RESEARCH PAPER

Contaminated Dietary Supplements and Unintentional Doping in Sports: A Global Bibliometric Analysis of Research Trends, Athlete Health, and Anti-Doping Risk

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ABSTRACT

Background: Contaminated and adulterated dietary supplements are a recognised route to unintentional doping, yet the research on this problem has not been mapped as a whole. This study presents a global bibliometric analysis of work on contaminated supplements, unintentional doping, athlete health and anti-doping risk published between 2016 and 2026.

Methods: Records were retrieved from Dimensions AI with a structured Boolean search and screened through a PRISMA-based protocol, leaving 1,145 open-access English-language journal articles from 6,041 initial records. VOSviewer was used for co-authorship analysis of authors, organisations and countries and for citation analysis of documents.

Results: Annual output grew from 47 articles in 2016 to 155 in 2026, and annual citations rose from 18 to more than 4,700. The United Kingdom (203 documents), the United States (113), Germany (108), Italy and Australia (92 each) led production, while Canada and the Netherlands showed the highest citations per document among countries with at least 20 documents. German Sport University Cologne (49 documents) and Mario Thevis (37 documents) were the central institutional and author hubs. The most cited papers were mainly International Olympic Committee consensus statements and position stands rather than product-analysis studies. Africa and South Asia were thinly represented.

Conclusion: The field is expanding and becoming more international, but it remains concentrated in a few European and English-speaking centres and is only loosely tied to athlete health outcomes. Regional surveillance, third-party certification and athlete education are needed to reduce unintentional doping risk.

Keywords: contaminated dietary supplements; unintentional doping; inadvertent doping; anti-doping; athlete health; bibliometric analysis; VOSviewer; Dimensions

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INTRODUCTION

Dietary supplements have become an ordinary part of athletic preparation. Surveys across sports and competitive levels suggest that 60% to 80% of athletes report current or previous supplement use (Jagim et al., 2023), and systematic reviews continue to document high consumption among elite and recreational athletes alike (Daher et al., 2022; Knapik et al., 2016). The International Olympic Committee (IOC) consensus statement accepts that a few supplements have good evidence of benefit, but it also warns that many products are sold on weak evidence and that some may contain substances prohibited in sport (Maughan et al., 2018). For an athlete the risk is far from theoretical. Under the strict liability principle of the World Anti-Doping Code, athletes are responsible for whatever is found in their sample, whether or not they took it knowingly.

The problem has several faces. Cross-contamination can occur when a production line shared with prohibited compounds is not cleaned properly. Adulteration involves the deliberate addition of an active drug to strengthen a product's apparent effect, and mislabelling arises when a label simply does not match the contents. Early international testing found that roughly one in seven non-hormonal supplements contained undeclared anabolic-androgenic steroids (Geyer et al., 2004), and later work showed that cross-contaminated and faked products stayed in circulation (Geyer et al., 2008). Recent evidence suggests little has changed. A narrative review of analytical studies reported that

between 14% and 50% of tested samples contained anabolic agents or other prohibited substances (Jagim et al., 2023), undeclared doping substances were found to be highly prevalent in commercial sports nutrition products (Duiven et al., 2021), and a 2025 Sport Integrity Australia survey of 201 products bought online found prohibited substances in 35% of them, with more than half of the positive findings missing from the label (Sport Integrity Australia, 2025).

The consequences reach beyond sanctions. In an analysis of 192 analytical anti-doping rule violations recorded in Norway between 2003 and 2020, 26% involved an athlete who said a dietary supplement was the source, and multi-ingredient pre-workout products and stimulants were prominent (Lauritzen, 2022). Reviews also show that weight-loss and muscle-building products are especially likely to be tainted (Mathews, 2018), and U.S. regulatory warnings have linked hundreds of supplements to unapproved pharmaceutical ingredients (Tucker et al., 2018). Steroids, stimulants and other pharmacologically active contaminants carry toxicological and cardiovascular risks that athletes rarely anticipate (Zapata-Linares & Gervasini, 2024). Unintentional doping is therefore an integrity issue and a health issue at the same time.

Two developments make the topic harder to ignore. Laboratory sensitivity keeps improving, so very low concentrations can now be detected, which raises difficult questions about how trace contamination should be interpreted in doping control (Thevis et al., 2021; Walpurgis et al., 2020). At the same time the regulatory frame is shifting. The 2027 World Anti-Doping Code, approved in December 2025 and due to take effect on 1 January 2027, widens the idea of a contaminated product into a contaminated source, which gives hearing panels more room to deal with inadvertent exposure (Bird & Bird, 2025; World Anti-Doping Agency [WADA], 2025). Third-party batch testing lowers risk but cannot remove it, and athlete education remains uneven (Maughan et al., 2018; Outram & Stewart, 2015).

Behavioural research adds another layer. Supplement use has been linked to more permissive doping attitudes and beliefs (Backhouse et al., 2013), psychosocial factors rank among the strongest predictors of doping (Ntoumanis et al., 2014), and prevalence estimates for doping in competitive sport remain uncertain (Gleaves et al., 2021). Separating accidental from deliberate cases is therefore a constant challenge for regulators and a source of stigma for athletes.

Despite the volume of research, the field has rarely been examined as a whole. Reviews summarise what has been found in contaminated products (Kozhuharov et al., 2022; Martínez-Sanz et al., 2017), but they do not show who is producing this knowledge, where, with whom, and which publications have shaped the debate. Bibliometric analysis fills that gap by quantifying publication patterns and mapping collaboration and citation networks (Donthu et al., 2021; Zupic & Čater, 2015). Dimensions offers broad multidisciplinary coverage with citation data (Hook et al., 2018; Singh et al., 2021), and VOSviewer provides a transparent way to cluster and visualise bibliometric networks (van Eck & Waltman, 2010).

This study therefore presents a global bibliometric analysis of research on contaminated dietary supplements and unintentional doping in sport from 2016 to 2026. Using a PRISMA-based record flow, we examine publication and citation trends, the countries, organisations and authors that drive the field, and the documents that form its intellectual core. We then interpret these patterns in relation to athlete health and anti-doping risk and suggest priorities for research, policy and practice.

The analysis was organised around four research questions.

RQ1. How have publication output and citation impact on contaminated supplements and unintentional doping evolved between 2016 and 2026?

RQ2. Which countries, organisations and authors lead the field, and how are they connected through co-authorship?

RQ3. Which documents form the intellectual core of the literature, and what themes do they represent?

RQ4. What do these patterns imply for athlete health protection and anti-doping risk management, and where are the gaps?

MATERIALS AND METHODS

Study design and reporting framework

This study is a descriptive bibliometric analysis supported by science mapping. Reporting followed the logic of the PRISMA 2020 statement (Page et al., 2021), adapted for bibliometric work: PRISMA was designed for systematic reviews of intervention effects, so we used it here to document, in a transparent and reproducible way, how records moved from the initial search to the final analytical sample. Items that concern effect estimates, such as risk of bias and certainty of evidence, do not apply to a mapping study and were not assessed.

Data source and search strategy

Dimensions AI was chosen as the search platform because it covers a wide range of journals, indexes publications from several disciplines, supplies citation counts and offers an open-access filter (Hook et al., 2018; Singh et al., 2021). The search was run in 2026 with the Boolean string shown in Table 1, which combines terms for contamination, adulteration and prohibited or undeclared substances with terms for doping, anti-doping, athletes and sport. Because the string uses wildcards, plural and variant forms were captured

automatically.

Table 1. Structure of the Dimensions AI search string

Concept block	Search terms (combined with OR inside each block)
Block A: contamination and prohibited substances	"contaminated dietary supplement*", "contaminated nutritional supplement*", "supplement contamination", "supplement adulteration", "adulterated supplement*", "undeclared substance*", "undeclared ingredient*", "contaminated sports supplement*", "contaminated sport supplement*", "prohibited substance*" AND supplement*
Block B: doping and sport context	doping, "unintentional doping", "inadvertent doping", "anti-doping", athlete*, sport*
Boolean logic	Block A AND Block B

PRISMA-based protocol and record selection

The PRISMA-based protocol is summarised in Table 2 and the record flow is shown in Figure 1. The initial search returned 6,041 records. Restricting the publication years to 2016–2026 removed 2,613 records and left 3,428. Limiting the publication type to journal articles removed a further 1,693 records and left 1,735. Applying the open-access filter removed 590 records and left 1,145 articles, all of which were in English. These 1,145 articles formed the final analytical sample. Dimensions assigns a single identifier to each record, so no additional manual de-duplication was applied. Records were not screened one by one for relevance, because the aim was to map the whole retrievable literature rather than to pool effect sizes; the implications of this decision are discussed in the limitations.

Table 2. PRISMA-based protocol applied to the Dimensions AI records

Protocol item	Application in this study
Objective	To map research trends, collaboration structures and the intellectual core of the literature on contaminated dietary supplements, unintentional doping, athlete health and anti-doping risk.
Information source	Dimensions AI, searched in July 2026.
Search strategy	Boolean string combining contamination and prohibited-substance terms with doping, athlete and sport terms (Table 1).
Inclusion criteria	Records matching the search; published 2016–2026; publication type Article; open access; English language.
Exclusion criteria	Records published outside 2016–2026; non-article records (for example book chapters, proceedings, preprints and monographs); articles not available in open access.
Selection process	Sequential database filters (year, type, access, language); no manual title or abstract screening.
Records at each stage	Identified 6,041; after year filter 3,428; after article filter 1,735; after open-access filter 1,145; final included 1,145.
Data items	Authors, affiliations, countries, publication year, citation counts and citation links.
Synthesis method	Co-authorship and citation network analysis in VOSviewer; descriptive statistics for trends.
Risk of bias and certainty	Not applicable to a bibliometric mapping study.

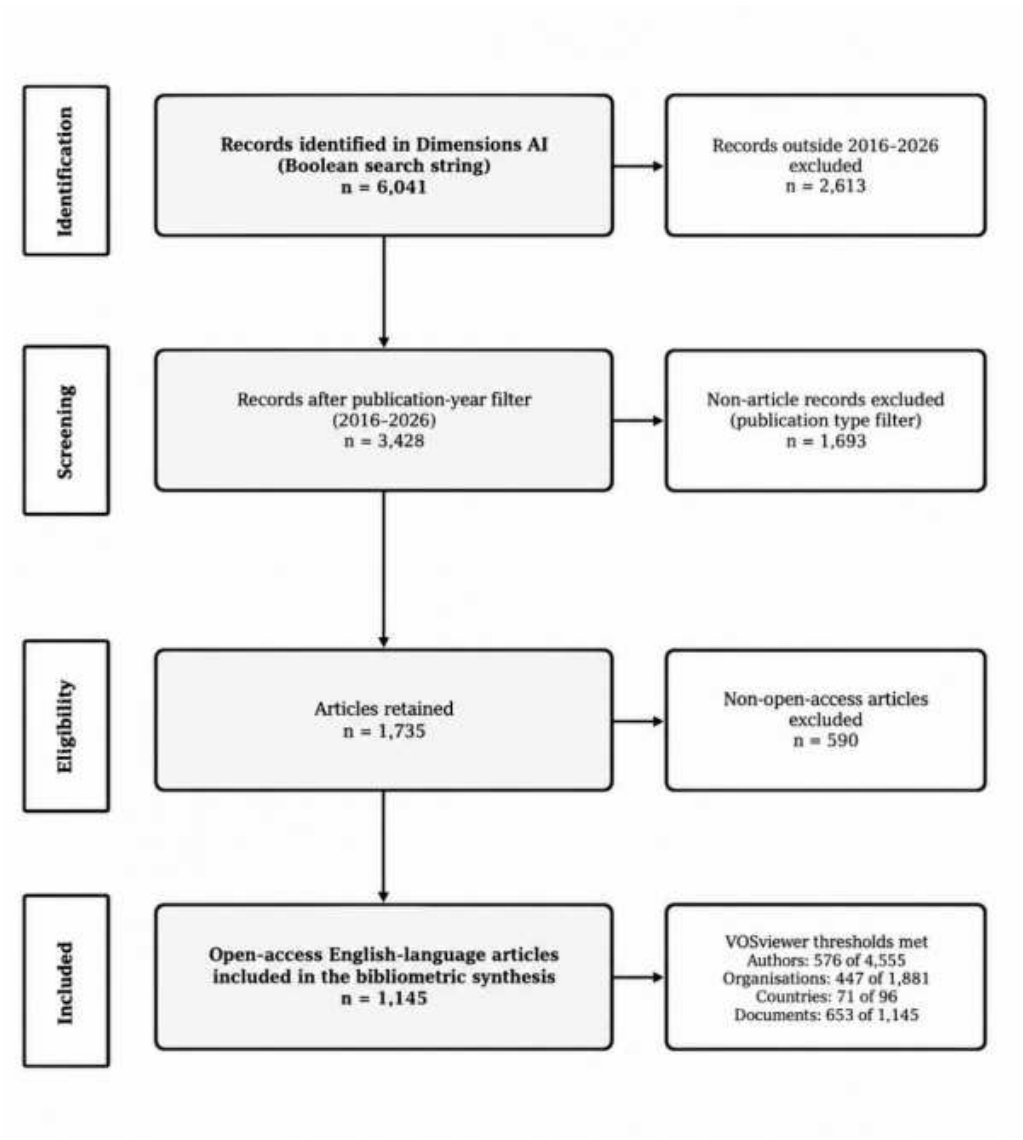


Figure 1. PRISMA-based flow diagram of record identification, filtering and inclusion.

Bibliometric analysis

The bibliographic data were exported from Dimensions and analysed in VOSviewer (van Eck & Waltman, 2010), which builds and clusters bibliometric networks using a unified mapping and clustering approach (Waltman et al., 2010). Four analyses were run: co-authorship of authors, co-authorship of organisations, co-authorship of countries, and citation analysis of documents. The thresholds and the number of items meeting them are given in Table 3. In the network maps, the size of a node reflects the weight of the item (documents or citations), the colour shows the cluster to which VOSviewer assigned it, and the thickness of a link reflects the strength of the relationship. Total link strength, which sums an item's collaboration or citation links, was used as the main indicator of how well connected an item is. Descriptive statistics, such as shares, growth rates and citations per document, were calculated from the exported tables.

Table 3. VOSviewer analyses and thresholds

Analysis	Unit	Minimum documents	Minimum citations	Items meeting threshold
Co-authorship	Authors	2	2	576 of 4,555 (12.6%)
Co-authorship	Organisations	2	2	447 of 1,881 (23.8%)
Co-authorship	Countries	2	2	71 of 96 (74.0%)
Citation	Documents	Not applicable	5	653 of 1,145 (57.0%)

ANALYSIS AND FINDINGS

Publication and citation trends

The final corpus comprised 1,145 open-access English-language articles. Annual output rose from 47 in 2016 to 155 in 2026, an increase of about 230% and a compound annual growth rate of roughly 12.7% (Table 4, Figure 2). Growth was not smooth. Output stayed between 47 and 78 articles a year until 2020, jumped to 104 in 2021 and 140 in 2022, and then levelled off at around 140 to 155 articles a year. The period 2021–2026 alone accounts for 840 articles, or 73.4% of the corpus. The 2026 data were collected before the year ended, so the 2026 count is incomplete and probably understates the final figure.

Table 4. Annual publications and citations of the corpus, 2016–2026

Year	Publications	Citations	Citations per publication
2016	47	18	0.4
2017	58	115	2.0
2018	53	309	5.8
2019	69	570	8.3
2020	78	1,065	13.7
2021	104	1,586	15.3
2022	140	2,115	15.1
2023	142	2,816	19.8
2024	151	3,447	22.8
2025	148	4,862	32.9
2026	155	4,759	30.7
Total	1,145	21,662	18.9

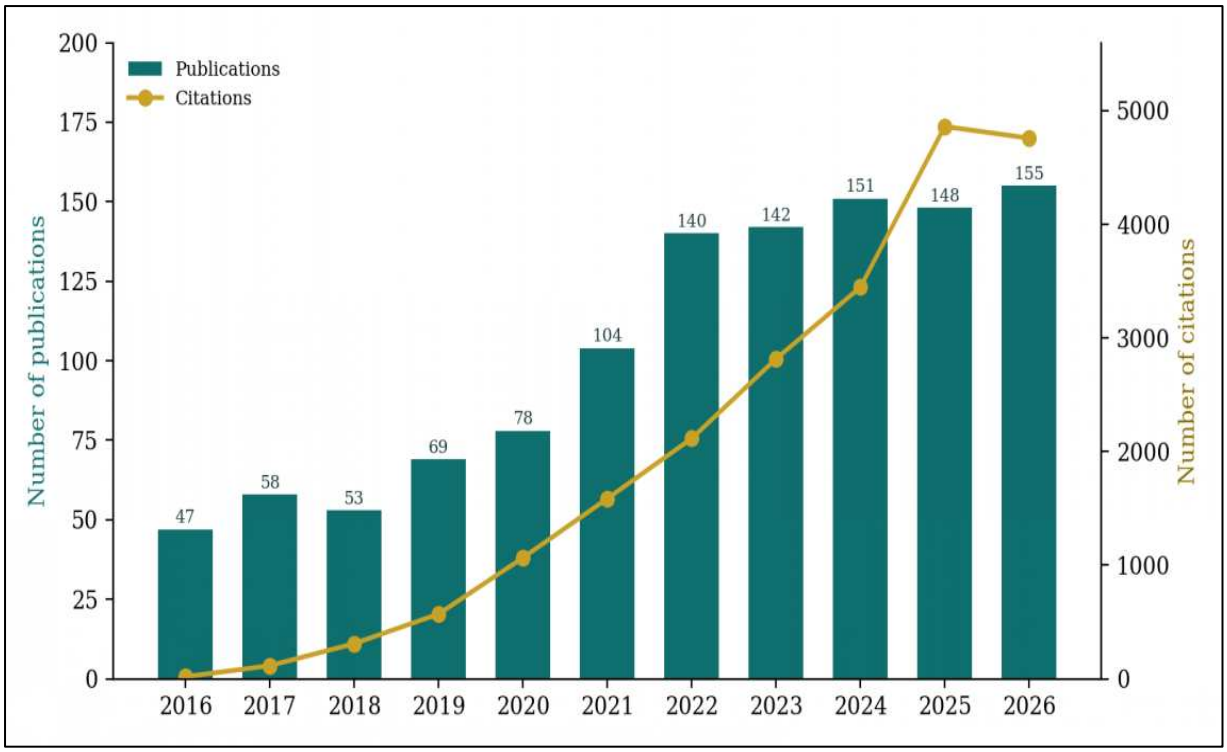


Figure 2. Annual publications and citations on contaminated supplements and unintentional doping, 2016–2026.

Citations followed a steeper path. Annual citation counts climbed from 18 in 2016 to 4,862 in 2025, and 4,759 had already been recorded in 2026. In total the corpus has attracted 21,662 citations, an average of 18.9 per article. The rising curve reflects both the growing size of the literature and the accumulating reach of older, influential papers.

Co-authorship analysis of countries

Seventy-one of the 96 countries in the dataset met the threshold, and 20 of them contributed 20 or more documents. The United Kingdom led by a wide margin with 203 documents, 7,571 citations and a total link strength of 353, nearly twice that of the next most connected country (Table 5). The United States (113 documents, 5,762 citations),

Germany (108; 3,258), Italy (92; 2,524), Australia (92; 5,483) and Spain (76; 2,782) followed. Counts overlap because an internationally co-authored article is credited to every participating country, so country totals add up to more than the 1,145 articles.

Table 5. Top 15 countries by number of documents (co-authorship analysis)

Rank	Country	Documents	Citations	Citations per document	Total link strength
1	United Kingdom	203	7,571	37.3	353
2	United States	113	5,762	51.0	199
3	Germany	108	3,258	30.2	175
4	Australia	92	5,483	59.6	174
5	Italy	92	2,524	27.4	172
6	Spain	76	2,782	36.6	122
7	China	70	1,817	26.0	64
8	Switzerland	56	3,705	66.2	133
9	Poland	52	742	14.3	56
10	Brazil	45	2,138	47.5	79
11	Canada	44	4,322	98.2	109
12	France	40	947	23.7	51
13	Belgium	35	1,171	33.5	79
14	Netherlands	33	3,078	93.3	110
15	Norway	32	2,134	66.7	93

Productivity and impact did not always travel together. Among countries with at least 20 documents, Canada (44 documents) and the Netherlands (33) achieved the highest citations per document, at 98.2 and 93.3, followed by South Africa (76.8), Norway (66.7), Switzerland (66.2) and Australia (59.6). By contrast, Poland (52 documents) averaged 14.3 citations per document, China (70 documents) 26.0 and Saudi Arabia (27 documents) 8.6. Part of the high impact of smaller producers is probably linked to participation in multi-author consensus statements, which attract a disproportionate share of citations.

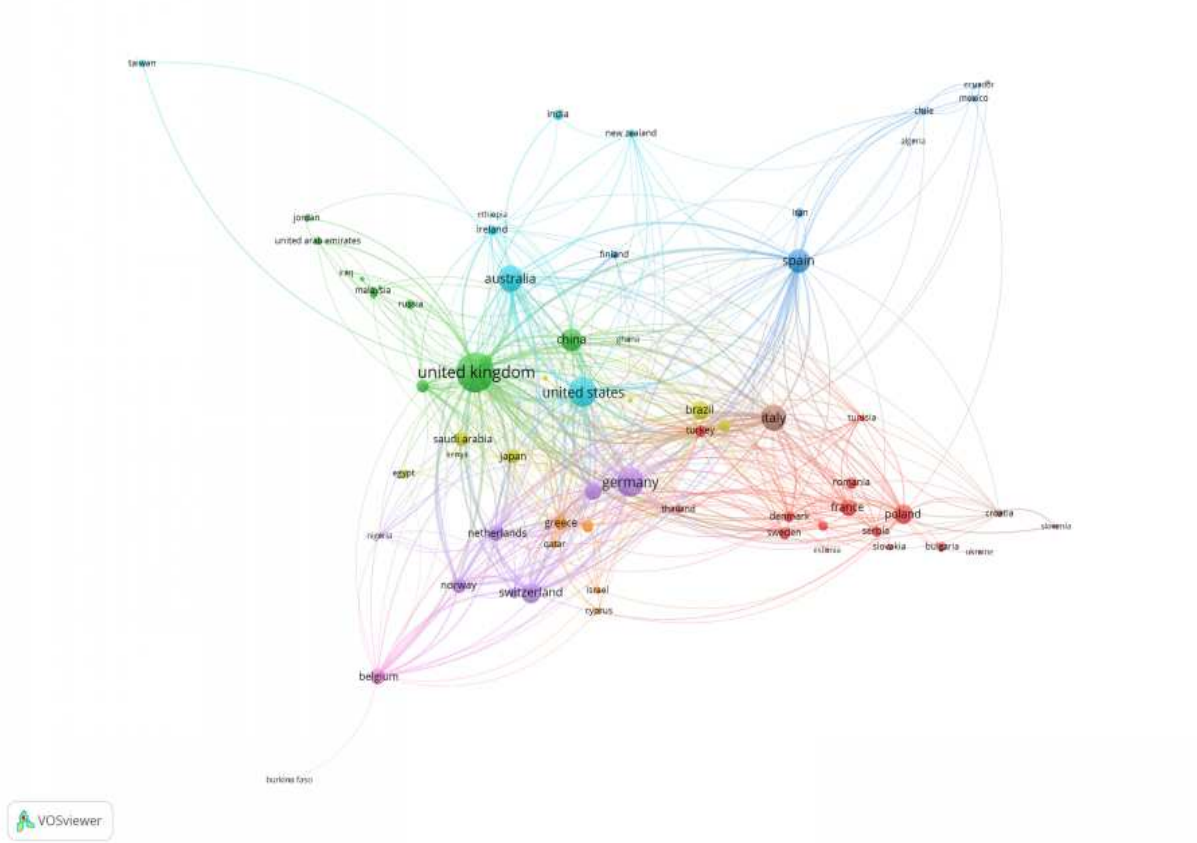


Figure 3. Co-authorship network of countries (VOSviewer; 71 countries).

The network map (Figure 3) shows a densely linked European core around the United Kingdom, Germany, Italy, Switzerland and Spain. The United Kingdom anchors a cluster that also includes China, Malaysia, Russia, the United Arab Emirates, Jordan and Iraq. Australia and the United States sit together with Ireland, New Zealand, India and Taiwan. Spain bridges to Latin American partners (Chile, Mexico and Ecuador) and to Iran, while Poland, Serbia, Croatia, Romania and other Central and Eastern European countries form a cluster with France, Denmark and Sweden. Belgium makes up its own small cluster, to which Burkina Faso is attached. India appears in the Australia–United States cluster with 14 documents and 114 citations, but its total link strength is only 5, which points to limited collaboration. Nine African countries are present (Algeria, Burkina Faso, Egypt, Ethiopia, Ghana, Kenya, Nigeria, South Africa and Tunisia) and together account for 55 country-level document counts, 23 of them from South Africa.

Co-authorship analysis of organisations

Out of 1,881 organisations, 447 met the threshold; 29 of these produced 10 or more documents, while 210 (47.0%) appeared in exactly two. German Sport University Cologne dominated the field with 49 documents, 1,901 citations and a total link strength of 86 (Table 6). It was followed by the University of Birmingham (31 documents), Leeds Beckett University and the University of Lausanne (28 each), Kingston University (24), Sapienza University of Rome (19), Aristotle University of Thessaloniki and KU Leuven (16 each), and Francisco de Vitoria University and King Juan Carlos University (15 each). The University of Birmingham had the highest total link strength (93), making it the best-connected institution, ahead of Cologne and Kingston University (86 each).

Table 6. Top 10 organisations by number of documents (co-authorship analysis)

Rank	Organisation	Documents	Citations	Total link strength
1	German Sport University Cologne	49	1901	86
2	University of Birmingham	31	655	93
3	Leeds Beckett University	28	570	54
4	University of Lausanne	28	358	57
5	Kingston University	24	420	86
6	Sapienza University of Rome	19	563	54
7	Aristotle University of Thessaloniki	16	331	56
8	Ku Leuven	16	189	54
9	Canterbury Christ Church University	15	189	38
10	Francisco de Vitoria University	15	570	50

Some organisations had a large citation footprint with very few documents. Australian Catholic University (8 documents) received 1,303 citations, the International Olympic Committee (3 documents) 1,033, the University of Guelph (11 documents) 1,012, the World Anti-Doping Agency (6 documents) 1,009, the University of Western Australia (5 documents) 988, Schulthess Klinik (2 documents) 976 and the Australian Sports Commission (5 documents) 942. This pattern is typical of institutions that took part in highly cited consensus and position documents rather than of institutions with a large volume of output.

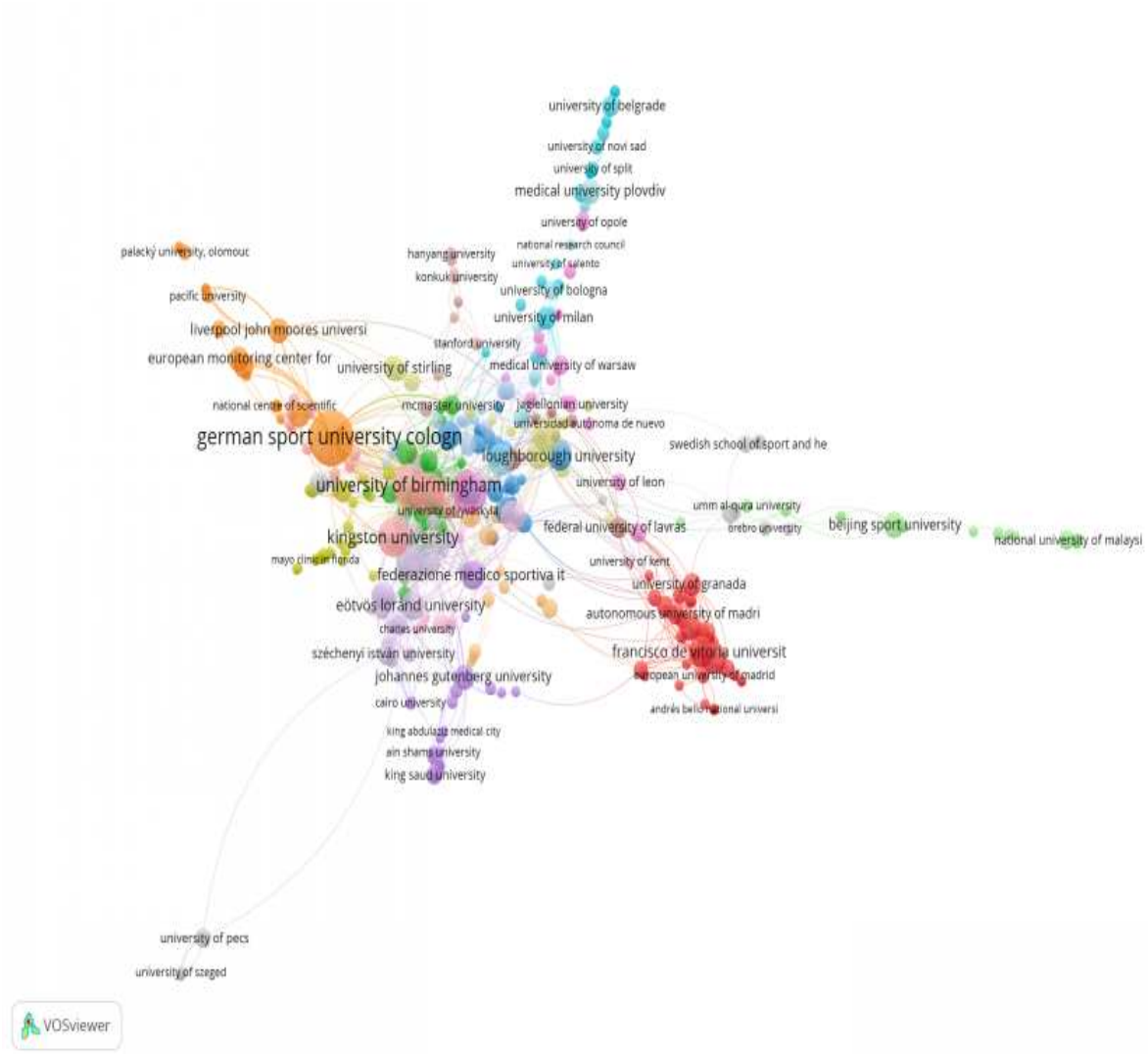


Figure 4. Co-authorship network of organisations (VOSviewer; 447 organisations).

The organisation map (Figure 4) places German Sport University Cologne at the centre of a crowded core that includes Birmingham, Kingston, Loughborough, Stirling and Lausanne. A distinct red cluster of Spanish universities (Francisco de Vitoria, Granada, Autonomous University of Madrid and the European University of Madrid) sits to the lower right, a cyan strand links Balkan and Italian institutions (Belgrade, Novi Sad, Split, Plovdiv, Bologna and Milan), and a purple group brings together institutions from Egypt and Saudi Arabia (Cairo, Ain Shams, King Saud and King Abdulaziz Medical City) with Johannes Gutenberg University. Beijing Sport University and the National University of Malaysia lie at the eastern edge of the map, and the Hungarian universities of Pécs and Szeged form a small detached pair.

Co-authorship analysis of authors

Out of 4,555 authors, 576 met the threshold. Only 14 had 10 or more documents, and 355 (61.6%) had exactly two, which shows a long tail of occasional contributors behind a small group of regular ones. Mario Thevis was the most productive author with 37 documents, 727 citations and a total link strength of 104 (Table 7). Andrea Petróczi followed with 26 documents and 415 citations, then Hans Geyer (18 documents), Fredrik Lauritzen, Vassilis Barkoukis, Philip Hurst and Susan H. Backhouse (14 each), Francesco Botrè, Juan del Coso and Andreas Thomas (13 each), and Tiia Kuuranne (12). Petróczi (92) and Barkoukis (63) were the most strongly connected authors after Thevis.

Table 7. Top 12 authors by number of documents (co-authorship analysis)

Rank	Author	Documents	Citations	Total link strength
1	Mario" "Thevis	37	727	104
2	Andrea" "PetróCzi	26	415	92
3	Hans" "Geyer	18	1,248	56
4	Susan H." "Backhouse	14	291	27
5	Vassilis" "Barkoukis	14	254	63
6	Philip" "Hurst	14	179	51
7	Fredrik" "Lauritzen	14	172	18
8	Juan" "Del Coso	13	602	42
9	Andreas" "Thomas	13	316	44
10	Francesco" "Botrè	13	232	32
11	Tiia" "Kuuranne	12	287	25
12	Ian D." "Boardley	11	229	33

Citation totals told a different story. Hans Geyer had the highest citation count (1,248 from 18 documents), but several authors reached more than 1,000 citations with only two to six documents, among them Ina Garthe (3 documents, 1,148 citations), Ronald J. Maughan (2 documents, 1,145), Mark Stuart (6 documents, 1,099) and Lars Engebretsen (3 documents, 1,033). These are authors of IOC consensus statements, whose reach is wide even though their contribution to the corpus is small.

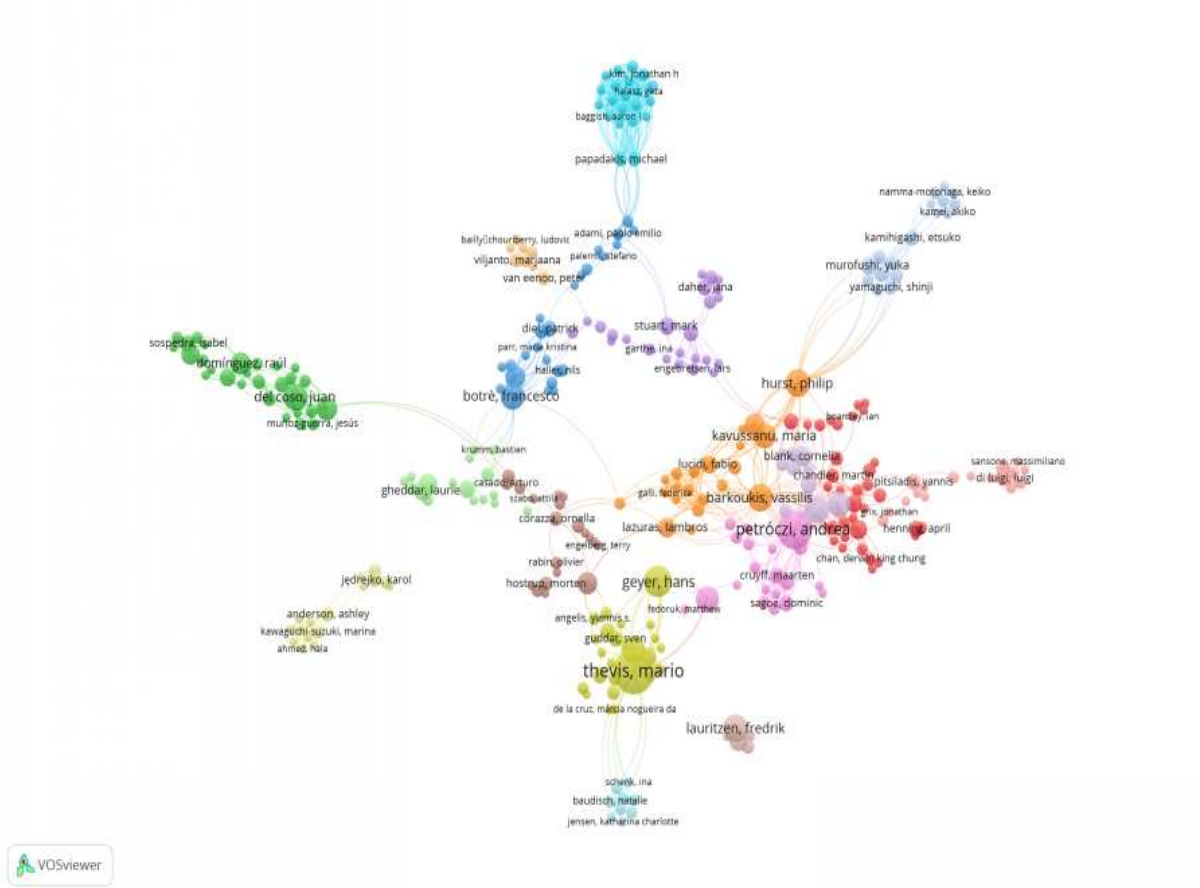


Figure 5. Co-authorship network of authors (VOSviewer; 576 authors).

The author map (Figure 5) is made up of separate communities. A yellow cluster around Thevis, Geyer, Guddat and Angelis represents the analytical and doping-control laboratory

community. A red, orange and pink block around Petróczi, Barkoukis, Hurst, Kavussanu, Lazuras and Backhouse represents behavioural and psychosocial research on doping, and it is closely connected to the analytical group through a few bridging authors. Botrè and colleagues form a blue Italian cluster, while del Coso, Domínguez, Sospedra and Muñoz-Guerra form a green Spanish cluster focused on supplements. A very dense cyan cluster (Kim, Halasz, Baggish, Papadakis and others) appears to be a sports cardiology group, and a Japanese group (Murofushi, Yamaguchi, Kamihigashi) and a small anti-doping laboratory cluster (Viljanto, Bailly-Chouriberry, van Eenoo) sit on the margins. Lauritzen, who writes from a national anti-doping organisation, appears as a largely isolated node.

Citation analysis of documents

Out of the 1,145 articles, 653 received at least five citations and together hold 20,988 citations. The median was 17 citations; 81 articles had 50 or more and 34 had 100 or more. The ten most cited articles accounted for 4,426 citations, or 21.1% of the citations held by the 653 documents (Table 8). Reardon (2019) was the most cited (1,249 citations), followed by Maughan (2018; 772), Guest (2021; 671), Garthe (2018; 373) and Collins (2020; 307). Labels follow the VOSviewer convention of first author and year.

Table 8. Ten most cited documents (citation analysis)

Rank	Document (first author, year)	Citations	Links
1	Reardon (2019)	1,249	9
2	Maughan (2018)	772	44
3	Guest (2021)	671	19
4	Garthe (2018)	373	50
5	Collins (2020)	307	15
6	Furrer (2023)	237	1
7	Domínguez (2017)	225	5
8	Martínez-sanz (2017b)	205	53
9	Hainline (2017)	204	5
10	Doherty (2019)	183	2

Several of these top-ranked documents are not about contamination as such. Reardon (2019) is the IOC consensus statement on mental health in elite athletes, Hainline (2017) is the IOC consensus statement on pain management in elite athletes, and Guest (2021) is the International Society of Sports Nutrition position stand on caffeine and exercise performance. They entered the dataset because they discuss supplements, medications or prohibited substances in an athletic setting. Maughan (2018), the IOC consensus statement on dietary supplements, is the only top-three document that deals squarely with supplement risk.

When the analysis is narrowed to documents that centre on contamination, adulteration and prohibited substances in supplements, the citation counts are considerably smaller (Table 9). Martínez-Sanz (2017b), a review of doping substances in supplements, had 205 citations and the largest number of links (53) in the whole network. Walpurgis (2020), Mathews (2017; published in print in 2018), Kozhuharov (2022), Jagim (2023) and Lauritzen (2022) follow with 140, 136, 113, 61 and 54 citations. These documents are the conceptual backbone of the topic, and each is well connected within the network.

Table 9. Core documents centred on contamination of supplements

Document (first author, year)	Citations	Links
Martínez-sanz (2017b)	205	53
Walpurgis (2020)	140	36
Mathews (2017)	136	30
Kozhuharov (2022)	113	31
Thevis (2021b)	63	22
Jagim (2023)	61	17
Lauritzen (2022)	54	25

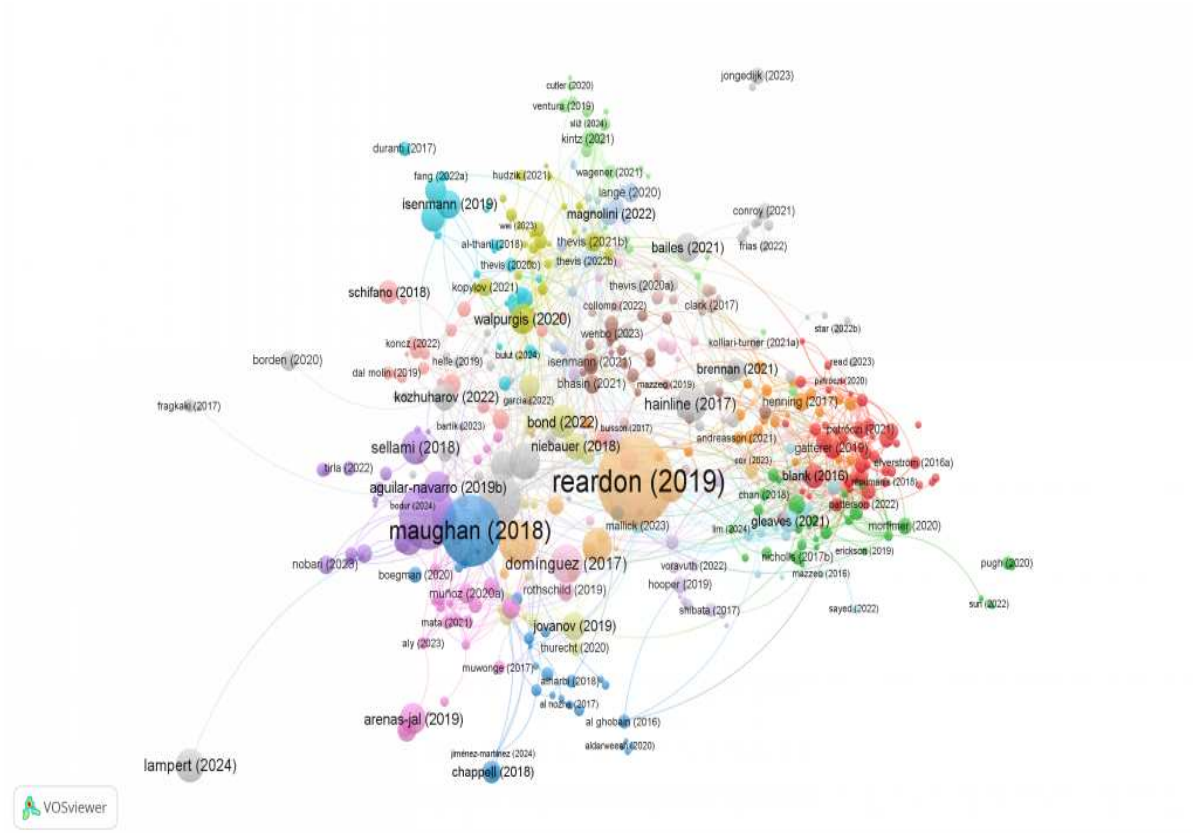


Figure 6. Citation network of documents (VOSviewer; 653 documents with at least five citations).

The document map (Figure 6) has a large central mass with Reardon (2019) and Maughan (2018) as its two largest nodes. A yellow-green group at the top, including Walpurgis (2020), Thevis (2021b) and Kopylov (2021), appears to represent analytical and doping-control work. A red group on the right, with Petróczi (2021), Gatterer (2019), Blank (2016) and Ntoumanis (2018), points to behavioural research on doping. Purple and pink groups on the left, which include Sellami (2018), Aguilar-Navarro (2019b), Muñoz (2020a) and Arenas-Jal (2019), seem to concentrate on supplement use and quality, and a green group on the right (Gleaves 2021, Mortimer 2020, Nicholls 2017b) is linked to prevalence and attitudes. Lampert (2024) is an outlying node with 175 citations and only three links.

DISCUSSION OF THE FINDINGS

Growth and maturity of the field

The steady rise in output, from 47 to 155 articles a year, shows that contaminated supplements and unintentional doping have moved from a niche concern to an established research topic. The step change in 2021 and 2022 followed the IOC consensus statement on dietary supplements (Maughan et al., 2018) and coincided with the 2021 Code cycle, and it is plausible that both raised the visibility of the issue. Our data cannot establish cause, however, and the growth of open-access publishing is likely to have contributed, because only open-access articles were analysed. The levelling off at about 140 to 155 articles a year since 2022 suggests that the field has reached a plateau of steady production rather than continuing to accelerate.

The citation curve is steeper than the publication curve, and annual citations have grown by a factor of more than 250 since 2016. This is partly a natural consequence of accumulation, because older papers keep being cited while new ones are added. It also indicates that the literature is being used: contamination studies feed into guidance documents, position stands and anti-doping education, which in turn are cited widely. The question is whether this attention converts into safer practice, a point to which we return below.

Geographic concentration and unequal participation

The United Kingdom, the United States, Germany, Italy, Australia and Spain account for most of the output and most of the collaboration links. Their prominence probably reflects long-standing sport science infrastructure, accredited anti-doping laboratories and funding for integrity research, but the dominance of English-language open-access journals in our sample may also

exaggerate it. The strong citation performance of Canada, the Netherlands, South Africa, Norway and Switzerland shows that small and medium-sized producers can have a large influence, usually through participation in multi-author consensus work.

The thin representation of Africa and South Asia is the most important geographic finding. Supplements are traded globally and increasingly online, as the Australian survey of products bought over the internet illustrates (Sport Integrity Australia, 2025), so contamination risk does not respect borders. Yet India appears with only 14 documents and a total link strength of 5, and the nine African countries together contribute 55 country-level counts. Regulatory frameworks for supplements differ widely between jurisdictions (Zapata-Linares & Gervasini, 2024), and athletes in settings with weaker oversight or limited access to certified products may face greater exposure than the literature suggests. Locally generated product-testing data and region-specific athlete surveys would help to close this gap.

Institutional hubs and the separation of research communities

German Sport University Cologne is the dominant institution, and its position, together with Mario Thevis's central place among authors, reflects the importance of analytical chemistry and doping-control laboratory science in this field. Birmingham, Kingston and Leeds Beckett form a second pole, and the author map shows that this pole is largely built around behavioural and psychosocial research led by Petróczi, Barkoukis, Hurst, Kavussanu and Backhouse. Work in this tradition has shown that supplement use and doping attitudes are related (Backhouse et al., 2013) and that psychosocial predictors of doping are robust (Ntoumanis et al., 2014).

The two poles are linked, but only through a small number of bridging authors, and the map suggests that analytical, behavioural, nutritional and clinical communities mostly work side by side. This matters because contamination is a problem that sits across all four: a laboratory can detect a contaminant, but only behavioural and educational research can show whether athletes change their choices as a result, and only clinical work can show what the contaminant does to the athlete's body. Peripheral nodes such as the sports cardiology cluster and practitioner authors writing from national anti-doping organisations point to knowledge that is produced close to practice but not yet integrated into the main network.

Intellectual structure: consensus statements and the contamination core

The most cited documents are mainly IOC consensus statements and position stands, such as Reardon (2019), Maughan (2018), Hainline (2017) and Guest (2021). They are highly cited because they define guidance for large professional communities, and several of them reach into the topic only indirectly. A second tier consists of reviews on supplements and herbal products (for example Sellami et al., 2018, and the systematic review of beetroot juice supplementation by Domínguez et al., 2017) and broader exercise physiology reviews (Furrer et al., 2023), which again suggests that part of the citation mass comes from the wide boundaries of the search rather than from contamination research itself.

The documents that deal directly with contamination, adulteration and prohibited substances in supplements are cited far less, but they are among the best connected in the network. Martínez-Sanz et al. (2017), Walpurgis et al. (2020), Mathews (2018), Kozhuharov et al. (2022), Jagim et al. (2023) and Lauritzen (2022) form the conceptual backbone of the topic. Two features of this core deserve comment. First, it is dominated by reviews and narrative syntheses, with fewer primary analytical surveys, even though primary surveys are what generate the prevalence figures that policy relies on. Second, its citation counts are modest relative to the field's size, which suggests that the specific problem of unintentional doping has not yet attracted the cross-disciplinary readership that the broader consensus literature enjoys.

Athlete health and anti-doping risk

Read together, the maps suggest that the field is better at describing the anti-doping side of the problem than the health side. Prevalence of contaminated products, analytical detection and rule-violation data are well represented. Studies that follow contaminated products through to adverse health outcomes in athletes are much harder to find. Yet the contaminants named in this literature, such as anabolic agents and stimulants, are pharmacologically active and have known toxicological and cardiovascular effects (Tucker et al., 2018; Zapata-Linares & Gervasini, 2024). The close association of the sports cardiology cluster with this corpus is a reminder that these risks are real, even where studies do not link them explicitly to supplement contamination.

From the anti-doping perspective, the evidence points to a persistent and measurable exposure. A quarter of the analytical anti-doping rule violations in one national programme were attributed by athletes to supplements (Lauritzen, 2022), and about one in three uncertified products bought online in a recent survey contained a prohibited substance (Sport Integrity Australia, 2025). Strict liability means that these findings translate directly into sanctions, careers and reputations. The move from contaminated product to contaminated source in the 2027 Code (Bird & Bird, 2025; WADA, 2025) will widen the range of exposures that can be considered, and the literature mapped here will need to expand accordingly, since

it currently focuses on products rather than on shared facilities, traditional preparations or accidental contact.

Implications for practice, policy and research

For athletes, coaches and sports medicine staff, the findings reinforce a cautious approach: a food-first strategy, supplements only when there is a clear need, a preference for products that have been batch tested by an independent certification scheme, and a written record of everything consumed. Sport-specific guidance already points in this direction (Peeling et al., 2019; Maughan et al., 2018). Physical education and sport science programmes can build these habits early by teaching supplement literacy alongside nutrition and anti-doping education.

For regulators and sport organisations, the geographic gaps argue for harmonised supplement regulation and labelling, closer cooperation between food-safety authorities and anti-doping organisations, and shared databases of products found to be contaminated. For researchers, five priorities emerge: standardised definitions that separate cross-contamination, adulteration and mislabelling; open and comparable analytical surveys of products in under-represented regions; studies that link contaminant exposure to athlete health outcomes; research on groups that are rarely studied, such as youth, recreational and para-athletes; and evaluation of whether education and certification schemes actually lower the number of inadvertent violations.

CONCLUSION

This bibliometric analysis of 1,145 open-access articles shows that research on contaminated dietary supplements and unintentional doping has expanded steadily since 2016, with output more than tripling and annual citations rising from 18 to over 4,700. The field is led by the United Kingdom, the United States, Germany, Italy, Australia and Spain; by hubs such as German Sport University Cologne, the University of Birmingham and Kingston University; and by authors such as Mario Thevis, Andrea Petróczi and Hans Geyer. Analytical, behavioural, nutritional and clinical communities are visible but only partly connected, and the most cited papers are broad consensus statements, while the contamination-specific core is smaller and more modestly cited.

Three conclusions follow. The first is that unintentional doping remains a real and measurable risk that is documented consistently from early testing studies to recent product surveys. The second is that the research base is geographically unbalanced, with Africa and South Asia largely absent from the collaboration networks, even though supplements are traded across borders. The third is that the health consequences of contaminated supplements are under-studied relative to their anti-doping implications. With the 2027 World Anti-Doping Code about to broaden the concept of contamination, the field needs surveillance that is more regional, studies that integrate laboratory, behavioural and clinical perspectives, and education and certification schemes that are properly evaluated. Such efforts would protect athletes' health and their careers at the same time.

LIMITATIONS

Several limitations should be kept in mind. First, only Dimensions AI was searched. Other databases, such as Scopus and Web of Science, index different journals and may give somewhat different counts and rankings. Second, the open-access, article-only and English-language filters exclude closed-access papers, book chapters, conference papers and non-English literature, so the results describe the open-access English literature rather than all research on the topic. Third, the Boolean string is broad. Because "prohibited substance" AND supplement is one alternative within the first block and terms such as athlete and sport are very general, some retrieved articles deal with supplements, medications or athlete health in general rather than with contamination specifically. Records were not screened manually, so citation rankings in particular include documents that are only partly relevant.

Fourth, the 2026 data are incomplete, and recent articles have had little time to accumulate citations, which disadvantages them in the citation analysis. Fifth, VOSviewer thresholds exclude small contributors, and the interpretation of clusters is partly qualitative. Author-name disambiguation, differences in how affiliations are recorded and the full-counting treatment of multi-country papers can all affect the totals. Finally, bibliometric indicators describe the visibility and connectedness of research, not its quality, and a high citation count does not guarantee that a finding is reliable or has changed practice.

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