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EVIDENCE-BASED LITERATURE REVIEW SAFE RUGBY TECHNIQUES

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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

Rugby Union is played in more than 100 countries across five continents by more than three million people between the age of six and 60 [15,16]. In South Africa, a reported total of 326 565 rugby players are currently participating in club and school rugby matches [39]. As with any contact sport, rugby has a high risk of injury. The incidences of match-related injuries are much higher than in other popular South African team sports. Two hundred and eighteen and 120 "time-loss" injuries per 1000 rugby match hours have been reported for international and club rugby respectively [1]. Soccer and cricket have much lower incidence with international and club soccer resulting in 42 and 26 injuries respectively per 1000 hours during matches and international and club cricket resulting in 2.8 and 1.8 injuries respectively per 1000 match hours [1].

The majority of injuries result from contact phases of play such as the tackle, taking the ball into contact, the scrum, the ruck and maul and the lineout [1,7]. Although the tackle situation has demonstrated the majority of injuries in South African schoolboy (55%) [34] and senior rugby players (40%) [3], the scrum carries a 60% greater risk per event [7]. Injuries to the head and neck resulting in permanent (>12 months) severe functional disability, which have recently been defined as "non-fatal catastrophic injuries" [7] are unfortunately also a part of the game [26]. Head and non-fatal catastrophic neck injuries have been shown to range from 12%-33% of all injuries [1]. A 2001 analysis [31] of published cervical spine injury data reported distributions of catastrophic cervical spine injuries in specific phases of play: the scrum resulted in 40%, the tackle resulted in 36%, the ruck and maul in 17% and other phases only resulted in 6% of catastrophic cervical spine injuries.

During recent years the incidence of head and cervical spine injuries has caused huge concern to the medical fraternity [1, 13, 19-21, 26, 31, 32, 37, 41]. Measures to reduce the number of catastrophic injuries have included law changes and educational initiatives [26, 31, 32]. Laws governing the scrum, including scrum engagements, and the tackle have been adapted to make the game safer and to avoid non-fatal catastrophic injuries to the cervical spine [17, 26, 31]. Examples of law changes introduced to reduce the incidence of catastrophic injuries include the Crouch-Touch-Pause-Engage sequence of scrum engagement and the outlawing of high and spear tackles. A recent evaluation [34] of a national injury prevention programme (the New Zealand RugbySmart programme) on serious spinal injuries in rugby union showed that its introduction has coincided with a reduction in the rate of disabling spinal injuries. Since the introduction of the programme in 2001, the incidence of scrum-related spinal injuries decreased from the predicted number (based on the injury rates of previous periods) of 19 to 8. Similarly, injuries resulting from tackles, rucks and mauls decreased from the predictor number of 9 to 7. This study demonstrates the benefit of teaching safe and effective techniques in rugby.

The need for coaches to emphasise correct technique is extremely important and one of the few possible modes to reduce injuries, such as non-fatal catastrophic injuries to the head, neck, brain and spine. The purpose of this section is not only to provide evidence of safe techniques during the contact phases of the game (tackling, taking ball into contact, scrum setting and engagement, lineouts as well as rucks and mauls), but also to provide empirical evidence that safe technique is effective technique. Coaches are thus able to ensure greatest safety to their players while improving their technical effectiveness.

TACKLING: SAFE AND EFFECTIVE TECHNIQUE

In studies reporting the incidence of rugby union injuries, tackling has been shown to be the cause of 25% and 14% of injuries in schoolboy and adult South African rugby players respectively [3,34]. The most frequent body sites injured during tackling (injuries to the tackler) were the upper limb (35%), including the shoulder and clavicle; the head, neck and face (28%) and the lower limb (27%) [42]. It has been reported that the injury with the highest incidence in tackling is a cervical nerve root injury for forwards and concussion for backline professional rugby players (1). These results are in agreement with previously reported injuries in South African schoolboys, which similarly demonstrated a large proportion of tackle injuries to the head and neck [34]. Roux et al. [34] also reported concussion to account for 14% of injuries incurred while tackling. Tackle injuries were most often associated with front-on tackling, rather than tackling from the side or from behind [33, 42].

The tackle has been shown to be the major contributor to serious catastrophic cervical spine injuries (36% of all reported non-fatal catastrophic cervical injuries) [31]. Trauma to the cervical spine may occur during tackling through vertex impacts and hyperflexion [26]. Although the mechanism of cervical spine tackle injuries have not been substantially reported in rugby union, it has been proposed to be a result of hyperflexion of the neck [26, 31]. The mechanism of catastrophic cervical spine injuries during the American football tackle has however been very well researched and documented [13]. Axial loading, which occurs during contact with the top or crown of the head or helmet (referred to as spear tackling in American Football) is the primary mechanism of catastrophic spinal injuries in American Football [13].

Non-fatal catastrophic cervical spine injuries which occur during tackling caused by both mechanisms described above are avoidable through coaching and implementing safe and effective technique. A general lack of skill from the tackler has been highlighted as a risk factor to catastrophic cervical injuries and concussion [10, 26, 31], and as the primary reason for a much higher rate of tackling injuries sustained amongst schoolboys [3]. It is therefore important, especially at lower levels, to emphasise the basics of safe and effective tackling technique, and primary emphasis should be placed on the head and neck

position in the tackle. Most importantly, players should be coached to place their heads in the safest area when tackling, e.g. place the head behind the buttocks of the ball carrier, and ensure that the face is always up when performing a side-on tackle.

The cervical spine is able to dissipate forces by controlled spinal motion through the paravertebral muscles, eccentric contractions and intervertebral discs [40]. When the natural lordosis (curve) of the cervical spine is lost, due to head-down contact, the forces generated by contact to the top of the head are transmitted along the vertical axis of the spine and are no longer able to be dissipated [13]. It is under these conditions that the spine fails in a flexion mode, resulting in fracture, which may sever the spinal cord and cause instant paralysis [26]. Forced hyperflexion from entering the tackle with the head flexed may also result in a similar vertebral dislocation or fracture and subsequent catastrophic cervical injury.

Ex vivo laboratory experiments of the cervical spine have presented evidence to suggest that the cervical spine is able to bear greatest axial forces when in the natural lordotic position [27, 28]. Loss of lordosis has been shown to increase the risk of cervical spine injuries [28]. This principle also applies to the thoracic and lumbar vertebrae. The flexed and twisted spine was less able to resist applied axial torques, thus a loss of spinal lordosis may also increase the risk of torsional injury [22]. Although the tackler's anatomical site of contact should always be the shoulder, safety must be ensured by keeping the face up and focused on the core of the approaching ball carrier. The spine should also always be in its strongest position of resisting front-on axial forces and sideways axial torques, and thus a tackle should always be performed with a neutral straight spine with natural lordosis (spine in line) with the tackler's shoulders above the hips. This position will not only reduce the risk of injury but also produce greater force development during the tackle and thus improve the effectiveness of the tackle.

Contrary to what is often believed, approaching the tackle half-heartedly may in fact place the tackler at greater risk of injury. Greater differential impact between the tackler and the person being tackled seem to be a major risk factor for injury to the player with lower momentum [10]. This emphasises the need to dominate the tackle situation and it has been suggested that players "gain momentum again as soon as possible after completing a phase of play in order to reduce the probability of being injured in the next tackle in which they are involved" [10]. Dominating the tackle situation requires the tackler to close down the space between himself and the attacking player while ensuring a powerful leg drive into the tackle. Shortening steps before contact, driving forcefully with the shoulder on the same side as the leading leg, and hitting into the trunk is the safest and most effective way to execute a tackle.

Tackles from the front (front-on) have been shown to result in the greatest number of injuries and injury burden (days off) per 1000 player-hours [33]. Although this finding is largely due to the high frequency of the front-on tackle, a focus on this specific event has the greatest potential to reduce morbidity of tackle injuries [9]. Furthermore, the nature of the game makes this tackle unavoidable and thus it is important to coach safe and effective techniques. Previous research [42] reporting injury frequency to the tackler has shown injury to be greater when tackling the trunk (57%) than when tackling low (43%), but this may also be explained by the higher frequency of the trunk tackle (130 tackles per match) compared to the low tackle (30 tackles per match). A recent study [33] has found the injury rate and injury burden (days off) per 1000 player hours to be lower when performing a tackle to the middle zone (trunk) of the ball carrier, compared to tackling low (legs). When assessing the tackling mode of all recorded "stopping" front-on tackles, which was the tackling mode presenting the greatest number of injuries to the tackler, reported in the study by Wilson et al [33], 64% of injuries occurred while tacking low (7 out of 11) and only 36% of injuries occurred while tackling the trunk (4 out of 11). An analysis of contact area playing styles has also observed that team success requires tackles to the waist, rather than leg tackles [17]. It may therefore safely be recommended that the zone between the upper thigh and the sternum be the target for contact when performing a front-on tackle on the advancing ball to ensure safe and effective technique.

In a recent effort to further understand the relationship between tackle-related injuries and fatigue it was demonstrated that an effective tackling technique under non-fatigued conditions does not necessarily result in effective tackling technique when fatigued [9]. This emphasises the importance of conditioning, and provides evidence for advocating the practise of safe and effective tackling technique training under fatigued conditions.

BALL CARRYING AND TAKING THE BALL INTO CONTACT: SAFE AND EFFECTIVE TECHNIQUE

Although most frequencies are similar, the bulk of the published literature has shown the incidence of injury to the ball carrier as being greater than to the tackler [1, 3, 18, 19, 26, 33, 34]. A recent comprehensive analysis of 52 248 tackle events in 10 050 player-hours has shown the burden (days off) of injury, which is a product of severity and rate of injury, to the ball-carrier to be nearly double the burden to the tackler [33]. Thus, it may be argued that coaching safe and effective ball-carrying and attacking techniques are more important than coaching correct tackle techniques.

Anatomical sites most often injured by the ball carrier include the lower limb (51%), the head, neck and face (17%), and the upper limb (15%) [42]. The majority of injuries were sprains/strains (43%) and haematoma/bruises (29%). It has been reported that the injury with the highest incidence to the ball carrier is a thigh haematoma for both forward and backline rugby players [1]. The injury resulting in most days absent in professional rugby players were anterior cruciate ligament and medial cruciate ligament

injuries to the forwards and backs respectively [1]. Non-fatal catastrophic cervical spine injuries have also been reported to occur to the ball carrier, in similar frequencies to that of the tackler [26, 31].

Catastrophic cervical injuries to the ball carrier are predominantly caused by illegal tackles [26, 31]. Both high tackles and spear tackles put the ball-carrier at huge risk of cervical spine injury. Spear tackling, which in rugby union is described as lifting the ball-carrier off his feet and driving him head first into the ground, has been outlawed and stricter enforcing of this law has recently been introduced [16, 26, 31]. The illegal high tackle is also outlawed due to its high risk [16, 26]. Tackles around the neck may force the neck into either hyperextension (bent backwards) or hyperflexion and rotation, which may be sufficient to cause fracture or dislocation of the cervical vertebrae and possibly severing of the spinal cord. Cervical injury due to axial loading (as described in *the tackle* section above) may also occur in the ball-carrier either from being spear tackled or by making contact with the top of the head by entering the tackle with the head down [26, 31].

The essential safe body posture of tackling also applies to safe technique when taking the ball into contact. When contact is unavoidable, the contact situation should always be entered with the head up and back straight. As explained in the *TACKLING* section, loss of spinal lordosis has been shown to be a weaker position, while greater force and torque may be transferred into the contact situation when a neutral back with natural lordosis is maintained [11, 22, 27, 28].

Effective and successful ball-carrying techniques have been well described [23, 36, 38]. Dominating contact [23, 36], evading contact [36], body position in contact (23, 38) and turning towards your support [23, 38] have all been shown to be associated with effective and successful ball-carrying. Sayers and Washington-King [36] characterised effective ball-carries into contact; their results demonstrated that maximal running intensity, running at an oblique angle and performing a forward step all resulted in the greatest number of positive outcomes while carrying the ball. Oblique evasive running (defined as running "*towards the defensive line, but not directly at defenders; e.g. where an attacker ran at the shoulder of a defender*") measured much greater positive outcomes compared to running at a defender or angled running (defined as "*runs not directed towards the defensive line; e.g. where an attacker tries to run around the defence using speed*") [36]. Performing a forward step (defined as an "*evasive movement involving stepping motions originated from the outside leg and involving predominantly forwards motion*"), displayed much greater positive outcomes than a lateral step (defined as an "*evasive movement involving predominantly sideways stepping motion*") and a swerve (defined as an "*evasive movement initiated from the inside leg*") [36]. Dominating the tackle situation is essential to crossing the advantage line. When the ball carrier was able to meet the tackler once he had crossed the advantage line, the ball was retained 67% of the time, compared to a ball retention rate of 44% when the advantage line was not reached [23].

As described for the tackler, the prevalence of injury is much greater to the player in the tackle situation with the lower momentum [10], thus dominating the contact situation will once again emphasise the concept of safe technique also being the most effective technique.

Evasion techniques such as oblique running and forward stepping will reduce the magnitude of the collision forces [36], thereby decreasing the effectiveness of the tackle while making the ball-carry safer and very effective. Ball carriers should not run directly at defenders, as this will not only decrease the effectiveness of the ball carry [36], but also place the ball carrier and the tackler under unnecessary risk of injury.

The low body position of the ball carrier and turning towards supporting players has also been shown to be associated with success in contact [23, 38]. Ball retention was the highest when the body position in contact was classified as low (55.5%), compared to a medium (46.6%) and a high (31.9%) body position, and when the ball-carrier turned his body towards his support (68.2%), compared to away from his support (61.5%) and not turning at all(42%) [23]. A more recent analysis of the contact situation [38] showed similar results; it was found that possession was retained 90% of the time when the ball was carried into contact with a low body position. A low body position is not only the most effective carrying position, but also the strongest and safest. A low body position will widen the base of support, lower the centre of gravity of the ball-carrier and allow for a more powerful leg drive into contact. Turning towards support in the tackle situation is a very significant action in retaining possession [23, 38], but also protects the ball carrier from injury caused by more defenders joining the tackle situation.

SCRUM SETTING AND ENGAGEMENT: SAFE AND EFFECTIVE TECHNIQUE

When scrumming injuries are reported as the incidence of injury per player-hours, the high risk of the scrum situation is often underestimated [7], but when comparing the propensity of a contact event to induce injury, the scrum is the contact phase bearing the greatest injury risk [7]. Risk of injury while scrumming was shown to carry a 60% greater risk of injury than the tackle situation [7]. It is furthermore worth noting that the vast majority (>80%) of scrum injuries occur to the hooker and prop ([26, 34], thus emphasising safe and effective technique in these positions is particularly important.

Injuries to the head and neck contribute to 42% of all schoolboy scrum injuries [34]. Scrumming has furthermore been shown to be the phase of play which induces the greatest number of catastrophic cervical spinal injuries [31]. Although comparative data has never been published, the risk of catastrophic cervical injuries per event for the hookers and props (front-row forwards) during scrumming would be considerably greater than any other position during any contact event [41].

It has been shown that the impulsive impact force on a scrum engagement exceeds the threshold of injury to the spine [24]. This emphasises firstly the importance of specific scrum technique training, which includes correct alignment of the head, neck and trunk, and adequate back, shoulder and neck strength to maintain a safe body position during engagement [24, 37].

More than 90% of scrum-related catastrophic cervical spine injuries occurred during either scrum engagement (47.1%) or a collapsed scrum (45.9%) [31]. The remainder of injuries were caused by front-row forwards actively extending their necks and driving the opposite front-row upwards. This has been termed "popping" [26], or more recently "scrumming up". This act places the opposition at great danger of catastrophic cervical injury, it is highly illegal and should be strongly discouraged [16].

During scrum engagement, vertex impacts caused by head-down contact (similar to what was described in the *TACKLE* section) has the potential to cause catastrophic cervical injuries [26, 31]. The crouch-touch-pause-engage sequence of scrum engagement was introduced to reduce the number of these injuries [2, 26]. Correct scrum setting and engagement techniques are extremely important, and if safe and effective techniques are sustained the scrum-related catastrophic cervical injury may be eliminated from the game [19].

The crouch signal from the referee should see the front row forwards assuming a stationary crouched position. Although no research has related crouch position to force production in the scrum, a crouch position similar to the position of maximal force production while pushing is recommended. It is therefore recommended, for maximal force development as well as assurance of safety that front-row players crouch with a low body position, a straight neutral spine (spine-in-line), face-up, and with their shoulders and hips at the same height. In the crouch position it is very important to emphasise a neutral cervical spine in natural lordosis. Players are therefore recommended to have their chin up and off their chests, but not hyperextended (tilted backward). Hyperextending in the crouch position will result in the need for flexion (bending the neck forward) in order to place the head under the opposite front-row. This act may place the front-row forward in a compromised position and increase the risk of catastrophic cervical injury. It is thus recommended that players imagine they are looking at their opposite number in the crouch position over a pair on sunglasses placed on their nose.

The engage signal from the referee should be followed by both sets of front-row players driving into one another, ensuring that they maintain spine-in-line for optimal force transfer and personal safety. Research has shown that the magnitude of forward force generated by a pack of forwards once they had engaged is greater when the front row is packed as low as possible [24], with the head, trunk and legs in alignment, and ensuring a maximal angle at the hip [14]. A practical evaluation of individual scrumming technique has shown that a horizontal spine is a strong predictor of scrumming performance [4]. The hip angle has been

shown to be a factor when building a model for predicting maximal pushing force in the scrum; the mean hip angle in this study was $123^0 \pm 24^0$ [29].

The cervical, thoracic and lumbar spine are placed under a great amount of strain during the scrum engagement, and evidence suggests that the cervical spine, thoracic and lumbar spine are able to bear the greatest amount of axial forces when the spine is in a neutral position with natural lordosis (spine-in-line) [11, 22, 27, 28]. The flexed and twisted spine was also less able to resist applied axial torques, thus a loss of the recommended spine-in-line may also increase the risk of torsional injury [22].

The collapsed scrum also presents a great risk of vertex impacts and forced hyperflexion with or without rotation when the heads of the front-row forwards, especially the hookers, strike the ground [26, 31]. The most effective way of preventing scrum collapse is to ensure that there are no downward forces exerted on the engage. In a study of the kinetics of the scrum, a downward force on all three front-row players was recorded at all playing levels except for international front-row forwards [24, 25]. This indicates poor technique in non-international front-row forwards. Maintenance of a flat, straight, neutral spine with natural lordosis (spine-in-line) will ensure maximal forward force transfer and no downward force generation.

THE LINEOUT: SAFE AND EFFECTIVE TECHNIQUE

The propensity of the lineout to cause injury has recently been described as “very low” [7], and it has the lowest incidence of injury when recorded as injury per player hours and per event [1, 7, 18, 19, 26, 34]. Interestingly, lineouts have the highest severity (days off per injury) of any contact phase [7], and should thus be an important consideration when assessing the risk factors for injuries [30]. Cervical or lumbar spine facet joint injuries accounted for the majority of match-related contact injuries occurring during the lineout in professional rugby players [7]. Although this study [7] reported that only 7% of all lineouts were penalised, a similar number of events resulting in medical on-pitch attention occurred in both penalised and non-penalised lineouts.

The reported high frequency of cervical and lumbar facet injuries sustained in the lineout [7] was in all probability the cause of jumpers losing their balance and falling, from their lifted position when jumping, to the ground. Preventing illegal actions (i.e. interfering with the opposite jumper or lifter in order to gain advantage), through stricter interpretation of the law and teaching the technique which offers the greatest stability to the jumping “pod” (jumper and two supporters), may both be effective ways of reducing lineout injuries.

For optimal force generation, players lifting the jumper should assume a low body position with straight spine. To ensure maximal height, the front supporter should grip the legs of the jumper just above the knees. Stability from the front supporter may be increased by rotating the grip around the legs so that the two hands act as a clamp, keeping the legs of the lifter together while also preventing lateral movement and imbalance of the jumper. The back supporter should keep his hands open and place the thumbs under the bulge of the buttocks (i.e. in the subgluteal fold) with the fingers folding around the back and outside of the thigh. Both the grips described above will provide greater stability and a more efficient lifting position at full extension than the frequently used "shorts grip". After the ball has been caught, the back lifter should close the space and move around slightly to protect the jumper from the opposition and prevent him from being interfered with. Supporters should be as close as possible to the jumper, as this will not only ensure the jumper reaches a maximal height, but also create a stronger base of support, and ensure a straight spine while driving the jumper forcefully using a multi-joint movement. By decreasing the horizontal distance between themselves and the jumper, supporters are able to decrease the resistive torque exerted by the jumper, and will therefore experience less force on their bodies [12]. It is thus clear that effective lifting technique is also the safest.

Once the jumper has captured the ball, the supporters should lower the lifter with controlled motion, as dropping or letting go of the jumper might cause severe injury. The jumper should always maintain a straight body position, avoiding any flexion at the hip or knee joints, and should ensure a contracted core is maintained. It is important that the jumper produces maximal power when initiating the jump. To ensure maximal power generation a countermovement (i.e. a step or drop) should precede a maximal effort jump utilising all three joints in the leg.

Although the specific lifting techniques mentioned above, and their ability to create a safer and more effective lift, has never been researched, reports and proposed technique in an analysis of lifting techniques [5], as well as reported biomechanical principles [35] support the abovementioned lifting techniques for maximum efficiency and safety.

THE RUCK AND MAUL: SAFE AND EFFECTIVE TECHNIQUE

The tendencies of sustaining ruck and maul injuries have recently been classified as low and average respectively [7]. The number of ruck and maul injuries sustained per 1000 events was lower than the equivalent measure in the tackle and in the scrum [7]. Haematomas of the calf or shin and medial collateral ligament injury caused the highest incidence and most days absent respectively for the forwards and backs during rucks and mauls [1]. Although prevalence of injury is not particularly high, a case series review has shown the ruck and maul to cause 17% of all catastrophic cervical spine injuries [31].

The nature of the ruck and maul contributes to various possible mechanism of catastrophic cervical injury [26, 31].

The ruck and maul situation might lead to forced flexion of the neck, either to the ball-carrier or a player at the bottom of a ruck, and head and neck injuries through vertex impacts caused by charging into a mass of players, either to the person charging and making head-first contact or to the person bearing the force of the contact [26, 31]. Fracture and dislocation may occur from vertex impacts or forced hyperflexion and rotation similar to the mechanism described in the other contact phases of the game [26, 31].

Players joining the ruck, which is formed once "*one or more players from each team, who are on their feet, in physical contact, close around the ball on the ground*" [16], should, according to law 16, "*have their head and shoulders no lower than the hips*". A strong effective technique with straight neutral spine with natural lordosis, face-up, shoulders above the hips and strong base of support will assist the necessary force production to clear opposition players off the ball and stability to stay on the feet, thus ensuring a fast and effective ball availability for the scrumhalf. A straight neutral lumbar, thoracic and cervical spine are recommended due to the increased stability of the spine in this position [12, 22, 27, 28]. The strongest position of the spine is essential in force production and injury prevention. Although players should be coached not to charge into rucks head-first, the risk of vertex impacts around the ruck situation should always be reduced by keeping the face up, as this avoids the risk of vertex impacts with a forward flexed cervical spine, which has been shown to be a very vulnerable position [11, 27]. The above recommendations apply to defending players entering the ruck situation and attacking players securing the ball. Players going off their feet or entering the ruck with their shoulders below the hips will not only be less effective at driving opposition players off the ball, but also cause their team to be penalised as this is a transgression of the laws of the game.

The fundamental difference between the ruck and a maul is that *"all players involved must be caught in or bound to the maul and must be on their feet*" [16]. The abovementioned principles of safe position in the ruck situation thus also applies to the maul. In the maul situation, the ball carrier, who remains on his feet, is also at risk when he remains facing his opposition with his head-down [26]. Players should be encouraged to, when held in a tackle, turn their back towards the opposition, as this action will enhance ball retention rate [23, 38] and safety when the maul is formed. This example once again demonstrates that safe rugby is effective rugby.

AUTHOR'S BIOGRAPHY

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