Stretching techniques on hamstring flexibility in female adolescents

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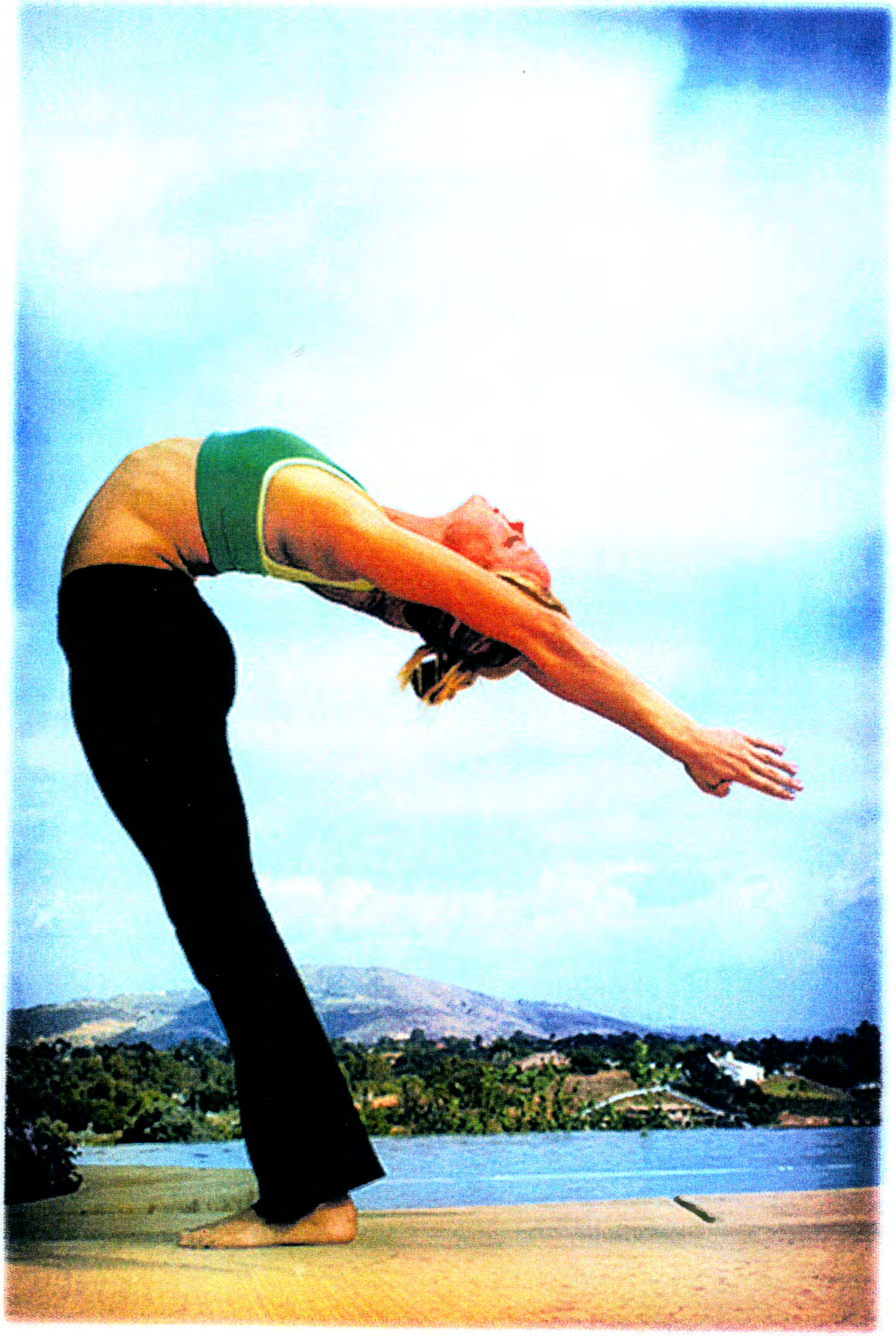

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

One of the main reasons why physical activity is emphasized these days is to maintain good health. With physical activity, which can vary from brisk walking to strenuous exercises, comes the ability to have more energy, maintain a healthy weight, perform daily tasks better, control chronic diseases, improve fitness levels, find stress reduction and enjoy overall health (Gloang, 1992:377).

One of the abovementioned benefits, the ability to perform daily tasks better - which include, for example, being able to move around more, bend, sit and stand up - is not possible without attaining some degree of a fitness component called musculo-skeletal flexibility.

Flexibility is defined as the ability of the neuromuscular system to allow a muscle to lengthen so that it can provide efficient movement of a joint or joints through their full range of motion, without any restrictions or pain (Prentice, 2010:106; Armstrong, Balady, Berry, Davis, Davy, Davy, Franklin, Gordon, Lee, McConnel, Myers, Pizza, Rowland, Stewart, Thompson, Wallace, 2005:85).

The question that has been raised over the past few years and is still asked today is whether flexibility is really that important. Limited time available in daily schedules often cause people to overlook flexibility as a component of physical activity and therefore in many cases, it then only becomes a concern for the average person after joints stiffen and muscles shorten as a result of injury, disuse or disease (Lucas & Koslow, 1984:615).

Di Lorenzo (1999:20) explains in her article entitled Physical Therapy Positive Change that for our bodies to move around 430 muscles and for those muscles to work efficiently, they need to be strong, supple and able to go the distance.

Stretching to improve flexibility has long been recognized as an important component of total fitness for generating and maintaining overall flexibility as well as for sporting events and activities of daily living (Wallmann, 2009:355). Together with the abovementioned, much literature with regard to flexibility emphasizes the importance of flexibility as an aspect of everyday human function (Davis, Ashby, McCale, Mcquain & Wine, 2005:27).

When a muscle loses its elasticity or suppleness it can cause a decreased range of motion around joints – which in turn can lead to other soft tissue restrictions, because the muscle's ability to deform decreases (Decoster, Scanlon, Horn & Cleland, 2004:330). In addition, a decrease in joint mobility and range of motion may lead to incorrect body alignment, chronically tight muscles, faulty compensation patterns, inefficient body mechanics and a potential increased risk of injury (Wallmann, 2009:355).

This is why muscle stretching has in recent years become such a widespread practice, and plays such an important role in preparation for athletic performance, rehabilitation of patients at all levels, general conditioning programs, public sports and especially high-performance sports (Magnusson & Renström, 2006:87; Decoster et al., 2004:330; Kubo, Kanehisa & Fukunaga, 2002:595; Handel, Horstmann, Dickhuth & Gulch, 1997:400; Guissard, Duchateau & Hainaut, 1988:47). Attempts to improve flexibility in order to reduce the possible risk of injury is one of the reasons why stretching is so common among the athletic population (LaRoche & Connolly, 2006:1000), and also why fitness instructors, therapists and personal trainers encourage people to participate in stretching programs. When a muscle has good flexibility the result is more effective and efficient movement, because the flexible muscle allows the muscle tissue to accommodate imposed stresses more easily - which can result in reduced risk of skeletal muscle strains during exercise (Wallmann, 2009:355; Bandy, Irion & Briggler, 1998:295; Magnusson, 1998:66).

It should be observed that a 'too high' degree of flexibility of certain joints might not be a positive desire after all, chiefly in contact sports. For example, there might be injury rate increases when a rugby player's shoulder joint is too flexible, because the muscles lose its ability to provide stability of the humeral head in the shallow glenoid fossa. Too much flexibility can lead to instability in contact and/or overhead sports and therefore flexibility needs be sport specific (Powers & Howley, 2004:439).

Still, a moderate amount of flexibility is needed to perform activities of daily living (Wallmann, 2009:355; Armstrong et al., 2005:85), and for that reason it is important that everyone must include a stretching program into their normal everyday routine (Masterson, Herrington, Muchow & Powell, 2008:68).

A variety of stretching exercises to improve the range of motion of a joint or joints have been implemented in sport programs, rehabilitation programs and general conditioning programs. Among these methods are the four most used stretching exercise techniques that have emerged and grown among the population: 1. Static stretching, 2. Proprioceptive Neuromuscular Facilitation (PNF) 3. Ballistic stretching and 4. Dynamic stretching (Prentice, 2010:109; Roberts & Wilson, 1999:259).

It is understandable and accepted that the static stretch is the most simplistic and safest stretching technique to use by any population, trained of sedentary, because of the above mentioned. Also, and the chance that the muscle will be stretched beyond its extensibility limits is small, given that the individual is in total control during its execution (Prentice, 2010:110; Roberts & Wilson, 1999:259).

For safety reasons and the fact that its advised that ballistic stretching must only be practiced and performed by highly-trained individuals (Prentice, 2004:126), this study will compare the effectiveness of the PNF contract-relax-, PNF hold-relax-, Static stretching- and dynamic stretching-techniques on the hamstring muscle group in order to determine the most effective technique to promote flexibility as well as the overall effectiveness of the four different techniques on flexibility in general.

1.2 MOTIVATION/ PROBLEM STATEMENT

Several studies over the past years have been done on various stretching techniques, comparing different methods of stretching, different designs to use; however, none of the investigations produced consistent results over the most effective stretching technique (Lucas & Koslow, 1984:615), as well as the intensity, frequency and duration of the methods to use (Feland, Myrer & Merrill, 2001:186). Flexibility is now known to play a vital role in younger as well as older populations and it is therefore necessary to gain more information on which stretching technique will be the most efficient to use in a stretching program.

Many people do not spend much or even any time at all on their muscle flexibility because of the lack of time to do these exercises, lack of knowledge on how much is needed and the lack of knowledge on how important it really is. Therefore, the studies that have been done can provide some basic information on the intensity, frequency and duration needed for improvement effects and effective stretching programs. For example, Bandy & Irion (1994:849) and Bandy et al. (1998:299), found that a single 30-second stretch is just as effective as a single 60-second stretch if one engages in a stretching training program for 6 weeks, 5 times per week. Also 3x30-second stretches are just as effective as a 1-minute stretch. Overall, the researchers reported that a 30-second stretch is efficient enough to improve flexibility if an athlete stretches 5 times per week. These studies were conducted using the common static stretching technique.

There are so many conflicting results in studies that have been done comparing stretching techniques. Sady, Wortman & Blanke (1982:263), Tangiwa (1972:725) and Holt, Travis & Okita (1970:614) found in their individual studies that the proprioceptive neuromuscular technique was superior to static stretching and ballistic stretching, while Davis et al. (2005:30) and Bandy et al. (1998:299) found the static stretch superior to the dynamic stretch and proprioceptive neuromuscular technique. Nonetheless, many other studies found no difference between the effectiveness of the techniques (Nelson & Bandy, 2004:257; Feland et al., 2001:190; Williford & Smith, 1985:32).

Due to contrasting results there is no one exact method or technique prescribed to use in practice today. Therapists mostly use the technique they are familiar with. Therefore, the current study will not only provide clarity with regard to which stretch is superior to others, if any, but will also be beneficial to therapists when prescribing flexibility exercises to different individuals in whatever setting they find themselves in.

1.3 PRIMARY AIM OF THE STUDY

The main aim of this study is to determine if there is a significant difference ($p<0.05$) between the 4 stretching techniques used by the experimental groups and the control group over a 6-week period. The second aim is to determine what stretching technique is more significantly superior ($p<0.05$) to other techniques over a 6-week period. The third aim is to determine which stretching technique to use ($p<0.05$) if increased flexibility is desired over a 3-week time span. For safety reasons and the fact that ballistic stretching must only be practiced and performed by highly-trained individuals (Prentice, 2004:126), this study will compare the effectiveness of the PNF contract-relax-, PNF hold-relax-, Static stretching- and dynamic stretching-techniques on the hamstring muscle group in order to determine the most effective technique to promote flexibility as well as the overall effectiveness of the four different techniques on flexibility in general.

1.4 OBJECTIVES

In order to achieve the aim of this study, the following objectives will be pursued:

1.1.1 A Literature review on all aspects of flexibility and stretching;

1.1.2 A 6-week flexibility-training program done by 4 experimental and 1 control group, using 4 different stretching protocols;

1.1.3 Data collection of hamstring muscle flexibility measures of each participant before, during and after completion of the training program, and

1.1.4 A comparison of the experiment's statistics.

1.5 BENEFICIARIES OF STUDY

1. Biokineticists in practice concerned with rehabilitation at all levels.
2. Physiotherapists treating sports- and everyday injuries.
3. Coaches and fitness trainers.
4. Competitive and recreational athletes of all ages to know the condition of their bodies prevent injuries and promote everyday activities, and benefit from long-term health.

CHAPTER 2: LITERATURE

2.1 INTRODUCTION

Flexibility training/stretching has in the last few years, after being touted for long, begun to be viewed from a different perspective and with new understanding as part of fitness and exercise. Sports medicine professionals, instructors and personal trainers now recognize the complexities of improved flexibility and has renewed their interest in incorporating stretches into exercise programs for injury prevention and sports performance enhancement (Costa, Graves, Whitehurst, & Jacobs, 2009:141; Torres, Conceicao, Sampaio, De Oliveira & Dantas, 2009:52; Woolstenhulme, Griffiths, Woolstenhulme & Parcell, 2006:799). Not only is flexibility and stretching important in reducing injuries, but it also holds benefits for everyday living and improved performance (Yuktasir & Kaya, 2009:11; Nelson, Driscoll, Landin, Young & Schexnayder, 2005:449; Spernoga, Uhl, Arnold & Gansneder, 2001:45), as well as the reduction of soreness after exercise (Herbert & Gabriel, 2002:468).

Lack of flexibility can create uncoordinated and awkward movement patterns resulting from the loss of neuromuscular control (Prentice, 2010:106) and can also lead to a series of implications including bad posture, muscle stiffness, spasms, back pain, limited range of motion of a joint or joints that could be associated with active process or joint diseases such as Osteo Arthritis (De Freitas, Silva, Fernandes, Carazzato & Dantas, 2007:347). If all is added up, lack of flexibility predisposes a person to risk of injury to ligaments, tendons or soft tissue and decreases the quality of everyday life (De Freitas et al., 2007:347). Still, many people do not realize the importance of incorporating flexibility training into their everyday routine and only focus on stamina and strength training, which can lead to painful syndromes and muscle imbalances in the long run. De Lorenzo (1999:20) explains this phenomenon by saying that the human body is designed to work in balance and that when a muscle is tight or weak it will cause painful imbalances in the body. Thus, a tight muscle is just as dangerous as a weak muscle and all components of fitness must be incorporated into an exercise program.

In addition to the definition provided in 1.1, flexibility has been defined as the range of motion that is available in a joint or joints that is influenced by muscles, ligaments, tendons and bones (Prentice, 2010:106; Youdas, Haeflinger, Kreun, Holloway, Kramer, Hollman, 2010:240; Prentice & Arnheim, 2008:66; Baumgartner, Jackson, Mahar & Rowe, 2006:255; Bandy & Irion, 1994:845). When one thinks of flexibility, one thinks of how far a limb can be moved; however there are two kinds of flexibility that should be kept in mind when assessing a person's flexibility: 1. Dynamic or Active flexibility and 2. Passive or Static flexibility.

Dynamic flexibility or range of motion is the degree to which a joint can be moved via a muscle contraction. Active flexibility is not necessarily a good indicator of the stiffness or looseness of a joint because it applies to the ability to move a joint efficiently, with little resistance to motion (Prentice, 2010:123; Prentice & Arnheim, 2008:67). Passive flexibility refers to the total range of motion (to the endpoint) a limb can be moved with passive resistance/force given by a trainer. No muscle contraction is therefore needed (Prentice & Arnheim, 2008:123; Prentice, 2004:123). When a muscle contracts, it can move through a specific range of motion; however when passive resistance is applied and no muscle contraction occurs, the limb can usually be moved through a further range of motion (Prentice & Arnheim, 2008:123). Both active and passive flexibility is important, especially in sporting activities. A muscle must be able to move through as much range of motion as possible without any restrictions or pain and should be able to handle forces that will stretch the muscle beyond its extensibility limits. This is the reason why passive range of motion is so important because it starts and continues where active or dynamic range of motion stops. Dynamic range of motion is just as important, for the performance of normal everyday exercises or activities without restrictions or pain (Prentice, 2010:123; Prentice & Arnheim, 2008:67). For this reason different stretches for each specific joint must be done to improve the articulations of a joint in all possible ways.

The main goal of a flexibility program should be to improve the range of motion of a joint by altering the extensibility limits of the specific muscle's musculo-tendinous unit and fascia to increase the range of motion and efficiency of movement of the specific joint or joints. The two kinds of flexibility will be discussed in more detail in the next section in terms of stretches.

2.2 TYPES OF STRETCHES

2.2.1 STATIC STRETCHING

Static stretching involves a stretch of a muscle or muscle group via passively placing the antagonist in a maximal position of stretch (Workman, 2010:2; Prentice, 2010:110; Prentice & Arnheim, 2008:70; Feland et al., 2001:187). Literature describes it to be the safest method of stretching because the stretch can be controlled by the subject and the likelihood of stretching the muscle past its extensibility limits are minimal. Less energy is also required to perform the stretch, which also minimizes the likelihood of muscle soreness (Sekir, Arabaci, Akoval & Kadagan, 2010:268; Prentice, 2004:126; Bandy & Irion, 1994:846).

Static stretching is probably the most used stretch in athletic, coaching, rehabilitation and recreational departments as part of a warm-up or cool-down (Youdas et al., 2010:240; Prentice & Arnheim, 2008:70; Chan, Hong & Robinson, 2001:81), but Murphy (1991:68) rejects the use of the static stretch and claims that the static stretch's passive nature does not aid in increasing the muscle's temperature and should therefore not be done prior to any sporting demands. Workman (2010:2), Prentice and colleague (2008:70) and Murphy (1991:68) suggest that prior to activity a dynamic stretch is probably the best choice to increase a muscle's temperature for the demands of the activity and that static stretching can still be done, but prior to the dynamic stretch.

In the rehabilitation department, static stretching is the main stretch used for increasing range of motion of the joint or joints after injury because of its passive nature. In addition, it can be controlled, does not cause soreness and a full-non-restricted range of motion can be obtained over time (Prentice, 2010:110; Plowman & Smith, 2002:582). Passive range of motion is important to prevent further or re-injury. In fact, research indicates that static stretching may also reduce the time needed for recovery after an injury was sustained (O'Sullivan, Murray & Sainsby, 2009:42). It has also been shown that static stretching improves joint position sense, which is crucial in retraining neuromuscular control, the mechanism for increased balance, which plays an important role in future sports participation (Costa et al., 2009:144).

One of the reasons why static stretching is said to be the **golden standard** for measuring flexibility and lengthening of a muscle is that the rate of change in the muscle length is slow when the limb is passively moved into position and then non-existent as the position is held (Davis et al., 2005:27; Plowman & Smith, 2002:583). A static stretch is usually held from 3- to 60-seconds (Prentice & Arnheim, 2008:70), which causes the dynamic phase of the neuromuscular spindle to be bypassed. The annulospiral nerve endings are then not stimulated to fire strongly, causing the absence of a strong reflex contraction (Francisco & Pilar, 2010:434; Plowman & Smith, 2002:583). When the stretch is held for longer than 3-seconds, the Golgi-tendon organ responds and overrides the impulses coming from the muscle spindle, causing a myostatic reflex that relaxes the muscles that are being stretched; this is also called autogenic inhibition (Prentice, 2010:108; Davis et al., 2005:27; Nelson & Bandy, 2004:257).

Numerous studies have been done on the efficient and appropriate parameters for static stretching programs for the improvement of flexibility. The duration, frequency, number of repetitions, daily dose and length of the program as well as efficiency have been studied, but many outcomes raise questions that still cause uncertainty as to the parameters that are most efficient (Francisco & Pilar, 2010:434; Davis et al., 2005:30; Chan et al., 2001:84; Bandy & Irion, 1994:849).

Table 2.1 summarizes the studies done, their parameters and outcomes that can help identify the most efficient and different parameters to use in different, individual programs to obtain maximum benefits from a flexibility program.

Table 2.1: Summary of studies done on static stretching

Author:	Intervention:	Results:
Francisco & Pilar, (2010:434)	Subjects were randomly assigned to 1 of 4 groups (3 treatment groups and 1 control group). The 3 treatment groups participated in an active stretching program 3 times per week for a 12-week period, holding each stretch exercise for a duration of 15, 30, or 45 seconds. The total daily dose of the stretches was 180 seconds for each group. The control group did not stretch.	No significant differences were found between the 3 treatment groups. This study indicates that 12 × 15-, 6 × 30-, and 4 × 45-second single durations of active stretching were equally effective at increasing hamstring length when performed 3 days per week for 12 weeks in this population.
Roberts & Wilson, (1999:259)	Investigated 2 groups over 5 weeks, stretching 3 times per week. First group: nine 5s stretches Second group: three 15s stretches	Holding stretches for 15 seconds as opposed to five seconds results in greater improvements in range of motion (ROM).
Bandy & Irion, (1994:845)	Investigated 3 groups over 6 weeks, stretching 5 times per week. First group: one 15s stretch Second group: one 30s stretch Third group: one 60s stretch	Effective increases in flexibility in the 30s and 60s groups. No significant difference ($p>0,05$) existed between the 30s and 60s groups. Gains was respectively 3.78° for the 15s group, 12,5° for the 30s group and 10,86° for the 60s group.
Decoster et al. (2004:330)	Three 30s supine and standing hamstring stretches, 3 times per week over 3 weeks.	Significant difference ($p>0,05$) for pre- and post measurements for both groups. No significant difference between the 2 groups.

Author:	Intervention:	Results:
Bandy et al. (1998:195)	Three 30s stretches, 5 times per week over 6 weeks for the hamstring muscle group.	Significant increase in hamstring range of motion of 10.1°.
Masterson et al. (2008:68)	Two groups stretched 5 times per week over 2 weeks. First group: three 30s stretches Second group: 5 times five 3s stretches.	No significant difference ($p>0,05$) between the 2 groups but the 30s group showed higher increases in flexibility gains.
Nelson & Bandy, (2004:245)	One 30s stretch, 3 times per week over 6 weeks.	Significant range of motion increases of 12.05°.
Chan et al. (2001:81)	Two intervention groups. First group: five 30s stretches, 3 times per week over 8 weeks. Second group: 2 times five 30s stretches, 3 times per week over 4 weeks.	Significant increase in hamstring flexibility in both of the two training groups. No difference in ROM gained between two training groups.
Davis et al. (2005:27)	One 30s stretch, 3 times per week over 4 weeks. First group: static stretching Second group: PNF stretching Third group: self-stretching	Increases in range of motion of hamstring muscle group in all groups but only static stretching showed significantly greater improvements than the control group.

From the different investigations and outcomes seen, it is the opinion of the researcher that a static stretch held for anything from 15 to 120 seconds is effective enough to significantly increase flexibility, and that anything from one repetition once a week, 3-7 days per week also seems to be efficient enough for increasing flexibility. The parameter with the most significant increases and best results still need to be investigated.

The main goal of any flexibility program is to cause plastic deformation of the connective tissue to gain permanent lengthening of the muscle (Chan et al., 2001:82) and for this reason a stretching program should contain the highest number of repetitions (›3) and done as frequently (›3/4days) as possible per week for the long haul in order to gain and maintain the necessary degrees of flexibility.

Literature reveals that the effect of position on a hamstring stretch does not make a significant difference in the magnitude of range of motion improvements. The most common hamstring static stretch used is the standing hamstring stretch, which according to literature is validated as an effective means of improving flexibility (Nelson & Bandy, 2004:256; Bandy et al., 1998:297; Bandy & Irion, 1994:847). Notwithstanding pelvic positioning whilst performing the stretch is directly proportionate to the significance of the stretch (Decoster et al., 2004:333). In a study done to compare the standing and the supine hamstring stretch, equal improvement was seen in the effectiveness of both stretches. It was suggested, though, that the supine hamstring stretch should be preferred to the standing hamstring stretch to ensure and enhance hamstring isolation. Also, in the supine position pelvic positioning does not need to be monitored and the stretch can therefore be used in unsupervised settings (Decoster et al., 2004:334). Sullivan, Dejulia & Worrel (1992:1387) emphasize that with the use of standing hamstring stretching with an anterior pelvic tilt and no hip internal or external rotation, more significant increases in range of motion can be attained, but that supervision is needed to ensure correct execution. Therefore, the use of the supine hamstring stretch is preferred and should be done to ensure maximal effectiveness.

2.2.2 PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION

The proprioceptive neuromuscular facilitation technique was introduced by Knott and Voss and involves a combination of contractions and relaxations of the antagonist muscle pairs whilst a partner/trainer applies a passive stretch. The classic PNF techniques are performed by the activation of muscle groups in a diagonal pattern (Youdas et al., 2010:240). It can also be explained by the involvement of isometric (relax phase) and concentric contractions (push-phase) that cause the Golgi-tendon organ to inhibit the muscle and uses the theories of autogenic and reciprocal inhibition to relax the muscle before it is stretched, to lengthen the muscle (Nieman, 2009:194; Davis et al., 2005:28; Bandy et al., 1998:296).

This is a fairly new technique and was first used by physical therapists for treating patients with neuromuscular paralysis, but more frequently been used by athletic trainers and rehabilitation therapists for increasing flexibility (Prentice, 2010:110; Prentice & Arnheim, 2008:70; Williford & Smith, 1985:30). When the antagonist muscle relaxes via a maximal isometric contraction during the push-phase of the stretch, the Golgi-tendon organ effect a reflex relaxation of the antagonist before the muscle is placed in a position of stretch; as was pointed out above, this is called autogenic inhibition. When the antagonist passively relaxes via the concentric contractions of the agonist muscle that moves the limb further into an agonist pattern and causes the antagonist to relax, it is called reciprocal inhibition. Reciprocal inhibition allows the muscle to be stretched while protected from injury (Fasen, O'Connor, Schwartz, Watson, Plastaras, Garvan, Bulcao, Johnson & Akuthota, 2009:660; Prentice, 2004:132).

According to some researchers this technique might produce larger gains in flexibility of some joints when compared to other techniques (Ekblom, Grahn & Nordenburg, 1985 cited in Fasen et al., 2009:660; Lucas & Kuslow, 1984:615), but the need of assistance in the performance of the stretch makes it less practical. The larger gain is due to a larger reduction of motor neuron excitation during stretching due to the submaximal isometric contractions (Nieman, 2009:195). Various authors have identified proprioceptive neuromuscular facilitation as the most effective stretch to improve flexibility (Sady et al., 1982:261; Tangiwa, 1972:725; Holt et al., 1970:611), but much controversy exists around this phenomenon as other authors that found static stretching to be more effective (Davis et al., 2005:28; Bandy et al., 1998:295) and because proprioceptive neuromuscular facilitation stretching requires an experienced practitioner to help with the safe performance of the stretch, these stretches should only be used in athletic populations when performed by experienced personnel (Roberts & Wilson, 1999:259).

Knowledge about the acute effects of stretches is important for determining the efficiency of stretching and expected improvements and because literature on this phenomenon is so scarce, more research is needed. Fasen et al. (2009:660) found the greatest improvement in hamstring flexibility after 4 weeks in their PNF stretching group as opposed to the static stretching group - which indicates that more research about the time effects of different stretching protocols is essential. Fasen et al. (2009:660) also investigated the term "neuromobilization" or nerve glide, such as the slump-test, stretches which are active stretches in which the nervous system is made taut and then slack, and its effect when used in combination with PNF stretches. The results of the study emphasized the fact that flexibility is not only influenced by muscle elasticity but also by connective tissue/nervous tissue extensibility. Shrier (1999:221) found a reduction in return to activity time after injury with the use of neuromobilization techniques, which correlates with Kornberg and Lew's assumption (cited in Fasen et al., 2009:661) that if abnormal neural retraction predisposes the hamstring to strain, then stretching these neural structures should improve flexibility and protect one against injury.

There are three proprioceptive neuromuscular facilitation techniques used regularly today. The [1]Hold-relax method that is the mostly used, is when the athletic trainer moves the limb passively into the agonist pattern, meaning that all muscle groups in the pattern are activated isometrically (Youdas et al., 2010:241). After the lengthened time held the athlete uses the antagonist muscle and performs a concentric contraction against resistance given by the trainer for the period of time stated. The limb is then again moved into the agonist pattern (Prentice, 2010:128; Prentice & Arnheim, 2008:70; Plowman & Smith, 2002:583).

In the [2]Contract-relax method, the rotators of the extremity are allowed to shorten, whereas all other muscle groups in the pattern contract under isometric conditions (Youdas et al., 2010:241). It starts with an isometric contraction of the antagonist muscle against resistance, followed by a concentric contraction of the agonist muscle against resistance to produce a maximal stretch of the antagonist (Prentice, 2004:126; Prentice & Arnheim, 2008:70).

The [3]Slow-reversal-hold-relax method combines both hold-relax and contract-relax procedures (Youdas et al., 2010:241). This technique starts with a concentric contraction of the agonist muscle that often limits range of motion in the agonist pattern, followed by an isometric contraction of the antagonist during the push-phase. During the relax-phase the antagonist is stretched via the contraction of the agonist muscle that moves the limb back into the agonist pattern (Prentice & Arnheim, 2008:70; Prentice, 2004:127; Plowman & Smith, 2002:583).

According to literature the holding times of the respective push-phases and the relax-phase vary from 3- to 10-seconds at 20-75% of maximum voluntary contraction per phase. (Prentice, 2010:127; Nieman, 2009:194; Feland et al., 2001:186; Lardner, 2001:259; Williford & Smith, 1985:31).

Although many sources speculate that proprioceptive neuromuscular facilitation can cause more muscle lengthening over time because of the neurophysiological mechanisms mediated by the Golgi-tendon organ and muscle spindle (Youdas et al., 2010:241), they also indicate that it can cause more muscle stiffness and muscle soreness than static stretching does and it is disadvantageous because an experienced trainer is needed to help with the execution of each stretch (Brooks, Fahey, White & Baldwin, 1999:453).

2.2.3 BALLISTIC STRETCHING

Ballistic stretching can be characterized by an action-reaction bounding motion that uses rhythmic motion and momentum of a swinging body segment to lengthen the muscle vigorously (Nieman, 2009:194; Plowman & Smith, 2002:582; Bandy et al., 1998:295). The repetitive bouncing-motion contractions of the agonist muscle group causes the antagonist muscles to relax thus, the group are stretched quickly and forced to elongate (Prentice, 2010:108; Plowman & Smith, 2002:582).

Although literature states that significant increases in range of motion can be obtained from ballistic stretching, many authors recommend that ballistic stretching should rather not be used as part of a flexibility training program (Roberts & Wilson, 1999:259; Bandy et al., 1998:295; Bandy & Irion, 1994:846). Their reason for the recommendation is due to the quick stretch that distorts the intrafusal fibres of the neuromuscular spindle and activates the annulospiral nerve endings that sends an impulse to the spinal cord that results in a strong myostatic stretch reflex of the muscles being stretched, which can alternatively cause a strain or rupture of the involved tissue (Plowman & Smith, 2002:582; Bandy et al., 1998:295).

Ballistic stretches do not last longer than six seconds, which means that the Golgi-tendon organ is not activated and that the lengthening of the muscle relies on the muscle spindle only. An example of ballistic stretching is a bouncing movement bending forward from the hips, keeping the legs extended and reaching for the toes via momentum (Prentice, 2010:108).

When compared with static stretching, La Roche and Connoly (2006:1006) found that both increased range of motion and stretch tolerance, with no changes in muscle stiffness, work absorption or delayed-onset-muscle-soreness (DOMS). In addition, both static and ballistic stretching cause's small amounts of DOMS (delayed-onset-muscle-soreness) in a manner similar to eccentric exercise and should provide as a protection shield against further damage. Further, they advised in their article to use ballistic stretching prior to eccentric exercise because it invokes a greater amount of eccentric muscle activity - which would place greater strain on the musculo-tendinous structures and therefore provide protection against future bouts of exercise and injury (La Roche & Connolly, 2006:1006), but must only be practised by high-performance athletes that are used to ballistic stretching and not by untrained or sedentary individuals.

2.2.4 DYNAMIC STRETCHING

Dynamic range of motion is a fairly new method of lengthening the muscles and was suggested by Murphy in 1991. He claimed that dynamic range of motion (DROM) has been shown to cause greater amounts of increases in muscular relaxation than other stretching techniques, is more effective at increasing range of motion and strength and prevents large discrepancies between active and passive flexibility and is therefore a better way to increase flexibility than static stretching because of static stretching's passive nature and in that it does not increase muscle temperature to prepare it for the activity to follow (Murphy, 1991:68).

Dynamic range of motion involves a gradual movement - a contraction of the antagonist muscle that cause the lengthened muscle at the joint crossed by the agonist muscle to move through a full range of motion at a controlled, slow tempo – from one body position to another (Nieman, 2009:194; O'Sullivan et al., 2009:38; Bandy et al., 1998:296; Murphy, 1991:68). When DROM is performed, metabolic processes increase that cause an increase in muscle viscosity and allows for a smoother contraction (Murphy, 1991:67; Nelson & Bandy, 2004:254).

DROM starts from the neutral position. The limb is then slowly (approximately 4- to 5-seconds) moved to its end range of motion, whereafter the limb is briefly held for 4- to 5-seconds at this end range and thereafter is moved back slowly to the original neutral position using an eccentric contraction (O'Sullivan et al., 2009:38; Murphy, 1991:68).

DROM is a fairly new technique and very few studies have been done comparing DOMS with other stretching techniques. Bandy et al. (1998:299) found in their experiment that both static stretching and dynamic range of motion cause increases in hamstring flexibility when both groups stretched for 5 days per week for six weeks, 30 seconds per day, but the static stretching group showed two times the increase in flexibility compared to the DROM group.

Stretching that is done in a controllable manner does not cause muscle soreness, which explains why dynamic stretching has become the technique of choice in the athletic population. Dynamic stretching can also be performed for any joint, which means that it can be more closely related to the type of activity or sport that the athlete engages in. In other words, dynamic stretching is highly functional when it comes to sport and is recommended for athletes prior to beginning an activity (Prentice, 2010:110).

2.2.5 COMPARISON BETWEEN DIFFERENT STRETCHING TECHNIQUES

Although all four stretching techniques have been demonstrated to increase or improve flexibility, there is still a considerable amount of debates concerning the technique that produces the greatest increases in flexibility and range of motion (Prentice, 2010:111). As mentioned, numerous studies have been done comparing different stretching techniques and parameters, but conflicting results cause uncertainty as to which stretching technique or which parameters to use to get the most benefit from your stretching program.

Although ballistic stretching has not been recommended because of its potential damaging effects, it causes similar amounts of range of motion increases than static stretching, and may be considered for highly trained athletes whose sport involves bouncing and rapid movements (Prentice, 2010:110; Nieman, 2009:194; Woolstenhulme et al., 2006:802). PNF stretching may produce slightly larger gains in range of motion than the other stretching techniques during one session or if one is looking to increase flexibility in a short time span, but is less practical than static-, ballistic and dynamic stretching (Nieman, 2009:194). PNF and static stretching produce greater gains in range of motion than dynamic stretching (Nieman, 2009:194).

Table 2.2 summarizes all studies referred to on comparison of techniques, the different parameters and results. The table can help identify the technique and parameters to use to obtain maximal results for the specific goal to be reached.

Table 2.2: Comparison of stretching techniques

Author:	Intervention:	Results:
Davis et al. (2005:27)	4 groups (3 intervention groups and 1 control) stretched 3 times per week over 4 weeks. Group 1: one 30s static stretch. Group 2: one 30s PNF stretch. Group 3: one 30s self-stretch.	All stretching techniques increase hamstring flexibility after 4 weeks, but only the static stretching group showed significantly greater increases compared with the control group.
LaRoche & Connoly, (2006:1000)	2 intervention groups stretched 3 times per week, over 4 weeks. Group 1: ten 30s static stretches. Group 2: ten 30s ballistic stretches.	After 4 weeks the range of motion was significantly higher in both static (9,5% ±6,7%; p=0,02) and ballistic (9,3%±9,3%; p=0,02) stretching groups.
Feland et al. (2001:186)	Two treatment groups. 1 repetition of 32 seconds. First group: static stretching. Second group: PNF stretching.	Both training groups significantly improved hamstring flexibility.
Williford & Smith, (1985:30)	Two training groups. Stretched 2 days per week for nine weeks. First group: static stretching. Second group: PNF stretching.	Both PNF and static stretching improved flexibility equally. No one was found more effective than the other.
Nelson & Bandy, (2004:254)	Three groups (2 intervention and 1 control group) stretched 3 times per week over 6 weeks. Group 1: one 30s static stretch. Group 2: six 5s eccentric exercises.	Increases in hamstring flexibility when comparing 2 intervention groups with the control group. No significant difference between 2 intervention groups in respective gains. Static group 12,79°. Eccentric group 12,05°.

Author:	Intervention:	Results:
Bandy et al. (1998:295)	Three groups (2 intervention and 1 control group) stretched 5 days per week for 6 weeks. Group 1: one 30s static stretch. Group 2: six 5s dynamic range of motion stretches.	Significant difference between control group and intervention groups. Significant difference (p>0,05) between static group (11,42°) and DROM group (4,26°).
Sady et al. (1982:261)	Four groups (one control and 3 intervention groups) stretched 3 times per week for 6 weeks. Group 1: two 6s static stretches. Group 2: two 6s PNF stretches. Group 3: 20s ballistic bounces.	Only the PNF group showed significant increases in flexibility (10,6°) when compared to the other 2 intervention groups and the control group.
Lucas & Koslow, (1984:615)	Three groups (3 intervention groups) stretched 3 times per week for 7 weeks. All groups did 5min of stretching of 20s each.	All groups showed significant increases in flexibility.

2.3 FLEXIBILITY AND AGE

2.3.1 CHILDREN AND ADOLESCENTS

Regular physical fitness and exercise are known to have favorable effects on growth and maturation of children and adolescents (Ribeiro, Portal, Da Silva, Monte & Dantas, 2010:38). The participation of children in organized sports and the emphasis on fitness and skills of these young athletes have increased tremendously in recent years - to such an extent that the number of sports-related injuries have multiplied in this population (Dahab & McCambridge, 2009:223; Micheli & Klein, 1991:6). Advancements in the duration and intensity of the sports discipline's training have increased in both children and adolescents' sports and generated new patterns of injury that was previously rare (Micheli & Fehlandt, 1992:713; Micheli & Klein, 1991:6).

Whether or not a lack of flexibility could be a direct cause of injury is still very much debatable, but its importance after injury is heavily documented in literature (Wallmann, 2009:355). Research shows that children have greater flexibility measures during elementary school phases and stages of development up until the age of 12 whereafter any changes in flexibility are negative (Valdivia, Canada, Ortega, Rodriquez & Sanchez, 2009:11). The cause of this greater flexibility/joint looseness, which can be seen during ages 10-14, is related to the release of androgens and estrogens during growth and start to decrease by the onset of puberty around age 12 (Valdivia et al., 2009:11). Physiological changes that occur with aging are responsible for the decrease in flexibility that comes with aging (Wallmann, 2009:356).

Despite the fact that flexibility often benefits maximal performance and the lack thereof predisposes adolescents and children to injury and restricted mobility, young athletes often overlook this part of their physical training, only emphasizing strength and endurance (Haywood & Getchell, 2001:333). It has therefore been suggested that flexibility is a quality that must be developed as part of the curriculum in primary and secondary schools (Valdivia et al., 2009:11).

Chronic overuse injuries were previously rare in this adolescent age group, but numbers have recently increased tremendously due to the repetitive microtrauma placed on the body during sports (Micheli & Klein, 1991:6). These overuse injuries can be divided into 5 broad spectrums, namely stress fractures, tendonitis, traction apophysitis, bursitis and joint disorders (Micheli & Klein, 1991:6).

Growth has also been identified as the central factor in the development of overuse injuries in the young athletic population (Micheli & Klein, 1991:7). From birth to four years the greatest growth rates are recorded in both boys and girls after which rates level off and eventually decrease until the rapid adolescent growth spurt (Micheli & Fehlandt, 1992:724).

It is also during the phases 3 to 12 years that "growing pains" are a common complaint in pediatric visits and a prevalence of 2,6 to 49.4% has been reported (Cardin, Magalhaes & Marcolin, 2008:2). Growth plates or epiphysis are growing areas of the long bones of the extremities which remains vulnerable to injury from childhood into adolescence (McDaniel, Jackson & Gaudet, 2009:18; Micheli & Klein, 1991:7). The apophysis undergoes slower growth with fewer proliferative-layer cells and increased longitudinal collagen fibers transversing the physis and reflecting forces placed upon it (Micheli & Fehlandt, 1992:724). During growth the soft tissues elongate passively in response to the longitudinal growth of the bones, which cause the muscle-tendon unit to tighten (Gallahue & Ozmun, 2006:252; Micheli & Klein, 1991:7). The apophysis then often becomes the "weakest-link" because of the muscle-tendon unit's tightening and the loss of flexibility that exposes the environment to apophyseal injury owing to increased forces transmitted across the joint and from the relative weakening of the apophysis caused by rapid clonal expansion of chondrocytes (Micheli & Fehlandt, 1992:725). In other words, during rapid growth, bone growth precedes muscle and tendon growth and results in a tighter muscle-tendon unit, making the athlete more susceptible to injury (Gallahue & Ozmun, 2006:252). This occurs especially during early adolescence when the bones grow in length and stimulates the muscles to grow in length, causing temporary loss in flexibility (Haywood & Getchell, 2001:335).

Girls begin their adolescent growth spurt at around age 9 and on average reach their peak height velocity at ages 11,5 to 12 years that tapers off at approximately age 14 (Valdivia et al., 2009:15; Haywood & Getchell, 2001:54). Ages 14 to 16 are the ages that girls are the most prevalent to injuries especially injuries to the growth plates if they participate in a program that does not take this into account (McDaniel et al., 2009:19). Data clearly indicate linear improvement in the average female's sit-and-reach scores from ages 10 to 16 years followed by a slight decline. Around age 17 a plateau is reached and regression might start occurring in flexibility scores slightly after this age (Gallahue & Ozmun, 2006:340-341). Girls as a group are usually more flexible than boys because stretching exercises are more soeially acceptable for girls than vigorous activity and girls tend to engage in dancing and gymnastics more typically than boys (Haywood & Getchell, 2001:335). Girls also tend to outperform their male counterparts at all ages which may be due to anatomical differences and sociocultural variances in activity (Gallahue & Ozmun, 2006:340).

Boys only start their adolescent growth spurt around age 11 and reach their peak velocity height at 13,5 to 14 years, which tapers off at 17 amounting to 10 to 13 centimeters of height gained more than girls because of the 2 extra years of growth spurt (Haywood & Getchell, 2001:54-55). Boys show declines in flexibility scores from age 12 and increases in growth plate injuries at around ages 11 to 13 years if not participating in a well-conditioned program, which might already be due to the rapid growth spurt during which the long bones grow faster than the muscles and tendons. A plateau and regression can also be seen at age 17 (Gallahue & Ozmun, 2006:340-341; McDaniel et al., 2002:19). From the aforementioned it can be concluded that girls do not necessarily lose flexibility measures during adolescent growth but stays linear or even improve, whereas boys show declines in flexibility from age 12 till 17 years.

As gender is a major factor in the timing as well as the extent of growth (McDaniel et al., 2009:18), it is essential that prepubescent and adolescent boys and girls engage in a proper stretching program along with strength and endurance training to counter the tendency of reduced flexibility (McDaniel et al., 2009:20; Gallahue & Ozmun, 2006:252 & 341). A good amount of flexibility can be maintained well into adulthood and beyond if appropriate activities and fitness parameters are maintained (Wallmann, 2009:356; Gallahue & Ozmun, 2006:341). Gallahue and Ozmun (2006:341) use the expression "Use it or lose it".

A study done by Valdivia et al. (2009:15) found that the greatest increases in flexor muscle performance range from ages 10-11 years, with a gradual decrease in flexibility as the age ranges increased. Twenty-nine and thirty-year old participants showed the minimum increase.

To prevent musculo-tendinous injury and especially overuse injuries, an assessment of any risk factors needs to be done (Micheli & Klein, 1991:8). It is necessary to assess the overall fitness, flexibility and medical condition of the sports candidate and measure it against the demands of the sport (Valdivia et al., 2009:11; Micheli & Klein, 1991:8). The guidelines for youth training programs should include the necessity of flexibility exercises and the need for slow, progressive increases in training and intensity (McDaniel et al., 2009:19; Micheli & Klein, 1991:8). The decrease in flexibility caused by the growth spurt or the decrease that accompanies the spurt should be addressed by a prophylactic stretching program (Micheli & Klein, 1991:7) to avoid weakening of the apophysis with subsequent injury or inflammation (Micheli & Fehlandt, 1992:725).

2.3.2 ADULTS

According to literature, falls is one of the most common causes for accidental deaths among elderly people, because old age is associated with time-dependant losses in physical capabilities (Hong & Robinson, 2000:29; Bassey, 1998:12). These dependent losses refer to the decrease in balance control, decrease in muscle mass and strength and increases in muscle stiffness. Although the improvement of physical function is frequently overlooked by physicians caring for the elderly, it has been shown that participating in physical exercise can significantly increase musculoskeletal function and help improve the so-called losses that are common in the elderly (Galloway & Jokl, 2000:37).

As stated in literature, children have greater flexibility in joints than adults (Wallmann, 2009:356), but as one ages the flexibility scores decrease. This is due to physiological changes that cause decreases in overall musculoskeletal flexibility. Loss of muscle function, increased intramuscular connective tissue, certain physical and biochemical changes that occur in collagen all result in decreased range of motion, a gradual decline in the efficiency of performance of activities of daily living and a decrease in muscle extensibility (Wallmann, 2009:356). For maintenance of the musculoskeletal function, balance and agility in the older population, an adequate amount of flexibility and ranges of motion is needed that will enhance an individual's functional capabilities; for example, bending, picking something up, reaching for something and in fact will also decrease the possible risk of injuries associated with joint or muscle stiffness. Although a physical program must place emphasise on cardiovascular and strengthening exercises, stretch training for all major muscle groups must also be included and done on a daily basis because flexibility usually declines and visibly reduces by the third decade of life and progresses with aging, and also because good muscle flexibility can counteract the decline in physical capabilities that is usually associated with the elderly (Wallmann, 2009:356; Armstrong et al., 2005:250).

2.4 STRETCHING AND INJURY PREVENTION

The use of stretching as part of an injury prevention program has been widely accepted and promoted among the sporting and athletic communities. Despite this widespread use of stretching regimens there is still no conclusive evidence to support this practice.

Stretching is believed to decrease visco-elasticity and increase the compliance of a muscle and through that increase the range of motion of the joint. Shrier (2004:268) defines compliance as the reciprocal of stiffness and points out that it is equal to changes in tissue divided by the force applied to achieve the changes in length.

In the literature it seems that the compliance of the muscle-tendon unit plays a critical role in what may cause a decrease in injury rates (Witvrouw, Mahieu, Danneels & McNair, 2004:445), and it is therefore of importance to understand how the muscle-tendon unit works during activities and stretching.

A muscle-tendon unit consist of both active- (contractile) and passive- (non-contractile) components, which both play a role in the absorption of energy (Safran et al., cited in Witvrouw et al., 2004:445). As seen in the basic literature (Anderson, 2005:219; Witvrouw et al., 2004:445), a muscle at rest can be associated with increased compliance and a decrease in the ability to absorb energy/forces; whereas an active muscle can be associated with a decrease in compliance and an increase in energy absorption of the force applied on the muscle. When the contractile (muscle) components are active to a high level, forces can be absorbed to a higher level, which again results in a reduction in muscle fiber trauma (Witvrouw et al., 2004:445). In accordance with that, if tendon (passive components) stiffness increases in the outer ranges of movement due to low compliance, greater passive forces are generated in the muscle that cause the force to be transferred to the contractile components, leaving little energy to be absorbed by the tendon tissue, but increasing forces to be absorbed by the active components, resulting in increased risk for trauma (Anderson, 2005:219; Witvrouw et al., 2004:445).

Therefore, the objective of any injury reduction regimen should be to decrease the compliance of the tendon tissue resulting in more energy absorption that then leads to reduced injury rates.

In two separate studies, researchers reported that tendon stiffness can be reduced through stretching exercises because periodic stretching leads to structural changes in the collagen. This decrease in compliance and stiffness of the tendon tissue leads to an increase in energy absorption by the stretched tendon, in turn resulting in lower injury risk because stresses on the tendon will less likely reach the maximal point of energy-absorption and less energy will therefore be transferred to the contractile components, thereby reducing the risk of muscle injury (Witvrouw et al., 2004:448; McNair, Dombroski, Hewson, Stanley & Stephan, 2001:355).

One problem that exist in stretching of the passive components is that it is necessary to initiate plastic deformation in order to effect a change in normal but short, healthy tissue, which is, on the other hand, not a recommendation in using it as part of a warm-up because of the potential damage or fatigue it can cause by overstretching of the tissues. It is also important to identify the end point before the muscle enters the plastic region through a point of stretch and not pain (Weldon & Hill, 2003:147).

Whether injury can occur when a muscle is stretched beyond normal length is another debate in literature. It appears that sacomere length is more related to exercise-induced muscle injuries than muscle length itself (Shrier, 2004:268), because when the actin and myosin myofilaments are stretched to a point where they no longer overlap, forces are transmitted to the cytoskeleton and muscle damage occurs (Anderson, 2005:219). This can even occur if a muscle has a normal range of motion and therefore it appears through the literature that under this hypothesis, muscle compliance may be irrelevant to injury, whereas sacromere's energy absorption capabilities is of greater importance (Anderson, 2005:219). According to the literature this also makes it difficult to identify the stretching technique that will cause the least muscle fiber damage, because even strains as little as 20% beyond resting fiber length can cause fiber trauma (Macpherson, Schork, Faulkner 1996, cited in Shier 2004:269).

Despite these claims stretching immediately before exercise may have different effects on muscles than stretching during other times or just after exercise as a cool-down and should be considered as different interventions.

2.4.1 STRETCHING BEFORE EXERCISE

Warm-up exercises prior to any activity whether moderate or strenuous, have always been a recommendation made for all involved in varies types of activities. A warm-up usually includes exercises that are directly related to the sport performance to follow; it can be identical to the sport or indirectly related to the sports performance (McHugh & Cosgrave, 2010:179; Powers & Howley, 2004:536). The main aim of a warm-up is to increase the body's temperature and to prepare the body for the transition from rest to the exercise state (Powers & Howley, 2004:325). According to Plowman & Smith (2002:586) stretching exercises alone do not increase body temperature and can therefore not be related to as a warm-up. In fact, cardiovascular exercises should be done prior to stretching to increase the body temperature to ± 39° Celsius that has shown beneficial effects, because increased body temperature leads to increased metabolic processes and decreased viscosity and also increase oxygen uptake and neuromuscular transmission and improve the elasticity of the collagen; which all lead to the muscle being more receptive to stretching (Prentice, 2004:133; Plowman & Smith, 2002:587; Brooks et al., 1999:146).

Although considerable confusion exists about the relationship between warming-up and stretching prior to exercise/performance it is generally accepted that stretching will increase joint range of motion (Powers & Howley, 2004:536) and will especially be beneficial to individuals partaking in sports that requires extreme range of motion (Plowman & Smith 2002:587). McHugh & Cosgrave (2010:171) stated that stretching before performance may have an impact on some types of injuries and no impact on other types, for example, muscle strains where they plausible theorized it to (1) Stretching that makes the muscle-tendon unit more compliant, (2) increased compliance shift angle-torque relationship to allow greater relative force production at longer muscle length, and (3) the enhanced ability to resist excessive muscle elongation may decrease the susceptibility to a muscle strain injury, but they stated that more adequate research is needed in sports with a high incidence of muscle strains to thoroughly explain this phenomena and that it doesn't apply to non-contractile component injuries.

Several studies have examined the association between pre-participation stretching and injury risk (Table 2). Of the eight studies examined, only three showed no efficacy of stretching in reducing injury risk (Pope, Herbert, Kirwan & Graham, 2000:271; Van Mechelen, Hlobil, Kemper, Voorn & De Jongh, 1993:711) while the other five showed some efficacy of stretching reducing in injury risk (Hadala & Barrios, 2009:1587; Olsen, Myklebust, Engebretsen, Holme & Bahr, 2005:6; Amako, Oda, Masuoka, Yokoi & Campisi, 2003:442; Bixler & Jones, 1992:134; Ekstrand, Gillquist & Liljedahl, 1983:116).

Olsen et al. (2005:5) report a period prevalence of 129 knee injuries per 1000 player hours among 123 youth sports clubs after completion of a program that included ballistic stretching, warm-up running, technique, balance and strength and power. Of the 129 knee injuries 81 injuries occurred in the control group population. Bixler & Jones (1999:134) report a significant decrease in lower extremity injuries in their study on the effect of a 90 second static stretch followed by a 90 second warm-up just after half-time. Ekstrand et al. (1983:116) report an injury prevalence of 0,6 injuries per month for the intervention group and 2,6 injuries per month for the control group after completion of a 10 minute PNF stretching program, a warm-up and the use of leg guards, correct rehabilitation, supervision and taping by the intervention group. Amako et al. (2003:442) reported a muscle/tendon injury prevalence of 2.5% in the intervention group and 6.9% in the control group and a prevalence of 1% in the intervention group and 3.5% in the control group for lower back injuries. Together a total of a 66% reduction in musculo-tendinous injuries was found in the intervention group when compared to the control group, who actually performed some unsupervised stretches. Lastly, Hadala & Barrios (2009:1587) report that a 30 minute stretching session with two warm-up exercises resulted in a reduction of 82% in muscle injuries when compared to the same group in the pre-intervention season where 22 muscle injuries over a course of 9 days of competition was recorded, efficient in reducing the number of injuries when compared to no stretching.

In contrast to the above, Pope et al. (2000:271) found no significant difference in injury rates between the intervention group, who stretched statically for 20 seconds over a period of 12 weeks, and the control group. Pope et al. (2000:275) conclude that each recruit will have to stretch for 3100 training sessions to prevent 1 injury. In another study the same researchers (Pope, Herbert & Kirwan, 1998:165) again found no effect of a 20 second stretching plus warm-up protocol for one muscle group. Despite the limitation to the time of stretch, Pope et al. (1998:165) do not support the proposal that stretching before exercise might reduce injury rates. The researcher found one study that reported an increase in injury occurrence in the intervention group that followed a stretching program with a warm-up program twice a day for 16 weeks. The injury prevalence was recorded as 4,9 running injuries per 1000 hours for the control group and 5,5 running injuries per 1000 hours for the intervention group (Van Mechelen et al., 1993:711).

As seen in all the above studies, literature has failed to support this injury prevention notion. Although all of the above studies used static stretching protocols, no studies have been done to show that static stretching as means of establishing flexibility does anything to prevent injury (Murphy, 1991:68). In fact, static stretching can cause hypo-activity and lead to overstretching because of stretch tolerance increases (Shrier, 2004:33) and can cause instability, weakness and injury (Murphy, 1991:69).

Although static stretching was done in most of the studies that found positive outcomes between stretching and injury prevention occurrence, is was in all cases either followed by or done post other warm-up skills including running which support Plowman & Smith (2002) that cardiovascular exercises need to be done to increase body temperature to allow the muscle-tendon unit to become more resilient to the stretch. McHugh & Cosgrave (2010:179) present the following stretching recommendations as reasonable for injury prevention: (1) pre-participating stretching should target muscles susceptible to higher injury occurrence, for example, hamstrings strains in soccer and football, (2) at least four to five 60 second stretches to pain tolerance must be applied and performed bilaterally to decrease passive resistance to stretch, (3) to avoid lingering stretch-induced stretch loss, dynamic pre-participation drills must also be performed before actual performance.

Despite Plowman & Smith's outcome, Murphy (1991:67) doubt the use of static stretches even after cardiovascular warm-up because of its passive nature. He argues that passive activity does not increase temperature and therefore if done post cardiovascular warm-up will only allow the muscle to get cold again (Murphy, 1991:67). Therefore it is also important to note that the frequency for stretching may be different for different muscle groups because of different temperatures and different amounts of pennation for each muscle to be able to get most benefit out of a stretching session (Shrier, 2004:269). Murphy proposed the use of dynamic range of motion exercises to accomplish normal range of motion which is all that is needed because of sacromere heterogeneity and the fact that most strains occur during eccentric exercise and not in the outer ranges (Anderson, 2005:219), which will also prevent the detrimental factors of static stretching (Murphy, 1991:69). This type of stretch will not only accomplishes range of motion, but will also help the athlete to stay strong throughout the range of motion.

Although many sources do not support the use of any stretching exercises to decrease injury rates, dynamic range of motion exercises seem like a very good means to prepare the muscles for the activity to follow by increasing core temperature (Murphy, 1991:67) and loosening of the joints in normal range of motion limits when used in conjunction with warm-up exercises.

Therefore, the use of only stretching as warm-up is not supported and is not recommended. Intramuscular temperature should first be increased before stretching to get most efficiency out of a stretch during either a rehabilitation program or general conditioning program and it can be achieved with low-intensity warm-up exercises (Prentice, 2004:133).

Examples of dynamic range of motion exercises are listed in Table 2.3.

Table 2.3: Dynamic range of motion exercises

Dynamic stretching exercise:	Time (s):
Deep lunge walk	2 x 10
Swing leg in sagital plane while walking (every 3rd step)	2 x 15
Take frontal support against a gym ladder and swing leg in frontal plane	2 x 15
Stand in straddle position, take support, bend trunk forwards, catch ladder bar at hip level and bend deeper	2 x 10
Stand frontally on the lowest ladder bar, lower and lift heels	2 x 10
Straddle in sitting position, knees bent, lower knees alternately inwards touching the ground	2 x 20
Sit in hurdling position, bend trunk towards straight leg and back, slowly	2 x 20
Take frontal support against a gym ladder and swing leg high backwards	2 x 15
Take frontal support against gym ladder and circle free leg, knee bent	2 x 15
Lean against the gym ladder, both feet on the floor; lift heels alternately, the balls of feet resting on the floor	2 x 15

(Makaruk, Makaruk & Kedra, 2008:24)

2.4.2 STRETCHING EXERCISES DURING OTHER TIMES OR AS COOL-DOWN

The reason for the recommendation of a cool-down period after exercise sessions is to provide gradual recovery from the endurance or game phase (Armstrong, Balady, Berry, Davis, Davy, Davy, Franklin, Gordin, Lee, McConnol, Myers, Pizza, Roland, Stewart, Thompson & Wallace, 2009:154) and to return the heart rate and blood pressure to normal gradually (Powers & Howley, 2004:312), reduce potential post-exercise hypotension, facilitate dissipation of body heat, promote rapid removal of lactic acid and combat the potential, deleterious effects of the post-exercise rise in catecholamine (Armstrong et al., 2009:154).

Cool-down periods can vary from anything between 10-30 minutes of continuous activity, depending on environmental conditions, fitness levels and the nature of the training session (Powers & Howley, 2004:427). The cool-down usually includes low-moderate intensity cardiovascular exercise such as walking or jogging and can be followed by stretching (Armstrong et al., 2009:154; Powers & Howley, 2004:312).

Flexibility and extensibility of the muscles and fascia are important in maintaining a normal range of motion, which in turn is important for athletic performance (Murphy, 1991:69). Through stretching during the cool-down phase, but preventing excessive stretching to maintain normal muscle tension, the fascia can stay intact (Murphy, 1991:69), actin and myosin will not overlap and cause muscle damage (Anderson, 2005:219) and the athlete's performance will not be affected. Yet again Murphy (1991:68) disregards the use of static stretching even as part of cool-down because of its passive nature. The continuous activity during cool-down (Powers & Howley, 2004:427), but at lower intensity to redirect blood flow away from the muscles can be obtained via a dynamic range of motion exercises, which will also help the athlete to stay strong through the full range of motion of the joint (Murphy, 1991:69).

In a study done on infantry basic trainees, injury prevalence of 29.1 % for the control group and 16.7 % for the intervention group was recorded after 13 weeks of extra 3 times daily stretching by the intervention group (Hartig & Henderson, 1999:175). It was concluded that increased hamstring flexibility resulted in fewer overuse injuries and the use of flexibility exercises multiple times daily to maintain the stretch effect was recommended.

From the literature it follows that stretching during cool-down is most effective in improving or maintaining the functional range of motion needed for sport (Anderson, 2005:219) and that stretching over the long-term, several times daily, decreases injury rates.

Whether or not dynamic range of motion is the only beneficial means as part of a cool-down phase cannot be supported by the researcher. Further research on different stretching techniques during cool-down is needed to elucidate the issue.

2.5 EFFECTS OF STRETCHING ON PERFORMANCE

Athletic trainers and rehabilitation specialists usually recommends pre-exercise stretching and encourage their athletes or patients to perform stretching exercises before engaging in strengthening exercises or strength assessment tests to reach the ultimate goal of improved performance (Sekir et al., 2010:268; Marek, Cramer, Fincher, Massey, Dangelmaier, Purkayastha, Fitz & Culbertson, 2005:95; Ingraham, 2003:5). Although a majority of athletes will state that they feel better after stretching, authors of recent research have suggested that pre-exercise stretching may temporarily compromise a muscle's ability to produce maximal force and power (Torres et al., 2009:52; Sim, Dawson, Guelfi, Wallman & Young, 2009:2155; Beckett, Schneiker, Wallman, Dawson & Guelfi, 2009:444; Makaruk et al., 2008:25; Marek et al., 2005:95; Sekir et al., 2005:268; Evetovich, Nauman, Conley & Todd, 2003:486). Passive muscle stretching before engaging in physical activity is a common practice among many athletes, but their efforts to believe that the stretching effect may improve their performance might be futile, as recent evidence shows detrimental effects on performance when followed by acute stretching (Nelson et al., 2005:449).

Previous studies have examined the effects of acute stretching on performance and reported that static stretching does indeed decrease peak torque, maximum power output, isometric contractions, isotonic contractions and isokinetic power. In a critical review of pre-exercise stretching and its effect on performance, 20 studies were found that all reported diminished performance in force, torque and jump after acute stretching (Shrier, 2004:268). In the same review no studies were found that suggested that stretching is beneficial for performance (Shrier, 2004:268). A study on changes in isometric grip strength over ten trials in a sample of young adults reported a decline of 88,8% in isometric grip strength after 10 seconds of static stretching (Knudson & Noffal, 2005:350). Nelson et al. (2005:452) reported significant increases in 20 meter sprinting times after static stretching. In two studies that both examined maximal force production of the leg extensors and flexors a decrease of 7.3% and 8.1% was reported (Cramer, Housh, Miller, Coburn & Beck, 2004:239; Kokkonen, Nelson & Cornwell, 1998:413).

Two hypotheses have been made to explain the possible negative effect of acute static stretching on force/torque production. The first hypothesis is that mechanical factors such as alterations in the visco-elastic properties of the musculo-tendinous unit may be an attributor (Sekir et al., 2010:276; Marek et al., 2005:101). Also, increased muscle compliance may alter the length tension relationship of the muscle, increasing sacromere shortening distance and velocity and decrease force production due to force-velocity relationship (Cramer et al., 2004:239). It has also been hypothesized that neural factors such as decreases in motor neuron pool excitability that may reduce peripheral muscle activation or altered reflex sensitivity that may result from the inhibition of the acute response of musculotendinous proprioceptors, may contribute to the stretching-induced decrease in force (Sekir et al., 2010:276; Cramer et al., 2004:240). A reduction in torque may be due to a greater autogenic inhibition function and also decrease the ability to recruit motor units (Evetovich et al., 2003:484), which results in disruption of the stretch-reflex activity and the acute response of the muscle's and/or joint's proprioceptors (Nelson et al., 2005:453). Fowles, Sale & MacDougall (2000:1186) claims that the stretch-induced decreases in neural drive could only account for a percentage of the force deficit, and thus its mechanical and neural factors that contribute to the stretch-induced deficit. The negative effect of static stretches on running performance can be explained by these two hypotheses via the increased extensibility of the muscle-tendon unit (mechanical) and the enhanced autogenic inhibition reflex initiated in the Golgi-tendon organ (neurological) (Marek et al., 2005:101).

In sports where success depends on the rate of force production or power, rather than just the ability to maximize force output, prior-stretching can compromise the performance of the specific skill (Nelson et al., 2005:452). Rugby, soccer, basketball, badminton, sprinting and netball are examples of sports that require high stretch-shortening cycle movements (Witvrouw et al., 2004:446) and with static stretching this stretch-shortening cycle's effect is reduced - which results in the contraction that follows the relaxation to produce higher force or terminal velocity and therefore delay reaction time and duration of isolated movements (Makaruk et al., 2008:25).

The reduction in vertical jump height, standing jump height (4,4 %), counter movement jumps (4,3 %) and sprinting times can also be attributed to the diminishing effects of acute static stretching and is therefore said to influence all movements in sports with either pure concentric contractions (explosive take-off out of starting blocks) or a concentric phase followed by repetitive stretch-shortening cycle actions (long jump, high-jump) (Nelson et al., 2005:453; Young & Behm, 2003:21; Cornwell, Nelson, Kokkonen, Eldredge & Glickman-Weiss, 2001:307).

A recent study by Sekir et al. (2010:268) is the only known study to date that investigated the effects of static and dynamic stretching of the leg flexors and extensors on concentric and eccentric peak torque of the leg extensors and flexors in women athletes. The researchers found that concentric and eccentric quadriceps and hamstring muscle strength at both 60 and $180° s^{-1}$ displayed a significant decrease following static stretching and, in contrast, significant increases after dynamic stretching during quadriceps and hamstring muscle actions at both concentric and eccentric testing modes. Their finding suggested that dynamic stretching as opposed to static or no stretching may be an effective means of enhancing muscle performance during the pre-competition warm-up routine in elite women athletes.

The researcher can therefore, based on the abovementioned literature, not recommend static stretching as a tool to induce pre-exercise performance improvement. Moreover, the debate about the contrast between ballistic and dynamic stretching and whether it has a positive or negative outcome on performance also continues. Several other researchers also found that ballistic and dynamic stretching protocols prior to competition/performance increased vertical jump height and 20 and 40 m sprinting times (Taylor, Sheppard, Lee & Plummer, 2009:661; McMillian, Hutler & Taylor, 2006:492; Woolstenhulme et al., 2006:799). Negative results were found for ballistic stretching and proprioceptive neuromuscular facilitation stretching in two other studies consulted by the researcher (Marek et al., 2005:101; Kokkonen et al., 2001:417). One other study was found that showed significant increases in sprint performances after doing dynamic range of motion exercises as part of a warm-up routine when compared with static stretching (Makaruk et al., 2008:25). As to PNF stretching techniques and its effect on jump performance, it was found that it had no influence whatsoever on drop jump (Yuktasir & Kaya, 2009:11).

However, in the rehabilitation setting where stretching is used to maintain or improve functional range of motion for an injured muscle of joint, Marek et al. (2005:103) proposed the use of a risk-to-benefit ratio that weighs the risks of decreases in strength, power and muscle activation against the benefit of maintaining a functional range of motion. The regaining of range of motion during the early stages of rehabilitation is more important than regaining maximal muscle force production, while focus shifts during the later stages of rehabilitation where the redevelopment of strength and power is of importance. The clinician should also consider the possible effects of pre-exercise stretching on strength exercises before engaging in strength assessment tests used to make important decisions on rehabilitation progression (Marek et al., 2005:103).

Although pre-exercise stretching shows no beneficial effects on maximal force and power, the long-term effects of static stretching and proprioceptive neuromuscular facilitation stretching seem to indicate the opposite. An investigation into the long-term effects of static and PNF stretching exercises on jump performance reviewed six studies that all reported significant increases in jump performance and maximum torque. Table 2.4 summarizes the six studies and the findings regarding performance and torque.

Table 2.4 Studies on stretching and performance

Author:	Intervention:	Result:
Hortobagyi et al. (1985)	7 weeks of passive stretching	Significant improvement in speed of concentric contractions
Handel et al. (1997)	8 weeks of unilateral contract-relax stretching	Significant improvement in maximum torque and work, increases of concentric work for the knee flexor and extensor muscles
Wilson et al. (1992)		Increase in performance of bench press lift
Godges et al. (1993)	3 weeks of hip extension stretching or trunk flexion exercises	Significant improvement in trunk flexor muscle performance
Ferreira et al. (2007)	6 weeks of static stretching	Significant increases in muscular torque production of knee flexors and extensors
Worrel et al. (1994)	3 weeks. Two stretching techniques. PNF and static stretching	Significant increase in peak torque of hamstring acting eccentrically and concentrically

(Yuktasir & Kaya, 2009:18)

The positive outcomes seen through long-term stretching can be attributed to muscle hypertrophy that leads to an increase in both serial sacromere number and in the cross sectional area of the muscle fibers (Yuktasir & Kaya, 2009:19). These findings encourage the use of stretching exercises in sport and rehabilitation (Yuktasir & Kaya, 2009:19), but evidently more research is needed to clarify the effects of long-term stretching on power and strength, what technique to use, choice of exercises and time of stretching in the sport and rehabilitation setting.

In summary, acute bouts of stretching cause an increase in muscle compliance that may alter the muscle's length-tension relationship, increase sacromere shortening distance and velocity and results in a decreased force production due to the force-velocity relationship (Cramer et al., 2004:239). However, long-term stretching causes hypertrophy of the muscles and increase the number of linearly arranged sacromeres due to the increase in muscle length. This increase in thickness with an increase in the number of fibrils would then lead to an improved torque maximum and increase in work (Handel et al., 1997:404).

After all of the above mentioned findings, literature states that static stretching can in fact be done before performance but must be followed by a SKILL warm-up routine to dissipate the negative effects, and the same implies for a dynamic stretching protocol. The SKILL component needs to incorporate activities with very similar neuromuscular and energetic requirements as those needed to successfully perform the performance (Taylor et al., 2009:660).

It is the opinion of the researcher that pre-exercise stretching must be followed by a SKILL warm-up before engaging in sporting activities, regardless of the stretching technique, if muscle performance relies on maximum power output and torque. More research is needed to identify the parameters for long-term stretching in respect of performance and prevention.

2.6 IMPORTANCE OF STRETCHING IN REHABILITATION

One of the most essential components of a rehabilitation program is regaining full flexibility of joints or soft tissue. Flexibility can also be referred to as the range of motion of a specific joint and the degree of movement that occurs at a joint (Brukner & Khan, 2006:183).

Following injury, musculo-tendinous flexibility can be restricted by either pathological factors (resistance of the musculo-tendinous unit to stretch), contracture of the connective tissue, muscle imbalances, neural tension and joint dysfunction (Prentice, 2010:417; Brukner & Khan, 2006:183; Prentice, 2004:10). It is therefore of great importance that the therapist first evaluate what the cause of the limited range of motion is before engaging in either flexibility or mobilization exercises (Prentice, 2010:417). An experienced athletic trainer or rehabilitation specialist can detect soft tissue resistance to motion by the quality of the feel of the resistance at the end of the range (Prentice, 2004:533). Joint range of motion is usually decreased after prolonged immobilization or relative immobilization that causes adaptive tightening of the joint capsule or ligaments, muscles and tendons (Brukner & Khan, 2006:184). If range of motion is limited due to joint athrokinematics, mobilization traction exercises should be practiced first in order for the muscle flexibility exercises to be effective (Prentice, 2010:417).

Stretching exercises have been advocated widely as an effective means of reversing the serial sacromere loss and morphologic changes and induce the sufficient growth of normal tissue (Harvey, Batty, Crosbie, Poulter, 2000:1340) that occurs after injury. Stretching exercises to regain range of motion must be designed to restore normal functional range of motion to regain normal function and overstretching must be avoided to protect against further or re-injury (Prentice, 2004:121).

During the early stages of rehabilitation, modalities to restore range of motion is firstly addressed before focusing on progressive resistive exercises and endurance (Kjaer, Krogsgaard, Magnusson, Engebretsen, Roos, Takala & Woo, 2003:204). Although isometric strength exercises are done during the early stages of rehabilitation, they will not interfere with range of motion, as it is useful to increase static strength and decrease atrophy (Prentice, 2010:417).

Heavy resistance exercises or strength training during the early stages of rehabilitation might decrease range of motion because of limited movement possible during this stage and therefore the necessity of regaining normal range of motion before engaging in progressive resistive exercises is of great importance (Baechle & Earle, 2008:298). The athlete's focus must be on developing both antagonistic and agonistic muscles and exercise through a full available range of motion to prevent loss in range of motion and to gain most efficiency when starting with strength and endurance training (Baechle & Earle, 2008:298). Functional progression is the key (Prentice, 2010:420) and, therefore, the need for full, non-restricted range of motion is essential before the start of progressive, resistive exercises.

Only normal range of motion of joints and muscle flexibility are necessary in most sports in order to perform and, therefore, overstretching of the muscle-tendon unit is one of the biggest mishaps occurring. Uninformed athletes and coaches seem to think that increasing flexibility will lead to reduced injury risk or improved performances and spend a lot of time and focus on gaining flexibility. In cases where overstretching occurs, the subjects are more susceptible to injury because of lengthening of the muscle-tendon unit and passive structures and although muscles and tendons have the ability to return to normal length after stretching, ligaments and joint capsules do not, and instability occurs.

It is essential that the rehabilitation specialist is aware of the specific demands of the individual's sport (Brukner & Khan, 2006:109) and the physical requirements, including flexibility, for each specific joint (Prentice, 2004:125) to restore the normal range of motion after injury, yet preventing overstretching. Static- and dynamic range of motion exercises should be done to train the muscle for unexpected stretching beyond the normal extensibility limits that might occur during activities (Prentice, 2010:110). Passive (static) range of motion exercises are usually used during the early stages of rehabilitation when active (dynamic) range of motion exercises are too painful, while active range of motion exercises, for example proprioceptive neuromuscular facilitation stretches, are done later on to regain and maintain flexibility (Brukner & Khan, 2006:184). Passive range of motion exercises includes the static stretch, which is also the safest method of stretching because it is controlled (Prentice, 2010:110). Progressive resistive exercises are not yet a focus during these early stages and will therefore not interfere with the performance of the muscles if done as part of a warm-up (Makaruk et al., 2008:25, Marek et al., 2005:103). A combination of these two stretching modalities during the later stages of rehabilitation is essential to maintain the necessary passive and active range of motion needed for sport.

The trainer must also acknowledge the dangers that can occur with inappropriate stretches. The intensity, frequency and velocity needs to be monitored closely and progressed gradually during the rehabilitation process to prevent painful experiences and/or overstretching. The rehabilitation specialist also needs to be familiar with inappropriate stretches with specific injuries to prevent re-injury or pain (Brukner & Khan, 2006:6). Table 2.5 summarizes examples of stretches that must be avoided with specific injuries.

Table 2.5 Examples of stretches that must be avoided with injury

Injury:	**Stretch:**
Anterior instability	Avoid stretches of anterior capsule (Brukner & Khan, 2006:186)
Shoulder impingement or khyphosis	Avoid stretching rhomboids, rotator cuff and lower trapezius if muscles are inactive (Prentice, 2004:404)
Shoulder impingement	Avoid external rotation stretches because of anterior laxity of joint capsule (Prentice, 2004:404)
Disk disease	Avoid trunk and hip flexion stretching because of abnormal strain on the lumbar region (Prentice, 2004:678)

2.7 GUIDELINES FOR STRETCHING

Various techniques can be used to perform flexibility exercises and these vary from stretching while doing normal everyday activities to specialized techniques that involve muscle reflexes (Brooks et al., 1999:449)

A lack of knowledge about technique and parameters prevent the correct execution of stretching exercises in the general population. Guidelines and precautions need to be incorporated and taught to not only high-performance athletes, but also recreational athletes to ensure a complete understanding of flexibility training. Guidelines and precautions can be divided into a DO and DON'T list that will ease the identification of individual imprecision in a stretching program. Table 2.6 contains guidelines that can form a basis to inform and teach high-performance and recreational athletes about the correct execution of stretches.

Table 2.6 Guidelines for stretching

DO	**DON'T**
Warm-up before stretching	Do not stretch to a point of pain
Stretch on a regular 3-5 times per week basis	Ballistic stretching must be avoided if not highly trained
Perform stretching exercises on contra lateral sides	Do not stretch excessively around painful joints
Hold each stretch for 30 – 60 seconds with 60 second rest intervals	Do not overstretch ligaments and joints because of laxity risk
Stretch at least 3 times	Do not stretch muscles together if individual stretching has not been done
Breath normally while performing the stretches	Do not stretch a muscle after immobilization. Mobilize first.
If improvement in flexibility is desired, perform Static- and/or PNF stretches	Do not stretch swollen joints without supervision
• Stretch according to your own body	
• Stretch with care with osteoporosis and arthritis	

• Make sure the body is in good alignment when stretching • Stretch muscles of small joints in extremities first, then progress towards the trunk with muscles of larger joints • Feedback is essential when applying passive assistance	

Brukner & Khan, 2006:185; Prentice, 2004:134; Brooks et al., 1999:450

Stretching of the whole kinetic chain must be done as flexibility is described as movement of just one joint or a series of joints (Kjaer et al., 2003:142). Lack of flexibility in one joint can affect movement of the entire kinetic chain and can cause muscle imbalances, resulting in excessive pain (Prentice, 2004:132).

2.8 FLEXIBILITY AND RESISTANCE TRAINING

A joint's range of motion largely depends on a combination of muscular, tendinous and capsular characteristics including skeletal muscle, tendons and fibrous capsules with different proportions in various joints in addition to the neuromuscular activation of related muscle groups (Nobrega, Paula & Carvalho, 2005:842). The fast and safe recovery of patients from injury depends on numerous factors, which include resistance training and flexibility (Armstrong et al., 2009:165; Nobrega et al., 2005:842).

One would assume that a higher volume of flexibility training would have to be employed when practicing resistance/strength training, but the literature indicates that it might not be necessary after all. When a person spends a lot of time strength training it is often assumed that the person has a decrease in joint range of motion because of the large muscle bulk that that person develops (Prentice, 2010:106). Studies found that resistance training, in fact, has no effect on range of motion nor does it interfere with increments in flexibility, or change current levels of flexibility (Nobrega et al., 2005:842). Prentice (2010:106) agrees with the abovementioned, but emphasizes the necessity of performing the strength training exercises through a full range-of-motion, which will probably lead to increased dynamic flexibility.

However, when hypertrophy exists and a person has extreme increased muscle bulk, a strong flexibility program must be included in the regular training regime to avoid decreases and restrictions in range of motion (Prentice, 2010:106; Nobrega et al., 2005:845). The type of sport also plays a major role when considering the alteration of an individual's program. Although an athlete with large biceps and deltoids may experience difficulty in stretching the triceps, raking a power clean or holding a bar when performing a front squat, athletes such as shot-putters, offensive linesmen might need extreme joint mobility for injury prevention and it is advised not to alter their program (Baechle & Earle, 2008:298).

2.9 COMPONENTS OF IMPORTANCE IN STRETCHING

2.9.1 NEUROPHYSIOLOGICAL BASIS OF STRETCHING

A muscle or dynamic constraint system has nerve endings called mechanoreceptors, which function to detect the deformation of tissue and change that into neural signals (Prentice, 2010:108). Stretching is based on a neurophysiologic phenomenon that involves these mechanoreceptors and is called the stretch-reflex (Prentice, 2010:108).

Numerous muscles-spindles are present in a muscle and have parallel-arranged muscle fibers, each with sensory and motor neurons that detect changes in muscle length when stretched (McGinnis, 2005:278). Changes in joint position stimulates the sensory neurons that force muscles to change in length, after which the motor neurons reset the tension in the muscle fibers caused by the stretch, and contraction of the stretched muscle is facilitated (Prentice, 2010:108; McGinnis, 2005:279). The Golgi-tendon organ, situated in the tendon close to the muscle, is stimulated via tension within the tendon, caused by stretching or contraction of a muscle. When the stretch is held long enough, the motor neurons of the muscle spindle synapse with the sensory fibers of the tensed muscle, which cause relaxation (McGinnis, 2005:280). Unlike the muscle spindle's impulses, the Golgi-tendon organ's impulses cause relaxation of the antagonist muscle (Prentice, 2010:108), which serves as protection mechanism to prevent muscles from rupture or tearing via disruption of the active development of tension if tensile stress is too high (Prentice, 2010:108; McGinnis, 2005:280).

2.9.2 EFFECTS OF STRETCHING ON MUSCLES

Gains in muscle length due to stretching occurs via changes in the viscoelastic properties of the active and passive components of a muscle-tendon unit after several given durations and resistance to stretch (McHuge & Cosgrave, 2010:170; Prentice, 2010:109). Both muscle and tendon are composed of non-contractile collagen and elastic fibers that respectively enable tissue to resist mechanical forces and deformation and also assist in the recovery from deformation (Prentice, 2010:109). The viscoelastic properties of the muscle-tendon unit allow elongation over time via an external load or via stretching to a constant length.

The major contributor to the passive tension or stiffness inside the muscle-tendon unit is the connective tissue in the muscle-belly that consists of elastic components and parallel elastic components that both have viscous and elastic properties. The passive tension in the muscle-tendon unit is caused by elongation of the epimesium, perimesium and endomesium (collagen) of the muscle-belly, but largely due to the great number of perimesial and endomesial fibers (parallel elastic component) that prevent the muscle from being overstretched (Kubo et al., 2002:599). Unlike tendons, muscles have active components called actin and myosin myofilaments, which means that both the contractile and non-contractile components determine the muscle-tendon unit's capability to stretch and recover (Prentice, 2010:109).

It appears that the more intense the stretch the more muscle elongation is contributed by the non-contractile elements because of the primary resistance to the degree of lengthening, while the active components limit high-velocity deformation (Prentice, 2010:109). If the velocity of deformation is too high, the chance of exceeding the tissue's capabilities to undergo viscoelastic and plastic changes decrease. Passive stretching of a muscle causes autogenic inhibition to relax the muscle reflexively, which can cause the connective tissue to resist the stretch, but with active contraction the parallel elastic components are unloaded and the passive fibers are stretched according to the external force and workload the muscle develops while contracting (McHugh & Cosgrave, 2010:107). Autogenic inhibition allows for viscoelastic and plastic changes in muscle length if the stretching program is continued for long periods of time (Prentice, 2010:109). Any stretch training program's goal should be to lengthen the muscles permanently to keep normal range of motion and must therefore continue throughout someone's lifespan. An important goal of stretching before sports performance is to increase range of motion and to decrease resistance to stretch, allowing a freer movement pattern (McHuge & Cosgrave, 2010:170).

The literature consulted advises the use of low-load stretching if permanent elongation is desired which will also in turn, prevent too high-velocity contractions (Plowman & Smith, 2002:578).

2.10 BENEFITS AND RISKS ASSOCIATED WITH STRETCHING

The importance of stretching in sports and daily activities is recognized more and more by coaches, trainers and therapists. Through literature gathered by the researcher, stretching in sports have different outcomes of importance, but apart from that, more benefits, summarized in table 2.7, exist that can be associated with flexibility.

Table 2.7 Benefits of flexibility training

Most widely known benefits from flexibility training:
Injury prevention if done long-term
Muscular relaxation
Improved range of motion
Maintenance of good posture
Mental relaxation
Relief of aches and pain
Improved blood and lymph flow
Improved muscle coordination
Reduced risk of lower back pain
Enhanced enjoyment of physical activities
Joint health
Improved body position and strength in sport and everyday living

Yayes, 2007:2; Brooks et al., 1999:482; De Lorenzo, 1999:21

However, the demands of sports require a certain sport-specific musculo-skeletal flexibility and vary from sport to sport (Brukner & Khan, 2006:142). It is clear that gymnasts need excessive amounts of joint flexibility to perform routines and that a hurdler needs good hamstring flexibility to clear the hurdle with ease and improve stride length, but a long-distance runner does not need excessive flexibility and, therefore, individual sports requires individually designed flexibility programs (Prentice, 2010:106; Brukner & Khan, 2006:142).

Plowman & Smith (2002:579) modified a table with the most popular sports and physical activities and the relative level of flexibility required. Table 2.8 summarizes the levels

Table 2.8 Levels of flexibility required for sports

Skills requiring extreme range of motion in specific joints	**Skills requiring greater than normal range of motion in one or more joints**	**Skills requiring only normal range of motion in involved joints**
Figure skating Gymnastics Diving Hurdling Pitchers Dancing (ballet, modern) Karate Yoga	Jumping Swimming Wrestling Sprinting Racquet sports Team sports	Boxing Long distance running Archery Shooting Curling Basketball Cross-country skiing Bicycling Stair climbing Roller skating Horseback riding Resistance training

It is the responsibility of the coach/trainer to know the levels required for the sport and train the athletes accordingly to ensure that a lack of flexibility is addressed to avoid potential damage caused by exceeded muscle extensibilities and proneness to injury and to counteract the tendency of muscles to shorten via regular participation in flexibility training (Plowman & Smith, 2002:578).

ACSM Guidelines for exercise testing and prescription (2009) summarizes key points about stretching that will also be useful when prescribing a stretching exercise program. These are given in Table 2.9 below.

Table 2.9 Stretching key points

Key points:
Stretching exercises is most effective when the muscles are warmed up
Stretching exercises should be performed before or after the conditioning phase in the program
Sports for which muscular strength, power and endurance are essential must include stretching exercises
Stretching does not necessarily prevent injury
Stretching exercises should be performed 2/3 days per week
Static, ballistic, dynamic and PNF stretching exercises improve flexibility
Four or more repetitions per muscle group are necessary
Static stretches should be held for 15 to 60 seconds
For PNF stretches a 6 second contraction should be followed by a 10 to 30 second assisted stretch

2.11 FLEXIBILITY AND QUALITY OF LIFE

When one thinks of efficiency of movement and how it relates to flexibility, the first thing that comes to mind is POSTURE. Why it plays such a vital role in posture has in recent years been discussed so many times and the reason is always the same, to maintain good body mechanics.

Good posture is explained as a good habit that contributes to the well-being of an individual., With maintenance of this good posture, body mechanics will automatically be enhanced. This body mechanics requires that the range of motion in a joint or joints must be adequate but not excessive, because with excessive flexibility comes instability, which is not a positive desire (Kendall, Kendall, McCreary, Provance, McIntyre, Rogers & Romani, 2005:51).

It is optimal to explain the causes, precautions, and methods of correction for this abnormality, because incorrect or faulty posture is such a common sight in recent years. The most important implications of incorrect posture are the discomfort, pain and disability it causes. It involves a combination of lengthened and shortened muscles that interrupt the complete kinetic chain of the body that determines optimal and efficient movement in everyday life (Prentice, 2004:132). Stretching the shortened muscles, tightening the lengthened muscles and activating the inhibited muscles can help improve the muscle imbalances that are, in most cases the cause of the pain and discomfort and must be addressed for the long term. If not, the beneficial effect may only be temporary (Lardner, 2001:257).

Assessment of the entire kinetic chain is needed to identify the causes of posture-related syndromes. Only then can corrections begin through strengthening, stretching and activation. When muscles are in balance and the correct range of motion occurs around a joint, efficient movement - whether it is walking, running, playing a sport, sitting or picking something up from the ground - can be accomplished without the arising of pain and discomfort. Therefore normal flexibility is a huge attribute to form balance in all muscles of the body so that it can provide the correct alignment of joints, minimize stress and relieve undue strain on ligaments, muscles and bones.

2.12 SHORT- AND LONG-TERM STRETCHING

A major issue addressed by numerous authors is whether stretching does indeed have an influence on the muscle-tendon unit over short-term periods and/or for the long term (Magnusson & Renström, 2006:87; Kjaer et al., 2003:143).

If the muscle is held stationary at a fixed or new length, the tension will decline and the resistance to elongate (measured as joint moment) will decrease over time in a non-linear fashion. This is called viscoelastic-stress relaxation and shows that the muscle-tendon unit is indeed influenced by a stretch manoeuvre (Magnusson & Renström, 2006:87; Magnusson, 1998:74).

Kjaer et al. (2003:143) explain viscoelastic stress relaxation by stating that during the dynamic loading phase of a stretch, there is a non-linear increase in resistance to stretch, followed by a non-linear decline in resistance during the static loading phase and that this response's usually pronounced during the first 10 to 15 seconds of a stretch and significantly continues for approximately 45 seconds.

It appears that the literature attributes the acute effect of stretching in short-term period to the neurophysiologic events occurring during single stretching (Kjaer et al., 2003:144). Magnusson (1998:69) investigated the effect of five 90-second stretches with 30-second rest intervals to see if there was a lasting effect till up to 1 hour thereafter. He found significant decreases in stiffness (13%) and energy (30%) in the dynamic phase and a decrease in passive torque during the static phase, but the decline was only temporary and with measurement 1 hour later, the effects had already vanished.

As previously mentioned, the muscle-tendon unit consists of connective tissue with both elastic and parallel elastic components. Magnusson (1998:69) attributes the effect of the five stretches to the possibility of a load placed on both elastic and parallel elastic components, and points out that the viscoelastic effect seen can be due to acute adaptations of the parallel elastic components to reduce the load. Because muscle strains is the most common injury suffered by athletes in sports, and passive stretch in a physiological range results in 2% tendon strains and 8% muscle-tendon junction strains; stretching of the muscle-tendon unit is beneficial to reduce injury risk because of changes in the viscoelastic properties that results in less tension across the myotendinous junction where muscle strains occur primarily (Kjaer et al., 2003:144).

Through the available literature we can infer that repeated stretches have an effect on the short-term lengthening of the muscle and should be practiced by athletes before engaging in their sport (although the effect would be transient after 1 hour) to reduce possible risk of injury (Magnusson, 1998:70).

Long-term effects of flexibility are usually ascribed to the changes in the passive properties of the muscle, but Magnusson (1998:71) found in his investigation that after stretching two times per day for 45 seconds for 20 consecutive days, there was no difference in stiffness, energy and passive torque, but that the joint range of motion increased. He (1998:71) attributes this to an increase in stretch tolerance rather than changes in the viscoelastic properties of the muscle.

Although the mechanism for altered stretch tolerance is currently unknown (Kjaer et al., 2003:144), the increased tolerance that is seen on the stretched training side and lack of increased tolerance on the opposite side that served as controls, can be because of peripheral mechanisms with the possibility of central factor also playing a role (Magnusson, 1998:72).

Because long-term flexibility leads to improvements in joint range of motion with no changes in the passive properties of the muscle, it is advised that sport-specific stretcbing is done to meet the demands of the activity (Kjaer et al., 2003:145).

CHAPTER 3: METHODOLOGY

3.1 INTRODUCTION

3.1.1 EXPERIMENTAL APPROACH TO THE PROBLEM

A repeated measures design was used was used during this study to determine the effectiveness of 4 stretching technique training programs on hamstring muscle flexibility. The four techniques included: 1. Static stretching, 2. Hold-relax Proprioceptive Neuromuscular Facilitation, 3. Contract-relax Neuromuscular Facilitation and 4. Dynamic stretching. Determination of the most efficient parameters including intensity, frequency and duration of a stretching program, was also done by use of the data captured from the first three weeks of training and comparing the results with the data captured from the second three weeks of training.

Before the study commenced and before the subjects were recruited, the study was approved by the Department of Human Movement Science at the University of the Free State and the Ethical Board of the Department of Humanities.

3.2 SUBJECTS

A total of 100 girls between the ages of 13 and 17 years were recruited from a school hostel in Bloemfontein to participate in this study. Subjects were randomly assigned to either a control group or one of the 4 experimental groups with 20 subjects in each group. A meeting with the Principal was arranged in order to obtain full permission for execution of the investigation as well as to explain the procedures that followed. An informed consent form approved by the University of the Free State's Ethical Board and Department of Human Movement Science was handed out and had to be signed by the individual's legal guardians, because the partaking individuals were minors.

The minor individuals themselves received a child assent form that confirmed their participation and presented full explanation of the purpose of the study.

3.2.1 REQUIREMENTS TO BE MET BY THE SUBJECTS

1. Subjects had no history of impairment to the knee, hip, thigh or lower back in the past year.
2. Subjects were required not to participate in any other stretching regimens other than of this study for the period of time.

3.3 PROTOCOL

The ages of all subjects were documented. Hamstring muscle flexibility was measured before the initial start of the experiment, after 3 weeks of intervention and then after the last intervention session at the end of the 6 weeks flexibility-training program, by means of the 90°/90° knee extension test.

The training sessions took place 3 times per week over a period of 6 weeks, for a total of 18 training sessions. After initial measurements, the subjects were randomly assigned to 5 groups (4 experimental and 1 control group).

3.4 EQUIPMENT

- Hamstring muscle flexibility was measured using a double-armed goniometer of transparent plastic. A goniometer is marked off in degrees that are 1 degree increments apart from each other. A 30-centimeter ruler was attached at each arm of the goniometer to ease the reading and positioning of the goniometer.
- Subjects were measured in a supine position using a treatment plinth.
- Two examiners helped with the execution of all measurements and training sessions.
- Readings was captured and recorded by the use of a HP Laptop. Microsoft Excel 2007 was used to collect every individual's data on individual spreadsheets.

3.5 PROCEDURE

3.5.1 DATA COLLECTION

Testing took place at the University of the Free State's Exercise and Sport Science Centre. Three testing procedures were done over the 6-week period. The first testing was the initial determination of all the subjects hamstring flexibility. This first testing took place before the start of the flexibility training program and before subjects were assigned to groups. The second flexibility testing took place 3 weeks into the program. The last and final testing took place after the last training session.

Measurements (testing) were done by a registered Biokineticist. Data was captured by a final-year Human Movement Science Student from the University of the Free State.

3.5.2 TESTING PROCEDURE

Subjects lay in a supine position on their backs on the treatment plinth. The 90°/90° knee extension test was used because it has been shown to be a very reliable measure of hamstring flexibility (Nelson & Bandy, 2004:255). Two examiners helped with the testing. Examiner 1 placed the subject's leg in a 90° hip flexion and 90° knee flexion position, and made sure that the subject's pelvis stayed in neutral position. Palpation of the Anterior Superior Iliac Spine and the Lumbar Spinousse Processes was used to monitor pelvic neutralization (Davis et al., 2005:28). Examiner 2 then took the bent knee and straightened the lower leg while examiner 1 maintained the 90° hip angle. The limb was straightened until the subject reported a point of discomfort. It is important to note that when a stretching exercise is done, the limb must only be stretched to a point of tightness, to the end Range of Motion and not stretched until discomfort is induced (Armstrong et al., 2004:159). For measurement of flexibility, a point of discomfort is used to get full passive Range of Motion measurements.

The goniometer axis was then placed on the lateral condyle of the tibia, which can be felt by palpating on the lateral side of the knee. The arms of the goniometer were then be placed parallel to the longitudinal axis of the femur and tibia respectively. Although both legs underwent the stretching regime, only the dominant leg of the subject was tested for use in the statistical analyses of the study.

3.5.3 STRETCHING PROTOCOLS

Subjects who met the necessary requirements to participate in this study were randomly assigned to 1 of 5 groups. All groups were instructed to do a 5-minute warm-up jog before stretching exercises commenced.

Group 1 performed the static stretching protocol. Subjects in this group statically stretched for 300 seconds (5x30 seconds with five 30 second rest intervals between sets), 3 days per week for 6 weeks. The method described by Bandy & Irion (1994:847) and Bandy, Irion & Briggler (1998:297), was used by this group. Subjects were instructed to stand erect in front of a chair, both feet and toes pointing forward. The heel of the first leg to be stretched was then placed on the chair with toes pointing to the ceiling. The subject bent forward from the hips, keeping a neutral spine while reaching forward with arms. Both legs had to be extended at all times. Subjects flexed forward until a gentle stretch was felt at the posterior thigh region (hamstring muscles) and that position was held for 30 seconds. The same procedure followed with the opposite leg and for the other remaining stretches.

Groups 2 and 3 performed the Proprioceptive Neuromuscular Facilitation- stretching protocols. Group 2 performed the Contract-relax method and group 3 the Hold-relax method. Both stretching techniques consisted of a combination of isometric and concentric contractions and relaxation of the agonist and antagonist muscles (Prentice, 2004:126).

Subjects in the contract-relax group performed 8 Contract-relax cycles (Handel et al., 1997:401) that consisted of a 10 second pushing phase followed by a 10 second relaxation phase (Prentice, 2004:126), with a 20 second rest interval between cycles. A total of 300 seconds per session. The subjects were instructed to relax their limbs so that the trainer could passively move the leg into an agonist pattern to where a point of limitation is felt. This position was then held for 10 seconds. Following the passive stretch, the subjects performed a 10 second concentric contraction of the antagonist (hamstring muscles) against resistance given by the trainer. Thereafter the subject relaxed the leg and the trainer moved the leg passively through as much

Range of Motion as possible to a new point of passive limitation. The cycle was repeated 8 times followed by the same procedure for the opposite leg.

Subjects in the Hold-relax group also performed 8 hold-relax cycles. Eight cycles was used to keep equilibrium within the two PNF-groups because of the fact that both consist of the same basic combination of a 10 second pushing phase and a 10 second relaxation phase with a 20 second rest interval between cycles, and a total of 300 seconds per session. The subject was instructed to isometrically contract the antagonist (Hamstring muscles) against resistance given by the trainer for a period of 10 seconds; this was then followed by a 10 second concentric contraction of the agonist (quadriceps muscles) also against resistance given by the trainer to a point where a stretch was felt.

Group 4 performed the Dynamic-stretching protocol. Subjects in this group dynamically stretched the hamstring muscles for 300 seconds (10 X 30 seconds). Subjects performed a forward and backwards swinging action of the leg to the end range of motion each time.

Group 5 served as the control group. Subjects in this group were instructed not to participate in any stretching exercises for the length of this experiment.

Two registered biokineticists supervised all groups during every session. All the groups did 3 stretching sessions per week for a period of 6 weeks. To ensure accuracy and compliance, the trainers performed the stretches of both PNF-groups because of the difficulty and level of experience needed to perform a proprioceptive neuromuscular facilitation stretch.

An attendance list identified compliance at every session. Subjects that missed a session a week performed 4 sessions the following week to that ensure that all 18 training sessions were done. Subjects that missed more than 3 sessions were not accounted for in the study.

3.6 STATISTICAL ANALYSIS

Data was captured electronically by the researcher in Microsoft Excel (Microsoft Office 2007). Any further analysis was done by a biostatistician using SAS Version 9.1.3. Descriptive statistics namely means, standard deviations and minimum and maximum values were calculated for hamstring flexibility. The mean values of the 4 stretching intervention groups were compared to the control group. The mean values of each intervention group were also compared to the other stretching intervention groups. The student t-test was used to test for significant differences between the groups. For each of the 5 groups the mean difference over time within the groups (i.e. week 0 and 3, week 0 and 6 and week 3 and 6) were calculated. The student t-test was used to test for significant differences within the group. A significance level of 0.05 was used throughout the study.

CHAPTER 4:
RESULTS

4.1 INTRODUCTION
4.2 RESULTS

4.1 INTRODUCTION

One hundred girls between the ages 13 and 17 years participated in this study. Subjects were randomly assigned to 5 groups (i.e. one control group and 4 stretching intervention groups). Thus each group consisted of 20 subjects. Data collected was statistically analyzed to show the differences in hamstring flexibility measures (°) between the control and 4 stretching intervention groups as well as the differences between only the 4 stretching intervention groups. Data was further analyzed to show the differences at 0, 3 and 6 weeks of intervention. All analyses will be discussed subsequently.

4.2 RESULTS

Figure 4.1 shows the population distribution at the 3 different testing times namely: 0 weeks, 3 weeks intervention and 6 weeks intervention. At the start of the test (0 weeks) 59.00% of the candidates fell in the average hamstring flexibility group, which is 135°-150°. Of the remaining candidates 18.00% fell into the below average group (<135°) and 23.00% fell in the above average group (>150°). After 3 weeks of intervention the below average group fell to 2.50% with 33.75% in the average group and the remaining 63.73% of the candidates progressing to the above average group. After the last testing at 6 weeks the majority of the group 92.50% fell in the above average group with only 7.50% in the average group and none of the candidates were in the below average group.

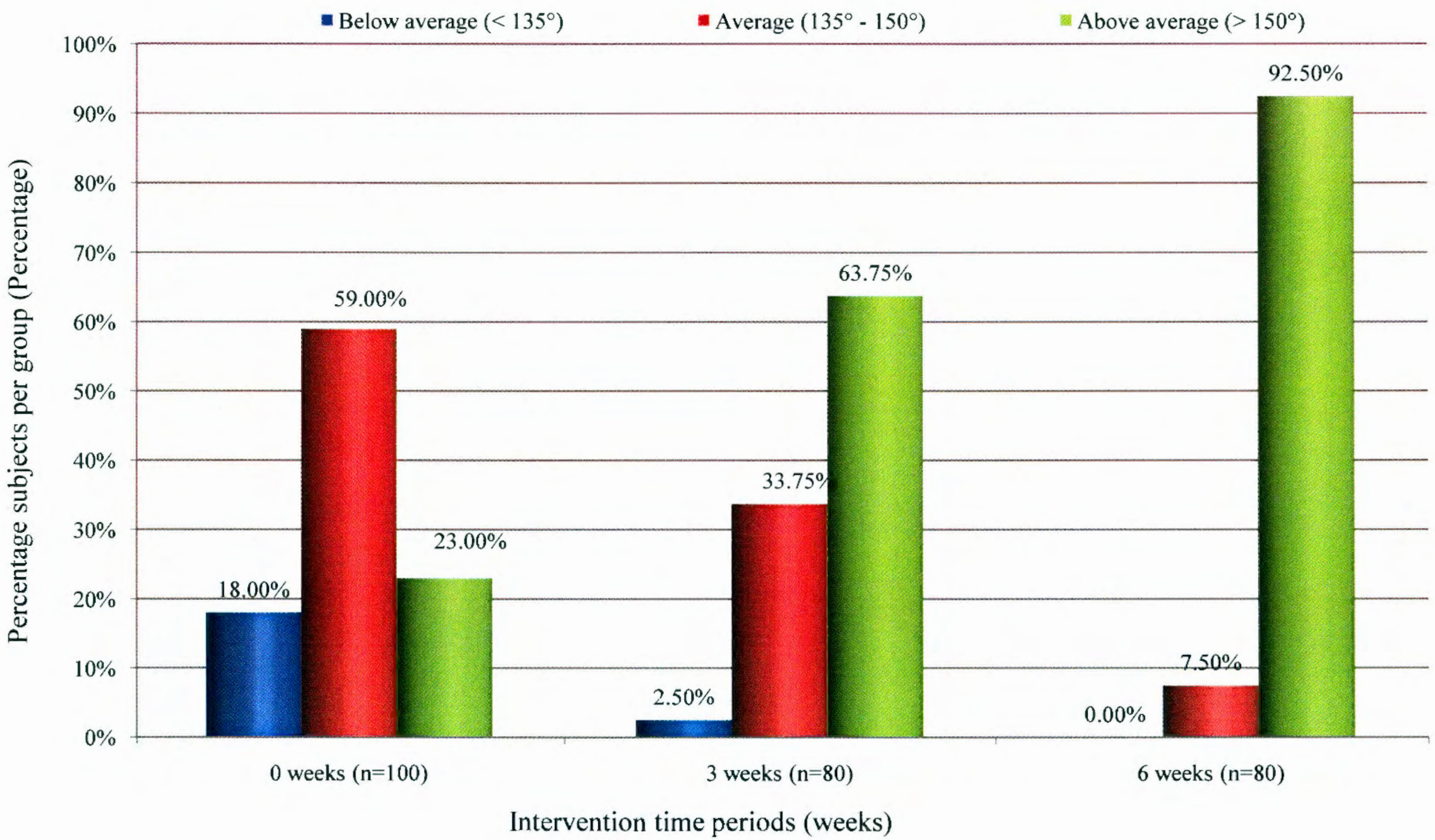


Figure 4.1: Population distribution progression over intervention time periods.

Table 4.1 shows the descriptive statistics of the control group and 4 different stretching groups. The control group showed a mean hamstring length value (measured in °) of 148 ± 13 (95%C.I.: 142; 154). The four intervention groups showed the following mean values (measured in °): Contract-relax PNF, 140 ± 9 (95%C.I.: 136; 144); Dynamic, 145 ± 10 (95%C.I.: 141; 150); Hold-relax PNF, 143 ± 8° (95%C.I.: 140; 147) and Static 142 + 10 (95%C.I.: 138; 147) respectively. These values were taken at the commencement of the study before any intervention programs were followed. The table further shows the same data at 3 weeks intervention and 6 weeks intervention, which will be discussed at a later stage in this discussion.
Additionally, no statistically significant difference was found between the 4 stretching techniques when compared after 3 weeks and 6 weeks of stretching.

Table 4.1 also shows the analyzed data of the difference in hamstring length. The first group is the difference in mean values after the initial 3 week training program, with the second group showing the difference in mean hamstring flexibility for the successive 3 weeks. The last group shows the total progression/regression made in mean hamstring flexibility after the total 6 week intervention period. P-values for all 3 time periods are also stated as well as 95 % CI for each group.

Table 4.1: Data of stretching techniques over times amongst girls.

	0 weeks					3 weeks					6 weeks				
	n	Mean	Std dev.	Min.	Max.	n	Mean	Std dev.	Min.	Max.	n	Mean	Std dev.	Min.	Max.
Control	20	148.25	12.71	129	169	20	146.70	13.42	128	170	20	147.85	12.66	130	174
Contract relax PNF*	20	140.20	8.81	122	158	20	150.75	9.43	133.00	175	20	164.50	9.17	143	178
Dynamic*	20	145.40	9.72	124	161	20	155.65	7.74	142	169	20	168	7.87	149	176
Hold relax PNF*	20	143.15	7.75	129	156	20	153.35	9.61	139	170	20	167.30	8.37	150	176
Static*	20	142.35	9.92	119	163	20	154.95	9.30	134	167	20	166.75	7.85	148	177

* $p < 0.001$ for 0-3, 3-6 and 0-6 weeks as well as compared to the control group.

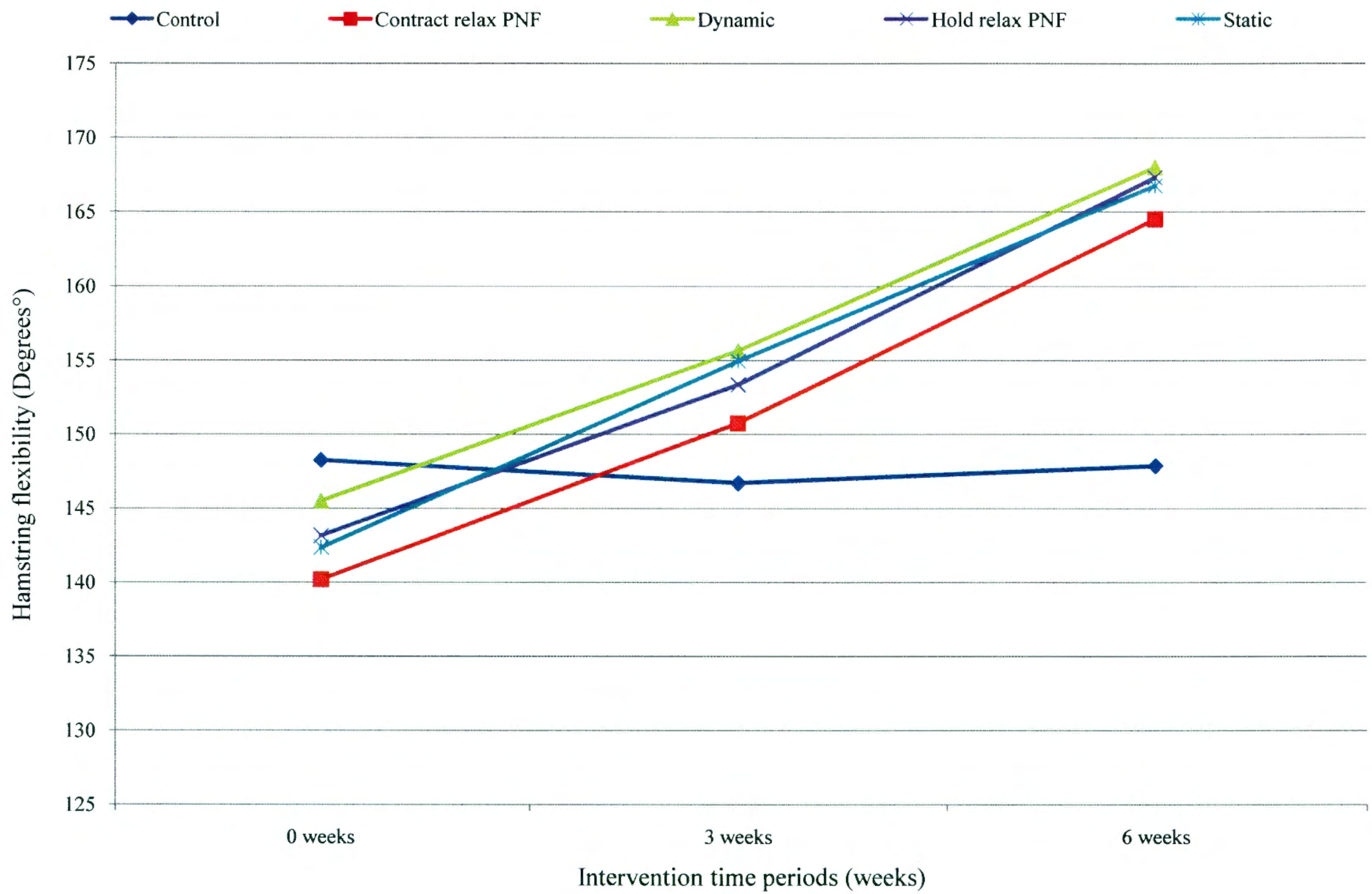


Figure 4.2: Interaction plot between technique and time.

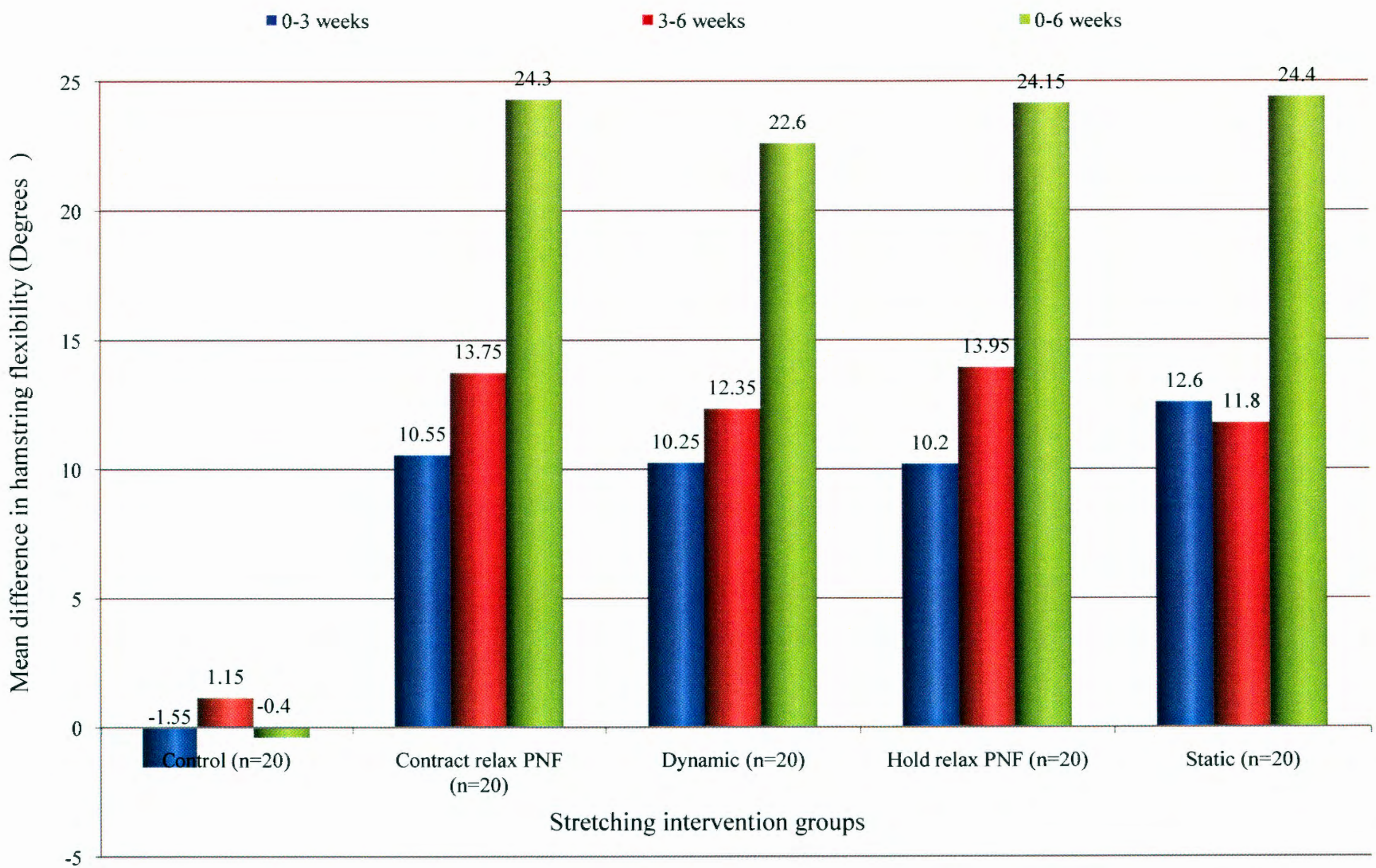


Figure 4.3: Illustration of mean value difference of hamstring length over time for different stretching techniques.

Figure 4.2 illustrates the progression/regression made for each of the groups over the different time period. The data shows that based on mean values, static stretching produced the greatest increase in flexibility at 3 weeks with the hold-relax stretch producing the greatest increase from week 3 till week 6. However, static stretching produced the greatest improvement over the total intervention period. Therefore, all 4 stretching techniques increased hamstring flexibility over a 6 week stretching program.

Figure 4.3 shows an illustration of mean value difference of hamstring length over time for different stretching techniques where improvement in each of the four intervention groups can be seen for the different measuring periods. The control groups' decrement and improvement is also illustrated where it can be seen and compared to the intervention groups' values.

CHAPTER 5: DISCUSSION

5.1 INTRODUCTION

The objective of this study was to compare 4 different stretching techniques to determine which one was most efficacious in improving hamstring flexibility. The 4 types of stretches studied were static-, hold-relax PNF-, contract-relax PNF- and dynamic techniques. The results of this investigation provide evidence to help answer 3 main questions: (a) Does stretching indeed help to increase flexibility significantly, (b) is there a difference in the effectiveness of 4 common stretching techniques when the stretching parameters are consistent among the stretching techniques, and (c) which stretching technique can be used if increased flexibility is desired in a short time span (3 weeks)?

This chapter will compare and discuss flexibility measure results obtained through this investigation at 3 weeks of testing and again after 6 weeks of testing, as well as the comparison with research already done on this subject.

5.2 DISCUSSION

5.2.1 HAMSTRING FLEXIBILITY – 3 WEEKS TESTING

This investigation demonstrates that significant improvements ($p<0.0001$) in hamstring flexibility can be achieved with a 3 week stretching program when comparing all 4 stretching intervention groups with the control group. All 4 intervention groups showed statistical significant ($p<0.0001$) increases, from their own baseline, in mean value after the first 3 weeks of stretching. Comparing only the 4 different stretching methods used, the results showed only little to no difference in mean value after the first 3 weeks of intervention. The static stretching group had a mean increase of 12.60 degrees followed by the PNF-contract relax with a mean increase of 10.55 degrees, the dynamic stretching group with a mean increase of 10.25 degrees and lastly the hold-relax group with only a mean increase of 10.20 degrees. The lower and upper 95% CL for the mean also improved in all groups (Table 4.2). All of the intervention groups except for the static stretching group showed least improvement (95% CL) during the first 3 weeks of stretching. Thus from the results it can be derived that although not statistically significant ($p<0.0001$), static stretching might be the method to use if increased flexibility is desired over a short time period of 3 weeks, followed by the contract relax PNF, dynamic stretching group and then hold relax PNF group.

The results of this study also supports the findings of Decoster et al. (2004:330), which also showed significant increases in hamstring length over a 3 week stretching period when stretching 3 times per week. The findings of Fasen et al. (2009:660), Woolstenhulme et al. (2006:799), Nelson & Bandy (2005:245), Bandy et al. (1998:295), Bandy & Irion (1994:845) and Sady et al. (1982:261) are also echoed in this study; they concluded stretching as an effective means to significantly increase flexibility over any period from 2-10 weeks.

This investigation contradicts the findings of researchers who reported static stretching as the most efficient stretching technique to significantly increase hamstring flexibility and also researchers who reported contract-relax PNF as the most efficient technique to significantly increase hamstring flexibility (Nelson & Bandy, 2005:245; Bandy et al., 1998:295; Bandy & Irion, 1994:845 and Sady et al., 1982:261).

5.2.2 HAMSTRING FLEXIBILITY – 3 WEEKS TO 6 WEEKS TESTING

The hold-relax PNF group showed the greatest mean increase (13.95 degrees) in hamstring flexibility, again not statistically significant, over the second 3 weeks of intervention followed by the contract-relax PNF group with a mean increase of 13.75 degrees then the dynamic group with a mean value of 12.35 degrees and then the static stretching group with the least increase of 11.8 degrees. Although the hold-relax group showed the greatest increase in flexibility over the second 3 weeks of stretching; static stretching still had the greatest overall increase in flexibility measure from baseline till 6 weeks.

The static stretching group was the only intervention group that showed the least increase (95 % CL) in flexibility during the second 3 weeks of stretching, all other group measurements showed increases greater than the first 3 weeks of stretching.

The second 3 weeks statistical findings of this study contradicts the findings of Davis et al. (2005:27) who also took measurements after 2 weeks and again after 4 weeks of stretching. They reported in their study that static stretching showed significantly greater increases in flexibility during the second 2 weeks of stretching. All other studies reported in the literature review only took measurements at baseline and after the completion of the study, therefore in terms of the results of this study and the study done by Davis et al. (2005:27) it can be advised that further investigation is needed to identify the stretching technique most effective for increasing flexibility during the later stages of a stretching program and to determine whether it might be more beneficial to do static stretching during the initial stages of a stretching program - as it was reported that static stretching showed most improvement during short time periods, and whether it is necessary to then convert to another stretching technique to keep exercising the best technique for improvement.

5.2.3 HAMSTRING FLEXIBILITY – 6 WEEK TESTING

After the 6 weeks of intervention, testing measures again showed significant improvements ($p<0.0001$) in mean value for all 4 stretching groups when compared to the control group.

Comparing only the 4 intervention groups' mean value measures from baseline, the static stretching group again showed the greatest mean increase (24.4 degrees) in flexibility followed by the contract-relax PNF group (24.3 degrees), the hold-relax group (24.15 degrees) and then with a 2 degree decrease from the other groups, the dynamic stretching group (22.6 degrees). This means that flexibility and the need to improve or have normal functional range of motion can be obtained via stretching, independent of the stretching method used.

All 4 stretching techniques (static, contract-relax, hold-relax and dynamic) produced significant improvements ($p<0.0001$) in flexibility from baseline when compared to the control group. Statistically significant improvements ($p<0.0001$) in flexibility can also be seen for each individual stretching technique from their own baseline (static, contract-relax, hold-relax and dynamic) at 3 weeks and 6 weeks of stretching.

Although static stretching showed greater improvements (not statistically significant) in flexibility over the 6-week period when compared to the other intervention groups, all other intervention groups also showed statistically significant improvements from their own baseline measures at 0 weeks, which suggest that no one of the four techniques can be labelled as the best stretching technique ($p < 0.0001$).

The results of this study harmonise with all other studies done on flexibility. LaRoche & Connoly (2006:1000), Davis et al. (2005:27), Nelson & Bandy (2004:254), Feland et al. (2001:186), Bandy et al. (1998:295), Williford & Smith (1985:30), Lucas & Koslow (1984:615) and Sady et al. (1982:261) all reported in their individual studies that stretching, independent of the technique used, showed significant improvements in flexibility over any time period from 2 – 9 weeks. All of the above authors also reported that although no difference exist between the different stretching techniques, significant improvements can be seen when comparing intervention groups with a control group.

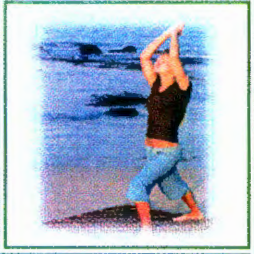
5.3 OVERVIEW

The results of this investigation suggest that all 4 stretching techniques were more efficacious compared to the control group for increasing hamstring length over a 6 week period when stretching 3 days per week for a total of 300 seconds per session.

The Range-of-Motion improvement in the straight leg raise static stretching group may be attributed to an increase in the subject's stretch tolerance or the viscoelastic property changes that occur; that is the Golgi-tendon organ that is facilitated - which may produce inhibition of the muscle that is stretched (Fasen et al., 2009:664). PNF stretching techniques uses the theory of reciprocal and autogenic inhibition via contraction of the opposing muscle, in this case the quadriceps muscle, which, according to researchers facilitates the hamstring muscle and can therefore not be related to the long-held theory of neural inhibition (Davis et al., 2005:31). However, adding a neuromobilization component to the PNF technique, for example, the slump stretch, emphasizes that flexibility is not only influenced by muscle elasticity but also by connective and/or nervous tissue (Fasen et al., 2009:662). During the isometric contraction of the PNF stretching technique the autogenic inhibition mechanism is triggered, which reduces the muscles' tension through stimulation of the Golgi-tendon organs, while the concentric contraction of the PNF stretching technique causes reciprocal inhibition – which, in turn, causes an active reduction in the target muscles' resistance (Yuktasir & Kaya, 2009:12). Magnusson (1998:65) reported in his study (that investigated the acute effects of PNF and static stretching via five 15 second stretches) that PNF stretching does indeed result in greater acute increases in range of motion due to an increased stretch tolerance. In contrast to the abovementioned statement concerning PNF stretching, the results of this investigation concluded that PNF stretching (hold-relax and contract-relax) is just as an effective means of increasing hamstring flexibility as static stretching over a 3- and 6-week period when compared with static- and dynamic stretching techniques.

On the basis of the results, any stretching technique can be used as an effective method of increasing hamstring length in young, healthy adolescents.

CHAPTER 6: SUMMARY & CONCLUSION



6.1 INTRODUCTION

This chapter will discuss the trends seen in the analyzed data and conclude the findings of this study. It will also discuss further recommendations concerning this particular subject matter.

6.2 SUMMARY

The questions subsequently answered were firstly if stretching does indeed help to increase flexibility significantly. Secondly, if there is a difference in the effectiveness of 4 common stretching techniques when the stretching parameters are consistent among the stretching techniques, and thirdly, which stretching technique can be used if increased flexibility is desired in a short time span (3 weeks)? The 4 types of stretches studied were static-, hold-relax PNF-, contract-relax PNF- and dynamic techniques. Answers to these questions from this research study provide groundbreaking results – not only towards the scientific literature but also for implementation with regard to the general well-being of individuals and for use in sport and rehabilitation industries:

- To date, generalization has been the only means to support individuals in the athletic and rehabilitation setting on how to improve muscle flexibility, and as to what stretching technique to use. Many different studies have been conducted on the different stretching techniques, comparisons of the different techniques, and the intensity, frequency and duration of a stretching program, but because of the different outcomes, only insufficient knowledge was still available for prescribing flexibility exercises for rehabilitation, sports preparation or general conditioning. This present investigation shed light on the possible superior stretching technique to use when trying to improve flexibility, warm a muscle up in the athletic industry or getting the range of motion back in an injured joint.

- Apart from insufficient knowledge with regard to the most effective stretching technique to use, the same issue exists with stretching parameters, including the frequency, intensity, and duration of a stretch. Most literature support the 30 second per stretch 3 times rule, but improvements have been seen in the timeframe, 15- and 120 seconds per stretch and from only one repetition. The results from this investigation as well as the literature reviewed on this parameter topic help to enlighten possible areas of darkness that may exists in the rehabilitation setting among therapists.
- Conflicting views also exist among therapists regarding the importance of flexibility in respect of the impact of stretching on the muscle and its implications prior to strength training and/or performance. Many of these therapists when randomly asked, believe that stretching prior to strength training or competition will lengthen the muscle to such an extent that all the power of the muscle will be extracted and the athlete will not be able to perform to his/her full potential; others feel that stretching must be done prior to performance to prevent injuries or to warm the muscle up for the demands to follow. The literature in this study provides some basic and helpful answers on when and how to use stretching exercises when it comes to strength training, performance and injuries.

6.3 CONCLUSION

The following conclusions can be reached from this study:

6.3.1 Stretching, regardless of the technique used, does significantly ($p<0.05$) increase hamstring flexibility over a 3-week and 6-week time span.

6.3.2 The results of this study showed no significant difference ($p<0.05$) between the 4 stretching techniques used to increase hamstring flexibility. Although there was no significant difference between the 4 stretching techniques, it appears from the results of the investigation that static stretching might be the more superior technique to use to increase hamstring flexibility.

6.3.3 Regardless of no significant difference ($p<0.05$) between the 4 stretching techniques over a 3-week time span, it seems that static stretching might be the more superior technique to use if increased hamstring flexibility is desired in a short time span (3 weeks), more than the other 3 stretching techniques used in this study.

The main aim of this study was to determine whether there is a significant difference ($p<0.05$) between the 4 stretching techniques and the control group over a 6-week period. Through results obtained, this study's main aim was achieved.

6.4 LIMITATIONS

Despite the randomized controlled design, this study has limitations. Not all items could be controlled, such as the activity levels of the participants. Another limitation of this investigation is the sample size. Despite the limited sample, the response to stretching was great enough in all the intervention groups to identify the statistically significant necessity of flexibility exercises and the time at the level of significance ($p<0.05$). The researcher attempted to obtain flexibility measures at approximate the same time of day for each measuring session. It is also important to remember that the sample included healthy subjects and the results should therefore not be generalized to persons outside the sample population. In addition, because only the hamstring muscles were tested, generalization of the results of this investigation to other muscles or muscle groups would be inappropriate.

6.5 PRACTICAL RECOMMENDATIONS

Only hamstring flexibility was tested in this investigation and it is be recommended that other muscles or muscle groups be tested with the same parameters used in this study. Studies on longer intensities, frequencies and durations would also provide interesting results as to which stretching technique might be significantly more superior over other techniques.

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ABSTRACT

Stretching techniques on hamstring flexibility in adolescent girls.

This study compared the efficacy of 4 different hamstring-stretching techniques. Flexibility can be achieved by a variety of stretching techniques, yet little research has been performed on the most effective method. The four most basic stretches includes: Static stretching where the limb is held stationary at and endpoint for a certain time period; Dynamic stretching, an active stretch where the limb is slowly moved from the neutral position to the endpoint; PNF hold-relax- and PNF contract-relax stretching which is also referred to as active stretches because of the concentric and isometric contractions throughout the stretch (Prentice, 2010:111). This study's aim was to determine which type of stretching technique is most effective in improving hamstring length. One hundred female subjects between the ages of 13 and 17 years were enrolled in the study. The 90°/90° hamstring length measure was used for all measurements to measure knee extension angle. All 100 subjects were included in a randomized controlled trial of 5 different groups comparing different hamstring-stretching techniques. Outcome measure (hamstring length) was recorded on all subjects initially, at 3 weeks and at 6 weeks. After 3 weeks of stretching, there was a statistically significant improvement in hamstring length ($p<0.0001$) using all stretches when compared to the control group. From weeks 3 through 6, hamstring length for all groups again showed statistically significant improvement when compared to the control group. No significant difference was found comparing the intervention groups after 3 weeks or after 6 weeks of stretching. After both 3 weeks and 6 weeks of stretching the straight-leg-raise (static stretching) group had the greatest improvement in hamstring length, although the difference was not statistically significant.

(flexibility, stretching, hamstring length, neutral position, stretching techniques, endpoint, daily dose, knee extension angle, straight leg raise, time period)

ABSTRAK

Strektegnieke op hampese soepelheid van vroulike adolessente.

Hierdie studie het die effektiwiteit van verskillende strektegnieke op hampese soepelheid vergelyk. Verskeie strektegnieke kan gebruik word om soepelheid te verbeter, maar as gevolg van gebrek aan navorsing oor die onderwerp is die effektiefste strektegniek nog nie duidelik uitgewys nie. Daar bestaan vier basiese strektegnieke: Statiese strekke waartydens die ledemaat by 'n sekere eindpunt gehou word in 'n statiese posisie vir 'n sekere tydperk; Dinamiese strekke, 'n aktiewe strek waartydens die ledemaat stadig beweeg word vanaf die neutrale posisie tot by die eindpunt; PNF "hold-relax"- en PNF "contract-relax" strekke waarna ook as aktiewe strekke verwys word as gevolg van die konsentriese- en isometriese- kontraksies wat plaasvind gedurende die strek (Prentice, 2010:111). Die doel van hierdie studie was om die strektegniek wat die effektiefste sal wees om hampese soepelheid in vroulike adolessente te verbeter te identifiseer. Een honderd vroulike deelnemers tussen die ouderdomme 13- en 17-jaar was vir deelname aan die studie gewerf. Die 90°/90° hampese soepelheids metings-toets was vir alle metings gedurende die studie gebruik om sodoende die knie ekstensie hoek van elke deelnemer te bepaal. Die groep van 100 deelnemers was ewekansig in 'n gerandomiseerde proef wat bestaan het uit 5 verskillende groepe verdeel. Elke groep het 'n ander strektegniek beoefen om sodoende na afloop van die studie die effektiefste strektegniek om hampese soepelheid te bevorder te bepaal. Resultate (hampese lengte) van elke deelnemer was by 3 weke en 6 weke na aanvang van die studie verkry. Na 3 weke intervensie was daar 'n statisties betekenisvolle verbetering in alle intervensie groepe vergeleke met die kontrole groep wat geen intervensie ondergaan het nie. Die tydperk week 3 tot week 6 het weereens 'n statisties betekenisvolle verbetering getoon wanneer intervensie groepe vergelyk is met die kontrole groep. Geen betekenisvolle verskil was tussen die verskillende intervensie groepe verkry wanneer resultate vergelyk is met mekaar gedurende die eerste 3 weke of 6 weke na intervensie nie. Na beide periodes (3 weke en 6 weke intervensie) het die statiese strekgroep (reguit-been-lig strek) die meeste hampese lengte verbetering getoon, hoewel dit nie statisties betekenisvol bewys is nie.

(soepelheid, strekke, hampese lengte, neutrale posisie, strek tegnieke, eindpunt, knie ekstensie hoek, daaglikse dosis, reguit-been-lig, tydsperiode)

ANNEXURE A

16 January 2010

MR SOLLY MAGALEFA
Head of Communication and Liaison
Department of Education
BLOEMFONTEIN
9301

Dear Mr S Magalefa

RESEARCH PROJECT: STRETCHING TECHNIQUES ON HAMSTRING FLEXIBILITY IN FEMALE ADOLESCENTS

The need to identify the importance of flexibility in female adolescents during the growth spurt and the benefits of a stretching program has been identified in previous research done. Information on the most effective stretching technique to use to obtain these benefits however reflect controversy and therefore the need for further experimentation regarding this phenomenon has been identified by the Department of Human Movement Science at the University of the Free State. The Department hereby request permission for the participation of learners from a School in Bloemfontein in order to execute this research project. The title of the proposed study is called,

STRETCHING TECHNIQUES ON HAMSTRING FLEXIBILITY IN FEMALE ADOLESCENTS.

The purpose of this study will be to identify the most effective stretching technique to promote or maintain muscular flexibility. The importance of stretching is often overlooked as part of a daily exercise program and only becomes a concern after muscles or joints become stiff due to injury, inactivity or illness. Therefore flexibility exercises must form an integral part of a daily exercise program and play a vital role in the performance of athletes, sport injury rehabilitation, improvement of quality of life, sports and high performance sports.

The study will be executed over a six week period with three stretching sessions per week. Scholars will be divided into one of four groups where each group will perform a different stretching technique.

There are no risks involved in participation in this study.

The Principle of a school in Bloemfontein, granted permission for the participation of her learners in this experiment and will receive a parental informed consent form to be completed by their legal guardians and each learner will receive a minor's consent form to be completed.

Through this research project, information regarding different controversies on the flexibility, performance and injury phenomenon will be gathered and used to inform coaches and trainers on the correct usage of flexibility in all settings of activity among scholars as well as the benefits and potential risks associated with stretching. All partaking learners' information will be handled confidentially at all times.

I trust that my application will meet your approval.

LIZL JANSE VAN RENSBURG
(RESEARCHER)

DR. F.F. COETZEE
(PROMOTOR)

ANNEXURE B

INFORMATION DOCUMENT

Stretching techniques on hamstring flexibility in female adolescents

You are invited to take part in a research study of the Department Exercise and Sport Sciences, University of the Free State. In this study, we are interested in how much improvement can be gained by a certain identified flexibility/stretching exercise done on your hamstring muscle group. We have asked your parents or caregiver to give permission for you to participate, but now we want to determine whether you agree to this.

If you decide to take part in this study, you will have to participate in a stretching session three times a week over a period of six weeks. You will also need to complete 3 flexibility measurements so that we can determine your improvement or lack thereof during these six weeks. Each stretching session will take approximately 15 minutes and will include a brief warm-up and then stretching.

We shall let you know when you need to come to the university. All the necessary first measurements will be taken and explained to you on that day. The benefits of participation in this study will also be discussed. There are no risks involved in participation in this study because of the nature of the stretches and in that a qualified biokineticist will attend and supervise all stretching sessions to ensure detailed execution of each stretch. All information will be kept confidential. Your answers/questions and measurements will be shared among the people conducting the research only and your name will not be used.

By signing this you are showing that you understand what is going to be happening and have asked any questions you may have about the research. You can also ask questions later if you cannot think of any now. Signing this form does not mean you have to finish the study – you may withdraw from this study at any time without giving reasons for doing so.

____________________________ ______________________

Signature (participant) Date

____

Lizl Janse van Rensburg
(Researcher)

ANNEXURE C

INFORMED CONSENT FOR MINORS

Stretching techniques on hamstring flexibility in female adolescents

The goal of this study is to determine the most effective stretching technique to promote hamstring flexibility in female adolescents.

This master's degree study will not only be of benefit to the participants in the better understanding and awareness of their muscles and their importance during the growth spurt of life but also provide quality information to the Department of Education, Department of Human Movement Science and coaches and trainers at school level for the further development and use of flexibility programs among adolescents.

Participation is voluntary and refusal to participate will involve no penalty or loss of benefits; the participant may also discontinue participation at any time without penalty or loss.

Measurements:

- A 90°/90° flexibility test of the hamstring muscle group before the start of the experiment
- The same flexibility test after three weeks of the program and again after six weeks on completion of the program

The participants and/or guardians will receive flexibility training prior to the start of the program for accurately execution during each stretching session. Each stretching session will last approximately 15 minutes.

The results of the research study will be used for an article published in health journals.

I have read the above information. The nature, demands, and benefits of the project have been explained to me. I understand that I may withdraw my consent and discontinue my child's participation at any time without penalty or loss of benefits to my child. In signing this consent form, I am not waiving any legal claims, rights, or remedies.

I, ________________________________, parent/guardian of ________________________, hereby give

permission that ________________________ (participant) may participate in this study, complete the forms and allow the abovementioned measurements to be taken.

________________________ ________________________

Signature: Legal Gaurdian Date

ANNEXURE C

CHILD ASSENT FORM

Stretching techniques on hamstring flexibility in female adolescents

I, ____________________________, understand that my legal guardians have given permission for me to take part in a study concerning stretching techniques on hamstring flexibility in female adolescents, under the direction of the Department Exercise and Sport Sciences, University of the Free State.

I have read and understand the information document provided to me concerning the nature of this study. I understand that I may withdraw form the study at any time without explanation and that there is no risks involved in participation.

____________________________ ____________________________

Signature (participant) Date

____

Lizl Janse van Rensburg
(Researcher)