CERN IdeaSquare Journal of Experimental Innovation, 2026; 10(2): 38-43
DOI: https://doi.org/10.23726/cij.2026.1840

ORIGINAL ARTICLE

Innovation through Co-Creation in Women's Boxing: A Situated Reflection on Boundary Objects

Nina Costa[1,2*], Carlos G. S. Cardoso[1,2,3], Ricardo J. Alves de Sousa[2,3]

[1]Research Institute for Design, Media and Culture (ID+), Department of Communication and Art, University of Aveiro, Aveiro, Portugal; [2]Centre for Mechanical Technology and Automation (TEMA), Department of Mechanical Engineering, Campus Universitário de Santiago, University of Aveiro, 3810-193 Aveiro, Portugal; [3]LASI—Intelligent Systems Associate Laboratory, Guimarães, 4800-058, Portugal
*Corresponding author: ndc@ua.pt

ABSTRACT

Women's participation in boxing has expanded rapidly, yet health management practices related to repetitive head impacts remain largely shaped by male-centred evidence, uncertain long-term consequences and formal clinical thresholds, creating persistent gaps around head impact exposure, where symptoms are diffuse, cumulative and often normalised in sports training culture. This article presents a situated practitioner–researcher reflection on an exploratory initiative in women's boxing by examining how biomechanical data and embodied experience are integrated through practice-based research. Instrumented mouthguard data were curated into visual reports and discussed with athletes as potential resources for health awareness and prevention. Three anonymised episodes are examined, including: differences in exposure patterns between athletes; the repurposing of the reports for tactical preparation; and the preference for impact location visualisations and comparative information. The reflections suggest that the reports functioned as boundary objects by bringing biomechanical measurements into dialogue with the athletes' embodied and tactical knowledge. However, they did not produce a change in daily practice. Athletes often prioritised immediate performance benefits over future health risks, while coach engagement with the data was uneven. The study contributes to an implicit everyday co-creation process and identifies both the innovation potential and the practical limits of prevention data communication in a pro-risk sport culture.

Keywords: Innovation through co-creation; Boundary objects; Women's boxing; Head impact exposure; Practitioner–researcher positionality.

Received: February 2026. Accepted: August 2026.

INTRODUCTION

Women's participation in boxing and other combat sports has increased substantially over the past decade, intensifying attention to athlete safety and long-term health outcomes. Despite this growth, health management practices, particularly those related to repetitive head impacts, remain unevenly developed and strongly influenced by evidence derived from male populations (Anderson et al., 2023; Merone et al., 2022). This misalignment is particularly important in boxing, where decisions on training intensity, exposure to sparring and competition preparedness are taken daily. Women who engage in sports may experience varied symptom patterns and recovery trajectories, yet many everyday health judgements are made outside clinical settings through tacit norms and embodied judgment. Consequently, subclinical brain stress that comes in the form of minor adjustments in fatigue, mood, cognition or body awareness often goes unnoticed or comes to be normalised, although it may have a cumulative effect (Gupte et al., 2019). These conditions position women's brain health in boxing as a complex problem situated at the intersection of data, experience, authority, and institutional responsibility.

Existing responses to this problem can be partially solved via technological innovation, such as impact-sensing devices or computational modelling. These devices are starting to be used at scale in sports such as rugby. However, they usually are used within discrete events (e.g. a specific game); and pay limited attention to how such data is interpreted, trusted or acted upon in practice. Athletes are frequently positioned as data sources rather than as knowledge holders and experiential insight is marginalised when it conflicts with formal indicators. Therefore, the practical meaning of technology should depend on how numerical information is interpreted alongside athletes' experience, tactical priorities and the authority of coaches and health professionals.

Co-creation has been proposed as a pathway to more inclusive and context-sensitive innovation by integrating diverse forms of expertise (Trischler et al., 2019). However, critical scholarship cautions that participatory approaches are deeply shaped by power relations and may reproduce existing hierarchies unless their epistemic and ethical conditions are examined (von Busch &

Palmås, 2023). This article examines innovation potential and limitation through a situated practitioner-researcher reflection guided by boundary objects (Star & Griesemer, 1989) and co-creation in women's boxing. The study addresses two research questions: (1) How did the curation and discussion of instrumented mouthguard reports bring quantitative exposure data into dialogue with athletes' tactical knowledge? (2) What do the observed episodes reveal about the possibilities and limits of implicit co-creation for prevention innovation in women's boxing?

THEORETICAL BACKGROUND

Innovation through co-creation in complex contexts

Co-creation innovation is becoming frequently applied in areas that are characterised by uncertainty, plural expertise, and decision-making, including health, care and high-risk working conditions. Instead of taking innovation as the linear exchange of expert knowledge into practice, co-creation outlines the significance of cooperation, whereby several actors can participate in the process of problem framing, knowledge production, and solution development (Trischler et al., 2019). In this sense, co-creation deals with the re-configuring of the emergence of innovation through the redistribution and negotiation of knowledge authority among heterogeneous stakeholders. In health-related contexts, this redistribution is specifically pertinent in a situation where the normalised metrics and protocols fail to capture the lived, situated, or longitudinal aspects of experience.

Sport and exercise research has identified a systematic under-representation of women in research and guideline development with the protocols developed failing to capture sex-specific physiology, recovery patterns, and symptom expression (Anderson et al., 2023; Merone et al., 2022). In this context, it is impossible to reduce innovation to technological progress, but rather the mechanisms need to be in place to allow the articulation, alignment, and conversion of various kinds of knowledge (i.e. biomechanical, clinical, experiential) into actions. Nevertheless, critical perspectives have warned that co-creation does not necessarily result in more equitable or productive results. Participatory initiatives can replicate hierarchies that already exist, instrumentalise the labour of the participants, or produce outputs that do not get institutional traction (von Busch & Palmås, 2023). These critiques represent the importance of looking at the way in which co-creation is exercised, what sort of knowledge it stabilises, and which material and organisational arrangements make participation consequential. From this perspective, co-creation can be understood as an experimental innovation process, whose impacts rely on the infrastructures that facilitate translation across domains, rather than on participation alone (e.g. workshops or focus groups). In this case, the process of innovation occurs in situational interaction that is mediated by trust, authority and role multiplicity, presenting ethical and epistemic challenges concerning who can and cannot speak, whose knowledge is acknowledged, and how knowledge generated through experience is circulated. These concerns connect co-creation with practitioner–researcher positionality, because embedded access can support translation while also shaping disclosure, trust and authority (Alvesson & Sköldberg, 2018; Dwyer & Buckle, 2009).

Boundary objects and knowledge production

To analyse how co-creation enables alignment across heterogeneous forms of expertise, this study draws on the concept of boundary objects. Originally introduced by Star and Griesemer (1989), boundary objects are artefacts, practices or representations that inhabit multiple social worlds simultaneously, enabling coordination without requiring consensus. Boundary objects have been utilised extensively in the analysis of scientific collaboration, design processes, and interdisciplinary innovation, especially in the areas where actors are subject to varying epistemic norms and accountability regimes (Johnson et al., 2017). In health innovation, the work of boundary crossing in line with the transfer of knowledge is precisely that of the previously mentioned protocols, dashboards, reports or other digital tools. The biomechanical head-impact data, symptoms, the coaching practices and the medical judgement is generated and interpreted in separate professional and experiential domains. These knowledge forms are still incomplete in the absence of the mediating structure such that they are restricted to inform practical decisions concerning training load, recovery or risk exposure. Boundary objects provide a way to understand how co-created artefacts, such as integrated reports or shared interpretive frameworks, can bring data and experience into a common interpretive space without erasing their differences. They embody assumptions about what counts as relevant knowledge, whose interpretations matter and how uncertainty is handled. Analysing which boundary objects emerge through co-creation, and how they are taken up in practice, therefore provides insight into the innovation effects of participatory processes beyond their immediate outputs.

Repetitive head impact exposure

Repetitive head impacts in combat sports often produce effects that fall below established clinical thresholds yet accumulate over time, manifesting as subtle changes in cognition, mood, sleep or hormonal regulation. This condition poses challenges for health management because it does not fall within binary classifications of "injured" versus "healthy", but rather extends in temporal scales (Gupte et al., 2019). For

female athletes, these challenges may be compounded by sex-specific physiological factors and by training cultures in which symptoms may be normalised or under-reported.

From an innovation perspective, repetitive head impacts can represent a challenge of knowledge integration. Although advances in biomechanics and sensor technologies generate increasingly granular data on head impacts, data alone does not determine how risk is perceived, communicated or acted upon in practice. Decision-making instead relies on contextual understandings of training demands (e.g. performance–health trade-offs), coaches' capacity to recognise potential signs of brain stress, and institutional norms governing performance and safety (e.g. combat rules as enacted by presiding referees).

This study approaches this concern as a context where innovation through co-creation becomes necessary to bridge gaps between what can be measured and what is lived. By examining how boundary objects emerge through participatory engagement, the analysis highlights the role of co-creation in producing interpretive infrastructures that support ongoing, situated decision-making under uncertainty. In doing so, it shifts attention from technological optimisation to the relational and epistemic conditions through which innovation becomes meaningful in everyday practice. In such conditions, innovation depends not only on producing new data, but on creating interpretive infrastructures capable of mediating between embodied experience, technical measurement and institutional authority.

METHOD AND DATA

Research design and epistemic positioning

This study adopts an exploratory case study design grounded in embedded, practice-based research (Schön, 1983; Alvesson & Sköldberg, 2018). It is situated within an ongoing action-oriented initiative focused on women's health and safety in boxing. The study approaches co-creation as a longitudinal, relational process unfolding through sustained engagement with the sport ecosystem, consistent with experimental and participatory approaches to innovation research (Trischler et al., 2019).

The research is informed by a practitioner–researcher positionality, where the first author occupies multiple roles within the field: as a former competitive boxer, certified jury member and referee. Such insider positioning is recognised in qualitative research as a source of situated access and tacit knowledge, while simultaneously requiring reflexive engagement with power relations and role boundaries (Dwyer & Buckle, 2009; Breen, 2007). Rather than seeking to neutralise this positionality, the study treats it as analytically productive, particularly in a domain where risk, authority and silence shape health-related decision-making (Haraway, 1988).

Empirical materials and data sources

The initiative took place between January and March 2026 in Portugal, involving six female boxing athletes. The material analysed in this paper derives from biomechanical head-impact data, collected using instrumented mouthguards during training and sparring sessions. This data was generated as part of parallel biomechanical research and provide quantitative representations of impact exposure. In line with science and technology studies approaches, these measurements are treated not as objective truths but as representational artefacts whose meaning emerges through interpretation and use in practice (Suchman, 2002). For the purposes of this study, mouthguard data function as inputs to collective sense-making, not as standalone diagnostic indicators. The sensor outputs were curated into individual athlete reports containing visual and numerical representations of exposure, including impact locations, intended to steer discussion about current and potential long-term health concerns and to support discussion about existing prevention strategies with athletes and coaches. Private conversations and personal symptom accounts are not treated in this study. Instead, the analysis uses anonymised episodes centred on how the reports were interpreted and repurposed.

Co-creation in practice: participation, power and ethics

Co-creation in this study emerged through situated interactions including informal conversations, collaborative interpretation of data and iterative feedback moments, constituting key sites of knowledge production. These distributed and ongoing forms of co-creation align with critiques of participatory design that emphasise everyday practices over staged participation events (von Busch & Palmås, 2023).

The first author's dual role as researcher and official created ethical and methodological challenges related to authority, consent and disclosure. Research literature highlights the necessity of explicitly addressing these dynamics, particularly where professional roles carry evaluative or disciplinary power (Dwyer & Buckle, 2009). To mitigate this influence, data collection was decoupled from situations involving formal authority, participation remained voluntary and analytical attention was directed toward how power relations shaped what could be said, withheld or reframed. These dynamics are treated as integral to the research and innovation process (Alvesson & Sköldberg, 2018). Invited athletes provided informed consent for the collection and use of the instrumented mouthguard data. The protocol received ethical approval from the Ethics Committee of the University of Aveiro, reference number 62-CEIC-UA/2025-D.

Analytical strategy

For this study, the authors selected three anonymised episodes exposing different relationships between measurement, athlete experience and potential action pathways. The episodes concern: (1) uneven head-impact exposure patterns and their preventive interpretation; (2) the repurposing of health reports for short-term tactical preparation; and (3) the iterative preference for visual impact-location information and comparisons between athletes.

They were interpreted abductively through the implicit co-creation with the athletes, supported by the boundary objects. The analysis asked how the process adopted was useful to change health practices; what the report made visible, how the athlete or coach interpreted it, whether communication changed and whether any stable practice followed, which enabled conceptual learning from situated experience while keeping the claims proportionate to the initiative's limited and reflective character.

RESULTS

Episode 1: Uneven exposure patterns and preventive interpretation

The reports corroborated observations that some athletes experienced higher levels of head impact exposure than others. Within the situated discussions, these differences were considered alongside contrasting boxing styles. For instance, athletes who adopted more aggressive tactics or maintained less defensive positioning, appeared to accumulate greater exposure. The quantitative reports did not establish a causal relationship between style and exposure, but they made the contrast visible enough to support a shared discussion of why apparently similar sessions could affect athletes differently.

From a prevention perspective, the high impact patterns suggested the potential value of longer recovery intervals and more deliberate defensive work. These possibilities were discussed with the coaches but were not systematically implemented. The initiative did not produce a routine in which the report automatically changed training load, rest or technical preparation. Some coaches had limited data literacy with the metrics or genuinely did not know how to effectively reverse or change these patterns.

The same report connected data derived from mouthguard sensors (Figure 1 and Figure 2), the athlete's tactical deficiencies (e.g. exposed upper-left side of the face) and pointed towards possible preventive responses in defence. This boundary object function enabled a conversation that had not previously been supported by athlete-specific data, but it did not produce substantial changes in training or post-impact recovery strategies.

Episode 2: Health-oriented reports repurposed for performance

The reports were initially created to help athletes recognise exposure patterns and reflect on possible future health strategies, while considering female-specific characteristics. In practice, however, athletes frequently focused on the data to adjust sport tactics or improve their next sparring session or competitive bout. The data was not collected continuously, at every bout, due to restriction of equipment, time, and athletes' routines, but it supported the identification of certain patterns i.e. more likely impact location; higher or lesser impact accumulation in comparison to other bouts. The exposure patterns were read as information about defensive weaknesses and the demands of a particular bout rather than prompts for long-term health risk reduction. This interpretation by athletes indicated that the probability of future health problems was uncertain, whereas the next competition and its performance demands were immediate. Additionally, the routine for data collection (which required using a specific mouthguard, with which athletes were unfamiliar), report development (which demanded approximately 1-week), discussions with athletes and coaches during training generated several effects including curiosity, but also, destabilisation of training. Creating sustained changes through time, including reflection of quantitative data, and health changes requires a more in-depth engagement with health information with the actors, something that was not planned in this short period. However, the study showcased how intertwined the practices, objects and information are in a risk-prone environment; and thus, how actionable information is also required for this everyday co-creation to happen.

Fig. 1. Smart mouthguard anchors the system in material, measurable exposure.

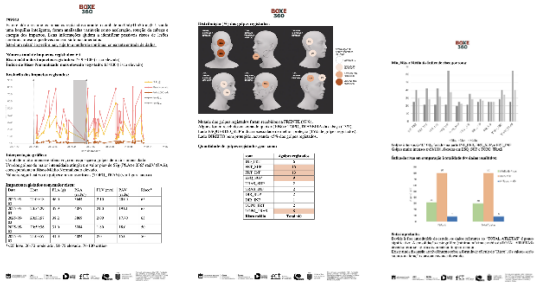

Fig. 2. Fictitious example of a report shared and discussed with athletes. The data are indicative and do not represent a real-life event.

Episode 3: Iterating visual communication and comparative meaning

Athletes engaged with different visual representations of the data collected and showcased particular interest in the mouthguard's detected impact location i.e., if an impact was registered on the left, right, upper or frontal region of the head. The reports were then discussed and iterated based on the on-going questions which emerged in-context. For instance, they questioned what the limit for "safety" was; how was calculated and this translated into the graph, they also tried to recap certain moments of highly intense, suffered strikes, and visualise them in the report, crossing this information with location.

Another situation revealed after a few reports were delivered was that athletes also wanted more comparisons among athletes, to understand how better or worse their performance was, in comparison to their counterparts. Individual results alone were difficult to interpret because they lacked a meaningful reference point for what was relatively high, low or unusual results. In one competitive session, both competing athletes wore instrumented mouthguards, allowing their reports to be viewed comparatively and that comparison generated greater interest and clearer tactical interpretation than a standalone report. However, paired data of this kind were available only rarely, considering field restrictions and access to athletes of the same weight (category), at the same time.

DISCUSSION AND CONCLUSIONS

The three episodes suggest that the process followed, the instrumented mouthguard and resulting reports can function as boundary objects when they allow heterogeneous forms of knowledge (i.e., biomechanical measurements, embodied experience and tactical judgement) to be discussed together. Their meaning emerged when athletes connected exposure patterns with boxing style, defensive positioning, impact location and future performance goals, supporting a restrained claim that co-creation increased the intelligibility and relevance of the reports, but it did not by itself change daily training practices or health strategies considering that these are still not embedded routines in this type of environment.

This study enabled athletes to take part in the interpretation process which helped understanding how information is prioritised from a multistakeholder point of view. For instance, visual and comparative information amongst athletes was considered paramount to understand performance, and thus additional information was added to the reports. However, existing hierarchies and performance pressures remained largely unchanged due to the exploratory nature of the study. Next steps should include a facilitated process developed with coaches and athletes; accommodating iterative data literacy sessions to help developing more effective strategies specifically for health prevention purposes, which, from the observations made, are consistently overshadowed by performance.

Despite the process and its limits, the boundary objects used created an important opportunity for shared discussions of tactics, performance and health in women's boxing, while also showing how health prevention and sex-specific data could be repurposed towards performance in response to the short-term objectives of coaches and athletes. As boundary objects, the reports supported coordination without requiring consensus: researchers viewed them as tools to raise awareness and stimulate discussion about sex-specific health; athletes frequently viewed them as tactical resources; and coaches presented mixed interpretations. Decision-making remained with the actors who controlled the training sessions and sparring practices. Based on this study, a broader approach at the institutional level is needed to support the translation of report-based insights into sustained preventive practices, while the absence of an agreed institutional response limited the reports' consequences.

The reflection is limited by its situated and exploratory character as it concerns one initiative. The mouthguard measurements describe exposure, not clinical outcome; but the connection between the measurements and the on-going experiences of athletes help us establish strategies for future work needed at the product design and service design level, for health. Observations regarding coach literacy, willingness to change practices; and sport priorities are understood as features of the episodes described in this study, but which resonate with the experiences surrounding women's boxing context. The first author's embedded roles as former athlete, and referee helped supporting discussion across these different actors, also bringing the issue to institutional levels of sport regulation (i.e. federation).

In conclusion, this situated reflection shows that introducing data into practice is not equivalent to producing innovation but can support opening pathways for new products and service solutions. The reports made

exposure visible and discussable and were iteratively adapted, especially through impact-location visualisation and comparative interpretation. Nevertheless, uncertain future health consequences competed with immediate performance goals, and communication alone was insufficient to create sustained preventive routines. Future initiatives should combine understandable visual reporting with explicit facilitation, a better knowledge and data literacy for coaches and athletes, co-defined preventive objectives and agreed opportunities to revisit action. In high-risk sports (e.g., boxing), co-creation can make different forms of knowledge intelligible to one another, but institutional commitment is required before that understanding becomes a durable change in practice.

ACKNOWLEDGEMENTS

This work was supported by FCT – Fundação para a Ciência e a Tecnologia, I.P., through project UIDB/04057/2020, grants PTDC/EME-EME/1239/2021, UIDB/00481/2020 and UIDP/00481/2020, and researcher contract 2023.15265.TENURE.037; and by CENTRO-01-0145-FEDER-022083, funded under the Centro Regional Operational Programme (Centro2020), through the PORTUGAL 2020 Partnership Agreement and the European Regional Development Fund. Carlos Cardoso acknowledges the support of FCT through doctoral scholarship 2025.00529.BDANA.

DECLARATION OF AI TOOLS

During the revision of this manuscript, the authors used ChatGPT (OpenAI) to assist with language editing and sentence restructuring. All assisted text was critically reviewed, revised and verified by the authors. The authors take full responsibility for the content of the manuscript. Generative AI was not used to generate, analyse or interpret the research data.

CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

REFERENCES

Alvesson, M., & Sköldberg, K. (2018). *Reflexive methodology: New vistas for qualitative research* (3rd ed.). SAGE.

Anderson, N., Robinson, D. G., Verhagen, E., Fagher, K., Edouard, P., Rojas-Valverde, D., et al. (2023). Under-representation of women is alive and well in sport and exercise medicine: What it looks like and what we can do about it. *BMJ Open Sport & Exercise Medicine, 9*, e001606. https://doi.org/10.1136/bmjsem-2023-001606

Breen, L. J. (2007). The researcher "in the middle": Negotiating the insider/outsider dichotomy. *Australian Community Psychologist, 19*(1), 163–174.

Dwyer, S. C., & Buckle, J. L. (2009). The space between: On being an insider–outsider in qualitative research. *International Journal of Qualitative Methods, 8*(1), 54–63. https://doi.org/10.1177/160940690900800105

Gupte, R., Brooks, W., Vukas, R., Pierce, J., & Harris, J. (2019). Sex differences in traumatic brain injury: What we know and what we should know. *Journal of Neurotrauma, 36*(22), 3063–3093. https://doi.org/10.1089/neu.2018.6171

Johnson, M. P., Ballie, J., Thorup, T., & Brooks, E. (2017). Living on the edge: Design artefacts as boundary objects. *The Design Journal*, 20(sup1), S219–S235. https://doi.org/10.1080/14606925.2017.1352771

Haraway, D. (1988). Situated knowledges: The science question in feminism and the privilege of partial perspective. *Feminist Studies, 14*(3), 575–599.

Merone, L., Tsey, K., Russell, D., & Nagle, C. (2022). Sex inequalities in medical research: A systematic scoping review of the literature. *Women's Health Reports, 3*(1), 49–59. https://doi.org/10.1089/whr.2021.0083

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. Basic Books.

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, 'translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–1939. *Social Studies of Science, 19*(3), 387–420. https://doi.org/10.1177/030631289019003001

Suchman, L. (2002). Located accountabilities in technology production. *Scandinavian Journal of Information Systems, 14*(2), 91–105.

Trischler, J., Dietrich, T., & Rundle-Thiele, S. (2019). Co-design: From expert- to user-driven ideas in public service design. *Public Management Review, 21*(11), 1595–1619. https://doi.org/10.1080/14719037.2019.1619810

von Busch, O., & Palmås, K. (2023*). The corruption of co-design: Political and social conflicts in participatory design thinking*. Routledge. https://doi.org/10.4324/9781003281443