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Review Article

Science mapping of social science research on anti-doping from 2004 to 2025: Insights into knowledge structures, focus of domains, and future directions

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ABSTRACT

Background: World Anti-Doping Agency (WADA) implemented the first World Anti-Doping Code in 2004 and launched its Social Science Research (SSR) program. Since then, there has been no comprehensive synthesis of the knowledge on how anti-doping SSR evolved. This review, therefore, employed a science-mapping approach to examine the knowledge structures and domain focus within anti-doping SSR.
Methods: A total of 431 social science research articles published between January 2004 and August 2025 were retrieved from Web of Science Core Collection for science mapping. An expert panel reviewed these publications using a staged cross-validation process, assessing their domain focus, level of influence, alignment with WADA's SSR priorities, and position within an international consensus on anti-doping SSR agenda.
Results: Anti-doping SSR over the period 2004-2025 demonstrated enriched knowledge structures at the social (e.g., collaboration networks), intellectual (e.g., research clusters, keyword bursts), and conceptual (e.g., thematic mapping and evolution) levels. The results of the expert panel review revealed significant shifts in the focus of anti-doping SSR domains and methodological approaches, within the level of influence, WADA's SSR priorities, and the international consensus SSR agenda.
Conclusions: The findings reveal a shift toward embracing more comprehensive social science methods to inform real-world anti-doping efforts. Researchers should critically address key gaps, such as the underrepresentation of consensus agendas, evaluate alternative anti-doping models, and embrace robust behavioural science. Funders should broaden their priorities to support challenging inquiry. Causal, behaviour-driven, and long-term impact evidence are needed to inform technology-empowered, effective, and ethically sound anti-doping practices.

1. Introduction

Doping, or the use of substances prohibited by the World Anti-Doping Agency (WADA), continues to be a concerning issue in sport, undermining the integrity and fairness of athletic competition (Clancy et al., 2022; Huseynli et al., 2025). To combat doping in sport, the WADA implemented the first World Anti-Doping Code (WADC) in 2004. In response to the evolving doping challenges, the Code was amended in

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2009, 2015, and 2021, providing clearer guidelines and enhanced reinforcement for key procedures in global anti-doping (WADA, 2026). While these regulatory efforts focus heavily on the detection-deterrence model (e.g., Overbye, 2016), WADA have increasingly recognised the importance of social science approaches to doping prevention. To foster social science efforts in anti-doping, WADA introduced its Social Science Research (SSR) program in 2005, which since then has invested over $6 million US dollars in more than 160 SSR projects (WADA, 2025a).

Since the launch of the WADA SSR program and with the increasing global effort in anti-doping, other international organisations supporting sport research (e.g., the International Olympic Committee) and funding bodies that did not previously focus on anti-doping SSR (e.g., the Partnership for Clean Competition, European Union) have started to fund SSR projects in anti-doping or made anti-doping SSR a field of priority. Despite the significant investment in anti-doping SSR and the co-creation of an international consensus on the key social science research needed to support anti-doping and clean sport (see Boardley et al., 2021), to date, there has been no comprehensive review of the knowledge structure and evolution of SSR in anti-doping. To offer anti-doping researchers and other stakeholders (e.g., policy makers) a fuller, clearer, and evidence-based picture of what have been done and what should be emphasised more in future anti-doping SSR, in the present research, we adopted a science mapping approach to understand global shares, key research clusters and emerging trends, as well as thematic evolutions in SSR on anti-doping since the first WADA code took effect in 2004.

Whilst to date there has been no comprehensive review of the knowledge structure and evolution of SSR in anti-doping, several reviews have synthesised knowledge and implications for specific SSR areas related to anti-doping. One important line of work is that of Ntoumanis et al. (2014, 2024). Taking a systematic review approach with a meta-analytical strategy, Ntoumanis et al.'s (2014, 2024) work offered strong evidence that social (e.g., pro-doping norm, exposure to appearance/fitness media), psychological (e.g., pro-doping attitude, morality, self-efficacy, motivation, body dissatisfaction), and behavioural (e.g., supplement use, antisocial behaviour, high training volume) factors predict doping use and intentions, highlighting the potential importance of SSR for doping prevention. Also, whilst Ntoumanis et al. (2014) identified only 63 independent quantitative studies, this increased to 211 by 2024, identifying a surge in publications over this decade (see Ntoumanis et al., 2024). As with quantitative anti-doping SSR, qualitative anti-doping SSR has also been well documented. Specifically, Williams et al. (2024) conducted a qualitative meta-synthesis examining barriers and enablers of doping. From the theoretical perspective of the COM-B (i.e., capability, opportunity, and motivation of behaviours; see Michie et al., 2011) model, Williams et al. (2024) concluded from 73 qualitative SSR on anti-doping that doping prevention efforts have been focusing too much on building athlete capability, overlooking opportunity and motivation aspects of doping.

Beyond Ntoumanis et al. (2014, 2024) and Williams et al. (2024), more recent research has also conducted meta-syntheses on factors influencing doping at system and educational program levels. Specifically, in their systematic review of education interventions for anti-doping, Filleul et al. (2024) identified 28 studies, of which 23 were published since 2004. Their findings suggest a popular focus on the knowledge-based approach in anti-doping education, raising concerns about the limited and uncertain long-term impact of existing preventive education (see also Gatterer et al., 2020). Building on and extending these works, Naughton et al. (2025) applied a systems-thinking lens to their systematic review, examining the role of broader systemic factors. Through a meta-synthesis of 56 relevant publications, Naughton et al. identified contributory factors within sport systems, ranging from lower, more micro (e.g., equipment, athletes) to higher, more macro (e.g., support resources, governing and regulatory bodies) levels. Their findings draw attention to the potential influence of support personnel, the limitations of the deterrence-detection paradigm, and the insufficiency in tackling higher-level influences at the team, organisation, sport system, and societal levels.

While we wholeheartedly appreciate these efforts in addressing how doping may be understood and prevented through the lens of social sciences, these reviews may have focused on specific aspects of anti-doping SSR and thus failed to examine and evaluate the broader development and evolution of SSR in anti-doping. One exception is Boardley's (2025) narrative review of the evolution of psychological theories and approaches in anti-doping research. Based on a re-analysis of the studies from Ntoumanis et al. (2024) and Williams et al. (2024), Boardley (2025) found divergent trends in the development of quantitative and qualitative research in psychology and anti-doping, concerning the timing of research (i.e., emerged later for qualitative research), the methodological approaches (i.e., less diversity in qualitative research), the theoretical grounds (e.g., greater consistency in quantitative research), as well as the varying topics of focus over time. However, this work is limited by its reliance on narrative analysis, such as potential for researcher bias in results synthesis, lack of systematic quantification, and difficulty in identifying overarching knowledge structures or evolving trends, as well as by its insufficient coverage and representativeness of anti-doping SSR due to the sole focus on psychosocial influences of doping.

To address the gaps and provide a more comprehensive understanding of the knowledge structure and evolution of anti-doping SSR, this research adopted a science-mapping approach that combines bibliometric analysis techniques with manual mapping via expert panel review. More specifically, science mapping utilises bibliometric analysis techniques to quantify the *knowledge structure* (e.g., the interconnection of research published in a certain field according to collaborative networks and topics) and *emerging research trends* (e.g., the burst of certain topics, the change or development of topics over time) using the bibliometric data of a set of published literature (see Donthu et al., 2021). Such an approach is enriched by visualisation and clustering techniques, thereby optimising the knowledge structure and emerging trends generated by the analysis of bibliometric data for comprehension and interpretation (Benomar et al., 2022). Importantly, the quantified and visualised science mapping results can foster evidence-based understanding of what has been done or what has happened in specific research fields, reducing researcher bias (Nakagawa et al., 2019). Therefore, we employed bibliometric techniques to conduct science mapping, examining the knowledge structure and emerging trends in anti-doping SSR since 2004, when the first WADC came into effect.

To supplement the bibliometric analysis techniques for a more comprehensive science mapping of SSR on anti-doping since 2004, we extended the traditional science mapping approach (via bibliometric analysis only) to an expert panel review that manually maps each of the eligible studies retained for bibliometric analysis into specific categories based on their *level of influence*, alignment with *WADA-SSR priorities*, and fulfilment of the *international consensus on SSR agenda* (Boardley et al., 2021). According to the details outlined in the WADA-SSR programme, anti-doping SSR should be considered in relation to its influence at six distinct levels: 1) athlete, 2) athlete support personnel, 3) education programme, 4) world anti-doping programme, 5) sport environment, and 6) society. These levels of influence are further broken down to inform twelve SSR priorities (for details, see WADA, 2025b). In addition to the levels of influence and the WADA-SSR priorities, an international consensus on the key SSR agenda was co-created by a group of representative anti-doping experts, highlighting eight critical areas of SSR that require attention for anti-doping purposes (see Boardley et al., 2021). For parsimony, we present our approach to manual mapping in the Methods section and summarise items or categories regarding levels of influence, WADA-SSR priorities, and the consensus SSR agenda for anti-doping in Table 3.

Overall, in light of the growing complexities in the field of anti-doping, we set forth this research to examine anti-doping SSR since the initial implementation of WADC in 2004. Through a cutting-edge

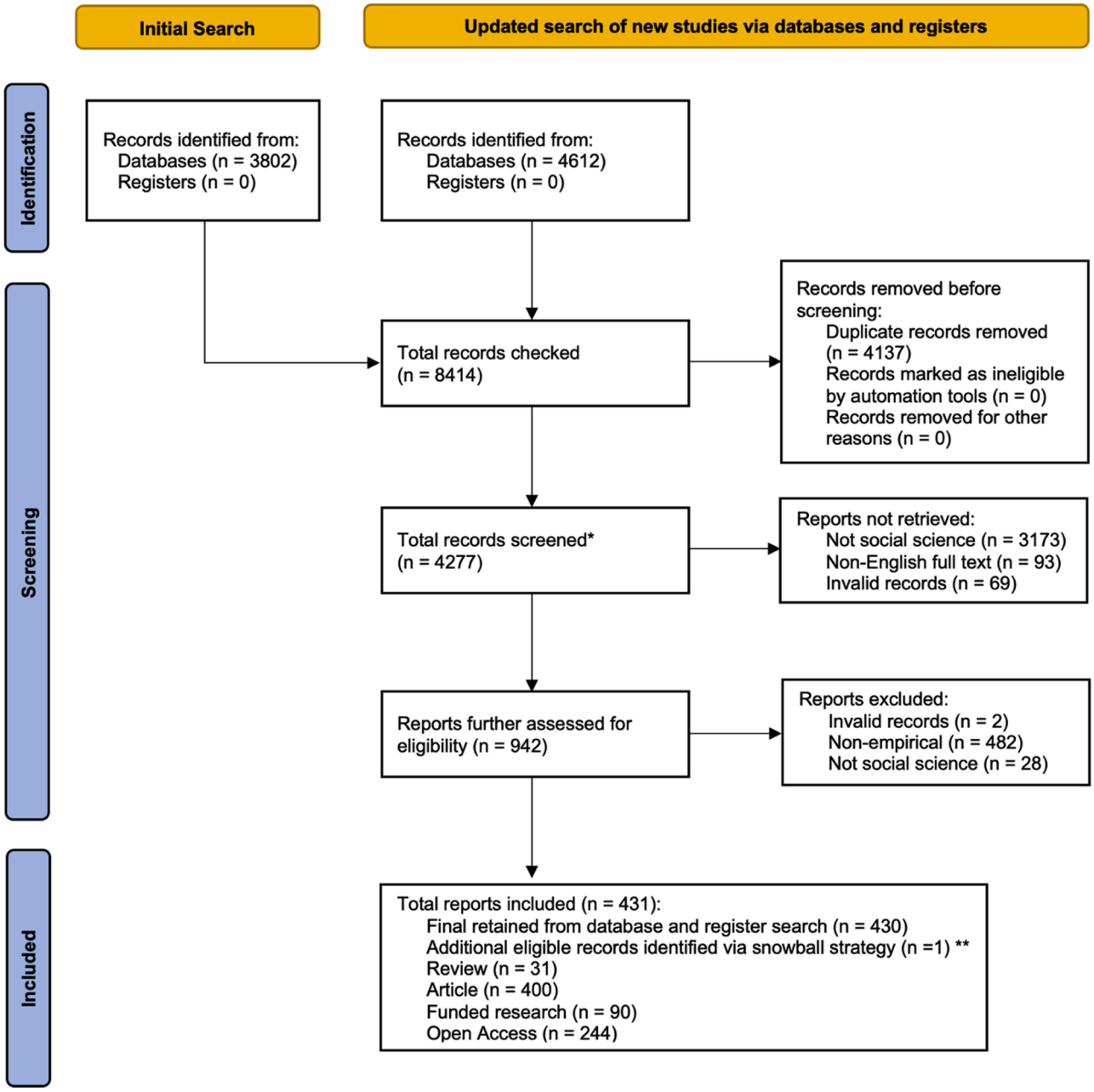


Fig. 1. A PRISMA flow diagram outlining the study identification and screening process.
Note. The initial search was conducted on January 2, 2025, for the purpose of a preliminary investigation and feasibility assessment. The refined, updated search was based on Web of Science (WoS) Core Collection as of updated by August 1, 2025. Full references of these articles are available in the Supplementary Material.
*The screening process combined the strategies of eligibility screening by checking WoS categories with title and abstract search. Non-English full text was screened on completion of the screening for social science research. Invalid records refer to WoS items that cannot be found or validated for original sources.
**The additional record was identified during the validation stage by comparing the final retained records and their cited references.

science mapping approach that combines bibliometric analysis and expert manual review, we systematically examined the knowledge structure and evolution (e.g., collaboration networks, key research clusters, thematic mapping; see Cobo et al., 2011b) within anti-doping SSR, while further evaluating existing anti-doping SSR regarding levels of influence, alignment with WADA-SSR priorities, and fulfilment of the international consensus agenda. The findings should provide a comprehensive, evidence-based overview of SSR development, trends, and gaps for anti-doping stakeholders (e.g., researchers, practitioners, policymakers, etc.), supporting capacity building, knowledge exchange, and resource leveraging that are key to WADA's Social Science Strategy 2025-2029 (WADA, 2025c). Given the substantial resources that have been invested in global doping control (e.g., over $51 million US dollars spent annually by international sports federations only; see Mountjoy et al., 2024) and anti-doping SSR (e.g., over $6 million US dollars since 2005 by WADA only; see WADA, 2025a), the findings of the present research would provide insights into how these limited resources can be allocated effectively, avoiding research duplication and target critical gaps to maximise the real-world impact of anti-doping initiatives.

Table 1
Global shares of scientific publications in the field of social science research on anti-doping between 2004 and 2025 from the perspectives of the top ten journals, countries and institutions.

Rank		n	ACI	TLS
	Journal			
1	Psychology of Sport and Exercise	40	3.30	-
2	Performance Enhancement & Health	28	3.70	-
3	Frontiers in Sports & Active Living	26	2.60	-
4	Journal of Sports Sciences	22	2.50	-
5	Scandinavian Journal of Medicine & Science in Sports	19	3.80	-
6	Substance Abuse Treatment, Prevention, & Policy	16	3.20	-
7	Journal of Science & Medicine in Sport	15	3.40	-
=8	British Journal of Sports Medicine	14	16.20	-
=8	Frontiers in Psychology	14	2.90	-
=8	International Journal of Drug Policy	14	4.40	-
	Country			
1	England	146	22.05	226
2	Australia	59	29.05	86
3	Germany	50	20.48	123
4	Greece	41	25.83	123
5	USA	40	16.05	71
=6	Italy	31	19.29	96
=6	Switzerland	31	19.94	68
=8	France	26	11.85	38
=8	Spain	26	18.08	34
=10	Austria	19	10.37	45
=10	Norway	19	19.32	22
	Institution			
1	University of Birmingham	43	18.74	62
2	Aristotle University of Thessaloniki	38	25.18	93
3	Kingston University	37	26.81	85
4	Leeds Beckett University	26	14.58	35
=5	Sheffield Hallam University	17	18.59	49
=5	Curtin University	17	27.00	34
=7	Canterbury Christ Church University	13	13.08	25
=7	University of Sheffield	13	68.08	18
9	Université de Lausanne	11	19.55	6
=10	University of Rome Foro Italico	10	15.60	38
=10	University of Münster	10	14.10	36
=10	KU Leuven	10	10.00	27
=10	University of Western Australia	10	35.10	18
=10	Sveučilište u Splitu	10	21.40	6

Note. n = number of publications contributed; ACI = average citation per item; TLS = total link strength of contributed publications from its corresponding collaborative network. ACI for journals was filled with the 2024 Journal Impact Factor from the Journal Citation Reports™. The rank order is based on the quantity of publications, not a reflection of the quality or impact of research.

2. Methods

2.1. Search strategy and data collection

We followed Donthu et al.'s (2021) step-by-step guide of bibliometric analysis to conduct the science mapping part of the current research[1]. To establish a valid dataset for bibliometric analysis, we chose the Web of Science Core Collection (WoSCC), including the SCIE, SSCI, AHCI and ESCI databases. Since the merging of bibliometric data from different databases (e.g., combining data from WoSCC and Scopus) can cause data contamination and other analytical errors due to the varying data formats and sources (Aria & Cuccurullo, 2017), we utilised the WoSCC only, because previous research suggested it is the most favourable multidisciplinary database compared to other competitors (e.g., Scopus) regarding the extent of publication coverage and data completeness when conducting bibliometric analysis (e.g., Echchakoui, 2020; Zyoud et al., 2017). We did not consider discipline-specific databases, such as PsycINFO and SPORTDiscus, or their equivalents, as they often yield incomplete search results that impact the validity of bibliometric analysis (Rogers et al., 2020).

When conducting searches in the WoSCC, we combined the use of concept-related keywords (i.e., "*doping*" OR "*anti-doping*" OR "*performance enhancement*" OR "*clean sport*") and context-/population-related words (i.e., "*sport*" OR "*sports*" OR "*athlete*" OR "*athletes*" OR "*coach*" OR "*coaches*" OR "*professionals*" OR "*personnel*"). Such a search strategy was developed based on a preliminary pilot search conducted in January 2025, followed by an expert panel review of the preliminary search results from February to June 2025 (involving three PhD researchers, three post-doctoral researchers, and three senior anti-doping SSR researchers), which was then refined and confirmed in August 2025. Publications between 1st January 2004 to 1st August 2025 that simultaneously contain at least one concept-related term and one context-/population-related term were retained for further screening. The requirement for at least one context-/population-related term (e.g., 'athlete', 'coach') was a deliberate choice to ensure the dataset remained focused on empirical research involving human subjects or direct social interactions. A post-hoc analysis of the metadata for the omitted studies identified during the review process revealed that research focusing primarily on macro-level organisational governance or policy implementation (e.g., compliance strategies or inter-organisational power dynamics) occasionally omits specific population keywords in favour of systemic terms like 'governance', 'harmonisation', or 'compliance'. While these studies are considerably relevant to the broader field, their exclusion at the retrieval stage was a systematic consequence of prioritising retrieval precision to minimise the inclusion of non-empirical legal commentaries or irrelevant literature (see Donthu et al., 2021; Manning et al., 2008), which often lack these specific social- and/or population-context descriptors.

After deduplication, the retained records were further screened for WoSCC research categories, followed by title and abstract screening, and then at the full-text level. Non-English, non-social science, and non-empirical publications were excluded. For clarification, we required studies that utilised empirical social science methodologies (e.g., surveys, qualitative interviews, ethnography, psychological experiments) involving human subjects or primary data on social structures (e.g., sport organisations). Purely legal analyses, historical accounts, or descriptive policy documents lacking primary empirical data collection were excluded. Since review articles are important sources for bibliometric analysis (Donthu et al., 2021), we retained reviews that employed a systematic approach to literature searches and meta-synthesis/aggregation of findings from empirical studies. However, books, book sections, conference proceedings, short communications, and opinion pieces were excluded due to their non-empirical or non-social science nature. Law studies, policy statements, and other publications that did not employ a specific social science method were excluded. We downloaded the full WoSCC bibliometric data for the retained publications.

Aligning with Donthu et al.'s (2021) guidance, this strategy prioritised retrieval precision (i.e., *the relevance of the retained publications*) over retrieval recall (i.e., *the absolute exhaustiveness of coverage*). In bibliometric science mapping, prioritising retrieval precision is considered a best practice to ensure that the resulting knowledge structures, such as co-citation clusters and thematic quadrants (see detailed methodologies below), are not contaminated by peripheral or non-empirical 'noises' (Zupic & Čater, 2015). Consequently, while the search strategy was highly effective at capturing the core empirical anti-doping SSR, it inherently favoured studies that explicitly declare their sport-specific context in their metadata. To compensate retrieval coverage whilst emphasising still maintaining emphasis on retrieval precision as

[1] We did not pre-register the bibliometric search and analysis due to the exploratory nature of this method and feasibility issues (i.e., to accommodate the synthesis of panel review process and the bibliometric search). While the bibliometric search was not formally pre-registered, we believe our iterative preliminary pilot search conducted in January 2025 and subsequent refinement through the expert panel (till August 2025) served as a rigorous internal validation process for the search strategy.

Table 2
The top ten publications with the highest number of citations in the field of social science research on anti-doping from 2004 to 2025.

Rank	Citations	First Author	Year	Title	Journal	Type
1	**242**	Ntoumanis, N	2014	Personal and psychosocial predictors of doping use in physical activity settings: A meta-analysis	Sports Medicine	Review
2	**191**	de Hon, O	2015	Prevalence of doping use in elite sports: A review of numbers and methods	Sports Medicine	Review
3	**150**	Morente-Sánchez, J	2013	Doping in sport: A review of elite athletes' attitudes, beliefs, and knowledge	Sports Medicine	Review
4	**129**	Backhouse, SH	2013	Gateway to doping? Supplement use in the context of preferred competitive situations, doping attitude, beliefs, and norms	Scandinavian Journal of Medicine & Science in Sports	Article
5	**128**	Ulrich, R	2018	Doping in two elite athletics competitions assessed by randomized-response surveys	Sports Medicine	Article
6	**125**	Martínez-Sanz, JM	2017	Intended or unintended doping? A review of the presence of doping substances in dietary supplements used in sports	Nutrients	Review
7	**123**	Alaranta, A	2006	Self-reported attitudes of elite athletes towards doping: differences between type of sport	International Journal of Sports Medicine	Article
8	**117**	Petróczi, A	2009	Measuring explicit attitude toward doping: Review of the psychometric properties of the Performance Enhancement Attitude Scale	Psychology of Sport & Exercise	Article
9	**111**	Lazuras, L	2010	Predictors of doping intentions in elite-level athletes: A social cognition approach	Journal of Sport & Exercise Psychology	Article
10	**109**	Petróczi, A	2007	Attitudes and doping: a structural equation analysis of the relationship between athletes' attitudes, sport orientation and doping behaviour	Substance Abuse, Treatment Prevention & Policy	Article

Note. The rank and number of citations were derived from the Web of Science Core Collection data as of August 1, 2025.

recommended for bibliometric analysis, we checked cited references within these retained publications using the Evidence Research Accelerator (TERA; Clark et al., 2020) to identify any additional eligible publications that might be missing from our search. Specifically, we extracted cited references from bibliometric data of the post-screening publications from the WoSCC and compared them with the pre-screening records (i.e., search results prior to conducting the screening) in the TERA for a duplication check, with those identified as non-duplicated records (thus definitely missing from our initial and updated search) retained for further check. Next, the non-duplicated records were screened manually by title and abstract to identify potential missing records that fulfil our inclusion criteria. Only the identified missing publication(s) that are eligible and have a valid bibliometric record in WoSCC were retained for further analysis and for methodological consistency (i.e., the use of WoSCC rather a combination of multiple databases to prevent contaminated bibliometric data). As such, the resulting dataset retained from our bibliometric science mapping should be of good coverage despite our priority of retrieval precision over sensitivity. The retained bibliometric data should be statistically robust for identifying the primary knowledge structures of the field, even if some omission of specific studies was inevitable due to their different indexing profiles (see also Manning et al., 2008). Fig. 1 presents a PRISMA diagram of the process we underwent in the literature search and screening.

2.2. Bibliometric analysis techniques

2.2.1. Preliminary analysis

With full bibliometric data of the eligible publications, we first conducted a series of performance analyses to understand the contribution (e.g., number of publications, citations) and contributors (e.g., journals, countries, institutions) of the retained publications. Collating from the citation reports generated via WoSCC, we utilised the publication and citation data of the included publications and performed a locally estimated scatterplot smoothing (LOESS) curve analysis to examine and visualise publication and citation trends of anti-doping SSR from 2004 to 2025 using the MSIR R-package (Scrucca, 2011). We further employed data (e.g., citation metrics such as average citations per item [ACI], productivity-impact measures such as the h-index) from the WoSCC to identify the top ten journals, countries and institutions contributing to anti-doping SSR, as well as the top ten publications that received the highest number of citations between 2004 and 2025.

2.2.2. The science mapping approach

According to Cobo et al.'s (2011) seminal review of science mapping techniques, science mapping is a key bibliometric analysis technique that enables a statistical investigation of scientific knowledge within a specific field. The examination of scientific knowledge through a science mapping approach can be applied at three levels: *social, intellectual*, and *conceptual* (see also Aria & Cuccurullo, 2017). In this research, we conducted science mapping across all three levels using appropriate bibliometric tools.

Social structure. First, we examined the *social structure* of anti-doping SSR published between 2004 and 2025 via collaboration network analysis using VOSviewer 1.6.20 (van Eck & Waltman, 2010). The social structure concerns how institutions and countries interact to produce scientific outputs (e.g., research publications) that shape the development of a specific scientific community (Cobo et al., 2011b). Using VOSviewer, we separately analysed the collaboration networks for countries and institutions in anti-doping SSR and examined the total link strength (TLS) of publications within these networks. TLS assesses the number of times each pair of countries and institutions on the same research output, thereby indicating the quantity of research collaboration, which is key to understanding the social structure of research in a specific field. Based on comprehensive TLS metrics for all retained publications, we visualised the collaboration networks of anti-doping SSR between 2004 and 2025.

Intellectual structures. Second, we examined the *intellectual structure* of anti-doping SSR via co-citation analysis using CiteSpace 6.4.R2 Advanced (Chen & Song, 2019). The intellectual structure of a specific field of research encompasses the frontiers and development of research, as well as how the work of an author or a group of authors influences a given scientific community (e.g., contributing to shared interests such as key topics, populations, methods; see Cobo et al., 2011b). This variation of science mapping applied two metrics (i.e., *modularity* or Q-score, *silhouette* or S-score) for clustering purposes. More specifically, the Q-score can range from 0 to 1, with higher scores indicating greater internal connections with a certain grouping cluster. For comparison, the S-score can range from -1 to 1, with a value closer to 1 indicating greater distinctiveness of a grouping cluster from other clusters, a value closer to 0 suggesting potential overlapping clusters, and a negative value reflecting misclassification (Newman, 2006). Using this technique, publications frequently cited together tend to be grouped into a cluster that constitutes both the citing articles (i.e., publications retained for science mapping) and the cited articles (i.e., articles cited by the citing articles), whereas the Q-score and S-score assess the validity of clustering (Chen & Song, 2019).

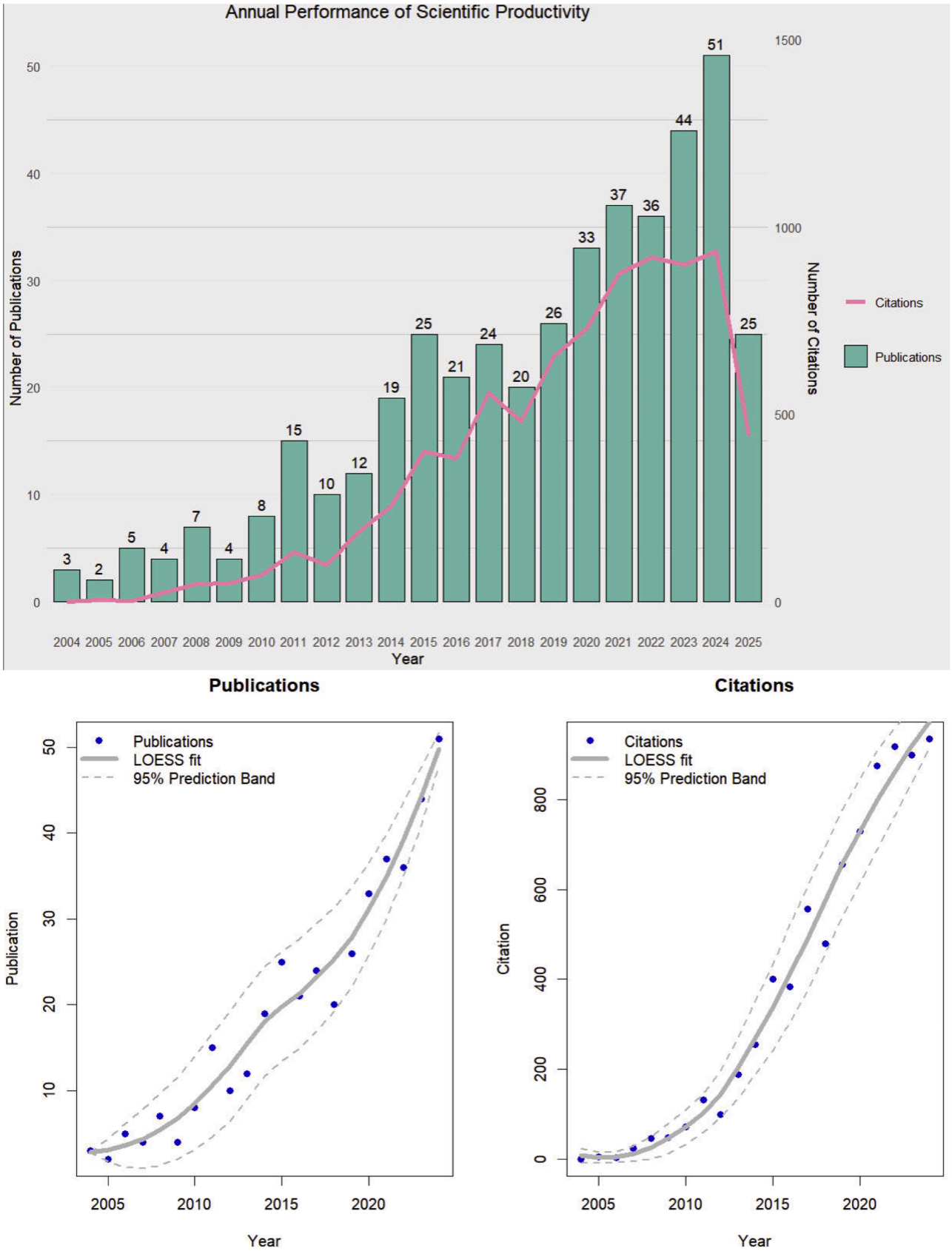


Fig. 2. The annual number of publications, citations, and the LOESS curve informed trends in the growth of social science research on anti-doping from 2004 to 2025.

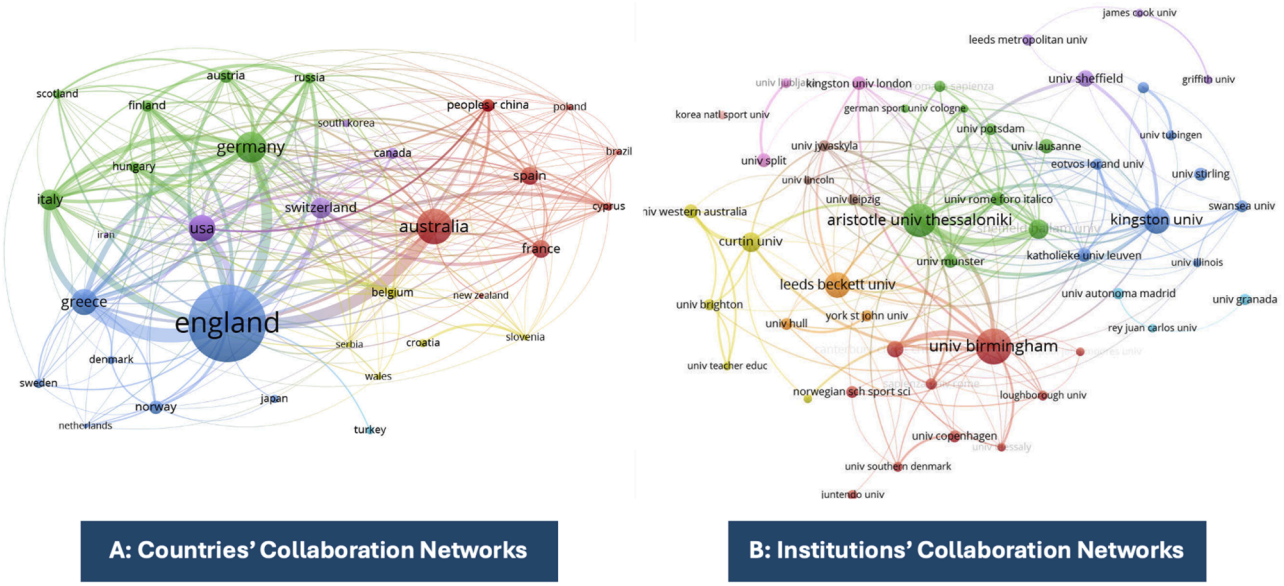


Fig. 3. Collaboration of countries (panel A) and institutions (panel B) based on co-occurrence analysis of social science research on anti-doping from 2004 to 2025.
* Each node represents a country or an institution in the relevant panel. The size of a node is determined by its total link strength, which is the sum of total links between nodes, reflecting the number of times two countries, institutions, or authors contributed to the same publication. Larger nodes and thicker links represent more frequent collaboration, not necessarily impact or quality of research. Nodes of the same colour represent a collaboration network.
**In the institutions' collaboration networks, it is noteworthy that Leeds Metropolitan University (purple cluster) was the former of the Leeds Beckett University (orange cluster), as was Kingston University London (pink cluster) to the Kingston University (blue cluster). This reflects the dynamics of a collaborative network among the same institutions over time or across varying bibliometric datasets. We did not manually combine or manipulate these data in the network analysis to avoid unwanted errors. However, we combined the publication production and citation data when presenting the institution performance data in Table 1.
***The countries' and institutional collaboration networks, by their nature, are driven by the publications of research teams and prominent individual researchers affiliated with them. These networks, therefore, reflect an accumulated 'record of status' based on publications from inception to date in the field, and could change to reflect shifts in the field's landscape in future due to the movement of researchers or research teams across institutions and countries.

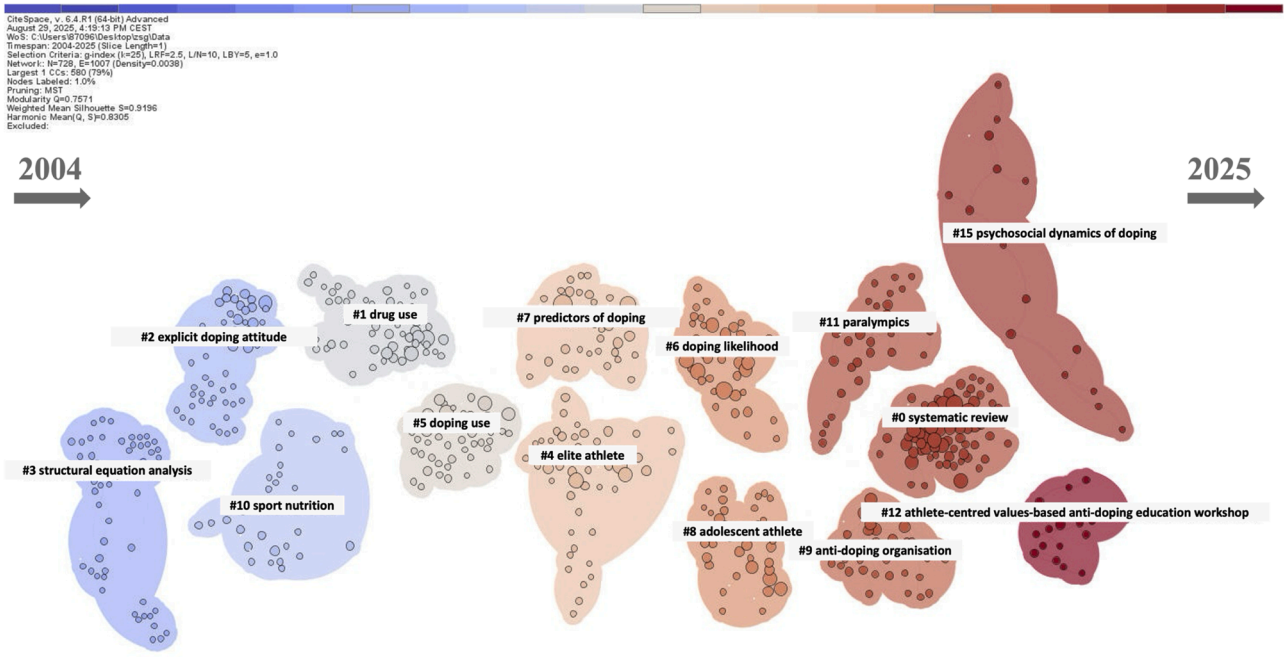


Fig. 4. Intellectual structure reflecting key topics, populations, and methods in anti-doping SSR from 2004 to 2025 based on reference co-citation analysis.
*Modularity Q = .76, weighted mean silhouette = .92, indicating goodness of clustering validity. Time slicing = 01-01-2004 to 01-07-2025; year per slice = 1; estimation approach = minimum spanning tree with pruning sliced networks; clustering algorithms = log-likelihood ratios.
**From left to right, the intellectual structure denotes the shift of key topics, populations, and methods in anti-doping SSR from 2004 to 2025 (shift as indicated by the change in cluster from cold to warm colours); each cluster consists of the co-cited references (i.e., the nodes), and the size of the cluster is determined by the number of publications it contains. The #number denotes the rank of the cluster size (i.e., number of items) and density (i.e., interconnection of items). A summary of research within each cluster, along with the relevant details of the most highly weighted publications, is provided in Supplementary Table 1.

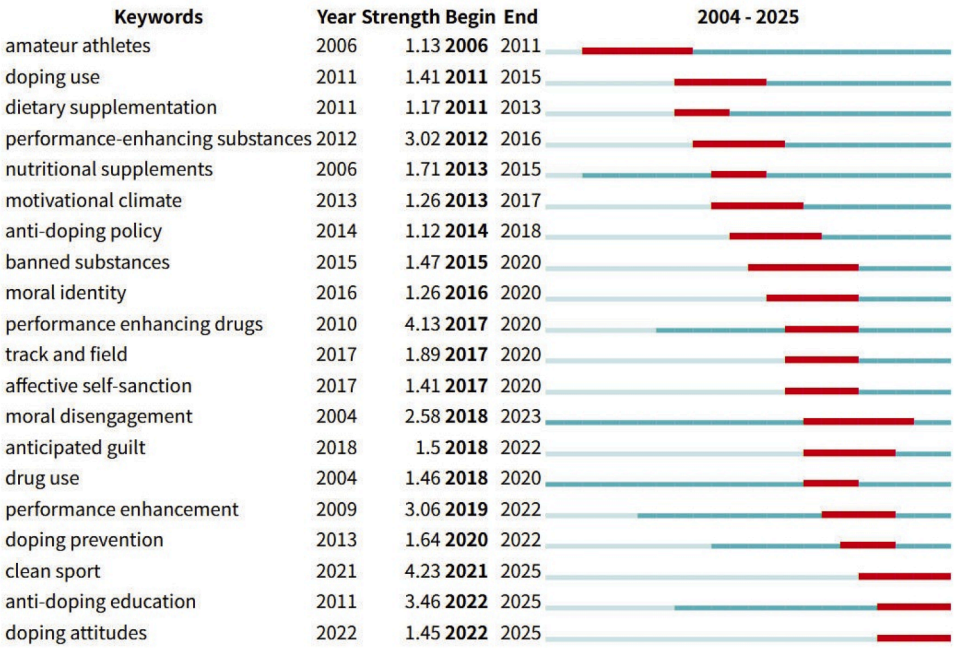


Fig. 5. The top twenty keywords with the strongest citation bursts in social science research on anti-doping from 2004 to 2025.
* The light blue timeline represents the last 20 years; the dark blue timeline represents the time period in which the keyword appeared; the red timeline represents the time period in which the keyword received a significant citation burst.

Once a cluster was formed, it was labelled using a log-likelihood ratio (LLR) algorithm that identifies the most representative descriptor, informed by the study titles and author keywords of the items in the cluster (see Ezugwu et al., 2021). To enhance the interpretability of the clustering results, we assessed each cluster label, reviewed the most weighted publications within each cluster, and made essential modifications to any cluster for which the LLR-generated label was vague or difficult to understand (see Supplementary Table 1). We first conducted reference co-citation analysis on all our retained anti-doping SSR published between 2004 and 2025 to understand its intellectual structure (e.g., using the clustering results and cluster labels to understand key topics, populations, and methods), then performed keywords burst analysis based on the reference co-citation to understand the most frequently occurring keywords and the period in which each of these keywords received a significant citation burst. We adopted the minimum spanning tree with pruning sliced network (MST) approach, which removes non-significant links and invalid clusters, facilitating the interpretation of mapping results (Chen, 2006).

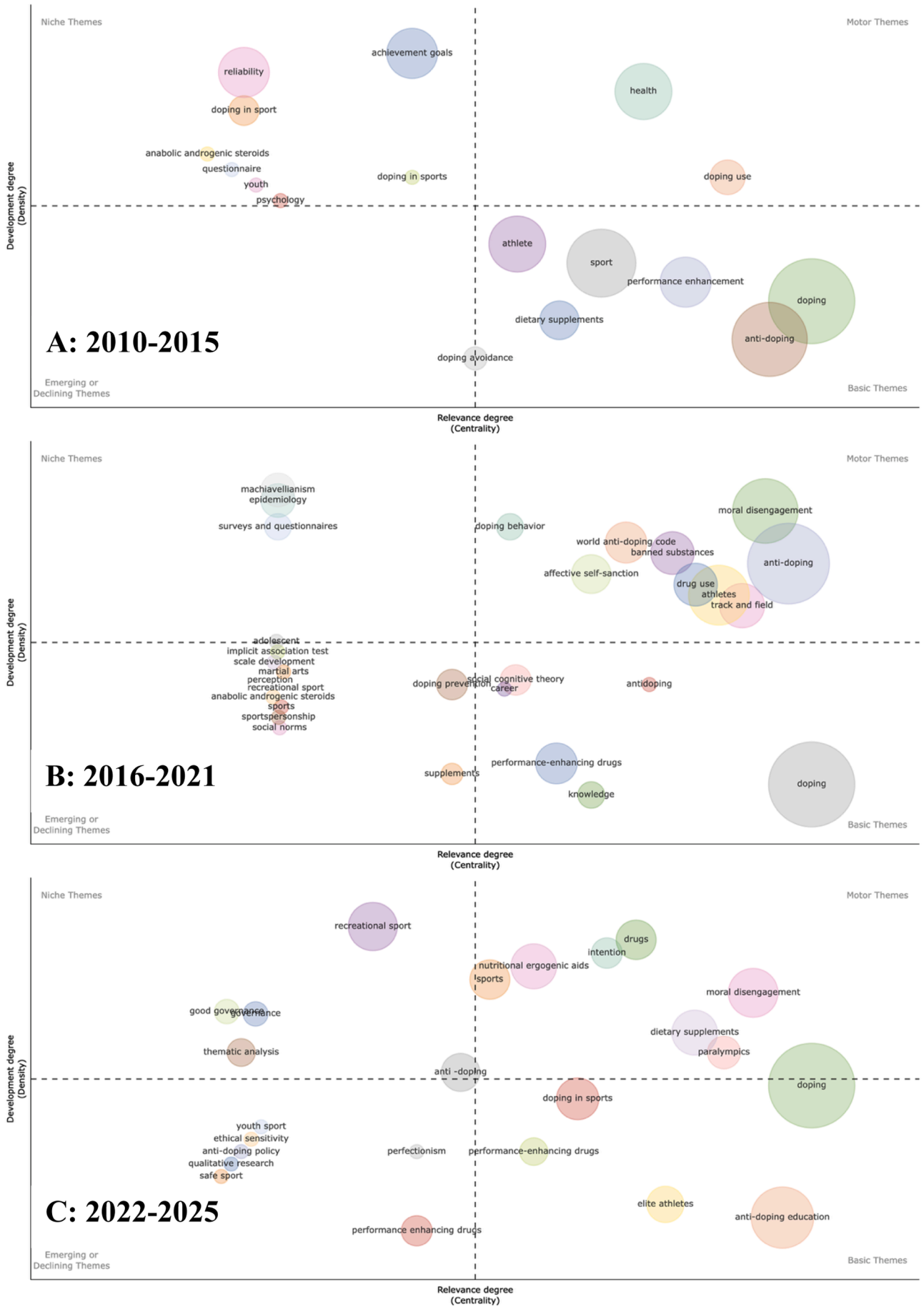
Conceptual structures. Finally, we examined the *conceptual structure* of anti-doping SSR through thematic mapping analysis using the Bibliometrix 5.1.0 R package (Aria & Cuccurullo, 2017). Different from examining social and intellectual structure in science mapping, the conceptual structure concerns what science talks about, such as what the main themes are, what the meaning and contribution of these themes to a specific field of research, and how the positions of themes change over time, thus providing an indication of thematic mapping and evolution (Cobo et al., 2011b). Although CiteSpace also enables the examination of conceptual structure, we employed the Bibliometrix 5.1.0 R package for its advantage in implementing Cobo et al.'s (2011a) quadrant system for thematic mapping.

Specifically, Cobo et al. (2011a) proposed a *centrality* and *density* measure to assess the relative position of a specific theme within the entire literature of a research field over a specified period. According to Cobo et al. (2011b), *centrality* measures the degree of interaction between an identified theme and other themes, thereby indicating the strength of external ties within the cluster and reflecting the relative importance of a theme within the extensive literature of a specific field. *Density*, on the other hand, measures the internal strength of an identified theme, thereby indicating the strength of the internal ties of all the keywords describing a specific theme and reflecting the theme's development or level of maturity. Given the centrality and density measures, a theme can be mapped onto a quadrant where the horizontal axis indicates the degree of centrality, whilst the vertical axis indicates the degree of density. Within this quadrant system, themes in the upper-right quadrant can be interpreted as well-developed (high density) and important to the field (high centrality), and are therefore referred to as the *motor or driving themes*. Following this principle, themes in the upper-left, lower-right, and lower-left are referred to as the *niche or peripheral themes* (i.e., high density low centrality), the *basic or transversal themes* (i.e., low density high centrality), and *either emerging or declining themes* (i.e., low density low centrality), respectively.

Using the Bibliometrix 5.1.0 R package, we conducted thematic mapping of key research themes based on author keywords co-occurrence networks, whilst specifically examining thematic mapping of key research themes in *2004-2009* (i.e., period before the first revision of the WADA code), *2010-2015* (i.e., period between the first and second major revision of WADA code), *2016-2021* (i.e., period between the second WADA code revision and the launch of the first International Standard for Education or ISE), and *2022-2025* (i.e., period after the first ISE took effect. In the meantime, we assessed changes in the relative positions of themes within the quadrant system, thereby providing insights into the evolution of themes over these key periods (Cobo et al., 2011a).

2.3. Expert panel review and manual mapping

To further understand the focus and areas of research of anti-doping SSR published between 2004 and 2024, we conducted an expert panel review beyond science mapping via bibliometric techniques, which manually map the retained publications into specific categories based on their *level of influence*, alignment with *WADA-SSR priorities*, and fulfilment of the Boardley et al.'s (2021) *international consensus on SSR agenda* (see Table 3 for all categories regarding level of influence, WADA-SSR



(caption on next page)

Fig. 6. Changes in thematic map of key research themes in social sciences research on anti-doping between 2010-2015 (panel A), 2016-2021 (panel B), and 2022-2025 (panel C).
* Data used = Author keywords from Web of Science core collections; Clustering algorithm = Walktrap; Size of the circle indicates relative weightings of a certain theme (i.e., minimum weight index set at .20). Details of all keywords within each theme are available in the Supplementary Tables 2-4.

priorities, and the consensus key SSR agenda).

To conduct this panel review, we formed an expert panel including 3 senior researchers who had collectively delivered all three tiers of WADA-SSR grant projects and had conducted or been involved in multiple anti-doping SSR collaborations funded by WADA and other funding bodies (e.g., the European Union), 3 post-doc researchers with a minimum of 5+ years of experience in anti-doping SSR, as well as 3 PhD researchers with a minimum of 2+ years of experience in anti-doping SSR. The 3 PhD researchers and 3 post-doc researchers were paired into 2 groups of 3. Subsequently, all publications retained for analysis were reviewed within each group and assigned a category based on level of influence, WADA-SSR priorities, and the consensus key SSR agenda. Upon completing the initial round of review, the two groups compared their mapping results and discussed in a series of meetings to reach agreements on the categorisation of each included publication. The 3 senior researchers then checked the mapping results, paying particular attention to discussing and deciding on the categorisation of each item that had been disagreed upon during the earlier panel review stages. Frequency counts of each category within the level of influence, WADA-SSR priorities, and the consensus key SSR agenda were further calculated for the entire period of analysis (i.e., 2004-2025), as well as for the periods of 2004-2009, 2010-2015, 2016-2021, and 2022-2025. Such an approach allowed for a comprehensive analysis of the focus of research through the lens of level of influence, WADA-SSR priorities, and the consensus SSR agenda, both for the entire duration since the first WADA code took effect and across the key periods of change given major WADA code revisions (i.e., 2009, 2015) and the launch of the first ISE (i.e., 2021). This timeframe was also adopted by the expert panel, which synthesised the methodological approaches used in anti-doping SSR from 2004 to 2025 and mapped the focus domains.

3. Results

3.1. Overview of anti-doping SSR from 2004 to 2025

We followed Montazeri et al.'s (2023) guideline for reporting the bibliometric review. To expand, our search strategies yielded a total of 8,414 documents from the literature search, which were retrieved for further screening. After deduplication using the Evidence Research Accelerator (TERA; Clark et al., 2020), 4,277 items were retained for screening, including publications that were not social science (n = 3,173), non-English (n = 93), or lacked valid bibliometric records (n = 69). Of the remaining 942 items, we conducted further screening at the abstract level or full-text (if necessary) and excluded additional items that were non-empirical (n = 482), not social science (n = 28), or lacked valid bibliometric records (n = 2). The remaining items were further checked for their cited references in TERA, through which we identified one additional eligible publication. Altogether, we retained 431 publications for further analysis. Fig. 1 presents a PRISMA flow diagram outlining the study identification and screening process.

Further analysis of the characteristics of the 431 retained publications revealed that 244 (56.6%) were open-access publications, and 90 (20.9%) received funding support. Sport sciences (268 publications, 62.2%), psychology or psychology applied (163 publications, 37.8%), and substance abuse (71 publications, 16.5%) were the major WoSCC categories that archived anti-doping SSR. The retained publications were linked to 88 distinct peer-reviewed journals. While the *Psychology of Sport & Exercise* (40 publication, 9.3%), *Performance Enhancement & Health* (28 publications, 6.5%), and *Frontiers in Sport & Active Living* (26 publications, 6.0%) appeared to be the three most popular journals publishing anti-doping SSR between 2004 and 2025 (see Table 1 for details of the top ten journals), *Sports Medicine,* despite not in among the top ten most popular journals for anti-doping SSR, was the most frequently linked title of the top ten most cited publications (see Table 2 for more details).

Plotting the 431 publications in the field of anti-doping SSR between 2004 and 2025, we found an upward trend for both the number of publications and citations per year (Fig. 2 top panel). Such an upward trend achieved statistical significance with approximately a 12% annual growth rate for both the number of publications and citations, according to the LOESS curve analysis (Fig. 2 bottom panel). Importantly, 167 (38.7%) publications had an international co-authorship profile, with only 11 (2.6%) single-authored publications, indicating a considerable level of global research collaboration in anti-doping SSR.

3.2. Collaboration networks of countries and institutions

An analysis of the country-related social structure of anti-doping SSR between 2004 and 2025 identified 70 contributing countries or regions. These contributing countries formed five major collaboration networks, of which *England* (blue cluster), *Australia* (red cluster), and *Germany* (green cluster) led the three largest collaboration networks (see Fig. 3 panel A). At the institution level, the analysis of social structure identified a total of 693 institutions that contributed to anti-doping SSR between 2004 and 2025. These contributing institutions formed ten major networks, of which the *University of Birmingham* (red cluster), *Aristotle University of Thessaloniki* (green cluster), *Kingston University* (blue cluster), and *Leeds Beckett University* (orange cluster) led the largest collaboration networks (see Fig. 3 panel B). Table 1 presents more details of the top ten most productive countries and institutions.

3.3. Research clusters, emerging topics, and keywords burst

Reference co-citation analysis identified 14 distinctive research clusters from 2004 to 2025 (i.e., clusters of anti-doping SSR that tended to be cited together; see Fig. 4). The analysis yielded a modularity/Q-score of .76 and a weighted mean silhouette/S-score of .92, indicating satisfactory internal cohesion and external distinctiveness of the identified clusters, respectively. Importantly, the reference co-citation analysis revealed two patterns of shift in anti-doping SSR from 2004 to 2025. First, the years 2007-2009 witnessed the emergence of the early research clusters, namely #3 *structural equation analysis* (early focus on quantitative methods to understand relationships between doping-related variables; e.g., Petróczi, 2007), #2 *explicit doping attitude* (early studies in quantifying doping attitude; e.g., Petróczi & Aidman, 2009), which informed anti-doping SSR in 2010-2019 reflecting a shift into #10 *sport nutrition* (later focus on nutrition, supplement use, and doping; e.g., Kondric et al., 2013), #1 *drug use* (later emphasis on the use of performance-enhancing and psychoactive drugs in sports; e.g., Henning & Dimeo, 2015), #5 *doping use* (research linking social cognitive factors to doping; e.g., Barkoukis et al., 2015), #7 *predictors of doping* (research examining antecedents of or factors influencing doping behaviours; e.g., Boardley et al., 2019), and #6 *doping likelihood research* (the incorporation of scenario-based measure for doping; e.g., Ring et al., 2019).

A second shift pattern in anti-doping SSR concerned the varying contexts in doping prevention. Around 2014, a distinctive cluster of #4 *elite athletes* emerged, emphasising the involvement of elite athletes in anti-doping SSR (e.g., Overbye, 2018). Such a focus on elite athletes, later shifted into new branches of research emphasising #8 *adolescent athletes* (e.g., Nicholls et al., 2020) and #11 *paralympics* (e.g., Blank

Table 3
Characteristics mapping of social science research (SSR) on anti-doping from 2004 to 2025 based on percentage qualified regarding level of influences, World Anti-Doping Agency's SSR priorities, and the international experts' consensus on key SSR agenda.

	Overall n = 431	2004-2009 n =25	2010-2015 n =90	2016-2021 n =161	2022-2025 n =155
Level of influence	**(1.8%)**	**(0.0%)**	**(1.1%)**	**(1.9%)**	**(2.6%)**
1. Athlete	63.5%	84.0%	73.0%	64.2%	53.5%
2. Athlete support personnel (ASP)	9.5%	-	6.7%	9.9%	12.3%
3. Education programmes	11.1%	-	4.5%	11.1%	16.8%
4. World anti-doping programmes	4.8%	-	7.9%	4.9%	3.9%
5. Sport environment	4.4%	-	1.1%	3.7%	7.7%
6. Society	6.0%	16.0%	5.6%	4.9%	5.8%
WADA-SSR priorities	**(2.6%)**	**(0.0%)**	**(1.1%)**	**(2.4%)**	**(3.9%)**
1. Athlete pathway and experience	34.4%	40.0%	43.8%	34.0%	28.4%
2. Clean sport behaviours	27.3%	44.0%	29.2%	29.0%	21.3%
3. Role and influence of ASP	5.5%	-	3.4%	6.2%	7.1%
4. Experience of ASP	3.7%	-	2.2%	3.7%	5.2%
5. People investment in anti-doping	2.3%	-	3.4%	0.6%	3.9%
6. Effectiveness of anti-doping/clean sport	10.6%	-	1.2%	11.7%	16.1%
7. WADA doping prevention model	0.9%	-	-	1.9%	0.6%
8. Anti-doping policy impact	4.2%	-	7.9%	3.1%	3.9%
9. Sport policy	1.6%	-	1.1%	1.9%	1.9%
10. Evolution of sport practices	1.6%	-	-	0.6%	3.9%
11. Horizon scanning	0.5%	4.0%	-	-	0.6%
12. Non-sport influences	6.2%	12.0%	5.6%	5.6%	6.5%
Consensus key SSR agenda	**(55.2%)**	**(92.0%)**	**(53.9%)**	**(58.0%)**	**(50.9%)**
1. Effectiveness of anti-doping/ education programmes	18.0%	4.0%	14.6%	16.0%	24.5%
2. Developmental influences from outside sport on young athletes	6.7%	-	11.2%	6.2%	5.8%
3. The role of athlete support personnel	5.5%	-	2.2%	6.8%	7.1%
4. ASP's knowledge and understanding	4.4%	-	4.5%	3.1%	6.5%
5. Long-term studies examining protective and risk factors for doping in athletes	2.1%	4.0%	2.2%	2.5%	1.3%
6. Clean athletes' perception of their representation and support within the anti-doping system	1.9%	-	1.1%	1.9%	2.6%
7. Long-term studies examining protective and risk factors for doping in ASP	0.2%	-	-	-	0.6%
8. The anti-doping system and athletes' experience of key procedures	6.0%	-	10.1%	6.2%	4.5%

Note. The percentage numbers were calculated based on the number of items in a certain category divided by the number of publications in the certain time

et al., 2023). More recently, the #9 *anti-doping organisation has* started to capture significant research attention (e.g., Petróczi et al., 2021), with #12 *athlete-centred, values-based anti-doping education* (e.g., Manges et al., 2022) emerging as a distinctive cluster in anti-doping SSR. Beyond the two shift patterns, #0 *systematic review* appeared to be the largest cluster based on co-citation analysis of anti-doping SSR between 2004 and 2025, highlighting efforts in synthesising previous research findings for effective interventions (e.g., Reynoso-Sánchez et al., 2025) and #15 *psychosocial dynamics of doping* (e.g., Ntoumanis et al., 2024). Fig. 4 illustrates research clusters and their shift from 2004 to 2025, whilst Fig. 5 displays keywords with the strongest citation bursts during this period. Details of each cluster are available in the Supplementary Table 1.

3.4. Thematic mapping and evolution

Thematic mapping revealed the emergence and evolution of various research themes based on keyword co-occurrence networks for anti-doping SSR in the periods 2010-2015, 2016-2021, and 2022-2025, but not for 2004-2009. During 2010-2015, *#health* and *#drug use* were the only two motor themes (i.e., high-density, high-centrality scores), whilst *#doping*, *#anti-doping*, *#sport*, *#athlete*, *#performance enhancement*, and *#dietary supplements* emerged as basic themes (i.e., low-density, high-centrality scores). Among these themes, *#drug use* and *#doping* remained motor and basic themes, respectively, in 2016-2021. *#Anti-doping* and *#dietary supplements* evolved from a basic theme in 2010-2015 to a motor theme in 2016-2021 and 2022-2025, respectively. Moreover, *#moral disengagement* emerged as a key motor theme for the period 2016-2021 and remains one of the most heavily weighted motor themes in 2022-2025. Several newly emerged motor themes in 2016-2021, such as *#world anti-doping code*, *#banned substances*, and *#affective self-sanction*, did not evolve or emerge during 2022-2025. The discontinuity of themes from 2016-2021 to 2022-2025 also occurred for most of the emerging themes (i.e., low-density, low-centrality scores) (e.g., *#implicit association test*) or declining themes (e.g., *#anabolic androgenic steroids*), as well as basic themes (e.g., *#social cognitive theory*). Regarding 2022-2025, *#nutritional ergogenic aids* and *#paralympics* appeared to be two new motor themes, whilst *#anti-doping education* and *#elite athletes* appeared to be new basic themes. For comparison, *#recreational sport*, *#governance*, and *#thematic analysis* appeared to be niche or peripheral themes (i.e., high-density, low-centrality scores), with several small but emerging themes evident in the thematic mapping of anti-doping SSR from 2022 to 2025. Fig. 6 illustrates the thematic mapping and the evolution of key research themes in anti-doping SSR. Details of all keywords within each theme are available in the Supplementary Tables 2-4.

3.5. Focus of domains, methodological approaches, and their shifts from 2004 to 2025

Our expert panel review identified several key shifts in the focus of anti-doping SSR domains over the period 2004-2025 (see Table 3). For the level of influence, the top three were #1 *athlete* (63.5%), #3 *education programmes* (11.1%), and #2 *athlete support personnel/ASP* (9.5%). While #1 *athlete* had been a dominating domain for level of influence, its proportional percentage[2] continually declined from 84% in 2004-2009 to 53.5% in 2022-2025. A similar trend was observed for #4 *world anti-doping programmes*, declining from 7.9% in 2010-2015 to 3.9% in

[2] The proportional percentage does not reflect absolute numbers or volume of research in certain anti-doping SSR topics. Instead, it reflects more a dominance index (i.e., the extent to which a certain topic received attention or interest compared to other topics within a certain period), which can be influenced by diversity of topic rather than actual volume of research outputs in a certain topic within a specific timeframe.

period. *Numbers in parentheses indicate the percentage of irrelevant publications. Detailed mapping information is available in the Supplementary Table 5.

2022-2025. In contrast, research on #3 *education programmes*, #2 *ASP*, and #5 *sport environments* has been increasing from 2010-2015 to 2022-2025.

Regarding alignment with the WADA-SSR priorities, the top three were #1 *athlete pathway and experience* (34.4%), #2 *clean sport behaviours* (27.3%), and #6 *effectiveness of anti-doping* (10.6%). Unlike the former two that had been declining, research addressing #6 *effectiveness of anti-doping* increased proportionally from 1.2% in 2010-2015 to 16.1% in 2022-2025. #10 *Evolution of sport practices* (1.6%), #9 *sport policy* (1.6%), #7 *WADA doping prevention model* (0.9%), and #11 *horizon scanning* (0.5%) were the least dominant or received the least cumulative interest in the field of anti-doping SSR since 2004.

Compared to only 1.8% and 2.6% of anti-doping SSR failing to tackle a valid focus of the domain regarding level of influence and WADA-SSR priorities, respectively, 55.2% of anti-doping SSR retained for the panel review were irrelevant to the consensus SSR agenda for anti-doping. The top three SSR agenda that received the greatest attention were #1 *effectiveness of anti-doping* (18.1%), #2 *developmental influences from outside sport* (6.7%), and #8 *anti-doping system and athlete's experience of key procedures* (6.0%). While most of the consensus key SSR agenda has been an increase in capturing research attention especially from 2010-2015 to 2022-2025, research addressing #2 *developmental influences from outside sport* (from 11.2% to 5.8%), #8 *anti-doping system and athlete's experience of key procedures* (from 10.1% to 4.5%), and #5 *long-term studies examining protective and risk factors in athletes* (from 2.2% to 1.3%) have been declining in this period. Detailed expert panel review results and the categorisation of each retained publication are provided in Supplementary Table 5.

Additionally, the expert panel review also uncovered significant shifts in the methodological approaches adopted by anti-doping SSR during 2004-2025. Specifically, while quantitative observational designs (e.g., cross-sectional surveys) using primary data have dominated anti-doping SSR since 2004, the use of such methodological approaches has been constantly declining proportionally from the period 2004-2009 (76.0%) to 2022-2025 (48.4%). For comparison, studies adopting experimental or interventional methods have more than doubled from the period 2004-2009 (4.0%) to 2022-2025 (9.7%), whilst studies adopting qualitative approaches using individual semi-structured interviews or focus groups have more than tripled from the period 2004-2009 (4.0%) to 2022-2025 (18.7%). The period 2022-2025 has also seen a surge in studies employing alternative qualitative methods, such as ethnography (5.2%) and case studies (2.6%), as well as mixed methods designs (2.6%). Table 4 presents the percentages and shift patterns in the use of different methodological approaches in anti-doping SSR from 2004 to 2025.

4. Discussion

The present study presents the first comprehensive science mapping of SSR on anti-doping, systematically analysing 431 publications spanning the critical period from 2004 to 2025. This timeframe, initiated by the implementation of the WADC and the launch of WADA's SSR programme, offers an unparalleled lens into the field's formative and evolving stages. By employing a rigorous science mapping approach that combines advanced bibliometric analysis with an in-depth expert panel review, this work provides novel, evidence-based insights into the dynamic knowledge structures, thematic evolution, and future directions of anti-doping SSR. The results unequivocally demonstrated a significant and sustained upward trajectory of anti-doping SSR, characterised by a shift toward more specific athletic populations or sporting contexts, increasingly sophisticated methodological approaches, and a profound reorientation in the focus of domains. The findings underscore the evolution moving from predominantly individual-level examinations to a more ecological and multi-layered understanding of doping. We present several noteworthy points below to provide insight into the key findings and their implications.

4.1. The maturation from broad to population-specific approaches

An important trend revealed by the science mapping is the progressive refinement in the population studies within anti-doping SSR. Our bibliometric analysis of the intellectual structure and thematic evolution of anti-doping SSR, particularly evident from approximately 2014 onwards, demonstrated a clear shift towards investigating distinct athletic groups. Specifically, with the initial emergence of 'elite athletes' as a prominent cluster, anti-doping SSR subsequently diversified into a dedicated focus on 'adolescent athletes' and 'Paralympic games' in more recent years. In the analysis of the conceptual structure of anti-doping SSR via thematic mapping of keywords, the emergence of '*Paralympics*' and '*elite athletes*' in the 2022-2025 period, as a new motor theme and a new basic theme, respectively, developed from the general and broad 'athlete' theme in the period 2010-2015 and 2016-2021, also underscores this maturation. This shift signals a crucial recognition that risk and protective factors, as well as intervention strategies and effectiveness, are not monolithic across all athletes. Indeed, elite athletes (e.g., Lazuras et al., 2010; Morente-Sánchez & Zabala, 2013; Qvarfordt et al., 2019), youth or adolescent players (e.g., Barkoukis et al., 2016; Kristensen et al., 2022; Mountjoy et al., 2019), and Paralympic athletes (e.g., Blank et al., 2023; Boardley et al., 2025; Vernec et al., 2024) are susceptible to different pressures, developmental issues, and encounter diverse life challenges and demands. This increasing precision in targeting athletic populations is therefore vital, as it enables the transition from generic prevention strategies to interventions that are more finely tuned to the diverse lived experiences and specific risk factors of varied athletic populations. Future anti-doping SSR would benefit from delving into more specific sports and athletic groups to deepen understanding of context-specific drivers and mechanisms (García-Durán et al., 2025; Hall et al., 2025; Shelley et al., 2023; Skoufa et al., 2022), thereby informing more effective and tailored education and prevention programmes.

4.2. Shift towards emphasising systemic influencers over individual factors

Beyond population specificity, our science mapping also highlights a fundamental shift in the risk and protective factors of doping, moving from an almost exclusive emphasis on athlete-oriented factors to a more holistic understanding that incorporates system-level influencers. In particular, the intellectual structure of anti-doping SSR revealed a shift from athlete-oriented research clusters and topics in the first half of 2004-2025 (e.g., measuring explicit attitude, predictors of doping) toward system-oriented research clusters and topics in the second half of this period (e.g., anti-doping organisation, psychosocial dynamics of doping). Emerging from our expert panel review, while the 'athlete' remains the most frequently studied level of influence, its proportional representation in research steadily declined from a dominant 84% or 21 out of 25 in 2004-2009 to 53.5% or 83 out of 155 in 2022-2025 (see Table 3). Conversely, research demonstrated a notable and sustained proportional increase during the same period, focusing on '*education programmes*' (i.e., from none to 16.8%), '*athlete support personnel*' (ASP; i.e., from none to 12.3%), and the broader '*sport environment*' (i.e., from none to 7.7%). This trend aligns with, and indeed extends, the systems-thinking lens advocated by Naughton et al. (2025), indicating a growing appreciation that doping is not merely an individual transgression but rather a complex behaviour shaped by an intricate network of contextual factors, including not only the knowledge and attitudes of coaches, medical staff, and other ASPs, but also the prevailing cultures, policies, and climate within sport organisations (see also Backhouse et al.'s 2018 call for taking action on the dopogenic environment for doping prevention). Future anti-doping SSR, therefore, would do well to embrace a

Table 4
Methodological approaches of social science research (SSR) on anti-doping from 2004 to 2025.

	Overall n = 431	2004-2009 n =25	2010-2015 n =90	2016-2021 n =161	2022-2025 n =155
Quantitative methods					
1. Cross-sectional or longitudinal analysis using primary data	57.1%	76.0%	66.7%	57.1%	48.4%
2. Retrospective or secondary data analysis	6.0%	16.0%	2.2%	6.2%	6.5%
3. Experimental or interventional designs	7.7%	4.0%	4.4%	8.1%	9.7%
Qualitative methods					
1. Interview (individual semi-structure or focus group)	16.9%	4.0%	18.9%	16.1%	18.7%
2. Others (enthrography, case study, qualitative survey)	2.3%	-	-	1.2%	5.2%
Mixed-methods					
1. Delphi or consensus methods	1.1%	-	1.1%	1.2%	1.3%
2. Others (a combination of quantitative and qualitative methods)	1.2%	-	-	0.6%	2.6%

Note. Reviews that adopted systematic approaches and/or meta-analytical strategies were excluded from this analysis.

systems-thinking approach that promises more comprehensive and sustainable anti-doping efforts by addressing the '*causes of causes*' and systemic vulnerabilities rather than individual-level culpability alone.

The robustness of this observed shift toward systemic influencers is further evidenced by its presence across various levels of SSR, including high-level governance and policy implementation research that sits at the periphery of athlete-centred empirical work. While our science mapping focused primarily on empirical social science involving direct human subjects or primary social data, the broader body of anti-doping SSR, including organisational and policy-heavy analyses, echoes the same maturation from individual-level culpability to ecological vulnerability. This convergence across different subsets of the literature reinforces the message that the field is undergoing a fundamental paradigm shift toward a more multi-layered understanding of doping (see Naughton et al., 2025).

Nevertheless, while our findings advocate for a systems-thinking approach, a true systems-level critique might be warranted to move beyond merely optimising the dominant IOC-WADA paradigm (see also WADA, 2025c). To rigorously interrogate the ethical, structural, and practical implications of current models, social scientists would do well to evaluate and compare alternative frameworks. This may include applying an SSR perspective to independently governed policies beyond the WADC (e.g., those in the NFL or NBA), critically examining provocative developments such as the Enhanced Games (Chandler & Boardley, 2025), and exploring broader systemic debates such as striving for eradication of doping vs a more pragmatic approach emphasising controlled use and harm reduction (Kayser et al., 2007). Engaging with these alternative paradigms, even when such inquiries fall outside the more heavily promoted funding priorities, plays a critical role in achieving a truly comprehensive understanding of effective doping regulation.

4.3. The imperative for behavioural science integration for advancing interventions

The heightened focus on systemic factors is inextricably linked to a marked increase in research evaluating the effectiveness of anti-doping interventions. Our findings reveal a substantial proportional rise in studies prioritising '*effectiveness of anti-doping/clean sport*', climbing from 1.2% in 2010-2015 to 16.1% in 2022-2025, as well as in studies addressing '*effectiveness of anti-doping/education programme*', rising from 4.0% in 2004-2009 to 24.5% in 2022-2025. While this shift towards evidence-based intervention research is commendable, prior systematic reviews (e.g., Filleul et al., 2024) suggest that many interventions remain single-component and predominantly rely on knowledge-based approaches that yield little long-term impact. The present science mapping also highlighted the increasing salience of social cognitive factors within research clusters and thematic evolution (e.g., 'moral disengagement,' 'affective self-sanction' as motor themes in 2016-2025), underscoring a critical direction for considerations in the field of anti-doping SSR. Consequently, simply advocating for more education is insufficient; education that goes beyond knowledge requires further pursuit. Future intervention-focused anti-doping SSR would benefit substantially from explicitly drawing on established behavioural change theories and integrating multiple social cognitive components or their underlying psycho-social-behavioural processes (e.g., Michie et al., 2011). However, researchers must demonstrate that education beyond basic knowledge provision is actually effective and worth continued investment. If it is not, the anti-doping organisations and sport federations should consider whether resources are better directed toward broader systemic interventions or practices, such as supporting athletes with alternative career transition or options in retirement (Crook et al., 2025), to alleviate the intense social and financial pressures often linked to doping (Overbye et al., 2015).

On a related and important point, implementation science is emerging as a vital area for advancing anti-doping efforts, particularly for bridging the gap between evidence and practice (Backhouse & Patterson, 2026). Although our science mapping findings reveal considerable investment to date in education and intervention programmes, we have been gradually generating knowledge on *which* interventions can reduce doping, yet we know far less about *how* to implement them effectively. This gap is amplified when considering implementation barriers across diverse contexts, such as varying cultures, organisational settings, and athletic populations. According to recent literature (e.g., Nilsen, 2015), implementation science provides robust, systematic frameworks for dissecting and addressing these barriers, offering insights into strategies to enhance the adoption and fidelity of evidence-based practices. It also contributes to generating actionable knowledge to sustain and scale up anti-doping efforts. By leveraging implementation science, the anti-doping community can develop targeted strategies to ensure that interventions are not only theoretically sound but also effectively integrated and sustained in practice, thereby enhancing the global efficacy of anti-doping programs.

Nevertheless, contrary to the position that anti-doping SSR to date has created considerable evidence on which interventions reduce doping, a closer inspection reveals that existing studies predominantly measure intentions to dope or doping willingness, thus a lack of direct evidence in reducing 'doping'. Indeed, there remain very few studies that causally demonstrate that athletes who receive education choose not to dope as a direct result of that experience, particularly when compared to a robust, non-educated control group. This highlights a profound gap in our understanding of actual behavioural impact. As the field strives to bridge the gap between evidence and practice (see Backhouse & Patterson, 2026), implementation science must be applied in tandem with more rigorous study designs to ensure that the interventions we are scaling up genuinely examine their causal effect and combat the complex social and policy components of doping behaviour, rather than intentions only.

4.4. The overlooked dimensions and gaps in anti-doping SSR

Despite the comprehensive nature of anti-doping SSR, our science mapping analysis revealed several noteworthy gaps. First, the lack of attention and clarity about how technology fits into anti-doping research

and practice is concerning. Given the potential of using virtual agents for anti-doping education (e.g., Barkoukis et al., 2022) and the adoption of large language models for education content and learning activity design and delivery (e.g., Perez et al., 2026), social science anti-doping researchers should more actively embrace generative artificial intelligence or GenAI for enhancing education (see Fenta, 2025; for a review). In the meantime, given the emerging evidence revealing the increased effectiveness by use of technology at the cost of greater burden in education settings (Wang & Chen, 2026), as well as athletes' concerns about the burden of surveillance and liability (Overbye et al., 2014) and privacy issues (Valkenburg et al., 2014), a critical sociological perspective is required for future anti-doping research and practices; that is, while embracing technology for anti-doping education, it is equally important for researchers, practitioners, and policy makers to consider how the incorporation of technology in anti-doping education can be optimised, preventing hyper-surveillance and unnecessary administrative and psychological burdens.

Second, existing anti-doping SSR is limited by a notable underrepresentation of "inadvertent doping" as a prominent research theme or cluster. While the concept of "unintentional or inadvertent doping" is not new (e.g., Boardley et al, 2019; Chan et al., 2016; McLean et al., 2025), it has not emerged as a key motor theme or a distinct, frequently studied area within the broader science mapping. This finding is particularly striking given that inadvertent doping, stemming from contaminated supplements, mislabelled medications, or a lack of awareness of prohibited substances, accounts for a significant proportion of anti-doping rule violations annually and poses a substantial challenge for clean sport (Greenbaum et al., 2023; Okada et al., 2022). The absence of this critical area from the thematic forefront of anti-doping SSR suggested a blind spot, in which research efforts may be disproportionately focused on intentional doping.

Moreover, our findings suggest that 55.2% of anti-doping SSR to date have failed to address the international experts' consensus agenda. Whilst this supports the efficacy of the consensus agenda which sought to identify key areas of research need (Boardley et al., 2021), we have seen a concerning signal regarding proportional declines in research addressing the consensus priorities such as 'developmental influences from outside sport' (i.e., from 11.1% or 10 out of 90 in 2010-2015 to 5.8% or 9 out of 155 in 2022-2025) and 'the anti-doping system and athletes' experience of key procedures' (i.e., from 10.0% or 9 out of 90 in 2010-2015 to 4.5% or 7 out of 155 in 2022-2025). Similarly, long-term studies of athletes and ASP, the WADA doping-prevention model, and horizon scanning consistently receive insufficient attention (approximately 1-2% or lower throughout 2004-2025). Indeed, gaps are evident in the WADA-SSR priorities (e.g., an emphasis on topics of interest rooted at varying levels of influence and within the dominant WADA-led paradigm; see WADA, 2025c) and in the recent consensus agenda for key areas of anti-doping SSR (e.g., a call for attention to underexplored domains and under-represented methodological approaches in generating doping prevention knowledge through anti-doping SSR; see Boardley et al., 2021). It is not impossible that existing funding streams for anti-doping SSR may inadvertently act as a "double-edged sword"; whilst driving necessary programmatic research, it might well restrict (even unintentionally) novel research, ideas, or approaches that might critique the existing governing bodies, doping prevention models, or anti-doping systems. Funding bodies for anti-doping SSR would do well to diversify their research portfolios by explicitly ring-fencing resources for exploratory, paradigm-challenging inquiries that critically evaluate the current system rather than merely validating it. Correspondingly, researchers in anti-doping SSR should tackle the underexplored agenda outlined in the recent international consensus on the key SSR agenda for doping prevention and remain vigilant in maintaining an independent, critical lens.

4.5. Advancing methodological rigour and overcoming structural barriers

While our science mapping highlights a gradual and encouraging shift towards experimental, qualitative, and mixed methods designs (see Table 4), the field of anti-doping SSR remains heavily reliant on cross-sectional, self-reported data. To elevate the impact and credibility of anti-doping research, the field urgently needs to embrace open science frameworks. Currently, practices such as study pre-registration, transparent reporting of recruitment and response rates, open data sharing, and replication studies are underutilised. Adopting these standards is not merely a procedural exercise; it is essential for producing robust, verifiable evidence, particularly as the field moves towards evaluating complex behavioural interventions.

Importantly, driving better anti-doping SSR requires acknowledging and addressing the significant structural barriers that hinder the conduct of high-quality research, such as robust randomised controlled trials (RCTs) and longitudinal studies (e.g., to tackle developmental issues). Gaining access to elite or high-performing athletic populations is another notoriously challenging process due to institutional gatekeeping, rigorous training schedules, and widespread survey fatigue. Moreover, conducting true experimental designs in anti-doping presents unique ethical complexities; researchers cannot ethically assign athletes to withhold mandated anti-doping education as an authentic control group to test the intervention's efficacy. To overcome these barriers, future anti-doping efforts should prioritise research collaborations that pool resources, allow for a more flexible timeframe, and advocate for sustained, long-term funding mechanisms, while leveraging innovative, ethically sound study designs that have yet to receive sufficient attention and effort (e.g., true experimental and longitudinal studies).

4.6. Limitations and future directions

While the present study's strengths lie in its comprehensive scope, spanning over two decades of anti-doping SSR since the launch of the first WADC in 2004, and in its novel integration of science mapping via bibliometric analysis with expert manual review, it was not without limitations. First, the science mapping findings may be biased toward the 'WEIRD' (i.e., Western, Educated, Industrialised, Rich, and Democratic; Henrich et al., 2010) contexts and regions. This is because the science mapping approach we adopted limited our focus to anti-doping research published in English, which was essential for interpretability and data consistency (i.e., essential for bibliometric analysis). Therefore, anti-doping SSR published in non-English languages, potentially drawing upon non-WEIRD populations, contexts, and regions were omitted from this science mapping. However, it is important to note that our science mapping followed a rigorous literature search procedure, and the eligible studies retained for the analysis involved 70 countries over all major continents. As such, while we acknowledge the risk that our findings may be 'WEIRD', we believe they provide a fair reflection of the work on anti-doping SSR since the launch of the first WADC.

Another limitation is our conscious decision to emphasise on the sport and athletic population as the focus of this science mapping. Since we aimed to systematically examine the knowledge structure and evolution of anti-doping SSR from the launch of the first WADC in 2004 onward, we chose to focus on the sport and competitive participants rather than exercisers. This may explain why research clusters, keywords, or themes related to appearance-enhancing drugs did not appear in our science mapping. Given that the use of appearance-enhancing drugs has become increasingly prevalent among exercise populations (Coquet et al., 2018; Lazuras et al., 2017), we consider that not being able to provide insights into this area of research is a limitation of the current science mapping study. Nevertheless, we believe it is even more important not to contaminate the findings of current science mapping on anti-doping SSR in sport and performance settings with insights from exerciser groups. Future research would benefit from applying similar science mapping methods to examine appearance-enhancing drugs,

thereby aiding understanding of prior work in this field and identifying future avenues.

Furthermore, we acknowledge that our findings should be interpreted in light of the inherent methodological limitations of science mapping via bibliometric analysis (i.e., a trade-off between retrieval precision and retrieval sensitivity; Manning et al., 2008). Although our search strategy was developed through pilot testing followed by expert review, which deliberately prioritised retrieval precision as recommended best practices for bibliometric methods (see also Zupic & Čater, 2015), this approach inevitably involved a trade-off with retrieval sensitivity (i.e., absolute coverage of literature). Meanwhile, to avoid data contamination due to varied data formats and sources given different databases, the recommended use of a single database (e.g., WoSCC) rather than a combination of multiple databases (e.g., merging bibliometric data from WoSCC and other publication databases) contributes to this inherent methodological limitation thus impossible to reach an absolute coverage of literature in a certain field of research (Aria & Cuccurullo, 2017). Consequently, some potentially relevant studies that fulfil our eligibility criteria may not have been retrieved due to a predefined search strategy that prioritises precision over coverage, institutional database subscription, database limits such as updating and indexing changes, as well as other unknown technical issues common to database maintenance (e.g., invalid bibliometric records).

Nevertheless, in bibliometric science mapping, the validity of the findings rests on the structural stability of the generated networks rather than the absolute inclusion of every existing document (Montazeri et al., 2023). With a set of 431 high-precision empirical articles, the dataset can be considered to have achieved thematic saturation; in other words, the intellectual landscape emerged from the co-citation (assessing the intellectual structure of the field) and keyword co-occurrence analyses (assessing the conceptual structure of the field) is shaped by the most frequent and strongly linked nodes, and thus, the addition of a small subset of studies[3] (which represent a fraction of the total volume) is statistically unlikely to reconfigure the identified research clusters or shift the trajectory of key themes (see Donthu et al., 2021).

Additionally, despite conducting a cited references check via the Evidence Research Accelerator (TERA; Clark et al., 2020) for the aim of achieving greater retrieval coverage whilst prioritising retrieval precision, which was an extension to existing guidance for bibliometric review (e.g., Donthu et al., 2021, Montazeri et al., 2023), we acknowledge that our cited reference check cannot be exhaustive because we can only do this manually due to the lack of automated software or techniques to screen, check, and synthesise bibliometric data emerging from the check. Such a manual screening for cited reference check and bibliometric data synthesis process (with those identified from initial and updated searches) might be prone to human oversight when processing large volumes of bibliometric data. Consequently, while the core intellectual structure remains stable, we acknowledge that specific studies may remain uncaptured. Future researchers adopting bibliometric methods should explore and examine practices for utilising enhanced cited reference checks as a means to optimise retrieval coverage while emphasising retrieval precision for bibliometric review.

[3] We express our appreciation to an anonymised reviewer who identified 11 additional relevant empirical studies. While a full re-computation of the bibliometric metadata (which requires synchronised extraction of citations and co-occurrence links) was not possible as a post-hoc stage, we conducted a manual sensitivity analysis for these publications. This process confirmed that these studies align with the identified knowledge structures and reinforce our findings regarding the field's shift patterns emerged from our original analysis (e.g., earlier focus on athletes whilst later focus on systemic and organisational influencers). For transparency and to support future research, we have detailed the thematic alignment of these publications and their full references in Supplementary Material Appendix 2.

5. Conclusion

This study provides a systematic science mapping of the empirical core of anti-doping social science research (SSR) from 2004 to 2025. By analysing a high-precision dataset of 431 publications, we reveal a clear maturation in the field's knowledge structure. Our findings demonstrate a significant and statistically robust shift from individual-centred examinations toward more complex, systemic, and ecological approaches. While no bibliometric search can claim absolute exhaustiveness due to varying database indexing practices, the consistency of the identified clusters and thematic evolutions across two decades suggests that these findings represent the primary intellectual trajectory of the field. To strengthen future impact, researchers should strategically address the identified gaps, such as inadvertent doping, the under-researched consensus agenda (e.g., long-term studies, clean perception within the anti-doping system), whilst also adopting a more critical lens, evaluating not only the dominant IOC-WADA paradigm but also alternative anti-doping models and systemic influences. Funding bodies are urged to diversify their investments and broaden their funding priorities (e.g., explicitly support paradigm-challenging inquiry rather than simply validating it). Practitioners and policymakers must leverage robust behavioural science from other fields to move beyond knowledge-only interventions, prioritising causal evidence over mere intentions. The field's evident shift toward systemic influencers, confirmed by both our primary bibliometric mapping and the post-hoc sensitivity audit, calls for future research to universally adopt approaches that address structural barriers, thereby informing technology-empowered, evidence-based design and implementation of education and interventions, as well as anti-doping policies that account for the complexity of the sporting environment.

CRediT authorship contribution statement

Shuge Zhang: Writing – review & editing, Writing – original draft, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization. **Barnaby N. Zoob Carter:** Writing – review & editing, Validation, Software, Methodology, Investigation, Formal analysis, Data curation. **Zhen Yang:** Writing – review & editing, Visualization, Software, Methodology, Investigation, Formal analysis, Data curation. **Ghada Al-Mousawi:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Martin Chandler:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Zsofia Keresztes:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Nathalia Medeiros:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Bethany Mullarkey:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Yushan Xie:** Writing – review & editing, Methodology, Investigation, Formal analysis. **Andrew Heyes:** Writing – review & editing, Validation, Methodology, Formal analysis. **Nikos Ntoumanis:** Writing – review & editing, Validation, Supervision, Methodology, Conceptualization. **Ian D. Boardley:** Writing – review & editing, Validation, Supervision, Resources, Methodology, Conceptualization.

Declaration of competing interest

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Statements and Declaration

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interpreted as influencing the research. The bibliometric data used for science mapping are publicly available in the Web of Science Core Collections, with full references to the publications retained for analysis provided in the Supplementary Material.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.peh.2026.100455.

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