr.
• Wheel of Fortune Jr. Jr.
• Jeopardy Jr. Jr. Jr.

Starting slowly is very safe for most people. Not sure? Consult your health professional.

For a copy of the Guide Handbook and more information: 1-888-334-9769, or www.paguide.com

Eating well is also important. Follow Canada's Food Guide to Healthy Eating to make wise food choices.

Get Active Your Way, Every Day - For Life!

Scientists say accumulate 60 minutes of physical activity every day to stay healthy or improve your health. As you progress to moderate activities you can cut down to 30 minutes, 4 days a week. Add-up your activities in periods of at least 10 minutes each. Start slowly - and build up.

Time needed depends on effort				
Very Light Effort	Light Effort	Moderate Effort	Vigorous Effort	Maximum Effort
60 minutes	30-60 minutes	20-30 minutes	10-20 minutes	5-10 minutes
• Strolling • Dusting	• Light walking • Volleyball • Easy gardening • Shopping	• Brisk walking • Biking • Easy yardwork • Raking leaves • Tennis • Basketball • Fast swimming	• Aerobics • Jogging • Hockey • Basketball • Fast swimming	• Sprinting • Racing

You Can Do It - Getting started is easier than you think

Physical activity doesn't have to be very hard. Build physical activities into your daily routine.

- Walk whenever you can - get off the bus early, use the stairs instead of the elevator.
- Reduce inactivity for long periods, like watching TV.
- Get up from the couch and stretch and bend for a few minutes every hour.
- Play actively with your kids.
- Choose to walk, wheel or cycle for short trips.
- Start with a 10 minute walk - gradually increase the time.
- Find out about walking and cycling paths nearby and use them.
- Observe a physical activity class to see if you want to try it.
- Try one class to start - you don't have to make a long-term commitment.
- Do the activities you are doing now, more often.

Benefits of regular activity:	Health risks of inactivity:
<ul style="list-style-type: none"> • better health • improved fitness • better posture and balance • better self-esteem • weight control • stronger muscles and bones • feeling more energetic • relaxation and reduced stress • continued independent living in later life 	<ul style="list-style-type: none"> • premature death • heart disease • obesity • high blood pressure • adult-onset diabetes • osteoporosis • stroke • depression • colon cancer

Source: Canada's Physical Activity Guide to Healthy Active Living, Health Canada, 1998 <http://www.hc-sc.gc.ca/hppb/paguide/pdf/guideEng.pdf>

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FITNESS AND HEALTH PROFESSIONALS MAY BE INTERESTED IN THE INFORMATION BELOW:

The following companion forms are available for doctors' use by contacting the Canadian Society for Exercise Physiology (address below):

The **Physical Activity Readiness Medical Examination (PARmed-X)** - to be used by doctors with people who answer YES to one or more questions on the PAR-Q.

The **Physical Activity Readiness Medical Examination for Pregnancy (PARmed-X for Pregnancy)** - to be used by doctors with pregnant patients who wish to become more active.

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For more information, please contact the:

Canadian Society for Exercise Physiology

202-185 Somerset Street West

Ottawa, ON K2P 0I2

Tel. 1-877-651-3755 • FAX (613) 234-3565

Online: www.csep.ca

The original PAR-Q was developed by the British Columbia Ministry of Health. It has been revised by an Expert Advisory Committee of the Canadian Society for Exercise Physiology chaired by Dr. N. Gledhill (2002).

Disponible en français sous le titre «Questionnaire sur l'aptitude à l'activité physique - Q-AAP (révisé 2002)»

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Appendix D

REPORT OF ACTION: EXEMPT/EXPEDITED REVIEW
University of North Dakota Institutional Review Board

Date: 9/23/2009 Project Number: IRB-200910-073
Principal Investigator: McGrath, Ryan
Department: PXW
Project Title: The Effects of Two Different Post-Exercise Stretching Modalities on Delayed Onset Muscular Soreness in Adults

The above referenced project was reviewed by a designated member for the University's Institutional Review Board on October 5, 2009 and the following action was taken:

- ☒ Project approved. **Expedited Review** Category No. 4, 7
Next scheduled review must be before: October 4, 2010
☒ Copies of the attached consent form with the IRB approval stamp dated October 5, 2009 must be used in obtaining consent for this study.
- ☐ Project approved. **Exempt Review** Category No. _____
☐ This approval is valid until _____ as long as approved procedures are followed. No periodic review scheduled unless so stated in the Remarks Section.
☐ Copies of the attached consent form with the IRB approval stamp dated _____ must be used in obtaining consent for this study.
- ☐ Minor modifications required. The required corrections/additions must be submitted to RDC for review and approval. **This study may NOT be started UNTIL final IRB approval has been received.**
- ☐ Project approval deferred. **This study may not be started until final IRB approval has been received.** (See Remarks Section for further information.)
- ☐ Disapproved claim of exemption. This project requires Expedited or Full Board review. The Human Subjects Review Form must be filled out and submitted to the IRB for review.
- ☐ Proposed project is not human subject research and does not require IRB review.
☐ Not Research ☐ Not Human Subject

PLEASE NOTE: Requested revisions for student proposals MUST include adviser's signature. All revisions MUST be highlighted.

- ☒ Education Requirements Completed. (Project cannot be started until IRB education requirements are met.)

cc: Dr. James Whitehead

Signature of Designated IRB Member
UND's Institutional Review Board

10/5/2009
Date

If the proposed project (clinical medical) is to be part of a research activity funded by a Federal Agency, a special assurance statement or a completed 310 Form may be required. Contact RDC to obtain the required documents.

(Revised 10/2005)

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