STRETCHING TECHNIQUES AND PRACTICAL GUIDELINES

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Providing coaches, referees, players, and administrators with the knowledge, skills, and leadership abilities to ensure that safety and best practice principles are incorporated into all aspects of contact rugby.

INTRODUCTION

Musculoskeletal injuries form a large proportion of the injuries reported in rugby players [10;11;18;21;44;65]. It is also well established that the lower limb area (in particular the knee, thigh and ankle) is where the most injuries in rugby union occur [11]. More specifically, muscle injuries, in particular the hamstring, calf, quadriceps and groin muscles, are the most common injuries sustained during matches by rugby players [11]. It is also well documented that there are many potential causes for muscle injuries and these include both extrinsic and intrinsic risk factors. Potential intrinsic risk factors for muscle injury include a previous injury, muscle strength imbalances, muscle fatigue, biomechanical abnormalities, and musculoskeletal inflexibility [12;62;104]. A decrease in musculoskeletal flexibility has been associated with both the aetiology of these injuries [93;98;99], as well as a consequence of these injuries [59;81;91]. Furthermore, it has been documented that flexibility training (stretching), using a variety of techniques, can effectively increase musculotendinous unit (MTU) range of motion in human subjects [22;37;39;57;78].

There are established clinical guidelines and norms for evaluating musculotendinous unit flexibility for most joints or groups of joints [16;46;53]. Clinical range of motion (ROM) testing of joints can identify ROM values that exceed the normal (hypermobility), or are less than the normal (hypomobility or inflexibility). In this review, hypermobility will not be discussed in detail. However, it should be noted that the causes of hypermobility are largely genetic, but there are also instances where hypermobility is associated with certain athletic activities, such as gymnastics or ballet dancing [31]. Furthermore, larger ranges of motion are present in females when compared with males, and in younger individuals when compared with older individuals [59]. Other causes for hypermobility are an increased musculotendinous unit temperature [94] and, in some instances, following injury or surgery, significant lengthening of soft tissue structures can also result in abnormally increased joint range of motion.

The use of flexibility training (regular stretching) as a means of treating hypomobility is widely advocated, and 1) is an important component in the design of a rehabilitation program following injury or surgery, 2) can possibly alter the risk of injuries [6;22;95;96;101;102], or 3) may alter (improve or reduce) sports performance. A number of health professionals, including those involved in rugby, are therefore involved in the prescription of flexibility training in the primary and secondary prevention of injuries and to ensure optimum performance in rugby players. These professionals include sports physicians, orthopaedic surgeons, physiotherapists, biokineticists, other rehabilitation workers, physical educators, athletic trainers, coaches and players.

This review article will therefore focus on the role of flexibility training in rugby, with particular reference to 1) the prevention and treatment of injuries, and 2) possible beneficial or negative effects that flexibility training may have on rugby performance. Practical guidelines on flexibility training and the timing of stretching sessions in the preparation of rugby players will also be provided.

TERMINOLOGY AND DEFINITIONS

The literature uses a variety of terms when stretching, flexibility or flexibility training is discussed. It is therefore necessary to define these terms, in order to clarify what will be referred to in the remainder of this review. A summary of the terminology and definitions used is depicted in Table 1.

For the purposes of this review, the following terminology is particularly important. The terms "musculotendinous unit length", "joint range of motion" and "musculotendinous unit flexibility" are often used interchangeably. Flexibility will be defined as the range of motion (ROM) available in a joint, or in a group of joints, that is influenced by muscles, tendons and bones [(2)]. A flexibility training session will be defined as a training session (usually lasting a few minutes) that incorporates stretching techniques that are designed to increase the range of motion of a joint or group of joints. Flexibility training will be defined as a training program that incorporates regular flexibility training sessions over a period (usually weeks) and that are aimed at increasing the range of motion of specific joints or groups of joints (also known as a stretching training program).

THE PHYSIOLOGY OF FLEXIBILITY TRAINING

A detailed discussion of the physiology of flexibility training is beyond the scope of this review. Furthermore, the detailed short- and long-term neural effects of flexibility training have recently been reviewed [(32)]. However, the scientific basis of applying a force to soft tissues, and the effects this has on the properties of the tissue, will be briefly discussed.

Flexibility training incorporates a number of possible stretching techniques. However, the main feature of these techniques is that a force is applied to a tissue, such as a musculotendinous unit, which then elongates the tissue. The physiological effects that flexibility training has on the musculotendinous unit include neural effects [(6;89)], plastic (viscous) effects [(69;76)], and elastic effects [(76;79)]. The physiology of each of these effects is discussed briefly.

Neural effects of flexibility training

There are three reflexes that primarily control the neural effects of flexibility training. These are the stretch reflex, inverse stretch reflex, and perception and control of pain by the Pacinian corpuscles. When a force is applied to the musculotendinous unit, the first reflex evoked is the stretch reflex. The origin of this reflex is situated in the intrafusal and extrafusal fibres of the muscle spindle [(6;25;89)]. The stretch reflex serves as a protective measure by causing a reflex contraction of the muscle to prevent overstretching of the musculotendinous unit. The magnitude and rate of contraction elicited by the stretch reflex in a musculotendinous unit, are proportional to the magnitude and rate of the stretch which is applied to that musculotendinous unit [6;55]. Both static and ballistic stretching techniques evoke a response in the stretch reflex when the end point of ROM is reached [6]. One method of observing the stretch reflex is through electromyography (EMG) or measurement of electrical activity in the muscle [19;58]. In this method, the stretch reflex causes a spiking of the neural activity, which is reflected by measuring EMG activity.

The inverse stretch reflex applies both to prolonged contraction and sustained stretching of the musculotendinous unit [2;6]. This reflex is responsible for preventing prolonged, increased strain of the musculotendinous unit, caused either by powerful active contraction, or by overstretching of the musculotendinous unit [2;6;25]. The origin of the inverse stretch reflex is located in the Golgi tendon organ (GTO), which is comprised of receptors situated in the musculotendinous junction of the musculotendinous unit. The GTO causes a dampening effect on the motor-neuronal discharges, thereby causing relaxation of the musculotendinous unit by resetting its resting length [6;89]. This usually occurs 6 to 20 seconds after the start of the stretch.

The third reflex of the musculotendinous unit originates in the Pacinian corpuscles, which are located throughout the musculotendinous unit. The Pacinian corpuscles serve as pressure sensors, and assist with the regulation of pain tolerance in the musculotendinous unit [6;89].

The three reflexes together are responsible for the neural effects that regulate musculotendinous unit flexibility, and are active during the application of stretching techniques at the time of flexibility training. The normal sequence of activation during a vigorous stretching technique would therefore be stretch reflex activation, causing reflex contraction of the musculotendinous unit, and Pacinian corpuscle activation, leading to a perception of pain. This would be followed in a prolonged stretch by GTO inhibitory effects and Pacinian corpuscle modification. The latter two reflexes will allow relaxation in musculotendinous unit tension and decreased pain perception [6;89].

It has also been suggested that prolonged exposure to significantly large and unusual afferent inputs can cause long-term changes in levels of neuronal excitability and thereby, indirectly, in levels of flexibility as well [89]. Therefore, musculotendinous units that are exposed to repetitive stretching demonstrate increased tolerance to the manoeuvre, resulting in an apparent increased ROM.

Plastic and elastic effects of flexibility training

Plastic deformation within the musculotendinous unit has largely been ascribed to changes that occur in the non-contractile elements within the musculotendinous unit [14;69;89]. The non-contractile elements (ligaments, tendons, capsules, aponeuroses and fascial sheaths) are predominantly comprised of connective tissue. Connective tissue is made up of collagen fibres, which vary in spatial arrangements and are of varying densities and strengths [69]. The non-contractile element of the muscle tissue is also comprised of a connective tissue framework, which is responsible for its resistance to stretch [69]. Scar tissue and adhesions are also comprised of connective tissue [69]. Prolonged flexibility training results in plastic elongation of the connective tissue [69;76]. The mechanisms of both increased plastic and elastic deformation have already been defined (Table 1).

FLEXIBILITY TRAINING TECHNIQUES

Several flexibility training (stretching) techniques have been developed to increase flexibility of joints. These include proprioceptive neuromuscular facilitation (PNF), ballistic stretching, static stretching and, more recently, other stretching techniques that incorporate the use of vibration [47;68;83] or imagery [85] and "awareness" [77]. Combinations of these techniques have also been advocated. All these techniques rely on the neural, plastic and elastic effects of deformation for their effectiveness.

Proprioceptive Neuromuscular Facilitation (PNF)

PNF is based on the theory that maximal contraction of the musculotendinous unit results in maximum relaxation, after active contraction, of that musculotendinous unit [2;61;67;88]. The PNF stretches that are used in sports have been adapted from neurological physical therapy treatments. The two techniques that are commonly used are Contract-Relax (CR) and Contract-Relax-Agonist-Contract (CRAC).

Contract Relax (CR)

In CR, a therapist stretches a limb to the point where limitation of ROM is felt. The therapist then holds this stretched position while the patient actively contracts the musculotendinous unit against the resistance of the therapist (Figure 1).

Figure 1: A typical position for performing an assisted proprioceptive neuromuscular facilitation (PNF) stretch technique

The muscle is then relaxed and moved passively to the new lengthened position, until a stretch is felt in the new position [34;88]. A rotational component, which entails a movement in the horizontal plane, may be added to the resistance, which is in the sagittal or longitudinal plane [34;88]. Modifications to this method include contraction of the musculotendinous unit before stretching, and contracting as described above [4;6;79]. The rationale behind the CR method is that increased stress through contraction of the musculotendinous unit will result in autogenic inhibition in the musculotendinous unit. The GTO activity will decrease tension and cause relaxation by resetting the musculotendinous unit length. This will facilitate the passive stretch procedure applied by the clinician.

Contract-Relax-Agonist-Contract (CRAC)

In CRAC, the musculotendinous unit is stretched as described above in the CR procedure. In addition to this, the opposing musculotendinous unit (antagonist) of the musculotendinous unit being stretched (agonist) is contracted isometrically while the stretch is applied. The stretch procedure applied by the clinician is then aided by contraction of the opposing musculotendinous unit (antagonist). This results in reciprocal inhibition of the musculotendinous unit being stretched, in order to reduce its tension [88].

It is well established that PNF stretching techniques are effective in increasing musculotendinous unit ROM [17;25;42;61;67;78;90]. However, if PNF is to be performed effectively, it requires expertise in all the stretching techniques, as well as an experienced clinician. These techniques therefore, although effective, are seldom prescribed to, or administered by, individual players [4].

Dynamic (ballistic) stretching

During dynamic stretching, the limb is moved (usually rapidly) to the end of its ROM where the stretch sensation is felt, either passively by the clinician or actively by the subjects themselves. Once this stretched position is achieved, repetitive bouncing or jerking movements are added [2;35;67;70;100] (Figure 2).

Figure 2: A typical position for ballistic stretching of the hamstring muscles. The player performs small oscillating movements in this position

This jerking motion during ballistic stretching could theoretically exceed the limit of available range and thereby cause a strain injury or tear in the musculotendinous unit [2;22]. In addition, this rapid jerking movement also elicits the stretch reflex, which then causes a reflex contraction against the direction of stretch in the musculotendinous unit. The resulting increase in tension may therefore increase the risk of injury [2;6]. Theoretically, this technique may not be as beneficial for increasing ROM, as the musculotendinous unit would undergo a reflex contraction at each bounce or jerk due to the stretch reflex. Relaxation, or lengthening, of the musculotendinous unit can therefore not be achieved [6;55;88].

This form of stretching has not been studied as well as the other forms of stretching. However, In one study, a static stretch, followed by ballistic stretching, increased musculotendinous unit ROM more than static stretching alone [89]. Given that all the stretching techniques are reported to increase musculotendinous unit ROM [69;78;79;89], it is not surprising that the addition of one technique to the other, thereby doubling the total stretching time, will result in greater increases in musculotendinous unit ROM than with one technique alone.

Although the use of dynamic stretching would appear to increase the risk of injury due to the increases in musculotendinous unit tension, there is no scientific evidence to indicate that this is the case. However, the use of dynamic stretching is more physiological and sports-specific and may the preferred form of stretching technique in preparation for a training session or a match. This will be discussed in a subsequent section.

Static stretching

Static (also referred to as slow or passive stretching) [100] is the most common method of stretching used by players, coaches and therapists [2;6]. Static stretching is characterised by the limb being moved slowly and gently to the end of its available ROM, in order to obtain a stretch sensation in the tissues (Figure 3).

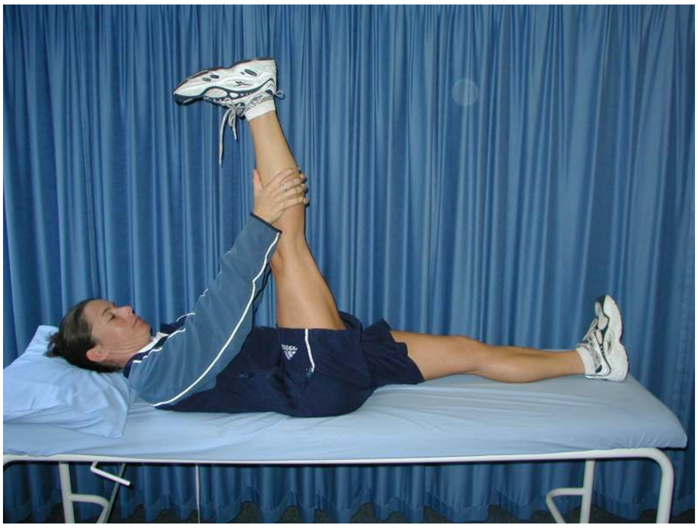

Figure 3: A typical position in which a player will perform a static stretch of the hamstring musculotendinous unit

This controlled stretch is maintained in this position for an extended period [6]. The end of the available range is determined by maximum tolerance of the subject to the stretch sensation just short of pain [4].

As mentioned, static stretching is sometimes referred to as passive stretching. Where this occurs, the distinction referred to is the mode of application. If the stretch is applied and held by the subject, it is referred to as static stretching. If the static stretch procedure is applied by a therapist or another person to the subject, it is sometimes referred to as passive stretching [6]. The danger of the passive stretch is that, when executed incorrectly by a teammate or partner, it has the potential to overstretch the musculotendinous unit. However, when administered by an experienced clinician, passive stretching can be very useful, and as effective as the standard static stretch [6].

Compared with other methods of stretching, static stretching produces the least amount of tension [58]. Theoretically it therefore has the lowest risk of injury, and is easy and safe to implement. The static stretching method is consequently the one most commonly advocated for use in a flexibility-training programme [6;13;54;88;104].

Other stretching techniques

More recently, novel techniques for increasing ROM in joints have been explored. These include the use of vibration [47;68], “awareness through movement” [83], and imagery [85]. In one study, a vibration device that was locally applied to a muscle group in young gymnasts, significantly increased ROM in that muscle group without affecting explosive strength [47]. These results were similar to other reports using vibration-assisted stretching [68], including whole-body vibration [83]. Similarly, in one study, stretching using “awareness of movement” resulted in significant increases in ROM [77]. However, the use of imagery alone was not associated with more significant increases in joint ROM [85]. More research is required to define the precise role of these newer techniques of stretching in flexibility training programs.

POTENTIAL BENEFITS AND RISKS OF FLEXIBILITY TRAINING

The general benefits and risks of performing flexibility training must be considered as 1) potential benefits and risks of the longer-term effects of regular flexibility training sessions that are performed over weeks to months, and 2) potential benefits and risks following a single flexibility training session. This distinction between the acute and longer-term effects of flexibility training has only recently been appreciated in the scientific literature.

Potential benefits and risks of regular flexibility training

As previously defined (Table 1), flexibility training consists of performing regular flexibility sessions over time (weeks to months). Players and trainers commonly perform flexibility training sessions as part of regular training and in preparation for competition. Flexibility training is also an integral part of most rehabilitation programs following injury or surgery.

Does regular flexibility training reduce the risk of injury?

Although regular flexibility training is commonly recommended to reduce the risk of injury [6;15;23;24], this is controversial, and has been the subject of past [30], as well as number of more recent, reviews [80;93;99;100]. The rationale behind the recommendation that increased joint ROM may be associated with a reduced risk of musculotendinous injury is that a musculotendinous unit that possesses greater flexibility is less likely to be overstretched during movements in sport. It has also been stated that increased flexibility decreases the risk of injury, because flexible joints can withstand a greater amount of “stress of torque” before injury, compared to relatively stiff joints.

In general, there have been two scientific study methods that have been used to determine whether regular flexibility training is associated with a decreased risk of injury. These two approaches are:

- to determine whether players that have reduced musculotendinous flexibility (usually determined in the pre-season or pre-training period) have a an increased risk of injury during the season (a prospective cohort study design)
- to determine whether a group of players that undergo flexibility training over time (weeks) have a reduced risk of injury during the season or training period (intervention studies)

Evidence from prospective cohort studies

It is also important to mention that a variety of research methodological issues make the interpretation of the results from prospective studies difficult. A summary of some of these methodological issues is as follows:

- The methodology used in the pre-season ROM measurements is variable
- Specific joint ROM and its relationship to the risk of injury in the specific muscle spanning across that joint has not always been studied
- There is a lack of uniform criteria for the definition of an injury
- There is variation in the exposure of the player to injury
- Variables that may affect ROM during the season are not always taken into account
- There may be variation of ROM during the follow-up period during the season

Despite these methodological issues, it appears that decreased ROM in a specific joint (usually measured in the pre-season assessment) has been shown to be associated with an increased risk of musculotendinous unit injuries in the specific muscle group spanning across that joint during a period of follow-up. Strong evidence in support of this comes from two recently published prospective cohort studies in soccer players. In these two studies, pre-season decreased hip abduction ROM, decreased hamstring flexibility and decreased quadriceps muscle flexibility were associated with an increased risk of groin muscle strains [(3)], hamstring muscle strains [(98)] and quadriceps muscle strains respectively [(98)]. In one other prospective cohort study, this relationship was not confirmed. However, this study was limited by small subject numbers [(7)].

Furthermore, in a number of prospective cohort studies, generalised joint laxity has been associated with an increased risk of injury if players or military recruits are followed for a season or a training period [45;50].

Evidence from intervention studies

As in the case of prospective cohort studies, it is also important to mention that a variety of research methodological issues make the interpretation of the results from intervention studies difficult. A summary of some of the methodological issues is as follows:

- Studies are not always randomized
- The methodology used in the administration of the flexibility training program is highly variable (including differences in the duration of holding stretches, number of stretch repetitions, frequency of flexibility training sessions per day/week, and the duration of the intervention)
- The administration of the flexibility training sessions in relation to a training session or a competition is also variable
- The effect of the intervention (flexibility training has not always been measured to confirm that the intervention indeed increased joint ROM)
- Specific changes in joint ROM, and its relationship to the risk of injury in the specific muscle spanning across that joint, has not always been studied (frequently an overall injury risk, or occasionally a subdivision into soft tissue and bony injuries was used)
- There is a lack of uniform criteria for the definition of an injury
- There is variation in the exposure of the player to injury
- Other variables that may affect ROM during the season are not always taken into account
- There may be variation of ROM during the follow-up period during the season

There are a number of intervention studies that have examined the relationship between injury risk and flexibility training sessions that are conducted immediately before training sessions or matches. These studies will be discussed later in this review. However, there are only two published intervention studies that relate regular flexibility training sessions (that are not conducted immediately before exercise training sessions or matches) to injury risk [20;36]. In the one controlled clinical trial, a company of military recruits who underwent regular flexibility training (five 30second hamstring stretches performed 3 times daily) over 13 weeks of basic military training had a significantly reduced incidence of lower extremity injuries when compared to a control group undergoing no flexibility training [36]. In the other retrospective intervention study, college footballers who were subjected to a static stretch program had fewer injuries during the season when they performed regular static flexibility training compared with the season when they performed no regular flexibility training [20].

In summary, there is evidence from prospective cohort studies to suggest that increased pre-season flexibility in certain musculotendinous units (notably hamstring, quadriceps, and groin) is associated with a decreased risk of injury in these muscle groups. Furthermore, there is some evidence that regular flexibility training sessions that are not conducted immediately before exercise sessions or matches is associated with a decreased risk of injury.

Does regular flexibility training prevent delayed onset muscle soreness (DOMS)?

Muscle soreness, which follows vigorous or unaccustomed exercise, is known as delayed onset muscle soreness (DOMS). Stretching has been advocated as a method to decrease DOMS [2;22]. Despite the widespread belief that stretching decreases DOMS, there are few studies to verify this. Most of these studies utilised a protocol whereby a flexibility training session was conducted immediately before, or immediately after, the exercise session [1;41]. The results of these studies will be discussed later in this review. No studies investigating the possible beneficial effects of regular flexibility training on DOMS could be found.

Does regular flexibility training improve sports performance?

In recent years, there has been an increasing interest to determine the possible effects that flexibility training may have on sports performance. It is important to note that regular flexibility training (sessions that are not conducted immediately or shortly before training sessions or matches) has to be considered separately. Furthermore, the possible effects that flexibility training sessions have on sports performance may differ when considering different performance parameters. The effects of flexibility training on a variety of sports performance parameters have been studied. These parameters can include the following: muscle power parameters (sprinting, standing long jump, vertical jump), muscle strength [1-RM (Repetition maximum), isokinetic peak torque], muscle strength endurance (isokinetic), running speed, and running economy.

In recent years, details of the published studies that have examined this relationship have been reviewed [56;66;74]. Therefore, a detailed discussion of each of these studies is beyond the scope of this review article. However, the effects of regular flexibility training (not the effect of flexibility session immediately before exercise sessions) on a variety of sports performance parameters will now be summarised.

In general, there is good evidence that regular flexibility training improves a variety of sports performance parameters (56;74). In particular, it has been shown that regular flexibility training improves the following parameters: maximum voluntary contraction (MVC), muscle contraction velocity, muscle force (eccentric and concentric), vertical jump height, standing long jump, and sprint time (26;48;66;74). More importantly, there are no studies that show a significant detrimental effect on performance parameters as a result of regular flexibility training (5).

The "dose" of flexibility training is variable among published studies. In general, a total of 20-30 sessions (30-40 min per session) over a period of about 6 to 10 weeks is required to improve sports performance (26;48).

Potential benefits and risks of a single flexibility training session

As previously defined, a single flexibility training session is usually conducted over a few minutes using various stretching techniques. Players and trainers commonly perform a single flexibility training session as part of preparation for training or just before a match. It is only in recent years that the potential effects of a single flexibility training session that is conducted just before a training session or a match, has been considered differently to the effects of regular flexibility training. The effects of a single flexibility training session on injury risk, prevention of delayed onset muscle soreness (DOMS), and sports performance will now be briefly reviewed.

Does a single flexibility training session before exercise reduce the risk of injury during training or competition?

A detailed analysis and review of the published randomised clinical trials (24;63;64;84), and controlled clinical trials (8;20) that relate a pre-exercise flexibility training session to injury risk has been conducted by a number of reviewers (72;73;75;80;93;99;100;103). In a well conducted review (93) that utilised evidence-based criteria, three of these studies were rated as being of high methodological quality (63;64;84). The results of these three studies showed that flexibility training sessions, performed at the time of warm-up before exercise or training sessions, did not reduce the risk of injuries. Similar conclusions were made by the other reviews (72;73;80;103).

It therefore appears that flexibility training performed shortly before a training session or match does not reduce the risk of injury. However, it must be pointed out that there is considerable variation in the type (mostly static stretching), duration of holds and number of stretches in these studies. The evidence is however strong that a static stretching session performed shortly before training does not reduce the risk of injury. It is however possible that more functional flexibility training, such as dynamic stretching techniques performed shortly before training or matches, may reduce injury risk but has not yet been investigated.

Does a single flexibility training session decrease the risk of delayed onset muscle soreness (DOMS) following training or competition?

It was first reported In 1961 [22] that repeated immediate post-exercise stretching (5 minutes during the first 22 hours after exercise) may reduce DOMS [22]. This has resulted in substantial interest in the possible role that pre- or post-exercise stretching may have in reducing DOMS. Since then, a number of studies have been reported where flexibility training has been used pre- and post-exercise to reduce DOMS. The results of these studies have been reviewed [1;41], and the conclusion is that neither pre- nor post-exercise stretching reduced DOMS. Therefore, flexibility training is not effective in alleviating DOMS.

Does a single flexibility training session alter sports performance?

The possible effects that a single flexibility training session shortly before a training session or competition may have on a variety of sports performance parameters, has been extensively researched [9;27;28;43;60;86;87;97] 535} and some of these studies have been the subject of published reviews [56;73-75]. It is important to note that a number of different flexibility training protocols (static stretching, progressive static stretching, dynamic stretching, proprioceptive neuromuscular facilitation) as well as various sports performance parameters have been studied. The sports performance parameters include the following: muscle power parameters (sprinting, standing long jump, vertical jump), muscle strength [1-RM (Repetition maximum), isokinetic peak torque], muscle strength endurance (isokinetic), running speed, and running economy.

A detailed discussion of each of these studies is beyond the scope of this review article. However, the effects of different types of flexibility trainings sessions performed shortly before exercise on sports performance parameters has been reviewed [74]. More recent studies [9;27;28;38;43;60;86;87;97] confirm the following general statements:

- There is very strong evidence that flexibility training performed shortly before an exercise session impairs a number of parameters of sports performance, notably muscle force, peak torque, and vertical jump.
- In general these reductions in sports performance occur irrespective of the type of flexibility training protocol, but it does appear that static stretching more consistently reduces these sports performance parameters

- These reductions have been observed irrespective of player gender, age, performance level, or the player's state of training
- The information of the effects of a session of flexibility training on sprinting is less clear, but it appears that static stretching, in particular, reduces sprint performance
- There is some evidence to suggest that dynamic (ballistic) training performed before exercise sessions may improve sprint performance [28]
- Running economy appears unaffected by pre-exercise flexibility training [38]

THE SCIENTIFIC BASIS OF RESPONSES TO FLEXIBILITY TRAINING

A number of factors are important in the successful implementation of a flexibility training session or a flexibility training programme, irrespective of the type of stretching technique that is employed. These include i) the **duration** for which a stretch is held, ii) the **number of times** the stretch is repeated in one session, iii) the number of **times the session is repeated** per day or week, iv) the **most effective anatomical position** in which to stretch a particular musculotendinous unit, and v) the **effect of warm-up on** the effect of stretching. Recently acquired data from research studies has identified the scientific basis for optimum static and PNF stretching and this has been reviewed (71). The main results from these studies are as follows:

- A static-stretch duration of 30-60 seconds is optimal for increasing range of motion in static stretching
- In a static stretch session, 3 stretches are optimal to increasing ROM and additional stretches do not add any further advantage to increasing the ROM
- A 10-second PNF stretch is as effective in increasing ROM as longer durations, i.e. up to 60 seconds
- Similarly, in a PNF stretch session, 3 PNF stretches result in the largest increase in ROM, but this was not significantly more than performing a single stretch
- Following a stretch session that is optimally based on recent scientific evidence, ROM is only retained for 4-6 hours
- The practical implication is that the frequency with which stretch sessions should be conducted during a day to achieve maximal benefit in increasing ROM is approximately every 6 hours (during awake hours)

- Flexibility training that consists of daily stretching (every 6 hours) can result in retention of ROM after as short a period as 7 days
- This protocol of flexibility training will result in a progressive increase in ROM of 15-20%, after 3 weeks
- An active warm-up alone appears to be ineffective in increasing ROM, but it may have an additive effect if performed prior to static stretching
- It appears that static stretching results in greater increases in ROM if performed with the muscle in a relaxed, non-weight bearing position

SUMMARY

- Musculoskeletal injuries are common in rugby players, and musculotendinous injuries of the thigh, groin and calves are particularly common
- Musculotendinous inflexibility has traditionally been linked to an increased risk of muscle injuries but recently this hypothesis has been challenged
- A flexibility training session can be defined as a training session (usually lasting a few minutes) that incorporates stretching techniques that are designed to increase the range of motion of a joint or group of joints
- Flexibility training can be defined as a training program that incorporates regular flexibility training sessions over a period (usually weeks), and which is aimed at increasing the range of motion of specific joints or groups of joints (also known as a stretching training program)
- There is some scientific evidence to suggest that reduced flexibility in specific muscle groups (hamstring, quadriceps, groin) is associated with an increased risk of musculotendinous injury in those muscles
- There is some scientific evidence that regular flexibility training can reduce the risk of injury
- There is no scientific evidence that regular flexibility training reduces DOMS following exercise
- There is some scientific evidence that regular flexibility training (with sessions not performed shortly before training sessions or matches) improves sports performance parameters

- There is good scientific evidence that a flexibility training session performed shortly before an exercise session does not reduce the risk of injury
- There is good scientific evidence that a flexibility training session performed shortly before an exercise session does not reduce the risk of DOMS
- There is good scientific evidence that a flexibility training session performed shortly before an exercise session can reduce sports performance, particularly muscle power and strength
- An optimal static flexibility training session should include 3 stretches (each lasting 30 seconds)
- An optimal PNF static flexibility training session should include 3 stretches (each lasting 10 seconds)
- Flexibility training sessions should be performed 2-3 times per day, resulting in an improvement in ROM of 15-20%, after 3 weeks

PRACTICAL APLLICATIONS AND EXAMPLES OF FLEXIBILITY TRAINING ROUTINES

Practical example 1: Flexibility training to improve sports performance

Regular flexibility training has been shown to improve sports performance. However, flexibility training sessions should not be performed shortly before (< 2 hours before) training sessions or matches as this practice negatively affects sports performance parameters, such as measures of muscle power and strength. Flexibility training for rugby should include all general muscle groups. The type of stretching technique used can be static stretching, or PNF stretching. More recently, dynamic stretching has been used with success, but fewer studies have confirmed the beneficial effects of dynamic flexibility training.

A typical weekly flexibility training program to improve sports performance will be as follows:

Type of stretching technique:	Static, PNF or dynamic (mainly static and PNF)
Muscle groups:	All general upper- and lower-limb muscle groups
Duration of hold during a stretch session:	Hold for 30 seconds (static) or 10 seconds (PNF)
Number of stretches during a stretch session:	3 times
Number of stretch sessions per day:	At least once per day
Duration of flexibility training program:	4-6 weeks minimum

A typical flexibility training program to improve sports performance shortly before a training session or competition:

Type of stretching technique:	Dynamic functional stretching (avoid static and PNF)
Muscle groups:	All general upper- and lower-limb muscle groups
Duration of flexibility training program:	As part of general sports-specific warm-up

Practical example 2: Flexibility training to reduce injury risk

Reduced flexibility of specific muscle groups (notably hamstring, quadriceps, groin and calf) has been associated with increased risk of injury during a season. Flexibility training sessions should not be performed shortly before (< 2 hours before) training sessions or matches as this practice has not been shown to reduce the risk of injury. Therefore, regular flexibility training performed at times other than shortly before training sessions or matches can be used to increase joint ROM. Flexibility training for rugby should start with a clinical assessment of the muscle groups in order to identify those muscle that have decreased flexibility. The type of stretching technique used can be static stretching, or PNF stretching. More recently, dynamic stretching has been used with success, but fewer studies have confirmed the beneficial effects of dynamic flexibility training on injury risk.

A typical weekly flexibility training program to reduce injury risk will be as follows:

Type of stretching technique:	Static, PNF or dynamic (mainly static and PNF)
Muscle groups:	All general upper- and lower-limb muscle groups
Duration of hold during a stretch session:	Hold for 30 seconds (static) or 10 seconds (PNF)
Number of stretches during a stretch session:	3 times
Number of stretch sessions per day:	At least once per day
Duration of flexibility training program:	4-6 weeks minimum

A typical flexibility training program to improve sports performance shortly before a training session or competition:

Type of stretching technique:	Dynamic functional stretching (avoid static and PNF)
Duration of flexibility training program:	As part of general sports specific warm-up

Practical example 3: Flexibility training to increase flexibility in a very inflexible joint (perhaps following injury with resultant scar tissue formation and contracture)

Regular flexibility training has been shown to increase joint ROM. The type of stretching technique used can be static stretching, or PNF stretching. More recently, dynamic stretching has been used with success, but fewer studies have confirmed the beneficial effects of dynamic flexibility training.

A typical weekly flexibility training program to increase joint ROM in an inflexible muscle:

Type of stretching technique:	Static, PNF or dynamic (mainly static and PNF)
Muscle groups:	Muscle groups that have been identified as inflexible
Duration of hold during a stretch session:	Hold for 30 second (static) or 10 second (PNF)
Number of stretches during a stretch session:	3 times
Number of stretch sessions per day:	2-3 times per day
Duration of flexibility training program:	4-6 weeks minimum

AUTHOR'S BIOGRAPHY

Professor Schwellnus is a sports physician, and co-ordinator of the Masters-degree program for the training of Sports Physicians at the University of Cape Town. He also is a partner in a Sports Medicine Practice, is a member of the IOC Medical Commission, and is Vice-President of the International Federation of Sports Medicine (FIMS). He serves on the Editorial Board of the British Journal of Sports Medicine and has published extensively in the field of Clinical Sports Medicine.

TABLE 1: DEFINITIONS AND TERMINOLOGY

Term	*Description*
Flexibility	The range of motion in a joint or in a group of joints that is influenced by muscles, tendons and bones (2;82)
Flexibility training session	A training session (usually lasting a few minutes) that incorporates stretching techniques that are designed to increase the range of motion of a joint or group of joints
Flexibility training	A training program that incorporates regular flexibility training sessions over a period (usually weeks) and that are aimed at increasing the range of motion of specific joints or groups of joints (also known as a stretching training program)
Elasticity	The property in tissues that refers to the return of the tissue to its original length when the force is removed (15;29;40;51;79)
Viscosity	The property in tissues that refers to the elongation of a tissue that remains once the force applied to it is removed (15;29;40;51;79)
Viscoelastic	A tissue that exhibits both viscous and elastic properties (15;29;40;51;79)
Extensibility	The ability of a tissue to elongate (14;33)
Stiffness	The ratio of the change in stress (force per unit area) and the change in length (strain) (33)
Stress relaxation	The decline in tissue tension that results when a tissue is lengthened and then held at that constant length (29;40;51;79)
Creep	The change in length of a tissue in response to a load that is applied and then maintained at that constant magnitude (29;49;52;79;92)
Hysteresis	The change in length of a tissue in response to a load that is applied in a cyclic fashion (29;76)

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