# ‘Tackling low, aiming high’

*Catastrophic front-on tackle injuries in South African Rugby –*
*Lessons Learnt and a Way Forward.*

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**This article's content is based on data collected by the South African Rugby Union via the BokSmart National Rugby Safety programme, as part of the overreaching South African Rugby Injury and Illness Surveillance and Prevention Project (SARIISPP).**

**Dr Wayne Viljoen**

(SA Rugby, Senior Manager: Rugby Safety, and University of Cape Town)

**Clint Readhead**

(SA Rugby, General Manager: Medical, and University of Cape Town)

**Lara Paul**

(University of Cape Town)

**Professor Mike Lambert**

(University of Cape Town)

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Senior Associate-Editor of the British Journal of Sports Medicine.

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# Executive Summary


## OBJECTIVE

Concussions and frequent non-concussive head impacts in rugby may pose long-term brain health risks. Most of these head impacts occur during tackles, making tackle safety a top priority. While lowering the legal tackle-height is intended to reduce head contact injuries, there is no research on how this change might affect catastrophic injuries, especially to the head, neck, and spine. This study analysed 16 years of BokSmart catastrophic injury data to identify tackle-related risk patterns and recommend safer practices within SA Rugby's new, lowered tackle-height framework.

## METHODS

Data on catastrophic head, neck, and spine injuries were collected from 2008 to 2023 using BokSmart's Serious Injury Protocol. Injuries were categorised into acute spinal cord injuries (ASCI), catastrophic traumatic brain injuries (Cat-TBI), and cardiac events. Each tackle-related incident was analysed using video footage (where available), self-report, referee- and witness reports, and then coded across 8 core descriptive criteria and 12 key interactions per player role. Patterns and injury mechanisms were visualised on a filled radar plot to assess the risks under different tackle scenarios, particularly in relation to body positions and tackle-heights.

## KEY FINDINGS

- **Tackle Involvement:** 61% of all catastrophic injuries occurred during the tackle, with 49 injuries (55%) affecting tacklers and 40 injuries (45%) affecting ball carriers.
- **Catastrophic Brain Injuries:** 23 of 29 Cat-TBIs (82%) were tackle-related, with 87% resulting in permanent damage.
- **Tackle Type Risk:** Front-on tackles posed the highest risk, accounting for 71% of tackler and 53% of ball carrier injuries.

- **Height Risk:** High tackles are seen as the main danger, but surprisingly, most catastrophic injuries occurred during middle-height tackles (the zone between the top of the chest down to the level of the hip and pelvis). Tackling low-positioned ball carriers significantly increased risk, especially due to knee or head-on contact.
- **Ball Carrier Posture:** A low body position (fully bent at the waist or with head down) increased injury severity for both players. For every non-permanent injury where a ball carrier entered low, there were two permanent injuries with residual damage remaining to tacklers.
- **Technique:** Many tackler injuries stemmed from poor technique, particularly direct head-on and head-to-knee contact. Ball carrier injuries often involve unsafe posture, such as leading with the head or dipping too low into contact.

**CONCLUSIONS & RECOMMENDATIONS**

- **Middle-height, front-on tackles and low ball-carrier entries are high-risk scenarios** for catastrophic injury.
- **Tackles targeting the 'safe zone' — between mid-torso and mid-thigh — minimise injury risk** for both players.
- **Tacklers need a clear, visible target,** which is compromised when ball carriers enter low into contact.
- **Ball carriers should be encouraged to enter contact with a braced, slightly bent posture (head up)** — not excessively low or head-down.
- **Leading low into contact raises the risk of permanent injury** for both tackler and ball carrier.
- **Coaching safe technique is critical:** Focus must increase on head placement, tackling form, and discouraging low contact — especially front-on at the knees.

**Final Thought**

Lowering tackle-height alone is not a silver bullet — it must be paired with clear player behaviour guidelines and technique coaching for both roles to limit the risk of concussion and catastrophic injury.

| **SUMMARY OF KEY FINDINGS – TACKLE-RELATED CATASTROPHIC INJURIES** | |
|---|---|
| **Key Insight** | **Recommendation / Risk** |
| Most catastrophic injuries occur in **middle-height, front-on tackles** | Monitor and refine tackle technique at this height |
| **Low body position** by the ball carrier increases risk | Avoid entering contact too low |
| The tackle **"safe zone"** lies between **mid-torso and mid-thigh** | Coaches should train players to target this area |
| Tacklers need a **clear, visible target** | Ball carriers should maintain a more upright, forward leaning, stable posture |
| Excessive **forward bending** by ball carriers increases risk | Limit how far players can bend into contact |
| Ball carriers should **lead with a braced, head-up stance** | Encouraged for safer contact and better visibility |
| Avoid **head-down, low entries** into tackles | Increases risk of catastrophic head/spine injuries |
| **Poor technique** remains a major factor in injuries | Emphasis and coaching on proper tackle and contact form |
| Avoid **very high (upright)** or **very low (knee-level)** front-on tackles | Both extremes pose elevated injury risks |

## Glossary of Terms

**ACUTE SPINAL CORD INJURY (ASCI)** – Acute Spinal Cord Injury (ASCI) refers to sudden damage to the spinal cord that results in a rapid onset of symptoms such as loss of movement, sensation, or automatic body functions below the level of injury. ASCI can involve **fractures or dislocations, or both, of the vertebrae, compression or tearing** of spinal cord tissue, and/or **bleeding or swelling** that damages the spinal cord. The effects of an acute spinal cord injury can range from temporary dysfunction to permanent paralysis (e.g., paraplegia or quadriplegia), depending on the severity and location of the injury. ASCIs in this study are grouped into outcomes, based on their severity: (a) near miss (full recovery expected, ambulant), (b) neurological deficit (some deficit remains, may walk with or without the requirement of assistive devices), (c) quadriplegic, and (d) fatal.

**BALL CARRIER** – A **ball carrier** in rugby is the player who is **in possession of the ball** and is actively running, moving, or attempting to gain ground or territory for their team.

Key points about the ball carrier:

- They are the **target of the tackle** by the defenders or the opposing team.
- They can **pass, kick, or run** with the ball, depending on the situation.
- Once tackled and brought to the ground, the ball carrier must **release the ball immediately**, usually by placing or passing it, to allow for a fair contest at the breakdown.
- A ball carrier can attempt to break tackles using **footwork, fends or hand-offs, or using physical force or power in contact.**

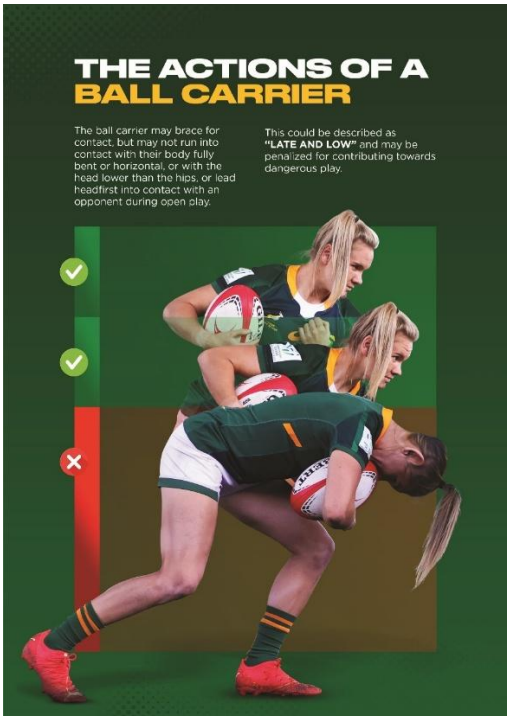
The ball carrier's job is to **move play towards the scoring tryline**, find or create space, either maintain possession or set up the next phase of attack, or score a try.

**BALL CARRIER CONTACT POINT** – The ball carrier contact point is the part of the tackler's body (or another surface) that the ball carrier's head or neck hits during a tackle. While a ball carrier usually makes contact with a tackler's body first, in this case, the term refers specifically to the contact that caused a catastrophic injury. This could be contact with the tackler's body, or with something else like the ground or goalposts.

**BALL CARRIER STANCE** – In rugby, the ball carrier's stance refers to the body position a player takes while carrying the ball into contact or during a run. A strong, effective stance helps the ball carrier maintain balance, absorb impact, and retain possession under pressure. The ball carrier's stance is all about control, strength, and preparation, helping the player carry the ball safely and effectively under pressure.

Key features of a good ball carrier stance:

- Ball secured – typically in two hands to keep the tackler guessing and when scanning or about to pass; one arm wrapped tightly in contact situations to prevent turnovers.
- Knees slightly bent – for balance and power.
- Hips low and stable – to stay grounded and resist tackles.
- Head up and facing forward
- Upper body projected forward – with a slight forward lean to drive through contact.
- Head and shoulders above the hips into contact
- Core engaged – to maintain control and absorb collisions.




- **Upright Ball Carrier** – In rugby, an **upright ball carrier** (**top** position) is a player who runs into or through contact while maintaining a **high or vertical body position**, rather than lowering their body into a more compact, powerful stance. Coaches typically encourage players to adopt a slightly **lower, more forward-bent, braced, and stronger body position** to maximise safety and effectiveness.
- **Forward-Bent Ball Carrier** – A **forward-bent ball carrier** in rugby (**middle** position) is a player who enters contact with their **torso angled forward**, typically with their **hips lower than their shoulders**, and their **knees and hips flexed**. This body position is often used to gain power, stability, and protect the ball during contact. A **forward-bent ball carrier** uses a low, powerful stance to drive into or through contact, improving performance and reducing injury risk when done with good technique.
- **Low-positioned Ball Carrier** – A **low-positioned ball carrier** in rugby (**bottom** position) is a player who enters contact with their **torso leaning significantly forward**, often to the point where their **back is horizontal**, and their **hips are in line with their shoulders**. This position is more extreme than a typical forward-bent stance. If the player's head is down, it increases the risk of neck injuries or head clashes. If using a fully bent (low) stance, players must keep **their head up and eyes forward** to see the contact area and protect themselves.

**BOKSMART** – BokSmart is a South African rugby safety and education programme developed by the South African Rugby Union (SARU) in partnership with the Chris Burger Petro Jackson Players' Fund. Its main goal is to make rugby safer for all participants, from grassroots to elite levels.

Key features of BokSmart:

- Focuses on injury prevention, especially catastrophic injuries (like head, neck, and spine injuries).
- Provides training and certification for coaches, referees, and medical staff.
- Promotes safe techniques in tackling, scrummaging, breakdown contests, and contact play.
- Educates players and support teams about concussion management, return-to-play protocols, injury prevention strategies, minimum rugby safety requirements, and general player welfare.
- Includes age-appropriate guidelines, policy updates, and safety resources.

The name:

- "Bok" refers to the Springboks, South Africa's national rugby team.
- "Smart" emphasizes informed, safe, and responsible participation in the game.

In short: BokSmart is South Africa's official rugby safety programme, aiming to reduce catastrophic injuries and make the game safer through education, awareness, and proper technique.

**CATASTROPHIC INJURY** – A Catastrophic injury was defined as any head, neck, spine, or brain injury that met the following criteria, and were reported to the programme's Serious Injury Case Manager or SICM:

1. The injury must be potentially life-threatening for the player.
2. The injury must be potentially debilitating or disabling.
3. The injury must result in the player being admitted to a hospital ward.

*It was designed as an operational definition for predominantly non-medical people, to open the net wider so that the programme would not miss any significant injuries that might meet such a definition. The terminology includes all spinal injuries (neck or otherwise), and head injuries (with and without brain injury) that meet the three reporting criteria. Most 'spinal' injuries are cervical spine, which we then differentiate as a 'neck' injury. All other spinal injuries, which are few, were classified as 'spinal' for recording and analysis purposes.*

**CATASTROPHIC TRAUMATIC BRAIN INJURY (CAT-TBI)** – Catastrophic Traumatic Brain Injury (Cat-TBI) refers to a **severe and life-threatening** brain injury caused by a **sudden impact or trauma**. This type of injury can occur from direct head impacts in sports such as rugby. Cat-TBI can typically involve moderate to severe brain swelling or bleeding, loss of consciousness for extended periods, a coma or vegetative state, or some level of brain damage remaining. It can also result in **significant** and permanent damage to the brain, long-term disabilities, or death. Cat-TBI in this study are grouped into outcomes, based on their severity: (a) fully recovered, (b) with disability (remaining neurological deficit) and (c) fatal.

**CARDIOVASCULAR INCIDENT (CVI)** – In a **sport setting**, a **catastrophic cardiovascular incident** is a **sudden and life-threatening heart-related event** that occurs during training, competition, or other forms of physical activity. These incidents are rare but extremely serious and often occur **without warning**, even in apparently healthy athletes.

Common types in sport:

- **Sudden cardiac arrest (SCA):** The heart suddenly stops beating, often due to an electrical issue like ventricular fibrillation.
- **Sudden cardiac death (SCD):** Death resulting from sudden cardiac arrest, usually within minutes if not treated.
- **Hypertrophic cardiomyopathy (HCM):** A common underlying cause in young athletes; a thickened heart muscle can disrupt normal heart rhythm.
- **Commotio cordis:** A rare event where a blunt blow to the chest (like from a ball or a collision) during a vulnerable moment in the heart's rhythm causes cardiac arrest.

Key points in sport:

- Can affect **athletes of any level**, though more commonly reported in **high-intensity sports**.
- Often associated with **undiagnosed heart conditions**.
- May occur with **minimal or no prior symptoms**.

**CONCUSSION** – A concussion is an injury to the brain caused by a direct or indirect blow to the head or by the head striking something else such as the ground. A concussion can occur whether or not a person is "knocked out." A concussion typically causes the rapid onset of short-lived impairment of brain function that resolves spontaneously with time.

**CONTACT-COLLISION SPORTS** – A **contact-collision sport** is a type of sport in which players **routinely make physical contact** with each other as part of the game, and where that contact often involves **high-impact collisions**. This includes **intentional physical engagement**, such as tackling, blocking, or checking, and the **risk of injury** from these impacts is relatively high compared to non-contact or limited-contact sports.

Examples of contact-collision sports include:

- Rugby
- American football
- Ice hockey
- Martial arts (like judo or MMA)

The term is often used in medical and safety contexts, such as in concussion protocols, because these sports carry **increased risks of head and bodily injuries** due to the frequent and forceful collisions.

**CONTACT EFFICIENCY** – **Contact efficiency** refers to how effectively a player utilises physical contact situations, such as tackles, rucks, or collisions, to achieve a desired outcome with minimal wasted effort or risk exposure. Contact efficiency is about being **smart, safe, and effective** in physical confrontations, getting the most out of every hit or contest without unnecessary risk or fatigue. In the context of rugby, high contact efficiency means a player can:

- **Win or dominate collisions** (e.g., drive the opponent back in a tackle)
- **Maintain body control and balance during impact**
- **Minimise energy loss** and stay ready for the next phase of play
- **Execute clean, legal techniques** that reduce the chance of penalties or injury
- **Influence the contest** (e.g., slow the ball, create turnovers, retain possession)

**FRONT-ON TACKLE** – A **front-on tackle** in rugby is when the tackler approaches and makes contact with the **ball carrier from directly in front**. This means the two players are moving **towards each other**, usually face-to-face or chest-to-chest, as opposed to a side-on tackle or a tackle made from behind.

Key features of a front-on tackle:

- The **tackler's chest** faces the **ball carrier's chest**.
- Often involves **front-facing or near front-facing contact**.
- Requires strong **body position and technique** to stay safe and effective.
- Common in situations where the defender is directly in the ball carrier's path, such as near the try line or in tight defensive structures.

Because of the direct nature of the contact, proper technique, like keeping the head to the side and using the correct shoulder, is especially important to avoid injury.

**HEAD ACCELERATION EVENTS (HAE)** – Head Acceleration Events (HAE) refer to **any incidents where the head experiences sudden movement or forceful motion**. These movements can be caused by **impacts to the head or body** that result in the head rapidly **accelerating or decelerating**, which can potentially affect the brain. **It** includes **both direct head impacts** (e.g., a tackle to the head) and **indirect forces** (e.g., whiplash from a hit to the body that causes the head to snap back). It can occur **with or without concussion symptoms** and involves **linear acceleration** (straight-line movement) and/or **rotational/angular acceleration** (twisting motion), both of which can influence brain injury risk. HAEs can happen during **tackles, rucks, scrums, collisions, or falls**.

**HEAD DYNAMICS** – **Head dynamics** is the study of the forces and torques that drive or result from head movement. While head kinematics focuses on **how** the head moves, head dynamics explores **why** it moves, specifically:

- The **forces** (linear) acting on the head (e.g., from impacts or tackles)
- The **torques** or rotational (angular) forces that cause the head to spin or twist
- The relationship between these loads and the head's **linear and angular acceleration**

Understanding head dynamics is vital in areas like injury biomechanics, as it helps identify how external forces can lead to head injuries such as concussions.

**HEAD IMPACT** – A **head impact** in rugby refers to any **direct or indirect contact to the head**, whether from another player, the ground, or an object (like the ball or goalposts). It can occur during tackles, collisions, falls, or accidental contact and is a concern due to the **risk of concussion, accumulated subthreshold head contacts (*those that do not lead to concussion*), and other head injuries**.

**Key points about head impact in rugby:**

- It includes **blows to the face, skull, or jaw**, whether intentional or accidental.
- Can result from:
    - Tackles (especially high or poorly executed ones)
    - Accidental clashes (e.g., heads colliding)
    - Falls to the ground
    - Contact with elbows, knees, or shoulders

- **Not all head impacts cause a concussion**, but all should be taken seriously and monitored.

**HEAD KINEMATICS** – Head kinematics refers to the study and description of the motion of the head without considering the forces that cause it. It involves measuring and analysing aspects such as:

- **Linear acceleration** – the rate at which the head's speed changes in a straight line.
- **Angular acceleration** – how quickly the head's rotation speed changes around an axis.
- **Velocity** – how fast and in what direction the head is moving.
- **Displacement** – the change in position of the head over time.
- **Orientation** – the direction the head is facing.

Head kinematics is a key focus in fields like biomechanics, sports science, and injury prevention, especially in understanding how head impacts occur during events like falls, tackles, or collisions, and how those impacts might lead to concussions or other traumatic brain injuries.

**HEAD-PLAYER CONTACT** – Head-player contact refers to **any situation in rugby where a player's head makes contact with another player's body, head, or limbs** during play, whether intentional or accidental. **Examples of head-player contact:**

- A **tackler's head** hitting the **ball carrier's head, shoulder, torso, hip, or knee** during a tackle.
- A **ball carrier's head** colliding with a **tackler's body or head** when running into contact.
- Two players' **heads accidentally clashing** in a ruck or maul.

**HIA (HEAD INJURY ASSESSMENT)** – An HIA (Head Injury Assessment) is a **standardised process used in rugby** to assess players for a concussion **or suspected concussion** after a **head impact or suspicious event**. HIAs are a sequence of clinical evaluations used by healthcare professionals in professional rugby to diagnose concussion. HIAs only apply to World Rugby-approved tournaments and matches in **elite-level rugby**, where temporary substitutions are allowed, and these off-field medical evaluations can be made. The HIA process includes **four stages**:

Stage 1: HIA 1 – Sideline Assessment (Immediate)

- Conducted **during the match**, after a potential **head impact or suspicious event**.
- Player is **temporarily removed** (for up to 12 minutes) for a medical assessment.
- Includes:
  - Symptom check
  - Memory and balance tests
  - Neurological screening
- If any signs of concussion are found, the player **does not return** to play.

Stage 2: HIA 2 – Post-Game Medical Assessment

- Completed **within 3 hours** of the match ending.
- A more detailed evaluation to confirm or rule out concussion.

Stage 3: HIA 3 – Follow-Up Assessment

- Occurs **within 36–48 hours** after the game.
- Ensures no **delayed symptoms** appear and helps determine return-to-play timelines.

Stage 4: HIA 4 – If **concussion is confirmed**

- Clearance to return to full play following completion of the individualised rehabilitation which includes the use of the HIA4 form.

**INCIDENCE** – The **incidence of injury** in rugby is a **statistical measure of how often injuries occur** and refers to the **number of injuries that occur over a specific amount of exposure time**, usually expressed as the **number of injuries per 1,000 player-hours** of match play or training. It is frequently used to assess and manage player safety considerations.

**Injury incidence** = Number of injuries ÷ Total exposure hours × 1,000

**LEGAL TACKLE-HEIGHT** – In **rugby union**, the **legal tackle-height** refers to the **highest point on the ball carrier's body** where a tackler is **allowed to make contact** when attempting a legal tackle. Prior to the implementation of the lowered tackle-height laws, the **legal tackle-height** in rugby union was **below the line of the shoulders**. World Rugby and many national unions have since experimented with variations of **lowered tackle-height laws in the community game.**

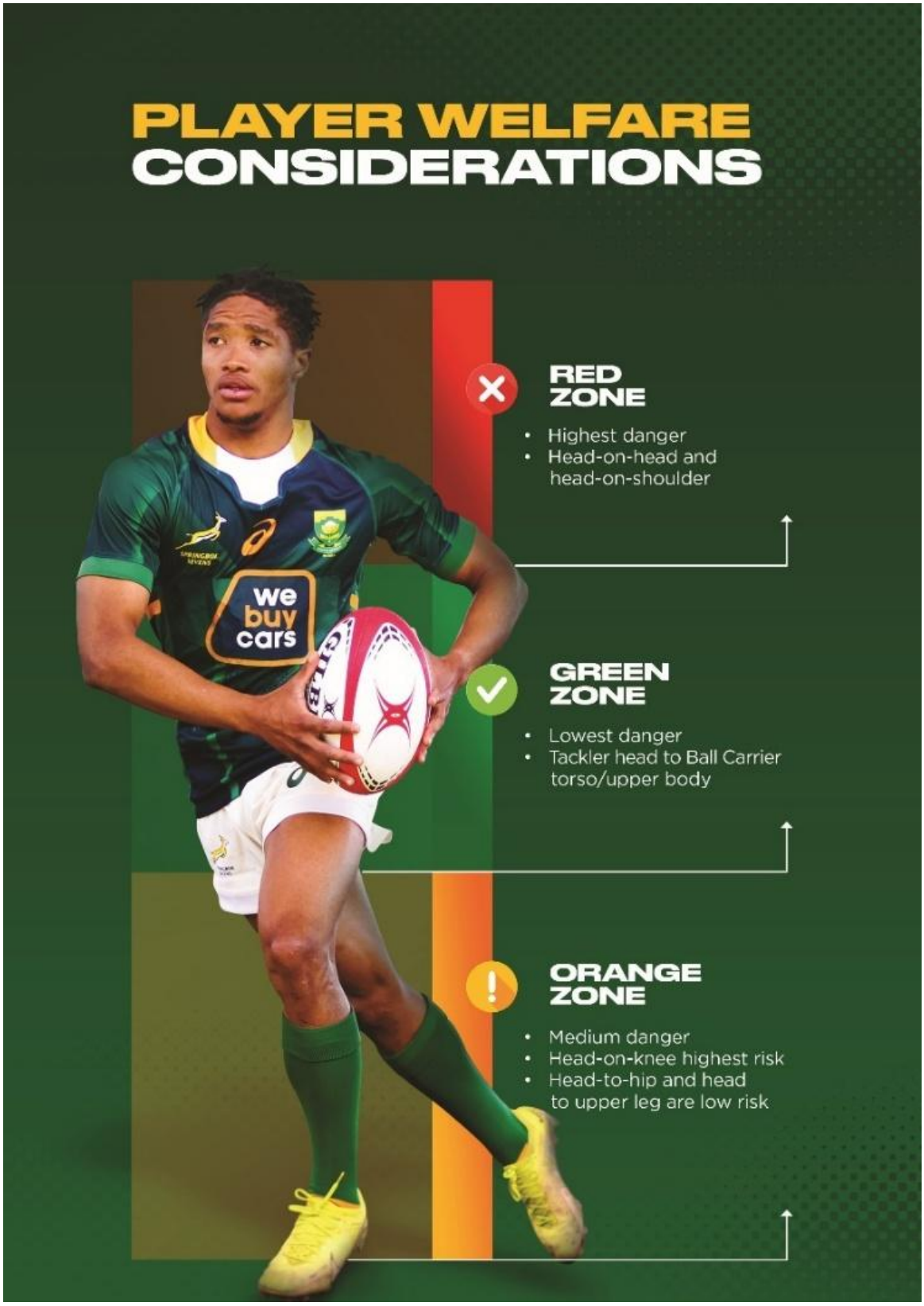
The **South African lowered tackle-height** has been adjusted since **2024** to the **base of the sternum** and below, with some additional laws related to ball carriers. More information can be found here: https://www.sarugby.co.za/news-features/articles/2023/12/08/tackle-safety-law-changes-for-school-and-club-rugby-agreed.

**MOMENT OF INERTIA** – Moment of inertia describes how **resistant** an object is in **rotating** around a particular axis. In biomechanics, especially in head dynamics, moment of inertia helps explain how the head reacts to rotational forces, an important factor in understanding injuries caused by twisting motions, such as concussions. It depends on two key factors: the object's **mass** and how that mass is **distributed** about the axis of rotation. Put simply: The **more mass** an object has, and the **further away that mass is from the axis**, the **more difficult** it is to **start or stop** its rotation. This results in a higher moment of inertia. For example, it's easier to swing a hammer when you hold it closer to the head than at the end of the handle. That's because at the head, the mass is distributed closer to the axis of rotation, reducing its moment of inertia.

**PERMANENT VS. NON-PERMANENT INJURY** – ASCIs and Cat-TBIs are broadly grouped into 'non-permanent' outcomes (near misses/fully recovered) and 'permanent' outcomes (with residual disability, including fatalities).

**PROPENSITY** – Propensity is the **rate or frequency** of an event, like a head injury, high tackle, or penalty, based on a standardised number of similar events, e.g. tackles of the same kind. This helps compare **risk or occurrence** across different players, positions, teams, tournaments, or matches. So, "**propensity per 1000 tackles**" would be a **statistical measure** used in rugby to describe **how often a specific event occurs** relative to every 1,000 tackles made of a **similar kind**, for example, there are 11.4 HIAs performed for every 1,000 upright tackles made. This can also be expressed as 1 HIA performed in every 88 upright tackles.

**SAFE ZONE** – The GREEN zone on the body of the ball carrier where the tackler makes contact and where both the tackler and ball carrier interactions pose the lowest risk of concussions to both players during the tackle contest. This zone stretches between the mid-thigh and the base of the sternum of the ball carrier.



**SERIOUS INJURY CASE MANAGER OR SICM** – The BokSmart Serious Injury Case Manager or SICM strategically sits as the Injured Player Welfare Officer or IPWO at the Chris Burger Petro Jackson Players' Fund. The SICM is responsible for assisting with the follow-up management of catastrophic rugby-related injuries and collecting data on these cases. The SICM also serves as a direct link to the Chris Burger Petro Jackson Players' Fund, which provides support to rugby players who sustain catastrophic injuries.

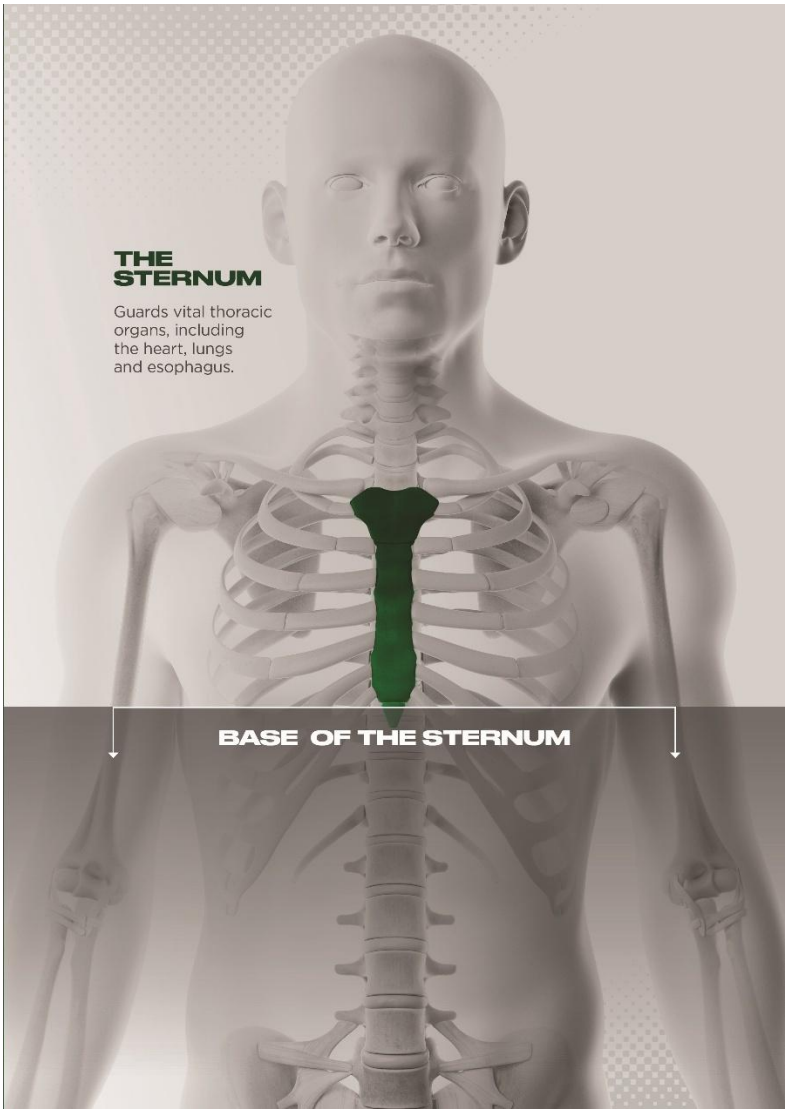
**SIDE-ON TACKLE** – A **side-on tackle** in rugby is when the tackler approaches the **ball carrier from an angle**, usually from the side, rather than front-on or from behind. In this situation, the ball carrier is typically running across or slightly away from the tackler's path, and the tackler comes in at a diagonal or lateral angle.

Key features of a side-on tackle:

- The **tackler makes contact with the ball carrier from the side**, often targeting the hips, thighs, or midsection.
- The tackler usually wraps their arms around the **waist or legs** and drives through with their shoulder.
- It often allows for **better visibility and control** compared to a front-on tackle.
- It can be a **safer position** for both players when performed with good technique, as it reduces the chance of head-on collisions.
- Tacklers must aim to get their heads behind the ball carrier to mitigate the risk to their heads and necks.

Side-on tackles are common in open play when a defender is tracking across the field or covering a line break.

**STERNUM HEIGHT** – The **sternum** is a flat bone in the centre of the chest. The **base of the sternum height** refers to the **lower end of the sternum (breastbone)**, which sits at the **bottom of the chest**, just above the **upper belly**. The **base of the sternum height** in rugby serves as a **safe, recommended tackle target zone**, helping players avoid high contact and promoting safer rugby tackles.




**SUBTHRESHOLD IMPACTS** – Subthreshold head impacts are **blows or forces to the head** (or body, causing head movement) that are **not strong enough to cause visible signs of concussion** or reach the clinical threshold for diagnosis, but still result in **head acceleration** and **brain movement or brain strain**. **Subthreshold head impacts** are important because **accumulated exposure** may affect brain health, even without any single, noticeable injury.

**TACKLE-HEIGHT:**


- **High Tackle-Height** – The RED zone from the top of the chest and above is considered a High Tackle-Height.
- **Middle Tackle-Height** – The GREEN zone between the top of the chest down to the level of the hip and pelvis is considered a Middle Tackle-Height.
- **Low Tackle-Height** – The ORANGE zone from the level of the hip and pelvis and below is considered a Low Tackle-Height.
- **Diving/Falling Tackler** – A tackler who makes a Low Tackle-Height tackle but does so by diving off their feet and/or falling towards the ground in doing so.

**TACKLER** – A **tackler** in rugby is the **player who brings the ball carrier to the ground** by making physical contact, using their arms and body to stop the opponent's progress.

Key points about the tackler:

- They must use **their arms** in the tackle — shoulder-only contact without wrapping is illegal.
- Once the tackle is made and the ball carrier is on the ground, the tackler must **release the player** and **roll away** or get to their feet before contesting for the ball.
- A tackler can be the **only person involved**, or part of a group effort (though only the first to make contact and bring the player down is the official tackler).

Good tackling technique involves:

- **Low body position**
- **Shoulders above hips and angled upwards**
- **Targeting the 'safe zone'**
- **Head up and forward and to the side** of the ball carrier (not in front)
- **Driving with the legs after contact**
- **Wrapping** the arms securely and pulling in the ball carrier

The tackler's role is key in both **stopping attacking momentum** and potentially **creating turnover opportunities**.

**TACKLER CONTACT POINT ON THE BALL CARRIER** – The tackler contact point on the ball carrier refers to the specific area of the ball carrier's body where the tackler makes initial physical contact during a tackle.

**TECHNICAL CAPACITY** (**TACKLER EXAMPLE**) – 'Tackler' technical capacity refers to a player's ability to consistently perform tackles with correct technique, control, and effectiveness. It involves the physical and technical skills needed to execute safe, legal, and efficient tackles under various conditions.

Key elements of tackle technical capacity include:

- Body positioning – maintaining a low, balanced stance with proper alignment
- Timing and decision-making – choosing the right moment to engage in making the tackle
- Target accuracy – aiming for the legal and effective tackle zone (e.g., mid-torso)
- Footwork and approach speed – closing space safely and under control
- Grip and follow-through – wrapping and finishing the tackle properly
- Fitness – The ability to manage fatigue improves a tacklers ability to focus and execute correct and accurate tackles more regularly and effectively.

Developing strong tackle technical capacity not only improves defensive performance but also reduces the risk of injury for both the tackler and the ball carrier.

# Introduction

Participating in sports offers numerous holistic benefits, whether social, physical, or psychological. Due to the physical, dynamic, and contact-collision nature of Rugby Union, the sport has a higher risk of injury [1][2]. There is also a risk, albeit very rare, of catastrophic injury [3][4][5][6][7]. Catastrophic acute spinal cord- (ASCI) and -traumatic brain injuries (Cat-TBI) are uncommon but are undoubtedly the most devastating injuries that can occur because of playing rugby [3][8][9][10]. Few of those who sustain Cat-TBI or ASCI come out completely unscathed. Not all have complete recoveries, many have long-term disabilities, not everyone can return to work, and several have shortened lifespans, regardless of their outcomes [5]. These traumatic injuries, which usually result from direct contact [5], have unfortunately always been part of a range of sports (diving, trampolining, equestrian sports), and also the game of rugby [9][11][12][13][14]. Over the last few decades, in rugby, these injuries have been given the respect they were due with the emergence of rugby safety initiatives such as the BokSmart programme in South Africa [15] [16], RugbySmart in New Zealand [17], Smart Rugby in Australia [18], Rugby Safe in the United Kingdom [19], Rugby Seguro in Argentina [20], and World Rugby's Rugby Ready [21]. Programmes of this nature have been successful in reducing catastrophic head, neck, and spinal injury numbers [22][11][23]. While extremely rare, because of the huge consequences to the individual, their local community and family support-base [5][6][8][9][24], it must therefore never be deemed acceptable that someone ends up catastrophically injured or passes away because of playing this wonderful game [25][26]. One of these injury events is simply one too many.

Contact-collision sports contribute to around 45% of youth sport-related traumatic brain injuries in the United States, and around 10% of all sports athletes sustain a concussion annually [27]. Concussion is the most common injury reported in professional rugby union matches [28]. Recently, contact sports have again come into the spotlight, but for different reasons. There has been an enormous amount of attention placed on acute and accumulated head trauma in contact-collision sports such as rugby [24].

In addition to this, rugby players accumulate multiple subthreshold impacts to their heads and necks throughout their playing careers, either directly or indirectly, which often do not manifest in symptoms. Consequently, an accelerated decline in brain function with ageing, potential adverse neurological effects, and possible long-term sequelae have been associated with playing rugby [29][30]. A direct causal link to head contacts alone is yet to be established, however, the individual, family and public health burden of the one to two permanent catastrophic traumatic brain injuries (Cat-TBI) and several acute spinal cord injuries (ASCI) that have been recorded yearly in South African Rugby Union, provide enough 'evidence' that something more needs to be done about the tackle contest.

No game is without some level of risk. Still, concussions, catastrophic traumatic brain injuries (Cat-TBI), and -acute spinal cord injuries (ASCI), are the three biggest threats to players and the game of rugby and therefore require further, deeper consideration for a better understanding of the real-world risks to these players. A better understanding of these injuries and their patterns is critical to guiding prevention efforts [5].

The tackle contest is the highest injury-causing contact event in rugby and has the highest incidence of injuries [31][2]. A hot topic of debate in the tackle, which has recently resurfaced and gained huge traction, is the concept of changing the existing legal tackle-height to limit the risk of head-to-head contact and concussions. There has been a resurgent drive to lower the tackle-height, a conversation that has been around since the 1970's [32][14], albeit that during those earlier days, this was largely around the increasing number of permanent catastrophic spinal cord injuries related to high tackles rather than a focus on concussion [13][14].

The average number of match tackles (tackled and tackling) ranges between 114 and 270 per match, which can lead to substantial inertial loading of both the head and neck over a player's rugby career [33]. For more context on player-specific exposure to tackles and ball carries, Burger et al. [2] provide a succinct synthesis of tackle-related injury prevention and performance research, which also highlights key tackle-frequencies, injury rates, tackle rates, risk factors, and performance measures.

## A FOCUS ON REDUCING HIAs (HEAD INJURY ASSESSMENTS) AND CONCUSSIONS

Newer research, largely driven by World Rugby and several tertiary education institutions [30][32][34][35][36][37][28][38][39], has largely focused on better understanding, defining, and monitoring concussions. In the professional game, the HIA (Head Injury Assessment), has evolved from such research. The HIA is a sequence of clinical evaluations used by healthcare professionals to diagnose a concussion. The scientific evidence following review of the HIA outcomes has identified a few central issues that need to be addressed if one wants to minimise the risk of sustaining unnecessary head contact, subthreshold blows to the head, concussions, or, from our data, potentially Cat-TBI. The overriding impression is that there is an express need to lower the legal tackle-height and to remove the tackler and ball carrier from situations where these two role players share head space in contact [40].

To address those components of the game that are available for intervention, the focus over the last decade has been on penalising and sanctioning head contacts. There have been great initiatives such as the High Tackle Sanction Framework (HTSF) and the currently utilised Head Contact Process (HCP) [36][41]. These interventions have increased the sanctions, i.e., penalties, yellow cards, and red cards issued, regarding dangerous high tackles, shoulder charges, and cleanouts. The 2019 Rugby World Cup showcased 74% and 138% increases in Yellow and Red Cards, respectively, and lowered tackle-concussion rates by 37% [36].

These procedures have significantly improved decision-making compared to what was historically available to referees to base their decisions on before these interventions. Both processes provide an open and systematic approach to reviewing and deciding on the appropriate penalty or sanction, using specific decision-making matrices. For this, however, to drive effective behaviour change, the sanctions, especially for the high-risk, more dangerous, illegal acts, must be harsh, and Yellow- and Red Cards must be used more frequently [36]. Red Cards and Yellow cards are still important deterrents but affect only a few high-risk elements [41]. It has nonetheless been shown that Red Card tackle-events are 271.5 times more likely to cause a concussion than legal tackles[41].

Most of the concussion risk in foul play events, however, lies with the ball carriers, whose risk is 133.7 times higher, compared to tacklers, who are 28.5 times higher, respectively, in a sanctioned high tackle event [41]. It must also then be acknowledged that practically, these in-game high-tackle penalties might have failed to change overall player tackle-behaviour sufficiently [39] for the simple reason that these sanctions are applied infrequently and because there are levels of leniency built into the system with sanction-lowering, mitigation considerations [41], as well as Law amendments such as the 20-minute Red Card trial.

As a result of cards and heightened implementation of the dangerous tackle laws, dangerous tackles and cleanouts already happen less frequently in the game [42][35], and the consequences and impact of punitive cards are therefore felt less by the players, coaching teams, and management. Even though the impact of these sanctions is perceived to be quite substantial at the time and a lot is said about them, due to their infrequent occurrence, they don't appear to have as positive an influence on changing the overall tackle behaviour and risk that one might expect. Players' actions across all levels of the game still regularly result in heads sharing the same airspace in contact and tackle-behaviour might not have changed enough to sufficiently alleviate the risk of dangerous head contacts or spinal injuries. For wholesale behaviour change to take place in players, a larger shift in the game's laws may need to be considered.

The most recent initiative, in the community game, aimed at reducing the risk of sharing head space and therefore the propensity for head contact, is to lower the legal tackle-height. Tackles made above sternum height increase the chances of needing an HIA substantially in both tacklers and ball carriers [41]. Referee-determined high tackles are roughly 36.5 times more likely to lead to a concussion. Head-to-head contact, head-to-ground contact, and head-to-knee contact in the tackle has a 39.9-, 21.8-, and 20.3-times greater risk of concussion than any of the other head-contact locations on the ball carrier's body, more commonly the trunk or torso; 70% of these concussions are to the tackler [35]. It is also the tackler who receives more head injuries and concussions than the ball carrier [43][35][36].

Tacklers at all tackle-heights and with their heads more commonly placed near the ball carriers, are at greater risk of making head contact with some part of the ball carrier's body during the tackle-contest [41]. Lowering the legal tackle-height is aimed at decreasing head-on-head contact, especially during front-on tackles [34], thereby lowering head injury risk for both tacklers and ball carriers. This tackle-height change is potentially the next evolution in the game when it comes to safety, while not altering the fabric of the game of which the tackle forms an integral part.

By driving tackles towards the more frequently occurring 'lower concussion-risk' areas, such as the middle-height trunk or torso tackles [32], one can potentially have a greater influence on improving contact safety, as head-to-head contacts and concussive events will happen less often. Nevertheless, these 'lower' or 'moderate' risk contact areas, even with lower propensities for head contact, can still contribute to absolute concussion and head contact numbers, simply by their higher frequency of occurrence in the game. Since these higher frequency events can still increase the physical number of concussions and head contacts recorded, there is a need to intervene here and address tackles at these lower risk areas too [35]. Again, this is where changing the legal tackle-height addresses the risk of head-on-head contact, but correct tackle technique, head position, and head placement [43], become even more critical for improved safety at these lowered tackle-heights.

## WHAT ABOUT CATASTROPHIC HEAD, NECK, AND SPINE INJURIES?

There is no doubt that concussions and the tackle are key injury prevention priorities at all levels of the game of rugby right now [44]. However, something that needs more consideration is the unintended consequences that might arise due to lowering the legal tackle-height. The tackle is also a leading threat for acute cervical spinal cord injuries or ASCI [10][24]. Different to the concussion prevention argument, traumatic spinal injuries, although rare, present a much larger challenge due to their potential for permanent life-long consequences and physical complications [27].

The literature focusing on lowered tackle-heights, does not discuss the potential effect on catastrophic head, neck, and spine injuries because of the lowered tackle-height and its altered influence on the tackle contest [1]. By lowering the legal

tackle-height, more tackles will theoretically be made in the mid- to lower-torso regions, but if pushed downwards even further, it would lead to more tackle events with head and/or neck making contact more frequently with the hip, upper leg, knees, and lower limbs. It has previously also been noted that tacklers are at higher risk for catastrophic injury, when tackling too low [11].

Where catastrophic injuries used to be more prevalent in the scrum, following law changes governing scrum engagement, this has now shifted towards more originating from the tackle-contest [11]. So, as much as we talk about concussions and head contacts, one must contemplate the potential outcomes of badly executed tackles and ball carries on catastrophic head, neck, and spine injuries. Historically, in South African Rugby, albeit in small numbers, Cat-TBI have mostly been permanent and fatal, and those where the spinal cord is involved, provide mixed outcomes, for both tacklers and ball carriers.

Rugby's governing bodies, including the South African Rugby Union, have adopted an evidence-based approach to rugby safety, utilising research to inform game-related decisions [45]. One must make decisions based on evidence and not opinions, and one must therefore also consider probable counter-effects before rolling out new law changes [23], such as lowering the legal tackle-height across the globe.

Introducing prevention initiatives such as law changes and concussion prevention programmes are crucial in providing a safer sporting environment [27]. However, this also needs to be balanced against potentially creating other unforeseen risk.

The catastrophic tackle-injury data collected via the BokSmart programme over the period 2008 to 2023 were pre-emptively explored to identify whether any potential high-risk causal interactions or injury-causing patterns emerged that might have an influence on future catastrophic head, neck, or spine injuries due to lowering the legal tackle-height. Any identified injury-causing interactions or patterns would then be used to highlight high-risk situations and to make safety improvements and recommendations or adjustments, within the framework of these lowered tackle-heights.

# Methodology

Catastrophic head, neck, or spinal injury data were collected between 2008 and 2023 via the BokSmart programme's Serious Injury Protocol, standardised Serious Injury Reports, and Serious Injury Follow-up Questionnaires [46]. Permission to analyse the data was obtained from the South African Rugby Union and Chris Burger Petro Jackson Players' Fund (CBPJPF) [47], and by the UCT Human Research Ethics Committee. Ethics approval was granted by the University of Cape Town for this ongoing research database and analyses: HREF Ref Number 438/2011.

A Catastrophic injury was defined [46] as any head, neck, spine, or brain injury that met the following criteria and were reported to the programme's Serious Injury Case Manager or SICM:

1. *The injury must be potentially life-threatening for the player.*
2. *The injury must be potentially debilitating or disabling.*
3. *The injury must result in the player being admitted to a hospital ward.*

An event meeting the above definition, but which was established to be cardiac-related (and not head, neck, spine, or brain), was also recorded as a 'Cardiac Event'.

Catastrophic injuries were therefore classified into three main groups: (1) Acute Spinal Cord Injury (ASCI), (2) Traumatic Brain Injury (Cat-TBI), and (3) Cardiac Events.

ASCIs were further grouped into outcomes, based on their severity: (a) near miss (full recovery expected, ambulant), (b) neurological deficit (some deficit remains, may walk with or without the requirement of assistive devices), (c) quadriplegic, and (d) fatal. Cat-TBI outcomes were similarly subdivided into: (a) fully recovered, (b) with disability (remaining neurological deficit) and (c) fatal. ASCIs and Cat-TBIs were also broadly grouped into 'non-permanent' outcomes (near misses/fully recovered) and 'permanent' outcomes (residual disability, including fatalities) [48][49].

Due to the relatively small number of injuries, this is a descriptive study in which injury profiles, interactions, and patterns are described from the catastrophic tackle-injury data that were collected prospectively between 2008 and 2023, prior to the implementation of the lowered tackle-height laws in South Africa. One must, however, keep in mind that most cases have no video evidence to support the information provided. Information was received from self-reports, witness reports, referee reports, standardised Serious Injury Report Forms and Serious Injury Follow-up Questionnaires, which were sent out after each confirmed case via the BokSmart Serious Injury Case Manager (SICM). The SICM strategically sits as the Injured Player Welfare Officer (IPWO) at the Chris Burger Petro Jackson Players' Fund [47]. In several cases, incomplete information was received, and not all cases were always well-described in their causality. The qualitative descriptions of the injury events were key to coding causality, and therefore only those cases that had usable data were included in the descriptive pattern analysis. A similar approach was applied to each sectional analysis, where there was missing information.

To analyse the various interactions between tackler, ball carrier, and other outcomes and characteristics, a filled radar plot was used (example provided, Figure 1). One variable was plotted using the outer ring, which moved around the circumference, and the comparative interactive variable was plotted using the inner rings, moving outward from the centre point towards the perimeter of the chart. The outer ring was always chosen as the primary characteristic under exploration. For example in Figure 1 below, the influence of tackle-height was viewed as the primary characteristic, and the interaction of ball carrier stance on tackle-height was viewed as the secondary variable or characteristic.

Only those interactive relationships that were more prominent and considered meaningful were highlighted and described in further detail.

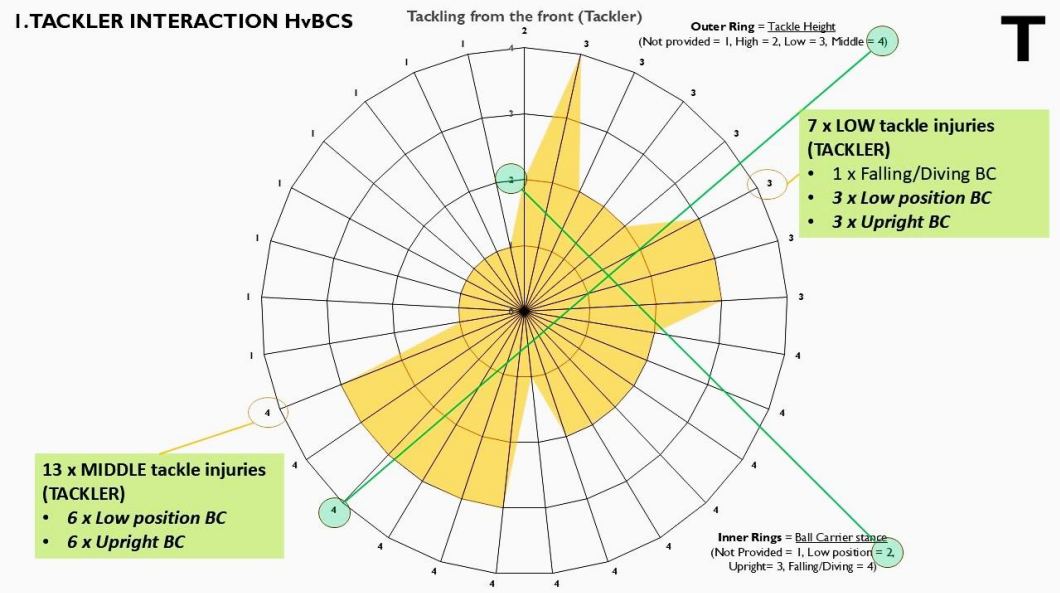



*Figure 1: Filled Radar Plot Chart example used to describe variable interactions.*

**Tackler**-related injuries were first explored and coded according to the following captured information:

1. A summary description of the events that led to the injury in words.
2. The contact point of the tackler's head or neck: *Not provided, Hip, Knee, Head on, Wrong head placement, Head contact undisclosed site, Ground contact, Other.*
3. Was the tackle-injury technique-related: *Unclear, Yes, No.*
4. The direction of the tackle: *Front-on, Side-on, Tackling from behind.*
5. The tackle-height on the ball carrier: *Not provided, High, Low, Middle.*
6. The ball carrier's stance going into the tackle: *Not provided, Low, Upright, Falling/Diving.*
7. The reported nature of the injury: *Not provided, Cat-TBI, ASCI.*
8. Outcome of the injury: *Not provided, Permanent, Not Permanent.*

The following 12 interactions were then visualised on a filled radar plot and analysed for **Tackler**-injuries (primary variable vs. secondary variable):

1. Tackle-Height vs. Ball Carrier Stance
2. Tackle-Height vs. Tackler Permanent/Non-Permanent outcomes
3. Tackle-Height vs. Tackler-Technique
4. Tackle-Height vs. Tackler Contact Point on the Ball Carrier
5. Tackle-Height vs. Tackler ASCI/TBI outcomes
6. Ball Carrier Stance vs. Tackler Permanent/Non-Permanent outcomes

7. Ball Carrier Stance vs. Tackler Technique
8. Ball Carrier Stance vs. Tackler Contact Point on the Ball Carrier
9. Ball Carrier Stance vs. Tackler ASCI/TBI outcomes
10. Contact Point on the Ball Carrier vs. Tackler Permanent/Non-Permanent outcomes
11. Contact Point on the Ball Carrier vs. Tackler Technique
12. Contact Point on the Ball Carrier vs. Tackler ASCI/TBI outcomes

**Ball carrier**-related injuries were explored and coded according to the following captured information:

1. A summary description of the events that led to the injury in words.
2. The contact point of the ball carrier's head or neck: *Not provided, Head-player contact, Head-ground contact, Other*.
3. Was the ball carrier-injury technique-related: *Unclear, Yes, No*.
4. The direction of the tackle made on the ball carrier: *Front-on, Side-on, Tackled from behind*.
5. The tackle-height on the ball carrier: *Not provided, High, Low, Middle*.
6. The ball carrier's stance going into the tackle: *Not provided, Low, Upright, Falling/Diving*.
7. The reported nature of the injury: *Not provided, Cat-TBI, ASCI*.
8. Outcome of the injury: *Not provided, Permanent, Not Permanent*.

The following 12 interactions were then visualised on a filled radar plot and analysed for **Ball Carrier** injuries (primary variable vs. secondary variable):

1. Tackle-Height vs. Ball Carrier Stance
2. Tackle-Height vs. Ball Carrier Permanent/Non-Permanent outcomes
3. Tackle-Height vs. Ball Carrier-Technique
4. Tackle-Height vs. Ball Carrier Contact Point
5. Tackle-Height vs. Ball Carrier ASCI/TBI outcomes
6. Ball Carrier Stance vs. Ball Carrier Permanent/Non-Permanent outcomes
7. Ball Carrier Stance vs. Ball Carrier Technique
8. Ball Carrier Stance vs. Ball Carrier Contact Point
9. Ball Carrier Stance vs. Ball Carrier ASCI/TBI outcomes
10. Ball Carrier Contact Point vs. Ball Carrier Permanent/Non-Permanent outcomes

11. Ball Carrier Contact Point vs. Ball Carrier Technique
12. Ball Carrier Contact Point vs. Ball Carrier ASCI/TBI outcomes

Based on the injury summary descriptions, and only where it was clear and obvious, one of the authors, **WV,** coded each injury as technique-related or not. A second author, **CR,** then reviewed the classifications and confirmed that each coding was an accurate interpretation prior to the final analysis. There were no discrepancies.

Using the coded 'soft' data, the authors aimed to extrapolate something tangible from the data that could tell a story about the tackle event and its potential catastrophic injury risks. With the game considering lowering the legal tackle-height at all levels, one must carefully consider the potential negative effects that this might have on catastrophic head, neck, and spine injury events too. This paper therefore explores this question and makes actionable recommendations for further consideration.

## Results

In South African Rugby Union during the period 2008 and 2023, there were 89 Catastrophic tackle-related injuries, 49 (55%) to the tacklers and 40 (45%) to the ball carriers. The tackle event contributed to 61% of all catastrophic injuries and medical cases.

Fifty-five (55) % of all Acute Spinal Cord Injuries (ASCI) were tackle-related, and 43% of these 55% were permanent outcomes. Of real concern, however, is the consistent number of permanent tackle-related catastrophic traumatic brain injuries (Cat-TBI) that were recorded during the same period. Twenty-three (23) of the 29 Cat-TBI (82%) were tackle-related, with 87% of these having permanent outcomes, 65% being fatal. There are 2.7 and 6.4 times more permanent tackle-related injuries represented compared to permanent scrum- and ruck-related catastrophic injuries, respectively.

When exploring the data even further, the front-on tackle and side-on tackle contributed to 35 (71%) and 11 (23%) of the tackler-injuries, with 3 cases having insufficient information. Similarly, the front-on tackle, side-on tackle and being tackled from behind contributed to 21 (53%), 9 (23%), and 7 (18%) respectively, to the ball carrier-injuries, and 3 cases with insufficient information (Figure 2).

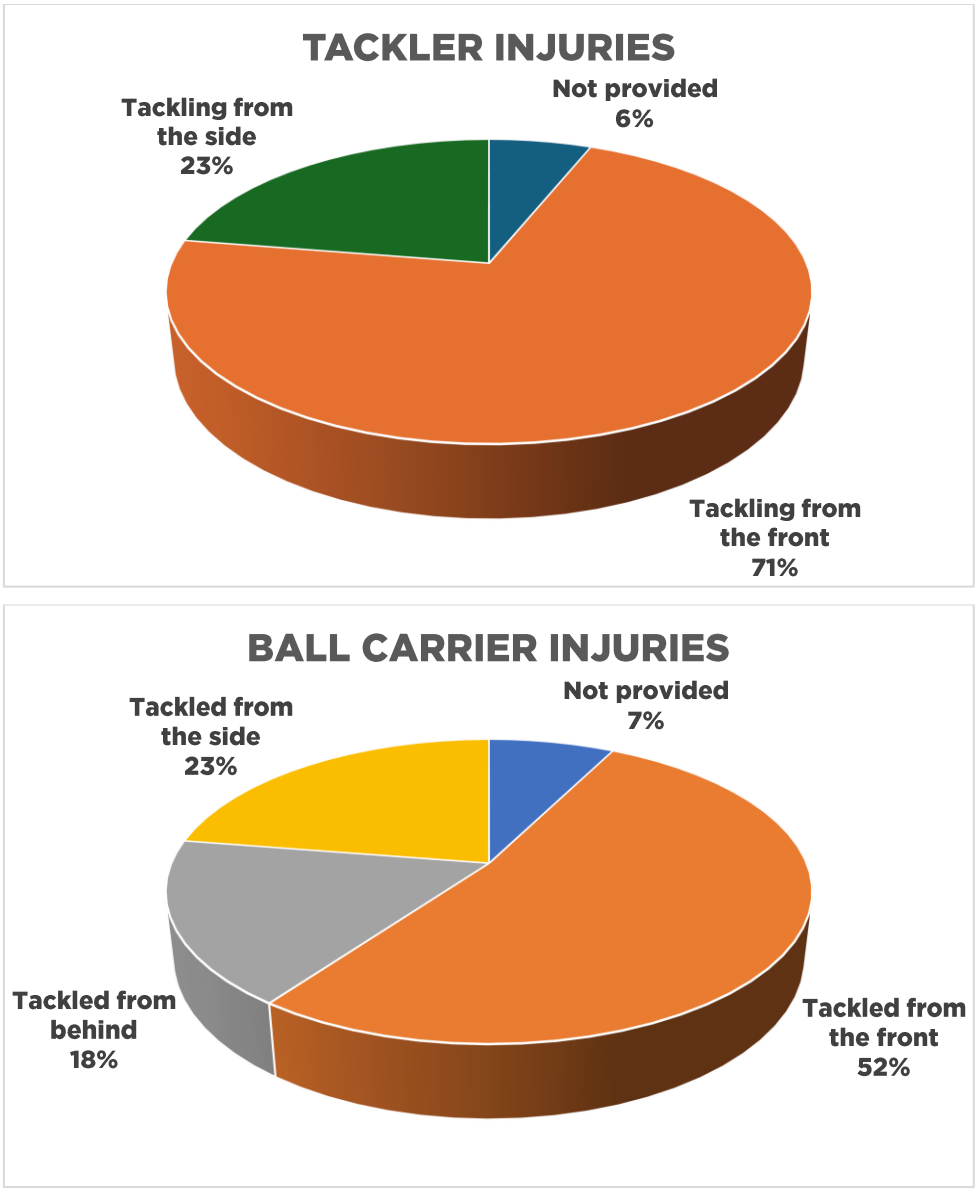



*Figure 2: Proportionate breakdown of tackler and ball carrier injuries based on direction of tackle.*

Tackling and being tackled front-on was the standout tackle type in catastrophic tackle injuries (ASCI and TBI combined, Figures 2 and 3). As a result, the focus of our descriptive analysis shifted to the front-on tackle. This dominated tackler- and ball carrier injuries at both club level (*Tackler: 81%, 60% of these front-on tackler injuries were permanent; Ball carrier: 52%, 43% of these front-on ball carrier injuries were permanent*), and at school level, albeit it to a lesser extent (*Tackler: 58%, 46% of these front-on tackler injuries were permanent; Ball carrier: 50%, 29% of these front-on ball carrier injuries were permanent*).

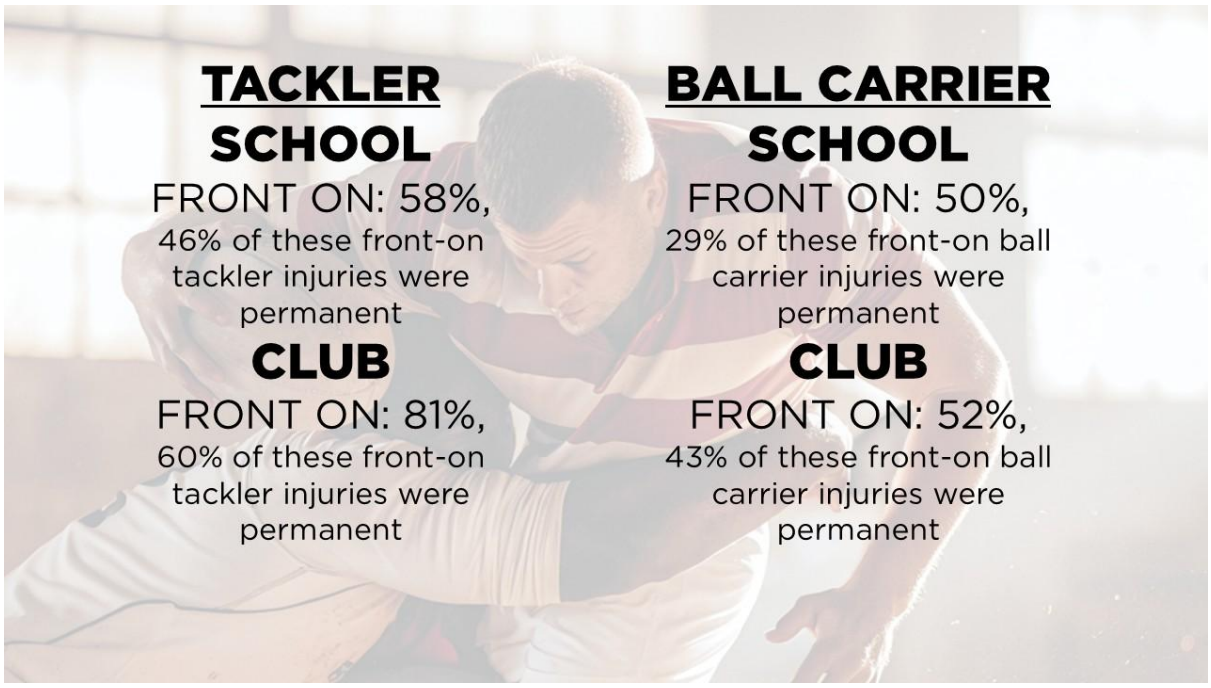



*Figure 3: Front-on tackles at School and Club level, and level of severity.*

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The following section highlights some of the key associations of relevance to increasing the risk of a catastrophic head, neck, or spine injury in both tacklers and ball carriers in the front-on tackle contest. In front-on Tackler catastrophic injuries (Figure 4T), most injuries occurred in middle-height tackles and then low tackles, with both upright and low-positioned ball carriers entering the tackle-contest contributing. In front-on ball carrier catastrophic-injuries (Figure 4BC) middle-height tackles again stood out, with low-positioned ball carriers over-shadowing the rest regardless of tackle-height. Falling/Diving ball carriers for the sake of this analysis can be included in the low-positioned ball carrier count.

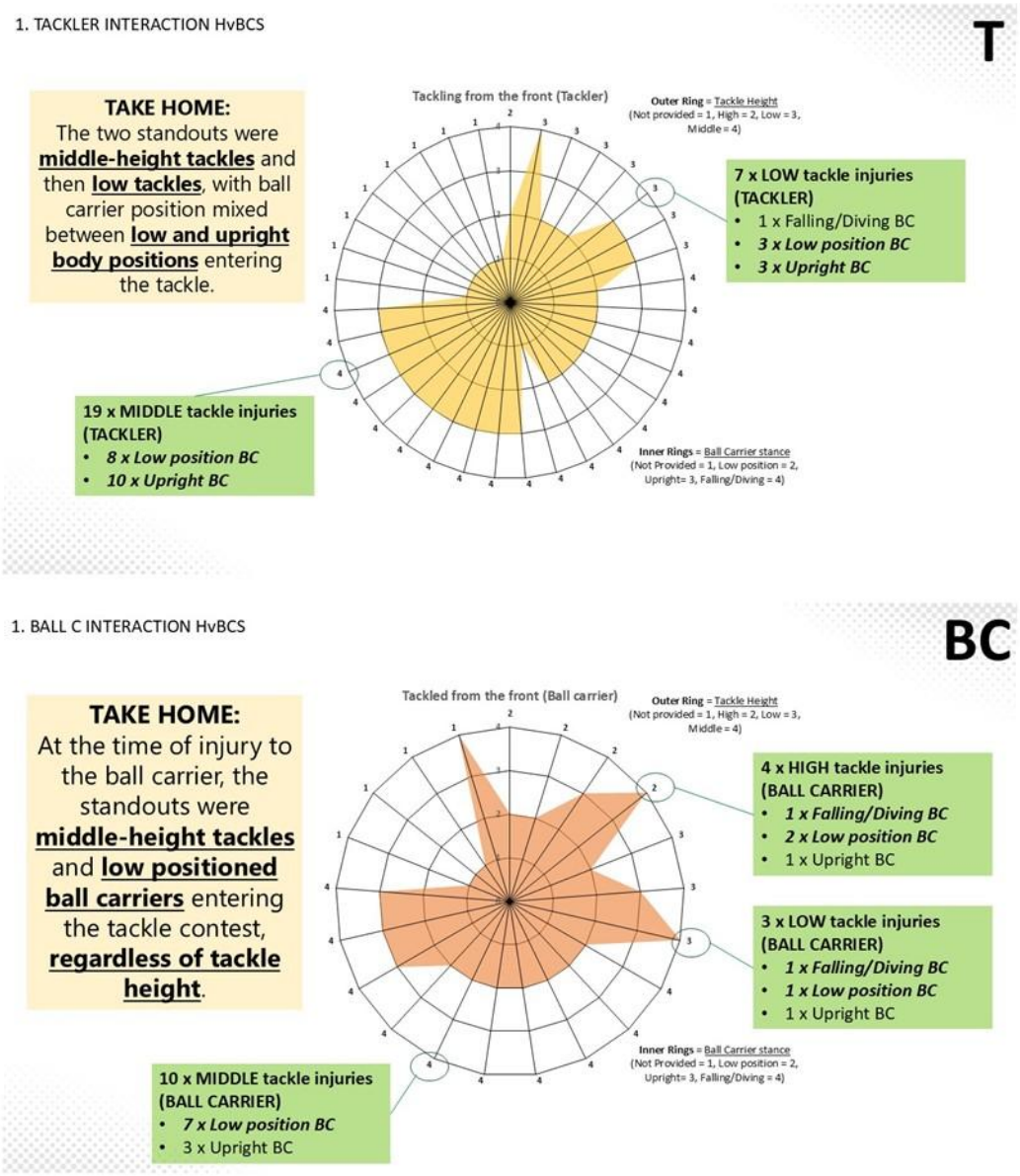


*Figure 4: Tackle-height and Ball Carrier Stance interaction in tackler catastrophic injuries (T) and ball carrier catastrophic injuries (BC).*

From the available data, it is evident that when the ball carrier enters the tackle-contest with a low-positioned body there is a higher risk of permanent catastrophic outcome in tacklers (Figure 5T), and a higher risk of head, neck, and spine injuries in ball carriers (Figure 5BC). While upright ball carriers had mixed effect-outcomes in tackler injuries, for every non-permanent injury-case, where the ball carrier entered low into the tackle-contest, there were two tackler-injury cases with permanent injuries. In the ball carrier-injuries, albeit that there was an equal proportion of permanent versus non-permanent outcomes, a low-positioned ball-carrier led to more injuries overall and contributed to more absolute numbers of permanent outcomes.

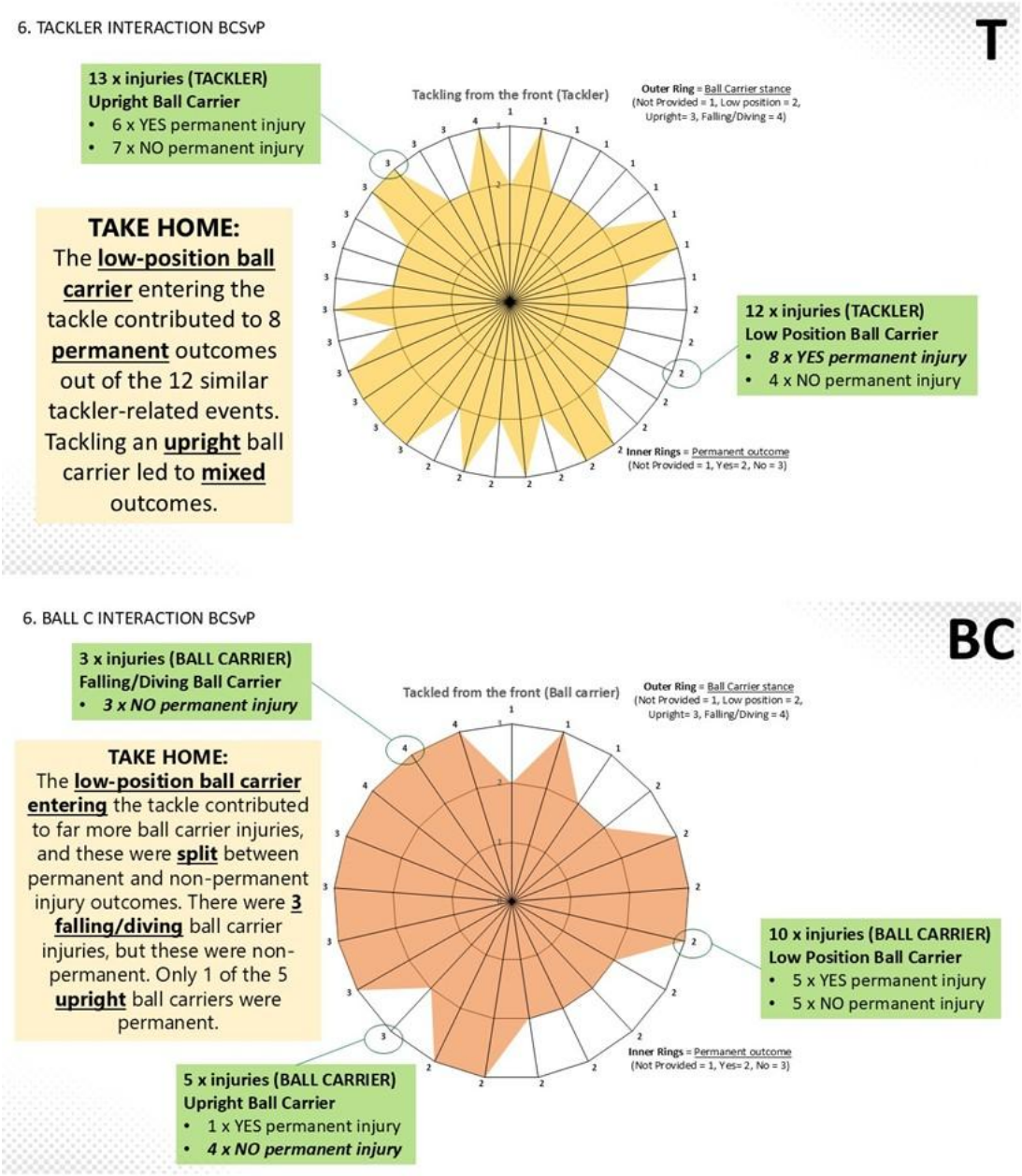


*Figure 5: The effect of Ball Carrier Stance when entering the tackle-contest on Permanent catastrophic outcomes in tackler injuries (T) and ball carrier injuries (BC).*

Regardless of tackle-height, ball carrier stance, permanent or non-permanent injuries, and contact point, there was a sizable portion of tackler catastrophic injuries deemed to be due to tackler-technique errors or unsafe technique (Table 1, Figure 6T). Direct head-on contact and head-to knee contact with the ball carrier largely added to these numbers. This was less obvious in ball carrier catastrophic injuries, apart from the head-player contact injuries, where most of these were seemingly related to unsafe ball carrier-techniques (Table 2, Figure 6BC). Where the ball carrier entered the contest with a low body-position or falling/diving approach, these were frequently technique-related errors.

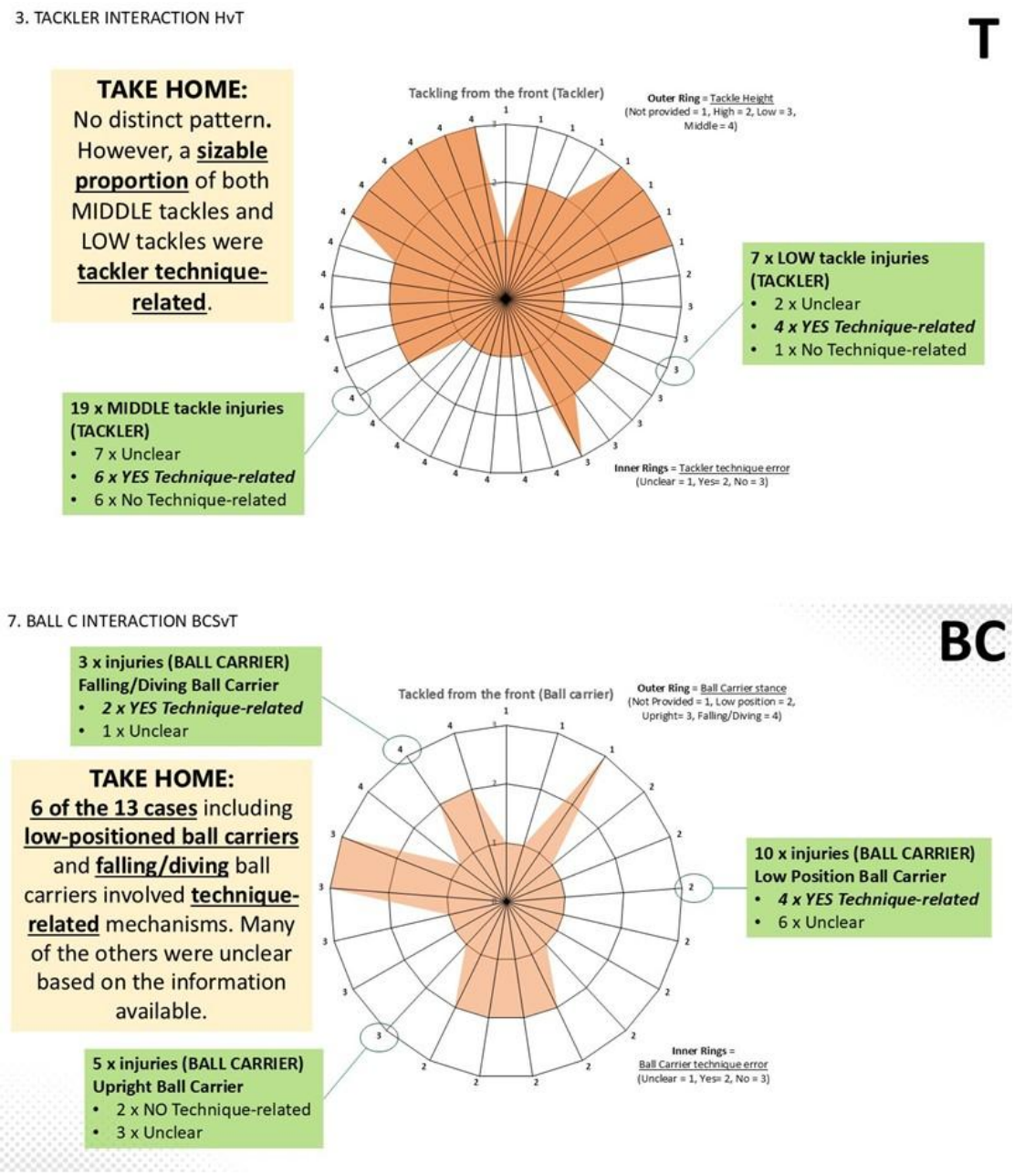


*Figure 6: The influence of tackler- and ball carrier technique in catastrophic tackler injuries (T) and ball carrier injuries (BC) respectively.*

Tables 1 and 2 describe the 'soft' data that was used for analysis of catastrophic injury risk in tacklers and ball carriers within the South African Rugby Union. Included in the Tables 1 and 2 are the reported clinical nature of these injuries.

*Table 1: Catastrophic front-on tackler-related injuries between 2008 and 2023.*

| CODE | Contact Point | TACKLER Technique related | TACKLE Direction | Tackle-height | Ball carrier's stance | Reported Nature of injury | ASCI-TBI | PERMANENT OUTCOME OR NOT |
|---|---|---|---|---|---|---|---|---|
| 808 | Ground contact | Unclear | Tackling from the front | High | Low position | T11/T12 Unstable fracture & compressed spinal cord | ASCI | PERMANENT |
| 910 | Other | No | Tackling from the front | Low | Falling/diving | T12 compression fracture with a fracture through the posterior rami of T12 | ASCI | NOT PERMANENT |
| 602 | Head-on contact | Yes | Tackling from the front | Low | Low position | C5/6 Bifacet dislocation with disc prolapse and cord compression | ASCI | PERMANENT |
| 1012 | Knee contact | Unclear | Tackling from the front | Low | Low position | TBI, Frontal lobe haemorrhage | TBI | PERMANENT |
| 1201 | Not provided | Unclear | Tackling from the front | Low | Low position | Severe head injury | TBI | PERMANENT |
| 708 | Knee contact | Yes | Tackling from the front | Low | Upright | Depressed skull fracture | TBI | NOT PERMANENT |
| 805 | Head-on contact | Yes | Tackling from the front | Low | Upright | C3/C4 Unilateral locked facet dislocation with no spinal cord damage | ASCI | NOT PERMANENT |
| 1104 | Knee contact | Yes | Tackling from the front | Low | Upright | Minor brain haemorrhage | TBI | NOT PERMANENT |
| 207 | Other | Unclear | Tackling from the front | Middle | Low position | C4/5 fracture dislocation | ASCI | PERMANENT |

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|---|---|---|---|---|---|---|---|---|
| 610 | Knee contact | No | Tackling from the front | Middle | Low position | C1 ring fracture with partial dislocation of the left occipital condyle on the C1 lateral mass | ASCI | NOT PERMANENT |
| 1005 | Wrong head placement | Yes | Tackling from the front | Middle | Low position | C5/C6 Fracture dislocation with some neurological fallout initially, which resolved once dislocation was reduced | ASCI | NOT PERMANENT |
| 1210 | Not provided | Unclear | Tackling from the front | Middle | Low position | A traumatic head injury with minor residual effects | TBI | PERMANENT |
| 1511 | Knee contact | Yes | Tackling from the front | Middle | Low position | C4/C5/C6 uni-facet dislocation and fracture, plus C4 pedicle and lamina fracture with NO spinal cord damage. | ASCI | NOT PERMANENT |
| 1508 | Knee contact | No | Tackling from the front | Middle | Low position | Cervical spine C6/C7 fracture and dislocation. Presenting with paralysis | ASCI | PERMANENT |
| 1616 | Wrong head placement | Yes | Tackling from the front | Middle | Low position | C2 Hangman's Fracture | ASCI | NOT PERMANENT |
| 1608 | Other | Unclear | Tackling from the front | Middle | Low position | C5/6 dislocation with resultant C5 complete quadriplegia | ASCI | PERMANENT |
| 1303 | Head-on contact | Yes | Tackling from the front | Middle | Not provided | Fatal head injury | TBI | PERMANENT |
| 211 | Hip contact | Unclear | Tackling from the front | Middle | Upright | Suspected C2 fracture | ASCI | NOT PERMANENT |
| 509 | Ground contact | No | Tackling from the front | Middle | Upright | C6/C7 Bifacet dislocation | ASCI | PERMANENT |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 711 | Not provided | No | Tackling from the front | Middle | Upright | C5 Fracture | ASCI | NOT PERMANENT |
| 710 | Head-on contact | Yes | Tackling from the front | Middle | Upright | C4/5 Compound fracture dislocation with spinal cord damage, presenting as a C5 quadriplegic | ASCI | PERMANENT |
| 1008 | Not provided | No | Tackling from the front | Middle | Upright | C6/C7 Unilateral Facet Joint dislocation, C6 Left Lamina fracture | ASCI | PERMANENT |
| 1102 | Not provided | Unclear | Tackling from the front | Middle | Upright | Traumatic Brain Injury fatality | TBI | PERMANENT |
| 1611 | Other | No | Tackling from the front | Middle | Upright | C5/C6 Unifacet dislocation | ASCI | NOT PERMANENT |
| 1607 | Ground contact | Unclear | Tackling from the front | Middle | Upright | Confirmed C7 body horizontal Fracture | ASCI | NOT PERMANENT |
| 1615 | Hip contact | Unclear | Tackling from the front | Middle | Upright | Fractures of C5/C6, Complete SCI | ASCI | PERMANENT |
| 1601 | Hip contact | Yes | Tackling from the front | Middle | Upright | Fatal traumatic brain injury | TBI | PERMANENT |
| 106 | Head-on contact | Yes | Tackling from the front | Not provided | Not provided | C1 fracture / Odontoid peg | ASCI | NOT PERMANENT |
| 310 | Not provided | No | Tackling from the front | Not provided | Not provided | C2 odontoid process fracture with brachial plexus palsy | ASCI | PERMANENT |
| 508 | Knee contact | Unclear | Tackling from the front | Not provided | Not provided | Head injury | TBI | PERMANENT |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1010 | Head-on contact | Yes | Tackling from the front | Not provided | Not provided | TBI with subarachnoid haemorrhaging, and coning of the brain. Additional C5 Fracture of the transverse process and of the C4 vertebral body | TBI | PERMANENT |
| 1101 | Ground contact | No | Tackling from the front | Not provided | Not provided | Traumatic Brain Injury fatality | TBI | PERMANENT |
| 1402 | Ground contact | No | Tackling from the front | Not provided | Not provided | C3/C4 Unifacet dislocation without damage to the spinal cord | ASCI | NOT PERMANENT |
| 1207 | Not provided | No | Tackling from the front | Not provided | Not provided | C6/C7 fracture and disc prolapse; no spinal cord damage | ASCI | NOT PERMANENT |
| 1512 | Knee contact | Yes | Tackling from the front | Not provided | Not provided | Fatal Traumatic brain injury | TBI | PERMANENT |

*Table 2: Catastrophic front-on ball carrier-related injuries between 2008 and 2023.*

| CODE | Contact Point | BALL CARRIER Technique related | TACKLE Direction | Tackle-height | Ball carrier's stance | Reported Nature of injury | ASCI-TBI | PERMANENT OUTCOME OR NOT |
|---|---|---|---|---|---|---|---|---|
| 511 | Head-ground contact | Unclear | Tackled from the front | High | Low position | T3/T4 compression fracture | ASCI | PERMANENT |
| 709 | Head-player contact | Yes | Tackled from the front | High | Low position | C5/C6 Unifacet dislocation with disc prolapse C5/C6 | ASCI | NOT PERMANENT |
| 1109 | Head-player contact | Unclear | Tackled from the front | High | Upright | Traumatic Brain Injury fatality | TBI | PERMANENT |
| 102 | Other | Unclear | Tackled from the front | High | Falling/diving | C3 fracture | ASCI | NOT PERMANENT |
| 912 | Head-ground contact | Unclear | Tackled from the front | Low | Low position | Unstable C2 fracture | ASCI | NOT PERMANENT |
| 901 | Head-ground contact | Unclear | Tackled from the front | Low | Upright | Jefferson's burst fracture of C1, both anterior and posterior arches, with no spinal cord damage | ASCI | NOT PERMANENT |
| 911 | Head-player contact | Yes | Tackled from the front | Low | Falling/diving | C5/C6 facet dislocation | ASCI | NOT PERMANENT |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 505 | Head-ground contact | Yes | Tackled from the front | Middle | Low position | Traumatic disc-prolapse C6/C7 with C5/C6 Unifacet dislocation | ASCI | NOT PERMANENT |
| 811 | Not provided | Unclear | Tackled from the front | Middle | Low position | C5/C6 Unifacet dislocation | ASCI | PERMANENT |
| 904 | Head-player contact | Yes | Tackled from the front | Middle | Low position | C4/C5 subluxation and fracture dislocation | ASCI | PERMANENT |
| 908 | Head-player contact | Yes | Tackled from the front | Middle | Low position | C5/C6 dislocation and disc rupture - C5 quadriplegia | ASCI | PERMANENT |
| 1111 | Not provided | Unclear | Tackled from the front | Middle | Low position | C5/C6 Unifacet dislocation with spinal cord entrapment and neurological fallout; motor and sensory incomplete | ASCI | PERMANENT |
| 1202 | Not provided | Unclear | Tackled from the front | Middle | Low position | Teardrop fracture of C4 with some spinal cord damage | ASCI | NOT PERMANENT |
| 1505 | Not provided | Unclear | Tackled from the front | Middle | Low position | Partially displaced fracture extending through the bilateral pars interarticularis and body of the C2 vertebral body. A Hangman's fracture with displacement of the bilateral pars interarticularis with minimal anteriolisthesis of C2 on C3. | ASCI | NOT PERMANENT |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1504 | Head-ground contact | Unclear | Tackled from the front | Middle | Upright | Displaced fracture involving the left C6 lamina, pedicle and facet. An additional suspected periosteal avulsion fracture from the left superior endplate of C7. Associated subtle grade 1 C6-7 anterolisthesis. | ASCI | NOT PERMANENT |
| 1515 | Head-ground contact | No | Tackled from the front | Middle | Upright | C5/C6 Unifacet fracture dislocation. | ASCI | NOT PERMANENT |
| 1604 | Head-ground contact | No | Tackled from the front | Middle | Upright | Traumatic Brain Injury resulting in brain haemorrhage. | TBI | NOT PERMANENT |
| 502 | Not provided | Unclear | Tackled from the front | Not provided | Not provided | C3-C4 Disc prolapse | ASCI | PERMANENT |
| 605 | Head-ground contact | Unclear | Tackled from the front | Not provided | Not provided | SCIWORA (Spinal Cord Injury Without Radiological Abnormality) | ASCI | NOT PERMANENT |
| 1502 | Head-ground contact | No | Tackled from the front | Not provided | Not provided | Fatal head injury | TBI | PERMANENT |
| 703 | Head-player contact | Yes | Tackled from the front | Not provided | Falling/diving | C4 & C5 hairline fractures with wedge compression and C6 avulsion. No spinal cord damage | ASCI | NOT PERMANENT |

Ball carrier contact points for tacklers were quite evenly spread, but within middle- and low-height tackles combined, contact with the knees and head-on contact with the ball carriers edged the others. Tackling low-positioned ball carriers lent itself to more knee-contact for the tackler, and generally, knee-contact led to more Cat-TBI (Figure 7T). Ball carrier contact points were mainly head-ground contact or head-player contact, with relatively more permanent injury risk because of head-player contact, even though the absolute numbers were slightly less. Most low-positioned ball carrier entries led to ASCI, with head-player contact as the leading cause. Ball carriers in relation to the tackle-contest mostly incurred ASCI as opposed to TBI (Figure 7BC). There were predominantly more Cat-TBI in tacklers, as opposed to ball carriers.

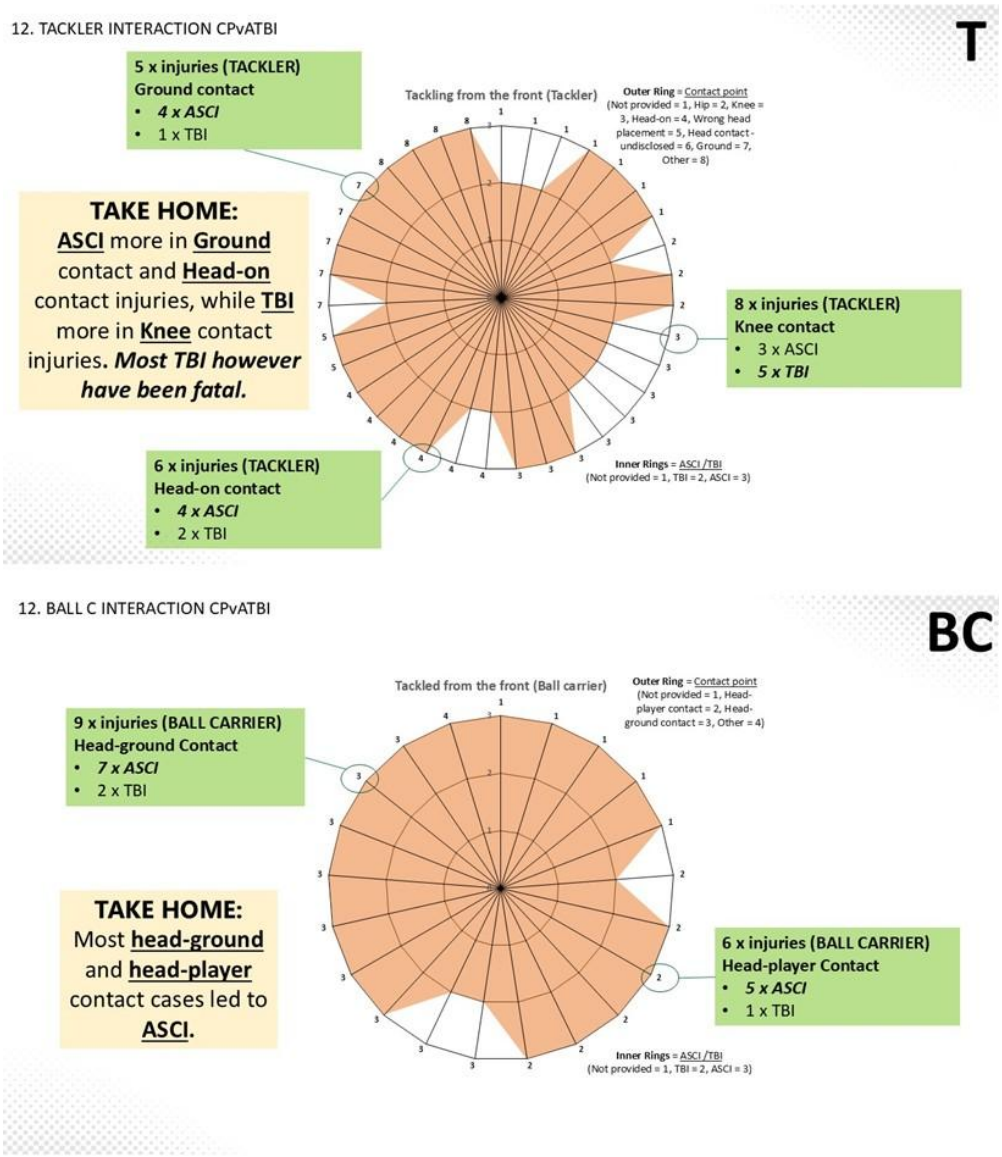


*Figure 7: Contact points and catastrophic injury classifications in tacklers (T) and ball carriers (BC).*

## Discussion

All contact sports and many non-contact sports have an intrinsic risk of injury, even catastrophic injury, associated with participating in the sport [6]. However, it is binding on those who control these sports to mitigate this risk wherever possible [50][10], with a focus on injury prevention strategies [6]. The difficult part is to do so without changing the very nature of what makes the game appealing to players and spectators in the first place. To our knowledge, this is the first paper that has explored tackle-catastrophic rugby injuries in this way, and this analysis has presented some novel findings, which require serious consideration when trying to make the game safer and simultaneously lowering the maximum legal tackle-height.

The tackle, contributing to 61% of all catastrophic injuries (Figure 8) in our dataset, is much higher than the 36% allocated to the tackle event in Quarrie et al.'s paper on spinal cord injuries [9], Berry et al.'s 29% [8], MacLean and Hutchinson's 47% [50], and Brown et al.'s 38% [48], when scrum injuries were still prominent. Before the introduction of the current amateur scrum laws in South Africa [51], scrum injuries dominated these statistics, with 82% of the scrum-related catastrophic outcomes being permanent, compared to only 50% of the tackle-related catastrophic injuries [48].

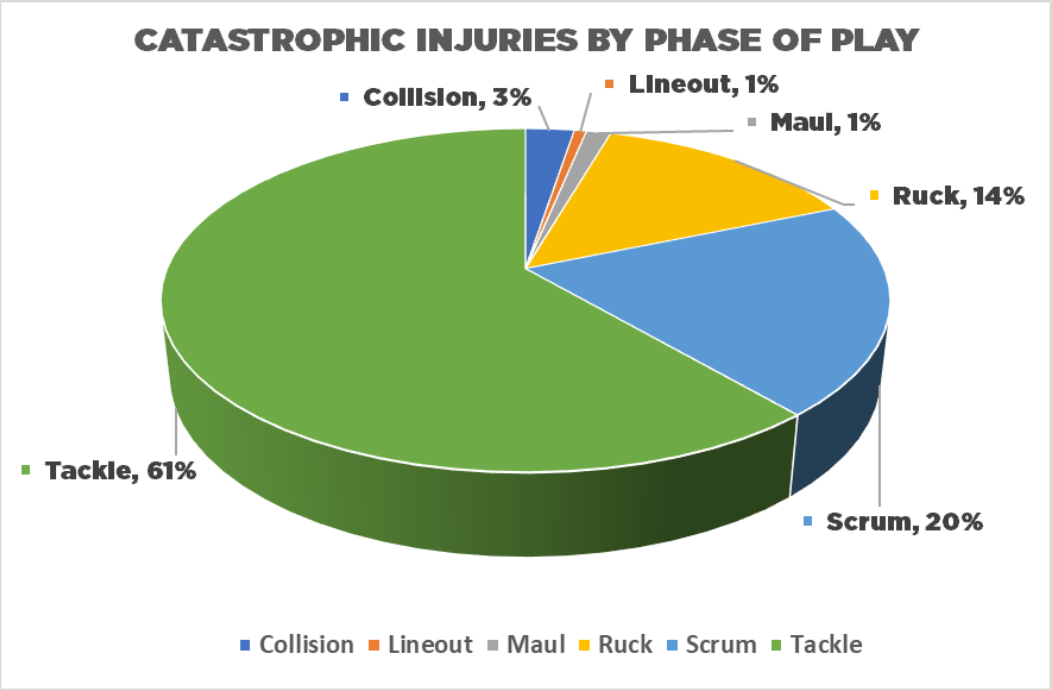


*Figure 8: Catastrophic injuries by phase of play between 2008-2023.*

Although the proportionate contribution of tackle injuries was notably higher in this study than in earlier studies, this is likely an artefact of the decline in scrum-related catastrophic injuries that has occurred over time, since the introduction of amateur scrum laws in South Africa. However, the proportion of permanent tackle-related outcomes remained similar at 43% in ASCI, and as high as 87% in Cat-TBI. Figures 8 and 9 show a visual indication of the tackler- and ball carrier catastrophic injuries respectively in relation to the direction from which the tackles were made.

**TACKLER INJURIES**

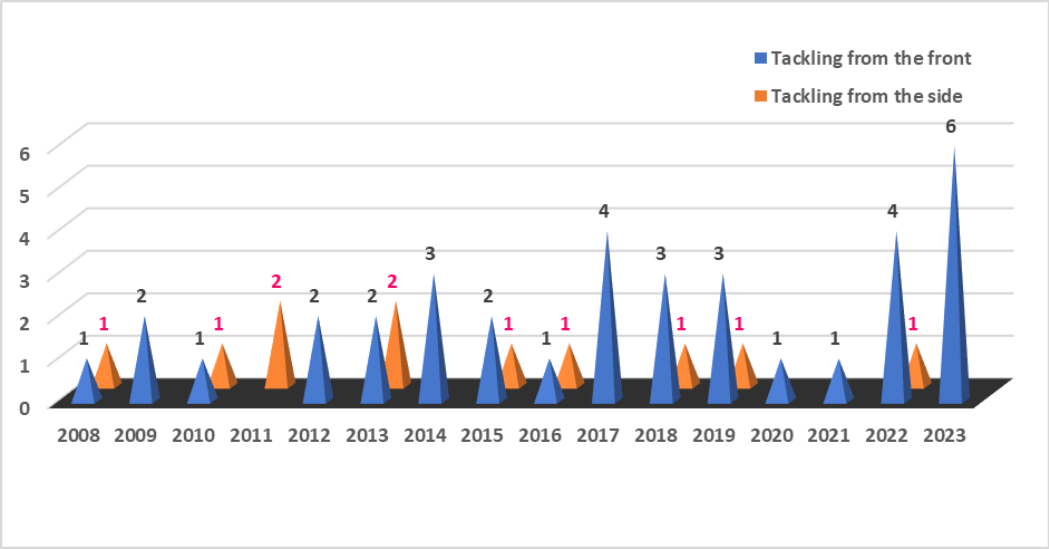


*Figure 9: Direction of tackle in tackler-injuries over time.*

**BALL CARRIER INJURIES**

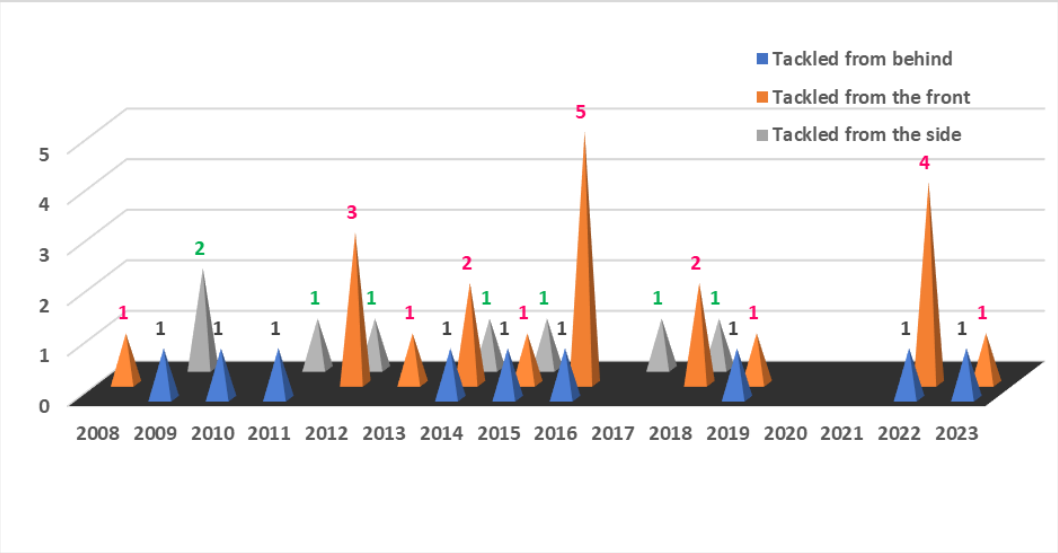


*Figure 10: Direction of tackle in ball carrier-injuries over time.*

Direction, speed, tackle type, acceleration, and body position of tackler and ball carrier all have an influence on the risk of unwanted head contacts [38]. The highest risk is where the two players involved, tackler, and ball carrier, are upright [52][53], and are accelerating into contact (2.49 times greater odds: tackler accelerating; 1.44 times greater odds: both accelerating, compared to the ball carrier only) [35]. This has also been shown where the tackler approaches the ball carrier at high speeds [33], with 2.64 times greater odds compared to low speeds [35]. The greatest inertial head kinematics (accelerations, velocities) and neck dynamics (forces, moments applied) in both ball carrier and tackler occurs when both are moving at higher speeds into contact.

An increase in speed for either player results in corresponding increases in kinematics and dynamics for both players [33]. If one can remove any, all, or a combination of these elements, then one can significantly limit the opportunities for head contacts and concussions [38]. Linear acceleration, angular acceleration and change in angular velocity of the ball carrier's head is 1.8 times, 2.2 times and 2.3 times greater in tackles to the upper trunk, particularly when the impact occurs above the chest of the ball carrier during front-on tackles, as opposed to front-on tackles made to the mid-and lower trunk [30]. Lowered tackle-heights may reduce the moment of inertia, and the size of the impact force when heads do collide, and improve long-term brain health risk. Linear acceleration, angular acceleration and change in angular velocity of the ball carrier's head could be reduced in the tackle by as much as 35%, 61% and 40%, if the tackle-height is lowered to below the chest [30]. This has huge implications for reducing concussion potential. Reducing the magnitude of inertial head kinematics will lower the concussion risk regardless of whether it affects a single tackle, or multiple impacts accumulated over hundreds of tackles [54]. Tackles made at head and neck height are 7.97 times and 15.34 times more likely to trigger an HIA than tackles made to the upper- and mid-trunk respectively [53].

Edwards et al. [54] found that linear head acceleration was highest for tacklers when they went in low for the tackle at the lower trunk level (around hip height) as opposed to tackles aimed at the mid- or upper torso. The ball carrier's peak linear and angular head acceleration increased with increasing tackle contact-height. They therefore propose that contacting the ball carrier around the mid-torso or above the hip area but below the pectorals, rather than the lower torso, may contribute to lowering the tackler's head injury risk, while not excessively raising the risk to the ball carrier. Because the tackler is more at risk of concussions and head contacts [53], this seems to be a balanced and sensible approach. Dropping the maximum legal tackle-height and forcing tacklers to drop height and get lower in the tackle, will bring the new tackle-height laws closer to current 'proper tackle technique' coaching standards [45]. Tackling at waist level or above has also been shown to be more effective for successful tackles, so this offers performance benefits as well. [4].

**TACKLE-HEIGHT**

However, in line with our original expectations, with the increasing push towards lowering the legal tackle-height, the main finding from our analysis is that middle-height tackles (Figure 11), which frequently happen in the game, was the tackle-height most commonly associated with catastrophic head, neck, and spine rugby injuries to both tacklers and ball carriers. Based on our study's findings, one must therefore be more aware of the catastrophic head, neck, and spine injury risk associated with tackling in this zone and implement additional proactive injury prevention measures to mitigate this potential risk.


*Figure 11: Broad zones for Tackle-Height classification.*

Tucker et al. highlight that, of the head injuries that happen in the tackle, 72% occur to the tackler, who has 2.6 times greater risk of concussion than the ball carrier [38][28].

Gardner et al., in a rugby league study, confirm that the propensity to undergo an HIA was around 1.74-fold greater for tacklers than for ball carriers [52], and this is why most of the literature concentrates on the tackler. However, one cannot simply look at the tackler role in isolation.

The ball carrier's body position and their approach leading into contact can drastically influence the outcome of the tackle, determining the target the tackler must aim at and attempt to defend successfully, effectively, and safely. Tackle-height, head contact or heads sharing the same airspace in contact are to some degree determined by the body positions of those players involved in or entering into the tackle-contest [53].

## TACKLER-BALL CARRIER INTERACTION

Our second major finding is that regardless of the tackle-height, the catastrophic head, neck, and spine injury events in tacklers and ball carriers, are more associated with ball carriers entering into the tackle-contest with a low body position.

With tackler injuries, this tackler-ball carrier interaction leads to proportionately more permanent injury outcomes, and with ball carrier injuries, this leads to a greater permanent and absolute number of catastrophic head, neck, and spine ball carrier-injuries.

Head-to-head contact in the tackle-contest has the highest risk of concussive injury in tacklers and ball carriers [28]. Both the tackler and ball carrier have lower risk of direct head contacts and concussions, if they are bent forward into contact as opposed to being upright [53][55] (Figure 12).


*Figure 12: A player demonstrating an Upright-positioned ball carry with head facing up-and-forward (top position), Bent-positioned ball carry with head facing up-and-forward (middle position), and Low-positioned ball carry with head leading into contact and facing down (bottom position).*

Gardner et al. in a rugby league study found that the propensity for a head-contact event to lead to an HIA was greatest when ball carriers were upright (2.45 HIAs per 1000 tackles versus bent-at-the-waist ball carriers, 0.16 HIAs per 1000 tackles). HIA incidence rates were also greatest for upright ball carriers while bent-at-the-waist ball-carrier HIAs were the least likely to occur. They did however show a 3.2-fold greater propensity for HIAs when tacklers were upright compared to being bent at the waist [52]. When the tackler was upright in contact, the risk of HIA was 1.9 times greater to self, and 12.8 times greater to the ball carrier [52].

Professor Ross Tucker, in an online scientific blog [40], also alludes to upright tacklers being 50% more likely to be injured than bent-at-the-waist tacklers, and this is irrespective of the ball carrier's body position, whether bent or upright, into contact [38]. When both tackler and ball carrier are forward bent into contact, there remains a 32% reduction in risk of being removed for an HIA [55].

So, regardless of the ball carrier being upright or bent, the greater risk of head contacts and or concussion for either player is when the **tackler is upright, and the tackle-height is high** [53]. This is mainly due to the tackler creating more frequent head-to-head and head-to-shoulder contacts with the ball carrier in that upright tackle position.

Early research into the tackle-height paradox [40] confirmed that head-to-head impact (1 HIA in 88 tackles) was far more likely (6.5 times more) to lead to concussions / HIAs than head-to-hip impacts (1 HIA in 565 tackles). Higher up on the body tackle contacts were 4.25 times more likely to cause concussive injury than lower tackles [55][38], which lends support for lowering the tackle-height. Tierney and Simms [32] showed in front-on tackles a 1.48 times relative risk of tackler HIA when tackling at the upper trunk level; mid-trunk 0.32 times, and lower-trunk had a 0.45 times relative risk of HIA. An early study by Stokes et al. [34] on lowering the legal tackle-height, did, however, show sizable improvements in tackle behaviour characteristics in a brief period of implementation. There were 15% fewer tackles above the line of the armpit with fewer ball carrier head and neck contacts. Tacklers were less upright in the tackles and targeted ball carriers lower more often. Ball carriers were also more 'partially' forward bent and less 'fully' forward bent in contact[34]. Ball carrier contact-evasion strategies might also have value in preventing head contacts and concussions [53].

Also, taking in Professor Ross Tucker's thread on the social media platform, X', regarding head contact and risk of having to undergo an HIA [55], the highest risk in contact is when both tacklers and ball carriers are upright (1 HIA in every 292 same type tackles). The lowest risk is when the ball carrier is upright, and the tackler is bent at the waist (1 HIA in every 622 same-type tackles). This tackler-ball carrier interaction and the lowered risk of head contact between a more upright ball carrier and a bent tackler aligns with our catastrophic injury picture and recommendations regarding ball carrier body position when entering the tackle contest.

As made clear in the data from our study, when a tackler must attempt to tackle a low positioned ball carrier, this creates a heightened opportunity for catastrophic head, neck, and spine injuries. The ball carrier action in this way affects the catastrophic injury risk to both tacklers and ball carriers and must therefore be avoided. Professor Tucker, in his scientific blog [55], again illustrates that the highest risk of head contact and having an HIA in ball carriers is when they are falling or diving low into contact (1 HIA in 143 diving low ball carries). Ball carriers are encouraged to lead into contact with a braced, bent-at-the-waist position to minimise concussions and reduce opportunities for head contact. Equally important, they are strongly discouraged from leading low into contact, especially with their heads down, as this leads to a heightened risk of catastrophic injury in the tackle-contest for both role players.

## CONTACT TECHNIQUE

Thirdly, regardless of the associations mentioned above, it was evident that there are still many opportunities to prevent these injuries by improving both ball carriers' and tackler contact techniques. Although based on the limited descriptive information available, there were a reasonably large number of cases where the player's contact technique seemed to play a contributing role in the injury event and eventual outcome. This seems to be a long-time problem [10] that was already evident in South Africa in the 1960's [14] and 1980's [13] and was again present in the current study.

Tacklers are encouraged to enter the contest in a head-up and forward position and to initiate ball carrier contact with the shoulder, chest, and arms while placing the head to the side of the ball carrier [4][56][31]. The head up position in the tackle will also instinctively raise the height of the tackler closer to tackling around waist height or above, which is safer and has more tackle-success than tackling below the waist [4].

When studying elite women's rugby union, it was found that even at this level of play, 50% of players had incorrect head-positions pre-contact, and 15% with incorrect head or neck placement at the point of contact. This, on average, led to 14 and 18 head and neck contacts (increased opportunities for head, neck, or spine injury) per game, in tacklers and ball carriers, respectively [56]. In Under 18 players, placing the head in front during tackles also stood out more often as the cause of concussions in front-on tackles at 11.26/1000 tackles made [57]. In a rugby league study, it was found that in roughly 53% of HIAs the tacklers' heads in contact were placed in front of the oncoming ball carriers [53].

Placing the head on the wrong side of the tackle was red-flagged in front-on tackle-injured rugby players compared to their non-injury control tackles, as was not keeping the back straight in the tackle, not having the centre of gravity ahead of the base of support, and not wrapping and pulling the player into the shoulder on contact [58]. Tackles made with the head down (roughly 15% of tackles) and heads placed across-the-bow (in front of the oncoming ball carrier) have also been associated with poor tackling technique and lower tackle success rates. Heads-up tackles have a tackle success rate of 80.7%, and inside shoulder tackles (heads placed behind the ball carrier) have a 90.8%. Inside shoulder tackles have around 84.8% of tacklers with their heads up in the tackle. Across-the-bow or head on the wrong side tackles have only a 72.4% tackle-success rate, with 59.8% of players with their heads up in the tackle [4]. Tackle technique training needs to concentrate on prioritising tackles aimed at the mid-torso while minimising tacklers placing their heads across or in front of the body of the oncoming ball carrier [43].

It has also been shown that where there is a head injury involved in either tacklers or ball carriers during front-on tackles, most cases are related to contact technique deficiencies in either or both role players. The tackler plays a significant part in this dynamic where head contact is involved. Key technical factors for tacklers when approaching the ball carrier are to level change from an upright to low position [45] just before making the tackle, by bending in the waist and at the knees [53] and keeping shoulders above the hips. The tackler must then position their head on the outside of the ball carrier and, while driving their legs through the hit, place the inside shoulder onto the ball carrier, keeping their head up and back straight, while completing the tackle as per the law [54][1]. Lowering the tackle-height on its own does not reduce the risk of injury or concussions in the tackle, if players continually place their heads in front of the ball carriers. Tacklers were 3.93 times more at risk of concussions during front-on tackles, simply by placing their heads in front of the ball carriers. Regardless of direction or tackle-height, head-in-front tackles are one of the most critical risk factors in concussions [53][57].

Getting clear inside shoulder contact (head placed behind the ball carrier) and heads up in the tackle, requires players to be in the right positions before making the hit [4]. Pre-existing technique deficiencies in repositioning from an upright to a crouched, bent-at-the-waist body position before contact in the tackle, and legally getting the inside shoulder onto the ball carrier as the first point of contact, have been associated with injured tacklers [58].

Serious head and spinal injuries have been linked to playing inexperience in Japanese youth rugby players. Relatively inexperienced players were more likely to sustain serious head (76% of cases), and spinal cord injuries (80% of cases) [59]. If the tackler's technical proficiency is low in the tackle and they do not get the upright to low height-drop right, or do not enter with a straight back, or place the head on the correct side of the ball carrier, the risk of head impact in both tacklers and ball carriers climbs substantially [60][58]. So, for the safety of those players contesting the tackle and for successful tackles or ball carries, these players first need to become technically proficient in both dominant and non-dominant shoulders [1], and secondly, must then be able to sustain their ability to use these safe and effective contact techniques throughout a match (otherwise known as having technical capacity), especially when fatigued.

Developing technical capacity has the benefit of reducing players' injury risk, improving their technical ability, and prepares players better for match play demands [61].

Although not all cases can be attributed to poor technique, the coaching of correct tackle technique and head placement in the tackle remains an imperative prevention focus [43][14]. Given the speed and intensity of rugby union, and despite having all the safe and effective technique knowledge, players frequently find themselves tackling with compromised and unsafe head positions [4]. Risk mitigation in the tackle-contest needs to concentrate primarily on modifying and improving player behaviour on-field [53].

So, how can one enhance players' technique or modify the players' actions during the tackle contest? Coach, player, and referee education is one avenue [6][22][53][62][23], but this knowledge gained does not always translate into practical training of the tackle-contest during coaching sessions [62][2][23][15]. Tackle-training programmes or 'Tackle-school' progressions need to be developed which address aspects such as appropriate resistance-training, conditioning, and muscle development, contact readiness in new players and during match warm-ups, players returning to contact after injury, contact capacity or maintaining contact proficiency while fatigued, and contact efficiency or maintaining high levels of tackle proficiency with minimal effort required to do so [2].

Higher head impact accelerations have been found in non-dominant shoulder tackles, which is likely due to the more passive nature of these tackles, and a lack of head stability and control during contact [1]. One needs to encourage coaches and especially novice players to do more work on their non-dominant shoulder in tackle-training, gaining better head and neck control in the tackle, limiting direct front-on tackles, and adopting a slightly offset-angled approach ($45^0$) to tackling. This will reduce head and neck accelerations and impact forces to the shoulder, head, and neck areas, while remaining effective and improving both tackle technique and player safety [1]. Progressive contact-skill coaching batteries can be introduced yearly in preparation for each new season of contact rugby.

To develop self-efficacy in performing these skills, players must consistently achieve the 'safe and effective' contact technique requirements in practices and matches [45]. This takes time and regular exposure to coaching of these elements.

Contact-skill proficiency scores in tackles, ball carries, and rucks are small to moderate effect sizes higher during training than in matches [63]. Having players who demonstrate good contact techniques during practice sessions does not always guarantee that they will apply the same techniques effectively in matches. Coaches and players are more likely to adopt and implement injury prevention initiatives if there are performance benefits attached to them [58]. Although no relationship was found between players' training and match characteristics, players with higher contact proficiency scores in tackles, ball carries, and rucks were associated with making a higher number of tackles and effective tackles, as well as a higher percentage of tackle breaks and a greater number of effective rucks in a match [63].

Therefore, together with becoming better at performing these skills, the more exposure to safe and effective contact techniques during training in structured and unstructured situations [58], the more this may over time translate and embed the correct skillsets in these players to contest the tackle-situation more effectively and efficiently during matches, and with less risk of catastrophic injury. Additionally, with the new tackle-height laws coming into play, adding drills to rapidly lower body height and to provide a more forward-bent trunk position in contact, would do well to improve tackle performance and mitigate injury risk [56].

## CONTACT POINTS IN THE TACKLE-CONTEST

Fourthly, in catastrophic head, neck, and spine tackler-injuries, knee-contact and head-on contact with the ball carrier were the most prominent impact points. In ball carrier-injuries, these were direct head-player contact with the tackler, and head-ground contact. Head-knee contact in tacklers was more prone to Cat-TBI, which also tends to have proportionately more permanent outcomes. Cat-TBI were in fact mostly found in tacklers. Forced neck flexion in contact, with spinal ligament sprains and bone damage, also has the potential to lead to neck injuries either with or without neurological complications [27].

So, to avoid concussion risk [35], Cat-TBI, or spinal injuries during front-on tackles, one must coach to avoid tackling head-on with the head down and to keep away from the knees especially. In the 1960s to 1980s, tacklers diving headlong into the ground or making head-first contact against the ball carriers' thighs were prominent causes that led to permanent tackler-related spinal injuries. In ball carrier injuries, forced neck flexion injuries were largely due to forceful high tackles from various directions, mostly with an arm around the neck and sometimes throwing the ball carrier to ground [13][14]. Since law changes are not effective in completely stopping players from going headfirst into contact with their heads down, educational strategies have been applied to raise awareness and discourage these types of player actions in the game [16][6][17][18].

## PREVENTING HEAD-CONTACT AND CATASTROPHIC INJURIES

In real-world pragmatic terms and combining head-injury and spinal-injury mechanistic knowledge, it is largely about doing what one can to avoid head-to-head contact, head-to-knee contact, and direct head-on contact, with opposing players and or the ground during the tackle-contest. The remaining preventative focus must be aimed at law changes, fixing tackle- and ball carrying techniques, head placement, and tackle contest execution.

Contact events account for approximately 87% of injuries in English youth rugby, with the tackle contributing to 48-62% of all injuries. Notably, concussions associated with tackling were significantly higher than those for ball carriers. Concussions were the main injury type recorded and contributed 23-28% of all injuries over the age-grades studied [44]. As such, reducing concussion risk during the tackle-contest remains a high priority for all rugby's stakeholders including the sport's governing bodies [45]. Focusing on those areas which protect the tackler will have a sizable impact on lowering overall concussion risk [43].

Tackling, however, forms an essential part of playing the game of rugby, so it would not be pragmatic to make too drastic law changes to this aspect of the game, as this would change its defining essence [13]. Even though the risk of sustaining a catastrophic head, neck, or spine rugby injury may be ranked as 'tolerable' or even 'acceptable' in terms of health and safety measures [49], the lifechanging consequences of these kinds of catastrophic injury events, more than justifies the

heightened focus needed to prevent these events from happening [49][11][12][14]. Therefore, there is a need to consider how best to lower the number of head impact events and concurrently lower catastrophic head, neck, and spine tackle-related injuries in rugby.

Catastrophic injury prevention initiatives in rugby union are not new. At youth level, progressively emphasising and teaching safe and effective tackling and ball carrying techniques must remain a fundamental development focus [13]. Law changes [2][51], particularly in relation to traumatic injuries and high-impact collisions [27], as well as evidence-based injury prevention education on safe contact techniques [64][23][15], have been available for some time now [9]. BokSmart education on safe rugby techniques such as scrums and tackles, has been linked to improvements in targeted catastrophic injury prevention behaviours in rugby players [64]. Such education must include detail on the health and performance consequences of unsafe tackle-injury behaviours, even more so in the female rugby playing population [65].

Law changes can have an immediate impact on injury prevention outcomes, but it is crucial that referees apply these changes consistently to enhance prevention efforts [42]. Nonetheless, to have the best chance of success and transfer into useful injury prevention, while simultaneously improving technical contact-skill and performance, one needs to combine evidence-based education, progressive tackle-technique training, and law changes [44][2]). Also, one must keep in mind that any safety intervention that potentially compromises tackle-performance during match play, will in all probability, not be implemented by players and coaches [45].

Table 3 summarises the various catastrophic risk indicators identified during the period 2008 to 2023, which are more likely to contribute to a catastrophic front-on tackle-related head, neck, or spine injury in rugby played under the auspices of the South African Rugby Union.

It is evident from the catastrophic data presented in Tables 1, 2, and 3, that at the beginning of every season, players might need to spend more time on practising and developing the safe and effective contact skills and techniques related to the tackle-contest, i.e. both tacklers and ball carriers.

Coaches must focus on coaching and reinforcing the same [3][9]. A change in mindset might also need to be made, in that some players during match play, despite having been coached on good tackle techniques, 'do whatever it takes' to bring the player down to ground, and this can happen at the cost of their safety and that of their opponent. Safe and effective technique is not their 'first instinct' [65].

Video recording, identifying, communicating, and intervening with constructive feedback for players who demonstrate deficient contact technique has shown positive results in corrective behaviours observed during training in both dominant and non-dominant shoulder tackles, with skill-retention and improvements evident even one week after the initial intervention [66].

With a relatively lower training age, a later introduction to the sport, and a shorter period available to teach and master the tackle-contest, it is also advised to approach the women's game with a different coaching style. Empowering them by consistently practising safe and effective tackle-contest techniques, with more individualised tackle coaching, and match-specific tackle-practice, is a good place to start. Co-creation of tackle-contest skill-development frameworks between players and coaches might also add value in terms of addressing context-specific alignment and population-specific training needs [67].

*Table 3: Core highlighted considerations for increased risk of front-on catastrophic tackler (T) and ball carrier (BC) related injuries.*

| TACKLER HNS INJURIES | BALL CARRIER HNS INJURIES |
|---|---|
| *Higher risk considerations for the front-on tackler 2008-2023.* **T**<br><br>**Tackle Height:**<br>• Middle-height tackles.<br><br>**Ball Carrier Stance:**<br>• Low position ball carrier entering the tackle.<br><br>**Tackle Height-Ball Carrier Stance interaction:**<br>• Middle-height tackles, with both low and upright positioned ball carriers.<br>• Low tackle-heights, with both low and upright positioned ball carriers.<br><br>**Tackler-Ball Carrier Contact:**<br>• Mostly ASCI, but notable amount of TBI present.<br>• ASCI more in middle-height tackles.<br>• TBI more present in low-height tackles.<br>• Knee-contact and head-on contact.<br>  ○ Knee contact – leads more to TBI.<br>  ○ Knee contact – tackling low positioned ball carriers.<br>  ○ Head-on contact – more ASCI.<br>  ○ Ground contact – more ASCI.<br>• Head-on contact, knee-contact, ground-contact sizable number of permanent injuries.<br>• Tackle technique in middle- and low-height tackles.<br>• Tackle technique with upright- and low-positioned ball carriers.<br>• Tackle technique with knee- and head-on contact. | *Higher risk considerations for the ball carrier tackled from the front 2008-2023.* **BC**<br><br>**Tackle Height:**<br>• Middle-height tackles.<br><br>**Ball Carrier Stance:**<br>• Low position ball carriers entering the tackle contest.<br><br>**Tackle Height-Ball Carrier Stance interaction:**<br>• Middle-height tackles, with low positioned ball carriers, regardless of tackle height.<br><br>**Ball Carrier Contact:**<br>• Mostly ASCI in ball carrier injuries.<br>• All low-positioned ball carriers and falling/diving ball carriers ASCI.<br>• Head-player contact and head-ground contact.<br>  ○ Head-player contact – low-positioned ball carriers and falling/diving ball carriers.<br>  ○ Head-ground contact – low-positioned ball carriers and upright ball carriers.<br>• Most head-player and head-ground contact injuries are ASCI.<br>• Ball Carrying technique in middle-height tackles.<br>• Ball Carrying technique in low-positioned ball carriers and falling/diving ball carriers.<br>• Ball Carrying technique mostly at fault in head-player contact. |

**FRONT-ON TACKLES**

## Limitations

Some injuries had video footage, which added significant value in improving reporting accuracy and verifying the injury-causing mechanisms. However, most injuries did not have video footage of the injuries, and here we had to rely solely on player self-report, referee-reports, witness-reports, and the Serious Injury Reporting forms as mandated by the BokSmart programme's Serious Injury Protocol, standardised Serious Injury Reports, and Serious Injury Follow-up Questionnaires [46].

Even though one could not always corroborate the 'soft' data reporting with video-evidence, the fact that 'rugby people' such as the players, referees and coaches were required to complete these forms, one would have to accept that they would have a certain level of 'rugby knowledge' and understanding of the questions asked in the reports, and would be able to provide believable witnessed or experienced detail as to the mechanism of injury, and the positioning and movements of the tacklers and ball carriers involved.

To determine whether technique errors played a role in the injury outcome, the worded descriptions were used unless video evidence was available. In several of the cases, these worded descriptions could not be used to determine technique errors, and for these we labelled them as 'Unclear'.

Due to various real-world issues, we were not always able to obtain complete information on all questions or items for every case, so we had to exclude a few of these components from the subsequent analyses. These were listed as 'Not provided' in the sections of relevance for transparency purposes.

However, the data sample we had to work with still provided a realistic, accurate, and thought-provoking picture of tackling and carrying the ball into contact and the inherent risk of catastrophic injury.

# Conclusion

From the data provided, it appears that middle-height front-on tackles and low-positioned ball carriers entering the front-on tackle-contest are more risky actions that have a greater opportunity for ending in catastrophic head, neck, or spine rugby injuries [59].

Tackle-height has a significant impact on ball carrier head kinematics [30], and ball carrier concussion risk is almost entirely due to tackles made at the head and neck area [43][41]. However, tackles made below shoulder and chest height remove most of the risk of head and or neck contact being made with the ball carrier [43][53], and therefore, by extension, most concussions, head, neck, and spinal injuries to the ball carrier too. However, controlling the ball carriers' actions has the potential to further reduce injury risk, by affording the tackler sufficient opportunity to target the 'safe zone' where injury risk to both parties is lowest, which seems to lie between the mid-torso [54][53][45] and mid-thigh regions [55][40]. Collectively, it seems that tackles, where the head is either very low (at the knees) or very high (with upright tackles), creates a greater risk of head contact injuries [52][32][53] and catastrophic head, neck, or spine injuries too. For the tackler to target the 'safe zone' and tackle the ball carrier safely and effectively while simultaneously having a sufficiently sized target visibly available to them, the ball carrier needs to be limited in terms of how far they are allowed to bend forward when carrying the ball into contact with the tackler.

What the South African Rugby Union's catastrophic front-on tackle injury data set has shown is that **if one lowers the legal tackle-height downwards, without limiting the degree to which the ball carrier can bend, there will be more tackles made in the danger zone for catastrophic head, neck, and spine injuries.** While the propensity for concussions, HAEs and subthreshold head contacts might be less, if the ball carrier's action is not adjusted or controlled to compensate for this potential risk, there could be undesirable, unintended consequences. If one wants the tackler to tackle lower, then one needs to limit the degree in which the ball carrier can bend before making contact, to allow tacklers to do so safely.

What also stands out is that tackler- and ball carrier technique remains an issue regardless of whether one lowers the maximum legal tackle-height or not. Concurrently, stronger efforts need to be made to ensure that more time is spent on correct head placement, safe and effective tackling and ball carrying techniques in players.

Another item that needs major rewiring into rugby players' 'DNA' is to avoid tackling front-on at the level of the knees. This creates greater opportunity for players to undergo an HIA [52], and potentially sustain Cat-TBI [59], and historically, Cat-TBI has proportionately more permanent and fatal outcomes than ASCI [3][48]. Cat-TBI is not uncommon in collision sports such as rugby union. Head trauma in sport contributed to 20% of all fatalities registered in Japanese student athletes. Rugby and judo were the two sports with the highest head trauma fatalities [68].

It must be clearly understood that changing the legal tackle-height is aimed at reducing (not removing) the risk to both tacklers and ball carriers of sustaining head-contacts, concussions, and having to perform HIAs. Rugby is a collision-based game with little to no protective equipment involved, so it is in the players' best interests to be informed of the risks, and be conditioned and appropriately prepared to participate as safely as possible in the sport and gain the full benefits of playing rugby with less risk involved [5][6]. As with any contact-collision sport, we may never fully eliminate all risk of concussions or injuries to the head, neck, and spine in rugby union [24], but we can certainly reduce it and make participation terms more acceptable to current and future players.

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