

Proprioception and the Rugby Shoulder

Ian Horsley

*Regional Lead Physiotherapist, English Institute of Sport
Manchester
UK*

1. Introduction

Rugby union is an international sport played by two teams of 15 players (8 forwards and 7 backs) over two 40 minute halves. It is ranked internationally, as a football code, second to soccer, and is the most popular world wide team contact sport involving collision (IRB, 2004). Professional rugby league is a contact sport involving two teams of 13 players (6 forwards and 7 backs), also played over two 40 minute halves. Each team has a set of six tackles to advance the ball downfield (Gissane *et al.*, 2003).

Little is known about the level and pattern of injuries occurring since rugby union became a professional sport, and the number of prospective studies among elite players is small (Brooks, *et al.*, 2005). Prior to Brooks *et al.*, (2005), there have been several prospective cohort epidemiological studies of injuries sustained in professional Rugby Union (Bathgate, *et al.*, 2002; Garraway, *et al.*, 2000. Targett, 1998).

The mean incidence of injuries recorded from three studies within professional rugby union is 86.4 injuries per 1000 player hours (Holtzhausen, 2001). Pooled data analysis of injury incidence in rugby league, found an overall injury rate of 40.3 injuries per 1000 player hours (Gissane *et al.*, 2002).

Brooks *et al.*, (2005) conducted the England Rugby Injury and Training Audit, which included all 12 Premiership rugby union teams, and England, England 'A', Under 21 and England 7's teams, during the 2002-2003 and 2003-2004 seasons. They used the operation definition which had been used previously by one of the authors in research into injuries in professional football; "any injury which prevented a player from taking a full part in all training activities typically planned for that day and match play for a period equal to or greater than 24 hours, from midnight of the day the injury was sustained" (Hawkins, and Fuller, 1999).

Detailed analysis of this audit, with respect to shoulder injuries, reports that the average number of tackles carried out during a Premiership match is 250, and that 65% of all shoulder injuries occurring during a match are to the shoulder. During the 2005-2006 season the number of days lost to training or playing due to reported shoulder dislocation or instability was 176 days per 1000 hours play (Heady *et al.*, unpublished). Thus the tackle appears to be the phase of play associated with the greatest risk of injury overall. (Brooks *et al.*, 2005; Bird *et al.*, 1998; Garraway and Macleod, 1995; yet there appears to be scant published research regarding the affect on shoulder joint position sense within rugby players, in general, and the effect that tackling has on it.

Stability within the glenohumeral joint is maintained via anatomical factors such as the degree of bony congruity, integrity of the capsuloligamentous structures and neuromuscular feedback loops involving the joint and musculotendinous mechanoreceptors that are integrated within the central nervous system (Suprak, Osternig, van-Donkelaar, & Karduna, 2006).

Despite this highly integrated passive and active control system the glenohumeral joint is regarded as one of the least stable joints within the body.

The passive ligamentous and capsular structures are often exposed to deleterious loads due to the failure of the active muscular control systems of the glenohumeral joint. This failure of active muscular control system reported in the literature has in part at least been blamed on a failure of proprioception (Janwantanakul, Magarey, Jones, & Danise, 2001).

The term "proprioception" was introduced by Sherrington in 1906 who described it as a type of feedback loop from the limbs to the central nervous system; afferent information arising from peripheral areas of the body contribute to joint stability, postural control and motor recruitment patterns. It has more recently been described as a combination of joint position sense (JPS, the ability of a person to identify the position of a limb in space) and kinaesthesia (the perception of active and passive motion) (Aydin, Yildiz, & Yanmis, 2001).

The awareness of the position of the joint (JPS) is obviously an important aspect of proprioception. An intact JPS has been shown to be necessary for normal muscle coordination and timing, and this has been shown to be especially evident where active muscle forces play a significant role, as in glenohumeral joint stability Blasier, Carpenter, & Huston, 1994; Cain, Mutschler, Fu, & Lee, 1987). JPS contributes to the maintenance of muscle stiffness and coordination about a joint to produce smooth limb movements, and has been found to be affected by ligamentous trauma, surgical intervention, and rehabilitation programmes (Lephart, Warner, Borsa, & Fu, 1994) Muscle fatigue, trauma and hyper laxity can be responsible for damage to the mechanoreceptors (deafferentation), which can reduce the afferent supply so that the central nervous system receives inaccurate information, and hence, responds with inaccurate output responses.

In the current literature it is generally agreed that tension in muscles, capsuloligamentous structures, and skin at a joint varies at the different points in the joint's range of movement (Allegrucci, Whitney, Lephart, & Fu, 1995; Dover, Kaminski, Maister, Powers, & Horodyski, 2003) Janwantanakul et al., 2001; Sullivan, Hoffman, & Harter, 2008). Because mechanoreceptors in tissues are activated by tension exerted on them, their activation would be expected to vary at different points in range as the tension in tissues around the joint varied. Consequently, position sense acuity may alter from one joint position to another. The accuracy of joint position reproduction at different criterion angles during JPS testing has been found to vary in studies involving the shoulder (Janwantanakul et al., 2001). In addition, Allegrucci et al. (1995) and Blasier et al. (1994) noted greater movement sense acuity at the shoulder complex, measured by the threshold for detection of movement test, at the end of range than in the mid joint range.

Joint position sense has been demonstrated to differ between participants in different sports and non-sporting individuals. Dover et al. (2003) showed baseball pitchers to have significantly decreased JPS at the extreme of external shoulder rotation than controls. This lack of awareness of joint position could potentially expose the glenohumeral joint to deleterious loading and result in injury.

Several factors have been reported to influence JPS including training, joint range, and fatigue (Myers & Lephart, 2000). Herrington, Horsley and Rolf (2007) and others (e.g.,

Dover, Kaminski, Meister, Powers, & Horodyski, 2003) have shown the level of training or nature of sports performance has a significant effect on JPS, with for instance, rugby players showing superior shoulder JPS to matched controls (Herrington et al., 2007). Janwantanakul et al. (2001) found that the joint angle set as the criterion angle to be matched had a significant effect on JPS, with JPS improving towards the end of the range position as the capsular structures became taut. Several authors (Carpenter, Blasier, & Pellizzon, 1996; Tripp, Boswell, Gansneder, & Schultz, 2004; Voight, Hardin, Blackburn, Tippett, & Canner, 1996) found fatiguing activities to have a significant effect on shoulder JPS, causing a decrease following fatiguing activity. The consensus from these papers was that muscle fatigue somehow decreases the sensitivity of the capsular receptors and thus decreases proprioception indirectly. Fatigue, as in the decreased ability to generate the required force, leads to a production of substances, such as lactic acid and bradykinins, which exhibit effects via the nervous system which lengthen the muscle spindles. Hence, when the stretch stimulus arrives, the muscle spindle is not at the expected length, and affects the spindle output. If this situation is repeated, then the resulting sub-optimal motor response may be responsible for anatomical injury. This injury may itself contribute to deafferentation in a cyclic response (Voight, Hardin, Blackburn, Tippett, Canner, 1996). It has yet to be investigated if fatiguing tasks influence the angle-specific effect outlined above. It could be hypothesised from the above studies that end of range JPS could be preferentially decreased following a fatiguing task. This would then potentially expose the passive structures of the shoulder to increased loading and injury. Herrington, Horsley and Rolf (2007) assessed the effect of a simulated tackling task on shoulder joint position sense in rugby players, and also attempted to assess if differences in JPS occurring between mid range and end of range JPS, and if the tackling task had angle-specific effects on these values, utilizing a repeated measures design with 22 asymptomatic professional rugby players. JPS was assessed using two criterion angles in the 90degrees shoulder abduction position (45degrees and 80 degrees external rotation) prior to and following a simulated tackling task against a tackle bag.

They concluded that JPS was significantly reduced following a fatiguing task. But this change was only true for the end of range position, with JPS in the mid range not changing. If the mechanoreceptors are unable to accurately report shoulder position in the outer range (stretch) position due to repetitive tackling, then there is a potential for the anterior structures to become stressed before any compensatory muscle contraction can take place. These results highlight the presence of sensorimotor system deficits following repeated tackling. These deficits were proposed to contribute to overuse injuries and micro-instability of the glenohumeral joint which may be related to the increasing rate of shoulder injuries in rugby.

Following this, the same authors repeated a similar study using 15 asymptomatic professional rugby union players, 15 previously injured professional rugby union players, 15 asymptomatic matched non-rugby playing controls and assessed their joint position sense, with the aim of identifying whether joint position sense (JPS) in the shoulder differed between un-injured rugby players, matched control subjects and previously injured rehabilitated rugby players. The study found a significant difference between groups in error score ($p = 0.02$). The testing angle also had a significant effect on error score ($p = 0.002$), with greater error scores occurring in the mid range position. They concluded that rugby players have better JPS than controls, indicating JPS might not be related to injury risk. Poor JPS appears to be related to injury, players having sustained an injury have decreased JPS despite surgery and/or rehabilitation and returning to sport without incident.

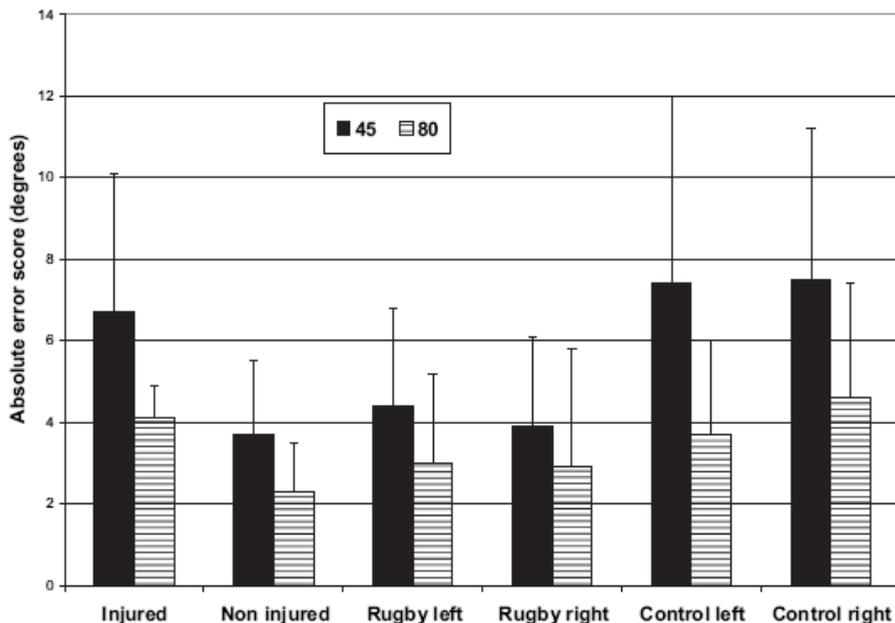


Fig. 1. Absolute error scores for the three groups.

Joint position sense can be defined as the ability to appreciate and recognise where a joint or a limb is in space (Ellenbecker, 2004). It has been reported in literature that joint position sense has great importance in avoiding non-physiological joint movements, such as extremes of movement - thus providing injury prevention and co-ordinates complex movement patterns (Jerosch and Prymka, 1996).

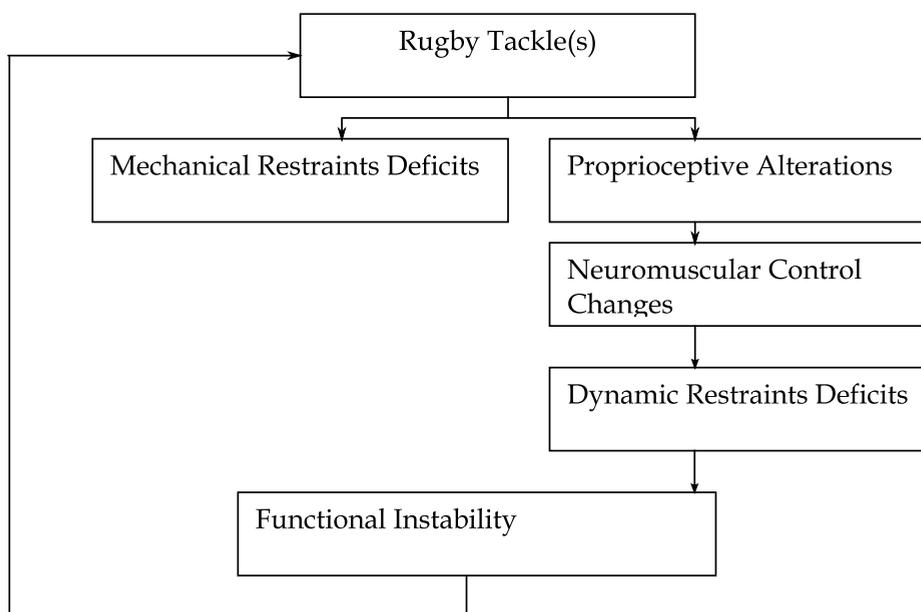
The mechanoreceptors found within the capsule of the glenohumeral joint aid in providing afferent proprioceptive input via both slowly and rapidly adapting receptors (Vangsness et al. (1995). The rapidly adapting receptors respond to sudden changes in tension within the passive joint structures, although decrease their input into the central nervous system if the tension remains the same, in order to process acceleration and deceleration within the glenohumeral joint.

Proprioceptive feedback is not only produced from the passive restraints of the shoulder but from contractile structures too (Myers and Lephart, 2000; Nyland et al., 1998). The muscles which span the joint have three methods of assisting with joint stability by activation of various muscular contraction reflexes (Jerosch et al., 1997) (Jerosch et al., 1993), regulation of muscular contraction (Speer and Garrett 1993). The feedback is via the muscle spindles and golgi tendon organs. The muscle spindles provide feedback to enable effective motion execution via the monitoring of muscle length and joint position, and the sensitivity of the muscle receptors can be altered via efferent input from higher brain centres (Nyland, et al., 1998). The feedback from the golgi tendon organs registers changes in muscle tension and joint position, which induces agonist relaxation and contemporary increased activity within the antagonist, as a method of protection.

Processing of this information is carried out within the central nervous system at spinal level, brain stem, cerebellum, or cerebral cortex (Lephart and Henry 1996) and affects the

function of the dynamic restraints surrounding the glenohumeral joint. This is via feed forward (anticipatory) and feed back (reactive) loops (Ghez, 1991). These two loops work in harmony, within the healthy shoulder, to indicate the actions of the dynamic restraints, which themselves are responsible for maintaining appropriate force couples across the joint, reflex action and regulating muscle stiffness (Myers and Lephart, 2000).

During the rugby tackle high trauma, or repeated minor trauma, could compromise the stability of the shoulder joint via increased joint laxity has decreased proprioceptive acuity compared to subjects with less joint laxity (Blaiser et al 1994). This laxity could bring about a cycle of events; described by Lephart and Henry (1996) as shoulder functional joint stability paradigm. Figure 2



Adapted from Lephart and Henry (1996)

Fig. 2. Functional joint instability due to a Rugby Tackle.

Patients lacking proprioception have demonstrated an inability to perform multi-joint movements, suggesting that deficits in joint position sense detrimentally affects the coordinated movements at other joints along the kinetic chain (Riemann and Lephart, 2002) Following trauma to the shoulder joint through a heavy tackle or repeated contacts to the shoulder, proprioceptive input appears to be disrupted - which in turn affects neuromuscular co-activation deficits (Myers and Lephart, 1994).

Rehabilitation following injury to the glenohumeral joint should take into consideration not only pain relief, reduction of inflammation and restoration of optimal muscle strength and joint range of motion, but should include functional movements which replicate the demands of the sport in order to increase proprioceptive awareness, dynamic stabilization, feed forward mechanism (through anticipatory muscle responses), and sound reactive

muscle function to athletic demands (Lephart and Henry, 1995). Proprioceptive training has been suggested as re-connecting the afferent pathways from the joint to the central nervous system with the production of complimentary afferent responses as a compensation for the joint position deficits produced by fatigue and/or injury (Myers and Lephart, 2000).

With shoulder joint injury there is much more than the soft tissues which are damaged; the sensorimotor system which is responsible for motor control and proprioception, and as has been demonstrated following shoulder injuries in rugby (Herrington, Horsley, Rolf, 2007).

2. Restoration of the sensorimotor system

Following disruption of the sensorimotor system it is imperative that restoration of functional joint stability is carried out as quickly as possible, in order to minimise the deleterious consequences. This rehabilitation needs to be able to replicate the demands placed on the joint, under controlled conditions but identifying deficits within the sensorimotor system in a clinical setting is not easy. Within scientific literature many sophisticated devices such as isokinetic dynamometers and motion analysis have been utilised. But these devices are not readily available in a clinical setting and thus render these techniques impractical.

The assessment of proprioception using "reproduction of passive positioning" is a valid and established method reported by Barrett (1991) Clinically joint angular replication tests – whereby the shoulder is placed in a position and the patient holds it in that position and consciously registers this position, then the arm is returned to a resting position. The subject is then asked to return the arm to the test position. This test has been described by Davies and Hoffmann (1993) and assesses both the static and dynamic shoulder joint stabilisers providing a thorough afferent pathway assessment (Lephart & Fu, 2000). Other examples of open kinetic chain exercises are;

Joint angle repositioning, whereby the shoulder joint is taken to a specific position in space (generally a combination of abduction and external rotation) by the examiner. The subject (who has their eyes closed in order to negate visual cues) is asked to hold this position for 5 seconds, then the limb is moved to the starting position, and the subject is asked to move to the test position. The degree of error from the stated position is recorded.

Contra lateral limb mirroring; the subject's uninjured shoulder is placed in a position in space (whilst they have their eyes closed) and the subject is asked to mirror that position with the "involved" limb. Once again the degree of error between the two sides is noted.

Rehabilitation:

The goals of neuromuscular rehabilitation according to Borsa et al., (1994) are:

- To improve cognitive appreciation of the shoulder relative to position and motion.
- To enhance muscular stabilisation of the joint in the absence of passive restraints.
- Restore synergistic muscular firing and coordinated movement patterns.

The progression of the rehabilitation programme should progress along continuum (table 1) of difficulty with respect to the sport or desired activity (Guido and Stemm, 2007) and evolve from bilateral to unilateral, supported to unsupported (Kennedy et al., 1982), utilising active and passive movement, with and without load. The act of gripping has been shown to activate reflex contraction of the rotator cuff muscles which will stimulate glenohumeral mechanoreceptors. (Shumway-Cook and Woollacott, 2001).

	Early Stress	End Stage
Support	Supported Bilateral	Unsupported Unilateral
Surface Stress	Stable Minimal Capsular Stress Mid Range	Unstable Maximal Capsular Stress Outer Range
Speed	Slow	Fast
Stress Application	Predetermined Stress	Random/ Sudden Stress
Movement Pattern	Simple Co-ordination	Complex Co-ordination

Table 1. Rehabilitation Continuum

Weight bearing exercises through the limb (closed kinetic chain exercises) facilitates the activity of the rotator cuff muscles, and can be utilised in positions of forward lean standing or in four point kneeling from a four point kneeling position joint position reproduction can be utilised (figure 3). These can be progressed to a three point position (by extending the other arm or either leg) and further progressed to two point weight bearing which will facilitate the posterior chain to aid with scapular stabilisation.



Fig. 3.

Further progression would be to change the surface from solid surface, to a wobble board or Swiss ball. The quality of the movement and exact local joint control needs to be monitored, as it is important to remember that arm movement, reflex stabilisation, postural control, and

somatosensory perception are not separate events but rather different parts of an integrated action. (Guido and Stemm, 2007). Only the number of repetitions that the patient can carry out correctly with consistency should be carried out, rather than dictating a pre-determined number of repetitions and sets. Thus each exercise repetition is bespoke for that patient to avoid fatigue – as motor control decreases rapidly with fatigue, as does joint position awareness.



Fig. 4.

Another possibility of improving the cognitive awareness of shoulder JPS, is to challenge the patient to find the balance point (figure 5) whereby in side lying, they are challenged to place their arm directly perpendicular to the glenoid and, initially, maintain this position against gravity. Dynamic balance can be further enhanced by asking the patient to maintain this position with a Swiss ball balanced on their hand (figure 6). To progress this exercise the patient is asked to stand from this position maintaining balance of the Swiss ball overhead.

The addition of externally applied forces (perturbations) will promote glenohumeral joint co-contraction, and rhythmic stabilisation (where by the patient's shoulder joint is placed in position and isometrically resists externally applied focus of the therapist, take advantage of the stretch reflex creating a change in the desired muscle length producing local muscular splinting).

As soon as it is applicable the exercises need to be carried out in more functional positions such as sitting and standing (rather than the early stage of lying positions), as body position has a significant influence on a patient's ability to replicate a target position and to be aware of upper limb movement (Janwantanakul et al., 2003).



Fig. 5.

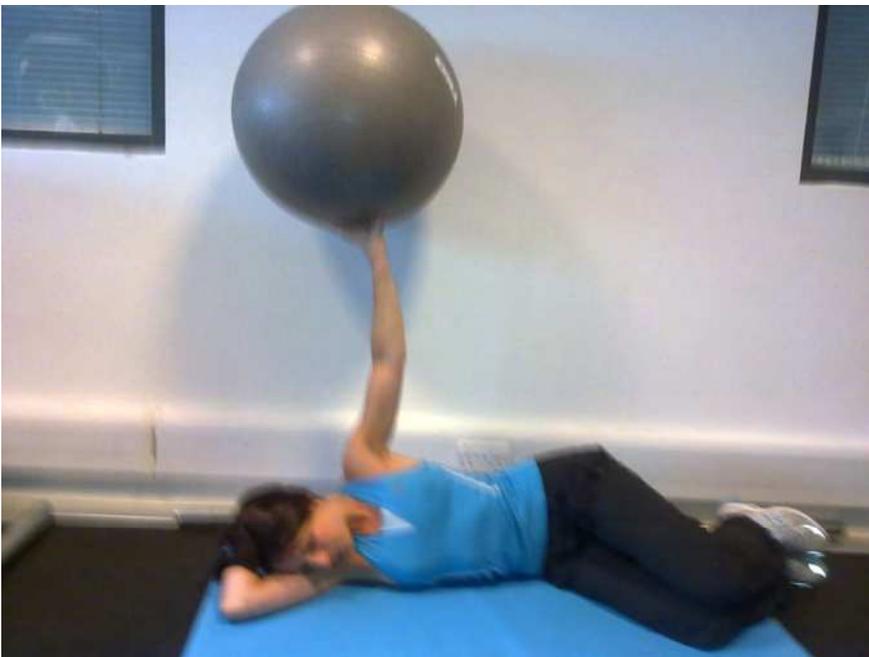


Fig. 6.

Another alternative to assess and rehabilitate proprioceptive acuity is to utilise a laser pointer. Targets can be placed on a wall, and a laser pointer attached to the arm that is being rehabilitated (fig 7). The patient is instructed to either follow a set path (such as a line) or land the pointer on a predefined mark.



Fig. 7.

3. Proprioceptive neuromuscular facilitation (PNF)

Improvements in the neuromuscular response can be improved by utilising PNF exercises to stimulate the muscle spindles and golgi tendon organs. (Borsa et al., 1994). These movements occur in diagonal plans, against some form of external resistance, and require movement at the glenohumeral joint at all three planes (Voss and Ionta, 1985) and are designed to stimulate normal physiological movement.

Shoulder	Flexion External Rotation Adduction
Forearm	Supination
Wrist	Radial Deviation
Fingers	Flexion

Table 2. D1 flexion Joint Specific Movements

Shoulder	Extension Internal Rotation Abduction
Forearm	Pronation
Wrist	Ulnar Deviation
Fingers	Extension

Table 3. D1 Extension Upper Extremity Joint Specific Movements

Shoulder	Flexion External Rotation Abduction
Forearm	Supination
Wrist	Radial Deviation
Fingers	Extension

Table 4. D2 Flexion Upper Extremity Joint Specific Movements

Shoulder	Extension Internal Rotation Adduction
Forearm	Pronation
Wrist	Ulnar Deviation
Fingers	Flexion

Table 5. D2 Extension Upper Extremity Joint Specific Movements

The basic principles of PNF include utilisation of manual resistance (which varies throughout the range in response to the muscle strength), verbal cues, visual stimulus, and proprioceptive input via specific hand placement on the skin, stretch and timing order.

4. Plyometric exercises

Polymeric exercises involve an eccentric load or pre-stretch followed by a concentric contraction, (Borsa et al., 1994) which is induced via the myotactic reflex. This, then, facilitates reflex joint stabilisation. It has been proposed that movement towards the end of

the shoulder range stimulates joint mechanoreceptors, as well as facilitating muscle spindle activity and decreasing GTO activity from the length – tension changes occurring at the musculotendinous structures (Swanik et al., 2002)

Common plyometric exercises include throwing motions trunk motions, resistive band exercises ball/ wall drills and plyometric push ups (Borsa et al., 1994).

A plyometric push up involves starting from the lower position of the press up, with the chest neat the floor, and rapidly extending the elbows with force, so that both hands leave the floor, then controlling the movement back to the start position eccentrically.

It is essential to demonstrate excellent dynamic control around the shoulder, through full range, with good proprioceptive acuity before progressing to these demanding exercises. (Gibson, 2004).

5. Compression

It has been reported that tactile sensations (along with vestibular and visual) aid with joint repositioning (Allegruci et al., 1995). Compression garments are believed to enhance sensory and proprioceptive awareness leading to an increase in proximal stability (Gracies et al., 1997) and stimulate mechanoreceptors to enhance joint positioning sense and body awareness (Hylton and Allen, 1997) (Ulkar et al., 2004). There is a reduced contribution of cutaneous proprioceptive information in proximal areas such as the glenohumeral joint (Grigg 1994) and the provision of compressive force stimulates mechanoreceptors within the skin to provide joint position sense to the central nervous system (Barrack et al., 1983) and has been reported to promote the cognitive feeling of joint stability (Jerosch and Prymka, 1996; Barrack 1983).

Functional stability of the shoulder is dependent on co activation of the musculature as well as reactive neuromuscular characteristics. Injury to any of the soft tissue structures has been postulated as a cause of disruption of this neuromuscular mechanism. Treatment of such a dysfunction needs to consider proprioceptive training and rehabilitation, since the function of the shoulder joint is optimal when proprioception is normalized.

6. Summary

Injuries to the shoulder are becoming increasingly more frequent in professional rugby. It has been cited that this is due to the increased intensity and frequency of the contact/tackle phase (Brookes et al., 2005). Recent studies have provided at least a partial explanation of why this is occurring. professional rugby players to have superior JPS than controls, indicating JPS might not be related to injury risk, when assessed in a rested state Following a tackling task JPS was significantly decreased in the outer range position potential exposing to the anterior structures of the shoulder to increased loading. JPS would appear to be significantly affected by injury, players who have sustained an injury having inferior JPS, compared to their peers These results highlight the presence of sensorimotor system deficits following repeated tackling. These deficits are proposed to contribute to overuse injuries and micro-instability of the glenohumeral joint (Lephart & Henry, 1996). Thus, it would appear advisable, when appropriate, to restrict shoulder joint activity following repeated tackling. One way of achieving this would be to place tackling drills at the end of the training sessions and not to match tackling with heavy upper body weight training sessions.

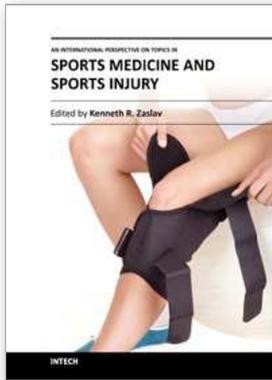
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For the past two decades, Sports Medicine has been a burgeoning science in the USA and Western Europe. Great strides have been made in understanding the basic physiology of exercise, energy consumption and the mechanisms of sports injury. Additionally, through advances in minimally invasive surgical treatment and physical rehabilitation, athletes have been returning to sports quicker and at higher levels after injury. This book contains new information from basic scientists on the physiology of exercise and sports performance, updates on medical diseases treated in athletes and excellent summaries of treatment options for common sports-related injuries to the skeletal system.

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Phone: +86-21-62489820
Fax: +86-21-62489821

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