Smart Mouthguards and Contact Sport: The Data Ethics Dilemma

Introduction

This year's Six Nations tournament brought with it renewed attention to the potential long-term health impacts the sport may have on its players, specifically concerning head and brain trauma. Head injuries and the impact thereof have been an issue of increasing concern in 'high contact sports' such as rugby union/league and American football over the past decade, with repeated head traumas strongly suspected of halting the on-pitch careers of players like Nic Berry,[1] Dominic Ryan,[2] and Harry Seward.[3]

Indeed, on-pitch brain injuries have potentially curtailed enough player's careers that over 375 former rugby union, rugby league, and football players have taken legal action against their respective sport's governing bodies for "failing to take reasonable action to protect players from permanent injury caused by repetitive concussive and sub-concussive blows."[4] In other words, according to those players, the governing bodies did not protect said players from the long-term health implications of traumatic head injuries, and such a claim is not without scientific backing; a recent landmark paper established a link between the length of a (rugby union) playing career and the risk of Chronic Traumatic Encephalopathy (CTE), a condition leading to dementia.[5]

With player health, legal liability,[6] and the various sports' representative bodies' reputation for promoting safety on the line, there are continuous efforts to better monitor, predict, prevent, and remedy player injuries. This often takes the form of structural and procedural changes regarding how the game is played or what happens when a head trauma may have occurred, with such measures looking to either reduce the number of dangerous collisions (e.g. the outlawing of high or reckless tackles) or, and of interest here, better detect and deal with any collisions that may have a severe impact (e.g. World Rugby's Head Injury Assessment Protocol (HIA)).[7]

One recently introduced monitoring method is 'instrumented' or 'smart' mouthguards. Beyond fulfilling a standard mouthguard's function—protecting one's teeth from the forces they might receive during play—smart mouthguards are embedded with sensors. These sensors measure collision force and frequency, thus providing teams "insight into head acceleration event frequency and magnitude during training and match-play."[8] If accurate, collected data, which will be held on an unspecified central server, should enable match officials, team doctors, and coaches to understand better the forces players experience during games and, rather than simply relying on observations and self-reports, provide empirical data on what happens during play and training. This means that even if a tackle is missed or doesn't appear serious, the smart mouthguards will register anything deemed excessive and alert officials that a player may need to come off the pitch for an assessment—as was the case with George Turner during this year's France v Scotland Six Nations game.[9] This is particularly useful as, according to World Rugby's Chief Medical Officer, one in six concussions present after a match ends.[10] So, currently, a player may become concussed during a game but be asymptomatic. This is hazardous not only because of the risks associated with an undiagnosed concussion but also because of the likelihood that, if not removed from play, that player will be subject to subsequent collisions, which may compound any damage.

Smart mouthguard data could be useful not just in the short term but over time, as a collision profile for individual players can be built covering a month, a year, or, in the long term, an entire career. This would

be an incredibly useful resource not only for match officials and team managers but also for any professional providing healthcare to players, be they still active in the game or retired. In other words, with more data comes a better understanding of player health and the events that may lead to eventual injury or disease, both in the immediate and distant future. A (perhaps cynical) concern related to this long-term health mapping is that clubs may consider such a trauma profile in player valuation decisions; if a player has a history of concussions, this might impact the terms and potentially even the likelihood of securing future contracts.

Beyond individual player monitoring, the data these devices collect could be used to identify dangerous training practices and procedures that might otherwise go unnoticed or appear standard. If data indicates that impacts which exceed acceptable levels often occur when players are under the stewardship of a specific member of training or managerial staff, this could indicate a red flag worthy of investigation and, if necessary, remediation. This could result in new forms of legal responsibility being placed upon clubs and managerial staff to take steps to recognise and address hazardous forms of training or play—however, addressing this issue in full sits outwith the scope of this paper. But, briefly, determining the exact parameters of this duty, and the threshold of tolerable risk would be a major task, and one which would undoubtedly involve gathering expert evidence from both medical and rugby bodies.

While we welcome the move towards a better understanding of the potential harm that players may experience, introducing a new avenue through which information about player performance and health can be collected brings several areas of ethical concern absent from traditional mouthguards. While not all of these concerns can be covered here, there are four which we believe to be of particular note: device and data efficacy, player choice, the inherent issues of this data's existence, and the harmful consequences of this data's usage and exposure.

Device efficacy and accuracy

The justifiability of smart mouthguards' inclusion in rugby (as well as other sports') safety practices relies upon their effectiveness at fulfilling the task they are designed for. Suppose they can only collect corrupt, incomplete, or inaccurate data. In that case, the envisioned benefits of using them will not manifest, and, in short, World Rugby's initial €2 million investment will have been wasted when much cheaper and ethically less contentious standard mouthguards will continue to be used.

Obviously, this concern is not limited to instrumented mouthguards, as all such devices need to fulfil their roles to justify their use. A pertinent example of this teleological failure can be found in American Football. In 2015, the National Football League (NFL) suspended the use of helmet-based concussion sensors, which they had hoped would provide usable data regarding head trauma.[11] The reason for the NFL's smart helmet suspension is simple: it didn't work, and the data obtained failed to satisfy the requirements of match doctors and officials. Interestingly, however, since 2019, the NFL has been using smart mouthguards for research.[12]

Whether smart mouthguards will meet expectations and produce valuable data is yet to be seen—World Rugby themselves have acknowledged the "relatively new and evolving nature of the technology" and have committed to reviewing their specifications for instrumented mouthguards every six months.[8]

In reviewing the utility and appropriate specifications, the device and the data produced will need to be considered across both analytical and clinical domains. To satisfy the requirements for analytical validity, the sensors must be proven to be technically accurate and reliable. Research by Field *et al.*, published in 2023, noted that instrumented mouthguards have "yet to be validated in professional rugby union" and their (pilot) study suggested that there may be analytical shortcomings when these devices are used alone: "biomechanical instrumented mouthguard approaches alone without video verification may be prone to false-positive readings and are limited to their predetermined filtering algorithms and trigger thresholds."[13] Powell *et al.* have also indicated that there are issues with existing devices miss-estimating head acceleration kinetics.[14] To establish clinical validity, one needs to show that the devices are not only technically accurate (i.e., they avoid false negative/positive results) but also that they can accurately identify or predict the clinical issues of interest. Here, this would require that the sensors be effective not only in identifying the fact of a collision but also in indicating when this is likely to result in the damage that underpins concussion. Finally, it is important to establish that these devices improve upon existing means of identifying/evaluating concussion (clinical utility). Suppose these devices do little to advance the identification and effective treatment of those players who experience collisions during rugby matches. In that case, it becomes harder to justify any of the data risks associated with using these sensors.

Existing studies[15–17] and the limited *in situ* application indicate that they at least help officials detect head acceleration events above a certain magnitude during play. And, while testing in the lab is a far cry from a continuous, real-world on-pitch application, there appears reason to be tentatively optimistic on this count—though questions remain about the analytical validity of the devices when used in isolation.[13,14] Matters of efficiency and accuracy remain a live issue in the ethical assessment of instrumented mouthguards. So, for the remainder of this paper, we will assume that the data collected accurately represents what is happening on the pitch and within the player's skulls.

Player choice

From January this year, World Rugby mandated that all elite players either wear smart mouthguards in both matches and training or become subject to the "recognise and remove" policy unless they have had an exception approved by their Team Manager, team Doctor, or World Rugby's Science and Medical Manager. Under the 'recognise and remove' policy, if a player not wearing a smart mouthguard sustains a "head impact that could be a concussion they will automatically have to sit out the rest of the game, rather than undergoing the in-game head impact assessment."[18] Therefore, players who do not possess a medical exception can, technically speaking, reject the use of a smart mouthguard and the collection of data accompanying its use—instead submitting to this policy. We suggest, however, that players are likely to face substantial pressure to concede to wearing a smart mouthguard so that they are not unnecessarily removed from the game. Star players may feel the pressure particularly strongly as teams look to avoid having their players unnecessarily removed from the field by match officials or medical staff. Conversely, those players whose positions within the team are less secure will also experience pressures to comply with the use of smart mouthguards as they seek to avoid giving their current club additional reasons to let them go or replace them with more compliant players.

Further, given the potential consequences of a player's decision to decline to wear a smart mouthguard for the wider team, it is not unreasonable to hypothesise that this technology's usage may become a contractual requirement. As noted by McChrystal, in the context of American Football:

> *Each of the standard player contracts contains some form of language stating that the player agrees that he will remain in top physical condition and is physically able to perform up to the best of his abilities. Due to the physically demanding nature of professional sports, teams require players to represent that they are in top physical condition, and the teams assert the right to examine players to assure themselves that this is so.*[19]

What 'examine' means in this context is somewhat opaque, but it is not a stretch to think that it could include monitoring player health and performance via a smart mouthguard. If this were to become the norm—that smart mouthguards' usage became so widespread as to be not only normal but contractually expected and enforceable—one would have to question whether players would have any meaningful ability to decline consent while maintaining their career (and thus, whether any 'consent' could be seen to indicate a meaningful expression of the player's autonomy).

Additionally, the widespread adoption of this technology might impact game performance as non-compliant players may be more hesitant to make tackles if they believe they are at an increased risk of being removed by match doctors under the recognise and remove policy compared to smart mouthguard-wearing players. While player safety must be the principal concern, apprehensions regarding player performance, given the remarkable quantity of resources that go into making professional sports what they are, cannot be ignored.

So, as things currently stand, players can theoretically use or refuse smart mouthguards. Nevertheless, the potential implications of picking one option over the other must be articulated clearly for any such choice to be meaningful. As the technology is rolled out and pressure to conform to increased monitorisation grows, the window for choice will likely contract.

The (embodied) nature of data tracking

Beyond the issue of player choice comes a broader concern regarding the data's existence. Professional athletes are subject to all kinds of health and fitness-related data tracking both in and out of training and during matches, from GPS-enabled bras which capture key performance indicators, including running speed, step balance, and stress loads[20] to the requirement that those competing at national or international levels always make themselves available for anti-doping testing.[21] Thus, it is reasonable to question whether adding an additional tracking method can be considered significant, given the biometric tracking loads under which athletes already labour. The elements of this concern can be separated into (roughly) two separate categories: the method of data collection and the nature of the collected data.

Concerning smart mouthguards, the physical data collection method appears to be minimally intrusive, given that players already wear mouthguards to protect their teeth from the extreme forces to which they may be subject during play and training. Including sensors in the mouthguards should create little to no

comparative discomfort, so the method via which the data is collected, at least in this instance, is of little concern.

The nature of that data, however, is a different story. One can argue that digital intrusions upon bodily privacy and integrity represent a unique and significant form of intrusion, regardless of the physical invasiveness of the device. The realities of the modern world mean that protecting bodily integrity requires that we take seriously the need to ensure self-determination over not only our *physical* boundaries but also our digital ones and recognise that harms in the digital world are no less 'real' or 'significant' than those in the offline world.[22] Where data is extracted from a person without their consent or on the basis of consent gained only as a consequence of coercion, one could argue that this amounts to a harmful violation of bodily integrity. This points to the fact that we must take potential data arising from this new intervention in rugby seriously, just as we do the physical harm that these mouthguards are trying to prevent. This does not necessarily mean that each risk of harm is of equal severity, but rather that neither can be ignored.

One could argue that all forms of biometric tracking of athletes have ethical implications; therefore, the introduction of another form of biometric tracking (and one that gathers information with longer-term health implications) compounds the ethical significance of all biometric tracking of athletes rather than being undermined by the fact that such monitoring already takes place.

Data usage and exposure

Smart mouthguards' usage in contact sports like rugby also raises ethical (and potentially legal) concerns regarding who holds any generated data, who has access to it, and how it might be used, especially because of the known and, in some cases, suspected, association of head trauma with serious, incurable health conditions, like CTE.

World Rugby's HIA Protocol[7] states that data will be used by two principal parties. First is the rugby teams themselves. Second, if player consent is given, is World Rugby. According to the protocol, this second group will use the data in an aggregated, de-identified form for research purposes. The protocol specifies that the data will be held on GDPR-compliant servers, which is undoubtedly a reassuring step. However, it is important to note that questions have been raised about the practical sufficiency of both the GDPR framework[23] and the process of data de-identification[24] to keep data safe within the modern (big) data landscape.

If a player's profile indicates a high occurrence of excessive head trauma, this could lead any parties with access to that data to adjust their behaviours and attitudes with regard to that player. For example, the existence of data linking players to a quantifiable heightened risk of life-impacting conditions may have implications for their access to some forms of insurance later down the line, such as life and health insurance. In other words, if insurance companies access this data, they may feel obligated to adjust the rates they offer certain players depending on that individual's impact profile or refuse to provide any cover at all (this echoes concerns which have been raised about the relationship between fitness trackers and insurance more generally).[25] While one might argue that this is an appropriate course of action for an insurance provider—that is, providing policies at a higher premium to higher-risk individuals—it is legitimate to question what data should and should not be used to inform such decision-making and

whether companies should have access to it. Now, we must note that, currently, such companies do not have access to this data. But that does not mean they will never have access. One way to address this concern in the short-medium term, particularly as the science in this area remains relatively new and continues to develop, could be to emulate the approach that some jurisdictions have taken regarding the use of predictive genetic testing by insurers and work with the insurance industry to create a moratorium on the use of this biometric data for (the majority) of insurance purposes.[26,27]

While this may not be an immediate concern, as the technology's novelty limits such dataset's size and usefulness, over the coming decades and the course of a player's career, a complete data set might paint a grim picture of the chronic load under which active or former players function. The concern is of particular significance in the context of American Football and in other sports that are predominantly played in countries with a private healthcare system where care and treatment access is reliant on insurance provision.

In addition to the potential harms of non-sporting bodies gaining access to this data, we also have some apprehension about the more immediate practice of data sharing between sporting bodies. Presently, World Rugby and the NFL share health data with each other and others.[12] The reason for this is simple: a more extensive data pool will likely provide more robust findings. Thus, collating data across national and international sporting bodies could help prevent harm and improve policy quicker than if each body siloed its resources. However, sharing data often brings a surrender of control as the intentions of the other body and the consequences of offering data access can never be fully known. Similar issues regarding the challenges of seeking consent for data-sharing without a clear understanding of potential future uses have been well-documented in other contexts, such as biobanking.[28] Also, if it is not made clear to those wearing the mouthguards that their data may go beyond the stewardship of their immediate overseeing sporting body (World Rugby for rugby, for instance), then questions of autonomy again come into play.

Beyond sharing individual data, collective concerns can also be raised about the generation and sharing of population-level data (the population here being elite rugby players). This will remain a relatively small population, and there is a clear risk of re-identifications even if the population dataset is anonymised or pseudo-anonymised.

Conclusion

All this is not to say that we are opposed to introducing smart mouthguards; far from it. We welcome the move towards better understanding the potential harm that players of any sport may experience and mitigating the impact thereof. Nevertheless, the widespread implementation of smart mouthguards—which collect data—is not without concerns, and it is important to identify and address these as soon as possible. Failing to do so could not only risk the mistreatment and misapplication of player data but also jeopardise the acceptability of a novel health monitoring method which has the potential to prevent long-term debilitating disease. In other words, if we use these devices, we must take them seriously and attend to their potential risks and benefits.

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