

Cognitive Load Monitoring of Elite Rugby Union Medical Teams During International Matches: Feasibility Study

Emma Howie

ehowie@ed.ac.uk

University of Edinburgh

Iain Murray

NHS Lothian

Andrew Murray

DP World Tour

George Gauntlett

Bath Rugby

Roger Dias

Mass General Brigham

Stephen Wigmore

University of Edinburgh

Richard Skipworth

University of Edinburgh

James Robson

Scottish Rugby Union

Steven Yule

University of Edinburgh

Research Article

Keywords: Cognitive load, Rugby union, sports medicine, performance

Posted Date: September 22nd, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10894997/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License. [Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

Pitch-side medical professionals must recognize and treat injuries under pressure; however, the role of cognitive load in their performance remains largely unexplored.

Hypothesis/Purpose

This study investigated the feasibility of using wearable sensor technology to capture objective cognitive load data in real-time and identify contextual stressors associated with changes in cognitive load during international rugby matches.

Study Design

Prospective, observational feasibility study.

Methods

Frontline medical practitioners ($n = 3$) from an international rugby team wore wrist sensors to record electrodermal activity (EDA) during five matches. Data were integrated with match video to identify medical and non-medical stimuli.

Results

Objective cognitive load measurement was feasible with no missing data. Higher cognitive load (measured via EDA) was observed during non-medical events compared to medical tasks. Significant differences in load were found based on match location ($p = 0.006$) and opponent ($p = 0.025$).

Conclusion

It is feasible to monitor the cognitive load of sports medics during live matches. Non-medical stimuli and away matches induced the largest load spikes, suggesting these factors may impact clinical performance and player safety.

BACKGROUND

Evidence detailing the long-term negative health effects related to head injuries, concussion and chronic traumatic encephalopathy in rugby union has dramatically accumulated in recent years[1, 2]. Detection of injuries relies on sports medical professionals performing at an elite level, with enhanced awareness for early detection of head injuries. Technology can augment this performance, with the use of smart mouthguards and video analysis aiding recognition of otherwise undetected injuries[3]. At present, research in elite sports mainly focuses on the athletes, but athletes alone are not fully responsible for successful performance, which relates to either the actual athletic performance or the delivery of athlete care[4]. There are few studies investigating “the team behind the team”[5]: the support staff that integrates medical, sports science and management roles into an interdisciplinary model. The multi-disciplinary support team (MDT) includes coaches for strength, conditioning, and tactics, nutritionists, physiotherapists, physicians, sports scientists, data scientists and managers, and may be as vital for championship-winning performance as the competing athletes[6]. The role of the support team is to optimise the team's performance by ensuring good clinical outcomes, player health and wellbeing. Dzendrowskyj states that “failure to recognise and address [non-technical] skills accounts for the vast majority of errors in modern medicine”[7], and sports medical professionals are unlikely to be immune to this [8, 9]. Indeed, effective communication and teamwork have been associated with reduced injury risk in sports[10, 11].

Cognitive load (CogL) is a finite mental resource that humans leverage to meet task demands[12]. Effective CogL management, an important non-technical skill, is increasingly recognised as a critical component of human performance, with growing attention to its role in high-stakes environments such as sport and surgery[13]. If task demands outweigh available cognitive resources, this can lead to fatigue, error, stress, impaired skills and the inability to complete a task to required standards with resulting implications for performance and outcomes[14]. For example, cognitive overload can lead to “choking” at crucial moments in a match. This has been studied in players but not in sports medical professionals[15]. These highly-trained medics are under immense pressure on matchday and are subject to several demanding situations with associated performance-related and organisational stressors[6, 16]. Chronic stress can affect an individual's CogL by triggering the hypothalamic-pituitary-adrenal axis, releasing cortisol that impairs cognitive function. Prolonged activation of this stress response system may impact clinical performance by impairing memory, attention, and decision-making abilities[17]. There are a handful of studies on stressors in the sporting MDT[18], including tactical coaches[8, 19], physiotherapists[20] and strength and conditioning coaches[21]. To our knowledge, none of these studies utilise established quantitative methods to measure CogL.

CogL can be assessed through subjective self-report tools (e.g. NASA-TLX[22]), and objective physiological measures (e.g. heart rate variability (HRV) and electrodermal activity (EDA) [23, 24]. While subjective methods offer valuable personal insights, they are often retrospective and impractical during real-time clinical activity. A technological advance is the use of digital physiological sensors to measure CogL, which can provide real-time, automated, and objective time series data as a proxy for an individual's CogL. However, despite the potential for enhanced insight from cognitive monitoring, to our knowledge, the use

of these devices within professional rugby medical teams remains unexplored in the scientific literature. By integrating physiological data with broadcast footage, we sought to investigate CogL and identify opportunities for targeted interventions to reduce strain and enhance performance.

To inform decisions regarding the development, selection, and implementation of CogL sensors in elite sport settings, we conducted a feasibility study focused on pitch side medical teams in international rugby. The primary objectives were: (i) to determine the feasibility of capturing objective CogL data in real-time, and (ii) to identify and quantify contextual stressors associated with changes in CogL.

METHODS

A prospective, observational study using repeated measures was conducted as a feasibility study following the CONSORT 2010 extension for Pilot and Feasibility Trials [25] and STROBE guidelines [26](supplemental material). Frontline medical practitioners from one international rugby team were recruited before the commencement of the study. The participants were studied during four matches from the 2023 Six Nations Rugby tournament and one match from the Summer Nations Series. A proxy for CogL was measured via the participants' EDA using the Empatica E4 (Cambridge, MA, USA) sensor – a lightweight, wrist-watch style device which gathers data continuously[27]. Additional data sources included (i) match video to review medical assessments and in-match events (e.g. tries, disciplinary action), and (ii) retrospective commentary from medical staff to elicit contextual information.

Key variables of interest included: the opponent, location of the match (i.e. home or away), match result and intra-match stimuli. The intra-match stimuli investigated were organised into four categories:

1. Medical events (e.g. head injury assessment, on-pitch musculoskeletal examinations, decisions to remove players)
2. Scoring events (i.e. tries, conversions, penalty kicks at goal)
3. Set match plays (i.e. scrums, lineouts)
4. Disciplinary action (i.e. red card, yellow card)

Data transformation and statistical analysis

Raw EDA data underwent continuous decomposition analysis in Ledalab software (Version 3.4.9)[28]. This process breaks EDA into the reactive, phasic skin conductance response (P-EDA), and the baseline, tonic skin conductance level (T-EDA) components. Statistical analysis was carried out using R statistical software (Version 4.3.3). Shapiro-Wilk normality testing demonstrated a non-normal data distribution, as is common with EDA data[29]. Descriptive and analytical statistical methods were utilised, specifically utilising the Finalfit package [30]. EDA traces were visually compared to investigate coordination and synchronisation[29].

Using standard techniques, the decomposed phasic and tonic EDA were standardised for individual differences to allow for comparison. Range-corrected scores were used for T-EDA, whilst the proportion of maximal response was used for P-EDA. THE minimum and maximum responses were taken as the individual's highest EDA level across all matches[29].

Equity, diversity and inclusion statement

The study population was limited to the medical practitioners from one international rugby team.

Patient and Public Involvement Statement

Patients (athletes) were not involved in the planning or execution of the study, but medical personnel with experience in pitch side sports medicine were consulted.

Ethics

Ethical approval

was granted by research and ethics committee at the University of Edinburgh medical school (22-EMREC-060). Participants gave informed consent before data collection commenced, with opportunities for clarification of queries. All experiments were performed in accordance with relevant guidelines and regulations, and the study was conducted in accordance with the principles of the Declaration of Helsinki.

RESULTS

Three participants (team doctor, physiotherapists) (n = 3) participated in four Six Nations matches. One participant additionally participated in one further international match. The range for standardised EDA data is 0–1(μ S) throughout, with lower EDA representing lower CogL. CogL through EDA measurements will be sub-categorised into the following divisions:

- Low: 0 to 0.33 μ S
- Moderate: 0.34 to 0.66 μ S
- High: 0.67 to 1 μ S

The results demonstrate that it is feasible to use innovative wearable devices to measure pitch side sports medical practitioners' CogL in real-time, with the devices consistently measuring EDA with no missing EDA data.

Coordination of cognitive load

Visual inspection of CogL measured via P-EDA identified high synchrony of peaks and increases in activity at similar times of matches between participants, **Fig. 1**. There were high peaks in the period prior to the match commencing, with the amplitudes decreasing towards 1st half kick-off. Notable increases in the amplitude (height) of phasic activity peaks were observed during the 15-minute half-time period, compared to activity during the 1st and 2nd halves.

Match section

Aggregated descriptive data for each match period across all five matches is displayed in Supplemental Table 1. Overall, reactive P-EDA activity was low, whilst background T-EDA activity was moderate. T-EDA was highest during the 1st Half and decreased throughout the match, whereas P-EDA was highest during half-time. Regression results are shown in Supplemental Table 2. Changes across either time period were not statistically significant. There were significant differences between some participants, with Participant 1 having the highest mean P-EDA. Participant 1's P-EDA fell into the moderate category compared to participants 2 and 3.

Key variables

Table 1 outlines descriptive and analytic results for three key match variables: result, location, and opponent. CogL was responsive to match location ($p = 0.006$). T-EDA activity was highest during the away match, whereas P-EDA activity was lowest. There was generally no significant difference in CogL depending on the match result, however, individuals were slightly more reactive, as demonstrated by phasic EDA activity results, when losing (mean range $0.002-0.376$), which was significant when considering other variables ($p = 0.048$). The match opponent had a significant effect on P-EDA activity ($p = 0.025$).

In-match stimuli

Tables 2 and 3 outline descriptive and analytic P-EDA data to evaluate the participant's response to each event. P-EDA was low across all events but dependent on whether the match was home or away ($p = 0.003$). Injury assessments induced the lowest CogL of the in-match stimuli, but the differences were not significant.

DISCUSSION

This study demonstrates that it is feasible to gather metrics representing CogL on medical team members via wearable sensors during international rugby matches. We found that several factors influence the CogL of pitch side medical practitioners. Providing medical attention to players did not appear to impact CogL.

Factors identified from this study that altered CogL included who the opponent team were, and if the match was away from home. Winning decreased CogL, but this was dependent on the opponent. Working away from home brings challenges such as the potential inconvenience of being in an unfamiliar environment, unfamiliar colleague medical professionals (e.g. independent doctors responsible for HIAs), and even language and cultural differences. There is also potential fatigue from travel and the variability of available resources away from the home workplace.

The team displayed coordination of changes to their physiology, demonstrating a shared mental model. Medical assessments did not increase P-EDA, indicating that medics were not more reactive during medical activities, likely due to their regular, systematic pitch side training and focus on the assessment rather than ongoing play. Overall, this may indicate (i) scoring plays reflecting situations beyond their individual locus of control cause spikes in CogL, (ii) experts free up cognitive resources during medical tasks, or (iii) EDA may better reflect sympathetic activation (stress) and arousal rather than working memory utilization. These results may vary in a more heterogeneous cohort with varying levels of experience.

Several internal and external stressors can contribute to a medic's match-day performance. Internal stressors are the stressors an individual places on themselves, e.g. performance anxiety, but external stressors are caused by factors outwith the individual, who do not control their occurrence, e.g. injuries, weather, and referee decisions [31]. An individual's background and demographics may influence their experience with stressors including coping mechanisms [32]. Figure 2 illustrates stressors that may impact sports practitioners' CogL identified in the present study. Examples of stressors facing these team members during play include injury assessment, communication, the influence of other players, team members and even spectator crowds - which all add pressure to "get it right" regarding medical team decision making [18, 20]. In this feasibility study, reactive P-EDA activity was highest during half time, corresponding to an increase in activity reported by the participants, where they can be expected to support and provide input into multiple individuals in a narrow time window, often whilst engaged in a team discussion involving both players and support staff. An increase in this reactivity can also be seen before kick-off, possibly representing increased cognitive activation and anticipation about the forthcoming match. Reactivity then decreased towards kick-off, corresponding to a moment of calm reflection during the national anthems. While some sideline decisions are supported by rules and frameworks, such as head injury assessment, on-pitch decision making can be influenced by these stressors, such as uncertainty over injury severity and perceived or actual pressure from a player to remain on the pitch and continue playing. Although there has been little specific investigation into factors that affect sports medical practitioners, similar stressors likely reach across professions within sports. For example, Unkelbach and Memmert (2010) found that noise affected referee decision-making [33], specifically relating to the home advantage. This may contribute to practitioners' CogL when working away from home, where the crowd noise is typically louder for the opposition team.

Sport, like traditional healthcare, is a complex, sociotechnical, organisational system. Athletes and support staff “do not operate in a vacuum in sport but instead in a highly complex social and organisational environment which can exert a major influence on them and their performances” and impose numerous demands[34]. Therefore, we can look to human factors approaches, such as CogL measurement, to advance knowledge of the interactions between sports professionals and the system they work in and how this impacts performance. CogL research across medical specialities is increasing, with many systematic reviews exploring the topic, but little research looking at pitch side practitioners has yet been carried out [23, 24]. Current sports human factors and CogL research has focused on the athletes [13, 15, 35], referees [33, 36, 37] and coaches[8, 38], and qualitative research rather than objective measures of load.

Clinical implications

Cognitive overload, where task demand outstrips available resources, can impair the successful execution of a task[12]. Increased CogL has been associated with medical error, including diagnostic errors or treatment errors, such as incorrect medication administration in cardiac surgery[39]. CogL impacts both technical and non-technical clinical skills; overloaded individuals will be less sensitive to task-related information, have poor visuomotor skills, and suffer impaired attention, affecting situation awareness and decision making [17, 23]. This has clear implications for the safety of athletes and sports team, and the wellbeing of medical practitioners. There is currently no standard or defined level of CogL that is considered too high. In the sports medicine context, cognitive overload may lead to an event requiring urgent assessment being missed or incorrectly perceived, leading to potential errors that delay care and affect player safety. It has been found that coaches felt that increased stress impacted their performance, focus and ability to make decisions [8], and similarly would apply to medical practitioners. Additionally, like athletes, medics can develop coping mechanisms, maximise their ability to focus their attention on the task and be less aware of inappropriate distractions[34, 40]. Identifying specific stressors that systematically increase CogL can allow for targeted interventions to reduce their impact. Although not investigated during this study, medics and coaches share a single radio channel for communications, which can lead to distraction and increased CogL during high-intensity periods of play. Having the ability to separate these into game-related and medical-related channels could prevent external pressure and reduce irrelevant communication traffic whilst medical staff are making critical decisions about players.

Limitations

Despite confirming the feasibility of using wearable sensors for real-time data capture, this study had several limitations that should be acknowledged. The sample size was small in terms of both participants and number of matches, although it included all pitch side medical team members across multiple international matches for one sports team, offering rich, context-specific data. Data should be reviewed in the context of this feasibility study. The practitioners were all highly experienced, male, and from one country and may not be more broadly representative of medics working at other levels of the same sport, in different geographies, with different demographics, or across different sports. Although data collection was feasible with this cohort, the ability to conduct research on a larger cohort or in other settings may be influenced by factors including variations in demographics, organisational culture and institutional or governing body support.

The frequency of some in-match events (e.g. red cards) was low, as expected by historical trends. World Rugby states the average number of cards given in one Six Nations match is one[41]. The study did not set out to assess the quality of medical performance such as decision making and therefore cannot conclude the effect of detected changes on performance. Baseline EDA data were not collected whilst participants were at rest, which would have provided information on each participant's response level (hyper- or hypo-) for comparison [29]. Nevertheless, the physiological data captured were sufficient to detect meaningful changes in physiological response to match stimuli. The retrospective review of match video was limited to TV broadcasts, which may not have captured the details of every medical event, and did not capture off-pitch actions of the medics in the period before on-pitch medical assessment. The presence of a researcher in-situ at pitch side for in-person data collection or bespoke video recording of the medical team may have generated higher quality data sources, but was outside the scope of this project. Future studies would benefit from in-situ data collection which could allow: a) capture of all medical events on video reliably, b) extending observations of medic behaviours before and after medical events, and c) providing the opportunity to directly collect participants' perspectives e.g. via NASA-TLX[22], or exit interviews regarding peak activity immediately after the event.

Abbreviations

Abbreviation Definition

CI Confidence interval

CTE Chronic traumatic encephalopathy

EDA Electrodermal activity

P-EDA Phasic EDA (skin conductance response component)

T-EDA Tonic EDA (skin conductance level component)

HRV Heart rate variability

MDT Multi-disciplinary team

NASA-TLX NASA Task Load Index

SCR Skin conductance response

SD Standard deviation

STROBE Strengthening the Reporting of Observational Studies in Epidemiology

CONCLUSION

The goal of cognitive load assessment for sports medics is to enhance player safety by identifying contextual risk factors of impaired decision-making that may affect medics' efficacy in injury prevention. By using wearable sensors for the objective measurement of CogL, combined with video footage of team performance and candid reflections of participants, we can target areas for intervention to increase performance and reduce sources of unwanted CogL. In the present study, we found that it is feasible to use wearable sensors combined with match-day footages. All in-match stimuli were associated with increased CogL, with non-medical stimuli and certain external stressors inducing the largest CogL spikes. Future research could consider extending this work to medical teams in domestic professional leagues such as the English Premiership, French Top 14, or the United Rugby Championship. These settings offer a broader range of contexts, participants and matches, allowing for richer and more generalisable data. Additionally, measuring the CogL of the team coaches could be considered to evaluate synchronisation between the medical and coaching teams in enhancing player safety and optimising on-pitch performance.

Declarations

Ethics: Ethical approval was granted by an academic research and ethics committee (22-EMREC-060) at the University of Edinburgh. Participants gave informed consent for participation and publication.

Competing interests:

The authors report there are no competing interests to declare. The authors do not disclose any relationships to technology companies or devices described in this study.

Clinical trial number

not applicable

Funding:

No specific funding was in place for this study. EH had funding from the Royal College of Surgeons of Edinburgh and Edinburgh Surgery Online for separate projects, but used the equipment acquired through these for this project.

Author Contribution

All authors have made substantial contributions to the study itself, including aiding in the drafting of this manuscript. All authors have approved the final version for publication and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. Term Definition Conceptualization AM, IM Methodology EH, SY, RS, IM, AM, JR Software EH Validation EH, JR, GG, SY Formal analysis EH Investigation EH, JR Resources EH, SY, SW, GG Data Curation EH, JR Writing - Original Draft EH, GG, SY Writing - Review & Editing EH, IM, AM, RS, SW, GG, JR, SY Visualization EH Supervision IM, AM, RS, SW, SY Project administration EH Funding acquisition EH, SY

Data Availability

Data are not publically available but are available from the corresponding author on reasonable request.

References

1. Kemp SP, Hudson Z, Brooks JH, Fuller CW. The epidemiology of head injuries in English professional rugby union. *Clin J Sport Med*. 2008;18(3):227–34. <https://doi.org/10.1097/JSM.0b013e31816a1c9a>.
2. Stewart W, Buckland ME, Abdolmohammadi B, Affleck AJ, Alvarez VE, Gilchrist S, et al. Risk of chronic traumatic encephalopathy in rugby union is associated with length of playing career. *Acta Neuropathol*. 2023;146(6):829–32. <https://doi.org/10.1007/s00401-023-02644-3>.
3. Liu Y, Domel AG, Yousefsani SA, Kondic J, Grant G, Zeineh M, et al. Correction to: Validation and Comparison of Instrumented Mouthguards for Measuring Head Kinematics and Assessing Brain Deformation in Football Impacts. *Ann Biomed Eng*. 2021;49(3):1119–20. <https://doi.org/10.1007/s10439-020-02701-y>.
4. Speed CA, Roberts WO. Innovation in high-performance sports medicine. *Br J Sports Med*. 2011;45(12):949–51. <https://doi.org/10.1136/bjsm.2010.075374>.

5. Arnold R, Collington S, Manley H, Rees S, Soanes J, Williams M. The Team Behind the Team: Exploring the Organizational Stressor Experiences of Sport Science and Management Staff in Elite Sport. *J Appl Sport Psychol*. 2019;31(1):7–26. <https://doi.org/10.1080/10413200.2017.1407836>.
6. Wagstaff CR. Organizational psychology in sport: An introduction. In: Wagstaff CR, editor. *The organizational psychology of sport: Key issues and practical applications*. (pp. New York, NY, US: Routledge/Taylor & Francis Group, xvii; 2017. pp. 1–7.
7. Dzendrowskyj P. Human factors in sports medicine (Part 1) - BJSM blog - social media's leading SEM voice. *BJSM blog - social media's leading SEM voice*. 2019.
8. Frey M. College coaches' experiences with stress—problem solvers have problems, too. *Sport Psychol*. 2007;21(1):38–57. <https://doi.org/10.1123/tsp.21.1.38>.
9. Flin R, O'connor P, Crichton M. *Safety at the sharp end: a guide to non-technical skills*. CRC; 2017.
10. Ekstrand J, Lundqvist D, Davison M, D'Hooghe M, Pensgaard AM. Communication quality between the medical team and the head coach/manager is associated with injury burden and player availability in elite football clubs. *Br J Sports Med*. 2019;53(5):304–8. <https://doi.org/10.1136/bjsports-2018-099411>.
11. Huffman S, Crundall D, Smith H, Mackenzie A. Situation Awareness in sports: A scoping review. *Psychol Sport Exerc*. 2022;59:102132. <https://doi.org/10.1016/j.psychsport.2021.102132>.
12. Howie EE, Dharanikota H, Gunn E, Ambler O, Dias R, Wigmore SJ, et al. Cognitive Load Management: An Invaluable Tool for Safe and Effective Surgical Training. *J Surg Educ*. 2023;80(3):311–22. <https://doi.org/10.1016/j.jsurg.2022.12.010>.
13. Russell S, Kelly VG, Halson SL, Jenkins DG. *Cognitive Load in Sport. Human Factors and Ergonomics in Sport*. 1st Edition. CRC Press; 2020. pp. 181–200.
14. Salmon PM, Stanton NA, Gibbon A, Walker GH. *Human Factors Methods and Sports Science: A Practical Guide*. CRC; 2009. <https://doi.org/10.1201/9781420072181>.
15. Fuster J, Caparrós T, Capdevila L. Evaluation of cognitive load in team sports: literature review. *PeerJ*. 2021;9:e12045. <https://doi.org/10.7717/peerj.12045>.
16. Wagstaff CR, Gilmore S, Thelwell RC. When the Show must Go On: Investigating Repeated Organizational Change in Elite Sport. *J Change Manage*. 2016;16(1):38–54. <https://doi.org/10.1080/14697017.2015.1062793>.
17. Moore LJ, Vine SJ, Wilson MR. *Attention and Visuomotor Performance Under Pressure. Stress, Well-Being, and Performance in Sport*. 1st Edition. Routledge; 2021. pp. 113–130.
18. Hings RF, Wagstaff CR, Anderson V, Gilmore S, Thelwell RC. Professional challenges in elite sports medicine and science: Composite vignettes of practitioner emotional labor. *Psychol Sport Exerc*. 2018;35:66–73. <https://doi.org/10.1016/j.psychsport.2017.11.007>.
19. Thelwell RC, Weston NJ, Greenlees IA, Hutchings NV. Stressors in elite sport: a coach perspective. *J Sports Sci*. 2008;26(9):905–18. <https://doi.org/10.1080/02640410801885933>.
20. Kerai S, Wadey R, Salim J, Sport. *Exerc Perform Psychol*. 2019;8(3):255–72. <https://doi.org/10.1037/spy0000154>.
21. Snarr RL, Beasley VL, Personal. Work-, and Client-Related Burnout Within Strength and Conditioning Coaches and Personal Trainers. *J Strength Cond Res*. 2022;36(2):e31–40. <https://doi.org/10.1519/JSC.0000000000003956>.
22. Hart SG, Staveland LE. Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. In: Hancock PA, Meshkati N, editors. *Advances in Psychology*. North-Holland; 1988. pp. 139–83.
23. Howie EE, Ambler O, Gunn EG, Dias RD, Wigmore SJ, Skipworth RJ et al. Surgical Sabermetrics: A Scoping Review of Technology-Enhanced Assessment of Non-Technical Skills in the Operating Room. 2024. <http://dx.doi.org/10.1097/SLA.0000000000006211>
24. Charles RL, Nixon J. Measuring mental workload using physiological measures: A systematic review. *Appl Ergon*. 2019;74:221–32. <https://doi.org/10.1016/j.apergo.2018.08.028>.
25. Lancaster GA, Thabane L. Guidelines for reporting non-randomised pilot and feasibility studies. *Pilot Feasibility Stud*. 2019;5:114. <https://doi.org/10.1186/s40814-019-0499-1>.
26. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. *Int J Surg*. 2014;12(12):1495–9. <https://doi.org/10.1016/j.ijsu.2014.07.013>.
27. Chandra V, Priyarup A, Sethia D. Comparative study of physiological signals from empatica E4 wristband for stress classification. *Communications in Computer and Information Science*. Cham: Springer International Publishing; 2021. pp. 218–29.
28. Benedek M, Kaernbach C. A continuous measure of phasic electrodermal activity. *J Neurosci Methods*. 2010;190(1):80–91. <https://doi.org/10.1016/j.jneumeth.2010.04.028>.
29. Braithwaite JJ, Watson DG, Jones R, Rowe M. A guide for analysing electrodermal activity (EDA) & skin conductance responses (SCRs) for psychological experiments. *Psychophysiology*. 2013;49(1):1017–34.
30. Harrison E, Drake T, Pius R, finalfit. Quickly create elegant regression results tables and plots when modelling in R. 2023. <https://github.com/ewenharrison/finalfit>. Accessed 28/3/2024.
31. Alsentali AM, Anshel MH. Relationship between Internal and External Acute Stressors and Coping Style. *J Sport Behavior; Mob*. 2015;38(4):357–75.
32. Arnold R, Fletcher D, Daniels K. Demographic differences in sport performers' experiences of organizational stressors: Demographic differences in stressors. *Scand J Med Sci Sports*. 2016;26(3):348–58. <https://doi.org/10.1111/sms.12439>.

33. Unkelbach C, Memmert D. Crowd noise as a cue in referee decisions contributes to the home advantage. *J Sport Exerc Psychol.* 2010;32(4):483–98. <https://doi.org/10.1123/jsep.32.4.483>.
34. Arnold R, Fletcher D. Stressors, Hassles, and Adversity. In: Arnold R, Fletcher D, editors. *Stress, Well-Being, and Performance in Sport.* 1st Edition. Routledge; 2021. pp. 31–62.
35. Arnold R, Edwards T, Rees T. Organizational stressors, social support, and implications for subjective performance in high-level sport. *Psychol Sport Exerc.* 2018;39:204–12. <https://doi.org/10.1016/j.psychsport.2018.08.010>.
36. Pizzera A, Laborde S, Lahey J, Wahl P. Influence of physical and psychological stress on decision-making performance of soccer referees. *J Sports Sci.* 2022;40(18):2037–46. <https://doi.org/10.1080/02640414.2022.2127516>.
37. Mascarenhas DR, Birtwhistle J, Martindale A. First-person video recordings with eye tracking glasses and cognitive task analysis as a framework for referee decision training. *Manag Sport Leis.* 2022:1–20. <https://doi.org/10.1080/23750472.2022.2134186>
38. Norris LA, Didymus FF, Kaiseler M. Stressors, coping, and well-being among sports coaches: A systematic review. *Psychol Sport Exerc.* 2017;33:93–112. <https://doi.org/10.1016/j.psychsport.2017.08.005>.
39. Zenati MA, Leissner KB, Zorca S, Kennedy-Metz L, Yule SJ, Dias RD. First Reported Use of Team Cognitive Workload for Root Cause Analysis in Cardiac Surgery. *Semin Thorac Cardiovasc Surg.* 2019;31(3):394–6. <https://doi.org/10.1053/j.semtcvs.2018.12.003>.
40. Gould D, Dieffenbach K, Moffett A. Psychological Characteristics and Their Development in Olympic Champions. *J Appl Sport Psychol.* 2002;14(3):172–204. <https://doi.org/10.1080/10413200290103482>.
41. World Rugby. 2023 Six Nations Statistical Report. 2023. <https://resources.worldrugby-rims.pulselive.com/worldrugby/document/2023/11/20/6924cd1d-a781-404e-99bc-d17252357221/2023-6-NATIONS-STATISTICAL-REPORT.pdf>. Accessed 26/3/2024.

Tables

Table 1

Descriptive and analytical statistics for each variable of interest across the five matches, based on the mean for each class of electrodermal activity. Please note there is no range for Team 1's away match as only one individual participated in this match. Significance level of $p \leq 0.05$ was chosen. These values are highlighted in bold in this table.

		Phasic (shifts in baseline activity)					Tonic (fluctuations over time in response to events)				
Independent variable		Mean (SD) (μS)	Range (μS)	p	Coefficient (95% CI, p) (univariable)	Coefficient (95% CI, p) (multivariable)	Mean (SD) (μS)	Range (μS)	p	Coefficient (95% CI, p) (univariable)	Coefficient (95% CI, p) (multivariable)
Match Result	Win (n = 3)	0.109 (0.106)	0.005- 0.299	-	0.00 (-0.08 to 0.08, p = 0.908)	-0.09 (-0.17 to -0.00, p = 0.048)	0.384 (0.153)	0.075- 0.651	-	-0.02 (-0.11 to 0.07, p = 0.659)	-0.01 (-0.12 to 0.11, p = 0.920)
	Loss (n = 2)	0.104 (0.140)	0.002- 0.376	0.908	-	-	0.404 (0.115)	0.288- 0.697	0.659	-	-
Match Location	Home (n = 4)	0.079 (0.114)	0.001- 0.625	-	0.12 (0.04 to 0.21, p = 0.006)	0.10 (-0.04 to 0.25, p = 0.162)	0.386 (0.142)	0.075- 0.651	-	-0.03 (-0.14 to 0.07, p = 0.544)	-0.30 (-0.45 to -0.15, p < 0.001)
	Away (n = 1)	0.051 (0.093)	0.000- 0.576	0.006	-	-	0.418 (0.113)	0.301- 0.697	0.544	-	-
Opponent	Team 1	0.039 (0.052)	0.002- 0.162	0.025	-	-	0.342 (0.168)	0.075- 0.697	0.413	-	-
	- Away	0.013 (0.012)	0.002- 0.034	-	-0.11 (-0.21 to -0.00, p = 0.045)	-0.11 (-0.21 to -0.00, p = 0.045)	0.418(0.113)	0.301- 0.697	-	-0.01 (-0.12 to 0.10, p = 0.812)	-0.01 (-0.12 to 0.10, p = 0.812)
	- Home	0.117(0.044)	N/A	-	-0.00 (-0.15 to 0.14, p = 0.968)	-0.00 (-0.15 to 0.14, p = 0.968)	0.512 (0.185)	N/A	-	-0.31 (-0.47 to -0.16, p < 0.001)	-0.31 (-0.47 to -0.16, p < 0.001)
	Team 2	0.195 (0.151)	0.021- 0.376	-	0.18 (0.08 to 0.29, p = 0.001)	0.18 (0.08 to 0.29, p = 0.001)	0.390 (0.122)	0.288- 0.646	-	0.05 (-0.07 to 0.17, p = 0.433)	0.27 (0.12 to 0.43, p = 0.001)
	Team 3	0.095 (0.108)	0.005- 0.278	-	0.08 (-0.02 to 0.19, p = 0.118)	0.08 (-0.02 to 0.19, p = 0.118)	0.427 (0.123)	0.282- 0.642	-	0.08 (-0.04 to 0.21, p = 0.165)	0.31 (0.16 to 0.46, p < 0.001)
	Team 4	0.120 (0.125)	0.018- 0.299	-	0.11 (0.00 to 0.21, p = 0.045)	0.11 (0.00 to 0.21, p = 0.045)	0.431 (0.651)	0.324- 0.651	-	0.09 (-0.03 to 0.21, p = 0.149)	0.31 (0.16 to 0.47, p < 0.001)

Table 2
Descriptive phasic activity per in-match event

Category	Event	Mean (SD) (μ S)	Range (μ S)	Incidence (n)
Injury	Participant team injury assessment	Low 0.046 (0.072)	0.001–0.342	11
Scoring event	Penalty kick at goal	Low 0.045 (0.068)	0.001–0.257	12
	Try	Low 0.062 (0.088)	0.000–0.455	32
	Conversion	Low 0.068 (0.101)	0.001–0.413	28
Set-piece	Scrum	Low 0.061 (0.090)	0.001–0.469	45
	Lineout	Low 0.069 (0.096)	0.000–0.486	144
Discipline	Yellow Card	Low 0.091 (0.091)	0.001–0.252	5
	Red Card	Low 0.012 (0.013)	0.001–0.035	2

Table 3
Descriptive and analytical statistics for each category of in-match stimuli

Independent variable		n	Mean (SD) (μ S)	Range (μ S)	p	Coefficient (95% CI, p) (univariable)	Coefficient (95% CI, p) (multivariable)
Event	Injury	11	0.050 (0.084)	0.001–0.508	-	-0.02 (-0.06 to 0.02, p = 0.411)	-0.02 (-0.07 to 0.02, p = 0.327)
	Scoring event	72	0.068 (0.107)	0.000–0.576	0.630	-	-
	Set-piece	189	0.075 (0.112)	0.000–0.625	-	0.01 (-0.01 to 0.03, p = 0.474)	0.01 (-0.01 to 0.03, p = 0.430)
	Discipline	7	0.073 (0.101)	0.001–0.286	-	0.00 (-0.05 to 0.06, p = 0.859)	0.01 (-0.05 to 0.06, p = 0.837)
Team	Team A	104	0.076 (0.113)	0.000–0.576	0.724	-	-
	All	38	0.068 (0.109)	0.001–0.598	-	-0.01 (-0.03 to 0.02, p = 0.514)	-0.01 (-0.04 to 0.01, p = 0.263)
	Team B	97	0.070 (0.106)	0.000–0.625	-	-0.01 (-0.02 to 0.01, p = 0.501)	-0.01 (-0.03 to 0.01, p = 0.310)
Match location	Away	1	0.051 (0.093)	0.000–0.576	0.003	-	-
	Home	4	0.079 (0.114)	0.001–0.625	-	0.03 (0.01 to 0.05, p = 0.003)	0.03 (0.01 to 0.05, p = 0.003)
Note: Team A's medical staff wore sensors; Team B were Team A's opponents who did not							

Figures

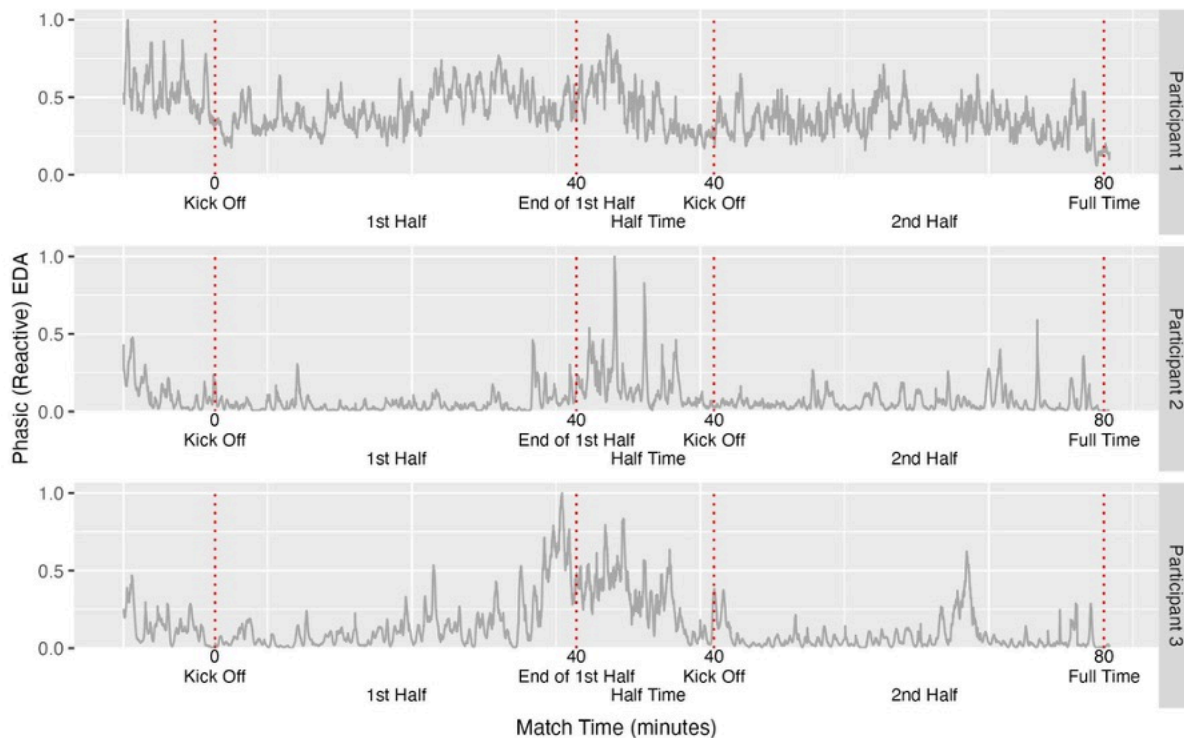


Figure 1

Legend not included with this version

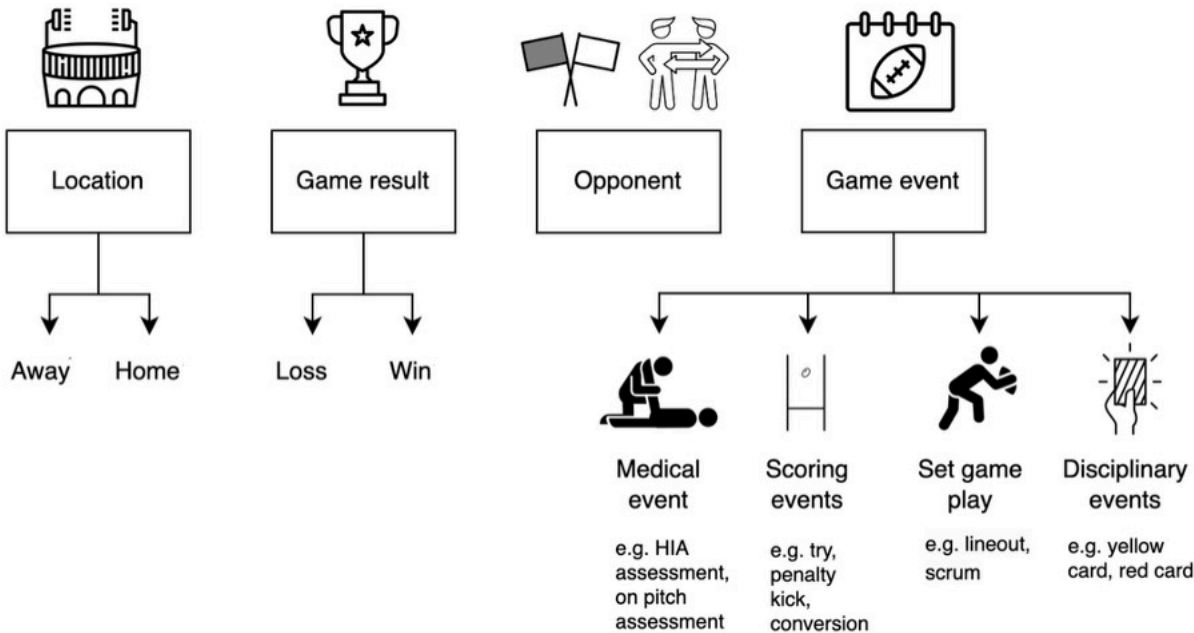


Figure 2

Legend not included with this version

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [STROBEchecklistcohortsru.docx](#)
- [Supplement.docx](#)