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DOI:
10.1016/j.drugpo.2023.104077

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Document Version
Publisher's PDF, also known as Version of record

Citation for published version (Harvard):
Hurst, P, Schiphof-Godart, L, Kavussanu, M, Barkoukis, V, Petróczi, A & Ring, C 2023, 'Are dietary supplement users more likely to dope than non-users? a systematic review and meta-analysis', *International Journal of Drug Policy*, vol. 117, 104077. https://doi.org/10.1016/j.drugpo.2023.104077

Link to publication on Research at Birmingham portal

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Download date: 02. May. 2024

International Journal of Drug Policy 117 (2023) 104077

Contents lists available at ScienceDirect

International Journal of Drug Policy

journal homepage: www.elsevier.com/locate/drugpo

Review

Are dietary supplement users more likely to dope than non-users?: A systematic review and meta-analysis

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ARTICLE INFO

Keywords:
Athlete health
Clean sport
Gateway hypothesis
Nutritional ergogenic aids
Safe sport
Sports supplements

ABSTRACT

In the past decade, a body of evidence has reported that dietary supplement use is related to prohibited performance enhancing substance use (i.e., doping). To help international and national sport organisations understand the degree to which dietary supplement use is related to doping, the objectives of this systematic review and meta-analysis were to 1) compare the prevalence of doping between dietary supplement users and non-users and 2) identify whether supplement use is related to doping social cognitive factors. We searched for studies sampling athletes and that measured both dietary supplement use and doping in EMBASE, MEDLINE, PsychINFO, CINAHL and SPORTDiscus from database creation to May 2022. Risk of bias was assessed using JBI Critical Appraisal Checklist for cross-sectional studies and the STROBE checklist. Twenty-six cross-sectional studies, involving 13,296 athletes were included. Random-effect models revealed that doping was 2.74 (95% CI=2.10 to 3.57) times more prevalent in dietary supplement users (pooled prevalence = 14.7%) than non-users (6.7%), and that users reported stronger doping intentions (r=0.26, 0.18 to 0.34) and attitudes (r=0.21, 0.13 to 0.28) compared to non-users. Preliminary evidence also suggests that dietary supplement users were less likely to dope if they were more task oriented and had a stronger sense of morality. Results of the review are limited by the cross-sectional design used in all studies and lack of consistency in measurement of dietary supplement use and doping. Data indicate that athletes using dietary supplements are more likely to self-report doping Anti-doping policy should, therefore, target dietary supplement use in anti-doping education programmes by providing alternative strategies for performance enhancement or highlighting the safest ways they can be consumed. Similarly, as a large proportion of athletes use dietary supplements without doping, further research is needed to understand the factors that protect a dietary supplement user from doping. No funding was received for the review. A study protocol can be found here: https://osf.io/xvcaq.

Introduction

The use of prohibited performance enhancing substances and methods in sport (i.e., doping) has been associated with acute and chronic ill-health (Kanayama et al., 2009; Nieschlag & Vorona, 2015; Pope et al., 2014). The World Anti-Doping Agency (WADA) aim to reduce or eliminate doping by standardising policies and practices to over 700 international and national sport organisations (WADA, 2022), with over US$300 million spent on co-ordinating anti-doping activities in the last decade (Gleaves et al., 2021). While a large proportion of this funding is aimed at detecting and sanctioning athletes who have doped, WADA also implement anti-doping education programmes to prevent doping. For anti-doping education programmes to be effective, they need to target the factors that are most strongly related to doping. Therefore, understanding factors related to an athlete's decision to dope is important for international and national organisations aiming to minimize doping.

In the past 15 years, a body of evidence has established that a number of factors are related to an athlete's decision to dope (Nicholls et al., 2017; Ntoumanis et al., 2014). Dietary supplements (e.g., creatine, caffeine, sodium bicarbonate), which are used by a large proportion of

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https://doi.org/10.1016/j.drugpo.2023.104077

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athletes (Knapik, Steelman, et al., 2016) to improve or facilitate performance (Maughan et al., 2018), is related to doping (Nicholls et al., 2017; Ntoumanis et al., 2014). Some researchers have suggested that supplements may act as a gateway to doping due to a shared mental representation (Hurst et al., 2017; Mallick et al., 2023), whereas other researchers have posited that doping grows out of the habitual use of performance enhancement methods, such as dietary supplements (Petróczi, 2013).

A number of studies have found relationships between dietary supplement use and doping use (e.g., Backhouse et al., 2013; Barkoukis et al., 2020; Dietz et al., 2013), as well as between supplement use and social cognitive factors, such as motivational orientations (Barkoukis et al., 2020; Hurst et al., 2022a), perceived acceptance of doping (Backhouse et al., 2013), and beliefs that supplements are effective (Hurst et al., 2019). A meta-analysis of the personal and psychosocial predictors of doping (Ntoumanis et al., 2014) reported that dietary supplement use was one of the strongest (odds ratio = 8.24). However, this review was published a decade ago and did not assess prevalence of doping use between dietary supplement users and non-users or explore the factors related to dietary supplement use and doping social cognitive factors. To help both researchers and anti-doping organisations assess whether doping use is more co-prevalent with dietary supplement use, and, in turn, help develop more effective methods to prevent doping, it is necessary to update, review, and synthesise current knowledge in the area. Given this, the aims of our systematic review and meta-analysis were to compare the prevalence of doping between dietary supplement users and non-users and identify whether supplement use is related to doping social cognitive factors.

Methods

The review is reported in accordance with the guidelines provided by the Preferred Reporting Items for Systematic Review and Meta-Analyses (Page et al., 2021).

Eligibility criteria

Studies needed to meet the following inclusion criteria: 1) observational (e.g., analytical cross-sectional, cohort, longitudinal), 2) quantitative measure of dietary supplement use, 3) quantitative measure related to doping, 4) direct comparison between dietary supplement use and doping, 5) sample of athletes competing in sports that are signatories to the World Anti-Doping Code (WADA, 2022), 6) published in a peer-review journal or part of a doctoral thesis, and 7) written in English. We set no geographical, date, or athlete sampling restrictions (e.g., all ages, types of sports, and abilities).

Information sources and search strategy

Using the search strategies shown in Supplementary Material, articles were searched in the following databases from their earliest records to 21st May 2022: Ovid EMBASE (1971 onwards), Ovid MEDLINE (1946 onwards), Ovid PsychINFO (1806 onwards), EBSCO CINAHL (1982 onwards) and EBSCO SPORTDiscus (1892 onwards). Searches centred around three themes: 1) athletes, 2) dietary supplements, and 3) doping. To find other potential studies, we consulted with academics researching dietary supplements and doping and searched reference listings of included studies and review articles (Backhouse et al., 2007; Backhouse et al., 2016; Chan et al., 2018; de Hon et al., 2015; Knapik, Steelman, et al., 2016; Maughan et al., 2018; Morente-Sanchez & Zabala, 2013; Nicholls et al., 2017; Ntoumanis et al., 2014).

Selection process

Identified studies were imported into the web app Rayyan (Ouzzani et al., 2016), and duplicates were automatically removed. Two reviewers (PH and LSG) read titles and abstract of each study independently, and a pilot screening of 100 studies was conducted to clarify inclusion and exclusion criteria. Intercoder agreement was assessed using Cohen's kappa (κ) (Cohen, 1960), which indicated high agreement regarding inclusion of studies (κ = 79%). If a lack of information was present in the title or abstract, the full text was retrieved. Any disagreements were resolved through discussion. The same reviewers independently assessed full texts of each study, and to ensure reliability of assessment, piloting was conducted on 10 articles (κ = 85%). Disagreements were resolved through discussion between authors and, if necessary, a third author was consulted. For studies reporting data in multiple publications, the most representative sample was included.

Data collection process

A data extraction form was created in Excel and the lead author extracted the data items from each study. Data were checked by the second author for accuracy and completeness, with disagreements resolved through discussion. If data were not reported or were unclear (Buckman et al., 2013; García-Grimau et al., 2021; Kisaalita & Robinson, 2014; Lazuras et al., 2017; Seifarth et al., 2019) authors were contacted via email.

Data items

Primary outcomes were prevalence of dietary supplement and doping use. Dietary supplements were defined in accordance with The International Olympic Committee's Consensus statement on dietary supplements (Maughan et al., 2018). Namely, a food, food component, nutrient, or non-food compound that is purposefully ingested in addition to the habitually-consumed diet with the aim of achieving a specific health and/or performance benefit (e.g., caffeine, creatine, nitrate). Medications, alcohol, tobacco, and other illicit substances were not included in this definition. Doping was defined as the use of a substance prohibited by the World Anti-Doping Agency (e.g., androgenic-anabolic steroids, amphetamines, human growth hormone). Dietary supplement users and doping users were identified as those who had reported current or past use. For multi-categorical measures (e.g., regularly, occasionally, never) and multi-type measures (e.g., listing of doping substances), those indicating any use were identified as "users".

Secondary outcome measures included doping intention[1] (e.g., intention, likelihood, susceptibility) and social cognitive factors related to doping (e.g., attitudes, motivation, norms). Only outcomes that directly examined both dietary supplement use and a doping measure are reported. In addition, study characteristic details were extracted from each eligible study, including study details (i.e., author, year, country, study design), sample (i.e., size, age, sex), description of measures (e.g., online vs. in-person, anonymity, and administration), and conclusions. No assumptions were made in case of missing data and such cases were coded as not reported.

Study risk of bias assessment

Two reviewers (PH and LSG) independently assessed the risk of bias for included studies using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for cross-sectional studies (Joanna Briggs Institute, 2016) and the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) checklist (Von Elm et al., 2014). The

[1] Studies often use various measures to assess an athlete's doping intention, such as consideration, likelihood, and willingness in both time-specific (e.g., whether during a season an athlete would dope) and hypothetical situations (e.g., if a doping substance posed no health risks, would the athlete be willing to use it). For simplicity and conciseness, in this review, the term doping intention refers collectively to the tendency of an athlete willing to use a prohibited performance enhancing substance.

JBI Critical Appraisal Checklist includes eight items related to the overall methodological quality of a study and reviewers rated the extent to which each study met the criteria for each item as "yes", "no", "unclear", or "not applicable". Studies were categorised as "low", "moderate", and "high" risk when yes scores were below 49%, between 50 and 69%, and above 70%, respectively. The STROBE checklist includes 22 items relating to each section of an article (e.g., abstract, introduction, methods) and reviewers scored each item dichotomously with "0" (i.e., high risk of bias) and "1" (i.e., low risk of bias) to each item. Scores for each study were summed and graded as "poor" or "good" if scores were between 0 and 13 or 14 and 22, respectively. Pilot testing was conducted on five studies to ensure agreement between terms, accuracy, and methods of assessments. Disagreements in assessments were resolved via discussion. Inter-class correlations were calculated to identify inter-coder reliability and revealed high agreement between reviewer assessments for both the JBI ($r = 0.91$) and STROBE checklists ($r = 0.83$).

Effect measures

For doping use among dietary supplement users and non-users, doping prevalence was calculated as a percentage by dividing the number of doping users by the supplement users within the respective user group (e.g., doping users/dietary supplement users). Odds ratio (OR) was used to compare differences prevalence rates between supplement users and non-users with an OR between 1.68 and 3.47 considered small, 3.47 and 6.71 medium, and above 6.71 large difference (Chen et al., 2010). For secondary outcome measures, where possible, zero-order Pearson's correlations (r) were calculated, and interpreted as small ($r \geq 0.1$), medium ($r \geq 0.2$), and large ($r \geq 0.3$; Gignac & Szodorai, 2016). For studies reporting different effect statistics (e.g., Cohen's d and OR), the metrics were converted using standard conversion formulas (Lajeunesse, 2009).

Synthesis methods

Frequency of dietary supplement and doping use were calculated and expressed as a percentage of the total sample size. Prevalence of doping for dietary supplement users and non-users was calculated by dividing the number of doping users by the number in the corresponding dietary supplement user group (i.e., users, non-users) and expressed as a percentage. Meta-analyses were performed using the Comprehensive Meta-analysis Software v4 (Biostat Inc., Englewood, NJ, USA). Given the likelihood of high heterogeneity between studies, we used random-effects models. Data from eligible studies for which sufficient data were available or provided were pooled for 1) prevalence of doping in dietary supplement users and non-users, and 2) relationships between dietary supplement use and secondary outcome measures. Dietz et al. (2013) and Seifarth et al. (2019) measured physical and cognitive doping, and we analysed the prevalence rate of the former as this was deemed similar to other studies included in this review. Similarly, Petroczi et al. (2011) measured doping prevalence via both self-report and hair analysis. We extracted the self-report data as this is similar to research studies included in the review. Data were synthesised both narratively and graphically using standard forest plots, and studies were ordered chronologically.

Heterogeneity was assessed using the I^2 statistic, with cut-offs of 25%, 50%, and 75% indicating, low, moderate, and substantial heterogeneity, respectively. Sensitivity analysis was conducted to examine the influence of individual studies (leave one out and cumulative analyses), study bias, and quality on meta-analysed effect sizes. To examine whether pooled effects varied in relation to different characteristics, moderators of the meta-analysed effects were analysed using a random effects meta-regression model. Moderators were selected based on availability of data across all studies, which included year of publication, mean age, percentage of females in the sample, if data were collected anonymously (i.e., no or yes), how data were collected (i.e., in person or online), JBI risk of bias score, and STROBE checklist score. Due to the small number of studies in each meta-analysis and concerns about statistical power, we assessed effects of moderators one at a time. All statistical analyses were two-tailed, with statistical significance set at $p < 0.05$.

Reporting bias assessment

We examined publication bias as a potential threat to the validity of each meta-analysed effect sizes using both Egger's (Egger et al., 1997) and Begg's (Begg & Mazumdar, 1994) tests. A significant of $p < 0.05$ from these tests, indicates that publication bias is likely to occur. We also calculated fail-safe numbers (FSN), which represent the number of studies required to be included in the analysis to render the true prevalence as zero (i.e., no effect). Publication bias is not considered an issue if the FSN N value is greater than the number of studies (k) that contributed to each analysis (Rosenthal, 1979).

Certainty assessment

The Grading of Recommendation, Assessment, Development and Evaluation (GRADE) system was used to assess the overall quality of evidence and level of confidence in the conclusions (Guyatt et al., 2008). GRADE assessment considers factors over and above individual study risk of bias and all observational research begins as low quality and can be upgraded or downgraded based on five criteria: 1) risk of bias in individual studies (e.g., high rating on the JBI assessment), 2) inconsistency (e.g., I^2 >90%), 3) indirectness (i.e., studies assessing a different population of interest), 4) imprecision (i.e., large confidence intervals of meta-analysed effects), and 5) publication bias (e.g., significant Egger's test; Balshem et al., 2011). Certainty was assessed by the lead author and judgements were confirmed by the second author. Assessments were reported narratively.

Results

Study selection

Fig. 1 summarises the selection process and studies included in the review. We identified 5,289 potentially eligible studies, of which 1,922 duplicates were removed. After screening 3,367 titles and abstracts, a further 3,066 were excluded. A total of 301 full texts were read and 275 were removed after not meeting inclusion criteria. Reasons for exclusion were: a review or commentary ($k = 77$), sampling a non-athletic population ($k = 71$), no quantitative measure of doping ($k = 45$) or dietary supplement use ($k = 43$), no direct comparison between dietary supplement use and doping ($k = 21$), qualitative study ($k = 9$), duplication of data ($k = 5$), and non-English ($k = 1$). One study was also excluded because outcomes combined both dietary supplement and doping use. We also searched the reference lists of the studies included into the review for additional studies to include, but no further articles fulfilled the inclusion criteria.

Five instances occurred in which studies met inclusion criteria but the prevalence of supplement use or the relationship between dietary supplement use and the doping outcome measure were not explicitly reported. Corresponding authors were contacted, with three authors providing data (García-Grimau et al., 2021; Lazuras et al., 2017; Seifarth et al., 2019); one was unable to provide the data (Kisaalita & Robinson, 2014), and another did not respond (Buckman et al., 2013). Studies in which data could not be sought were removed from analyses. In sum, 26 full-text studies met inclusion criteria and were included in the review.[2]

[2] Two studies (Hurst et al., 2019 and 2022b) were multi-study projects involving two different samples and were treated separately.

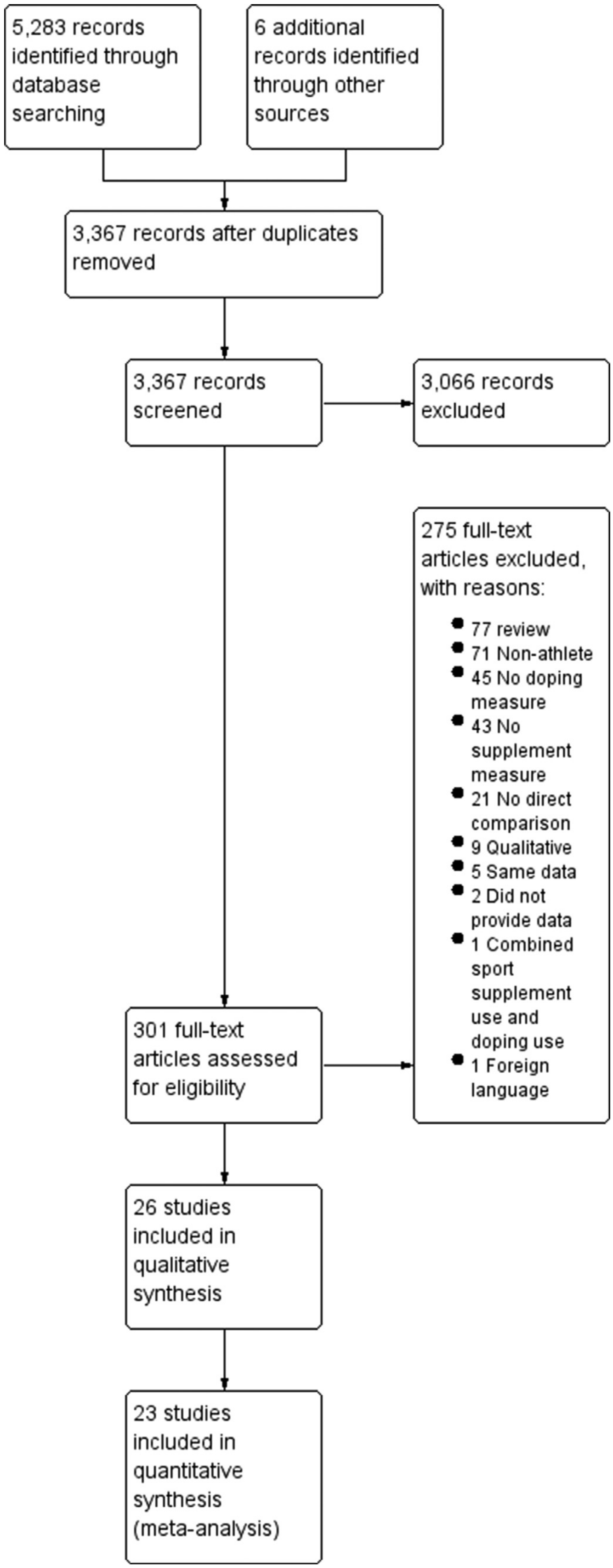

Fig. 1. Study flow diagram.

Study characteristics

Characteristics of the 26 studies are show in Table 1. All studies used a cross-sectional design, were published between 2008 and 2022, and were conducted across twelve countries: United Kingdom (k = 9), Slovenia (k = 4), Croatia (k = 2), Germany (k = 2), Greece (k = 2), Australia (k = 1), Brazil (k = 1), Italy (k = 1), Malaysia (k = 1), Saudi Arabia (k = 1), Spain (k = 1), and Switzerland (k = 1). A total of 13,296 participants (mean ± SD: 511 ± 646, range = 40 to 2,987) were recruited across all studies, of which the majority were male (n = 9,799, 74%). Mean age across all samples was 22.4 ± 5.8 years (range = 15.3 to 39.6 years).

Most studies reported that participants' data were kept anonymous (k = 24). Measures were distributed in person (k = 13), online (k = 6), or not reported (k = 7). For those distributed in person, participants returned questionnaires in a sealed envelope (k = 4), in a box (k = 2), in a sealed envelope and box (k = 1), or not reported (k = 6). Dietary supplement use was assessed via dichotomous (k = 13) or multi-categorical (k = 12) measures, with one study not reporting the type of measurement (k =1). Fifteen studies assessed participants' current use of dietary supplements with 10 assessing if participants had ever used a supplement. Prevalence of doping was the most common primary outcome measure (k = 12), which was assessed via dichotomous (k = 6) and multi-categorical (k = 6) instruments. Other primary outcome measures were doping intention (k = 9), doping attitudes (k = 2), doping descriptive norms (k = 2), and knowledge of doping substances (k = 1). Secondary outcomes that were compared with dietary supplement use were: dietary supplement beliefs (k = 6), motivation and achievement goals (k = 2), and morality (k = 2).

Reporting biases

Employing the JBI Critical Appraisal Checklist, two studies were rated as having high risk of bias and five as having medium risk. Most studies did not provide a description of sample inclusion criteria (k = 16) and more than half did not measure outcomes in a valid and reliable way (k = 15). Similarly, over a third of studies did not describe the study participants or setting in detail (k = 11) or were judged not to have measured outcomes in a valid and reliable way (k = 10). Based on the STROBE assessment, six studies were reported to have poor study quality. Nearly all studies did not clearly define all outcome measures (k = 19) or give reasons for non-participation and exclusion in the study (k = 19). Similarly, a large number of studies did not provide participant eligibility criteria and methods for selecting participants (k = 14) or explain how the sample size was arrived at (k = 14). Assessment of bias for both the JBI Critical Appraisal Checklist and the STROBE statement are found in Supplementary Material.

Results of individual studies

Dietary supplement and doping prevalence

Table 2 reports the prevalence of dietary supplement and doping use. Across all studies, dietary supplement prevalence was 56.3 ± 21.8% (range = 15.2% to 100.0%). Twelve studies measured doping prevalence (Al Ghobain et al., 2016; Backhouse et al., 2013; Barkoukis, Lazuras, Lucidi, et al., 2015; Barkoukis et al., 2020; Dietz et al., 2013; García-Grimau et al., 2021; Hurst et al., 2022b; Lazuras et al., 2017; Pedroso da Silva et al., 2017; Petroczi et al., 2011; Seifarth et al., 2019), with 9.4 ± 5.5% (range = 1.1% to 21.0%) reporting to have doped. Doping use was prevalent in 14.7% (95% CI = 8.9% to 20.5%) of dietary supplement users and in 6.7% (95 CI = 2.7% to 10.6%) of non-users. Moreover, 86.3 ± 7.4% of dietary supplement users and 93.3% ± 6.3% of non-users reported that they did not use doping substances.

In the majority of studies, doping use was significantly greater in dietary supplement users than non-users (Backhouse et al., 2013;

Table 1
Study characteristics of included studies.

Study details			Participants				Measures		Risk of bias	
Author	Year	Country	N	Sample characteristic	Age (years)	Gender	Anonymous	Format	JBI	STROBE
1. Mazanov et al.	2008	Australia	757	High performing athletes	Median range = 18 to 23	66% (n = 500) male; 34% (n = 257) female	Yes	Not reported	50%	17
2. Kondric et al.	2011	Slovenia	187	Elite athletes	22.0 ± 2.3	64% (n = 122) male; 36% (n = 65) female	Yes	Not reported	63%	14
3. Petróczi et al.	2011	United Kingdom	82	Student athletes	23.5 ± 2.9	48% (n = 39) male; 52% (n = 43) female	Unknown	Online	88%	9
4. Backhouse et al.	2013	United Kingdom	212	Competitive athletes	21.4 ± 4.5	65% (n = 138) male; 35% (n = 74) female	Yes	Online	38%	9
5. Dietz et al.	2013	Germany	2,987	Recreational triathletes	39.5 ± 9.2	87.3% (n = 2,576) male; 12.7% (n = 376) female	Yes	Person	38%	17
6. Kondric et al.	2013	Slovenia	64	High level tennis players	23.2 ± 2.8 for male; 21.6 ± 2.7 for female	32% (n = 21) male; 66% (n = 43) female	Yes	Not reported	38%	13
7. Loraschi et al.	2014	Italy	40	Elite under 23 athletes	20.7 ± 1.3	100% (n = 40) male; 0% (n = 0) female	Yes	Not reported	63%	15
8. Sekulic et al.	2014	Croatia	105	High level Rugby players	23.6 ± 4.2	100% (n = 105) male; 0% (n = 0) female	Yes	Not reported	50%	11
9. Barkoukis et al.	2015	Greece	650	Adolescent athletes	16.1 ± 1.5	68% (n = 442) male; 32% (n = 208) female	No	In person	13%	16
10. Al Ghobain et al.	2016	Saudi Arabia	1,142	Saudi male sport players	24.2 ± 0.2	100% (n = 1,142) male; 0% (n = 0) female	Yes	Not reported	38%	15
11. Balaravi et al.	2017	Malaysia	50	National elite athletes	median age = 22	66% (n = 33) male; 34% (n = 17) female	Unknown	Not reported	38%	14
12. Lazuras et al.	2017	United Kingdom	216	Adolescent athletes	17.4 ± 1.7	79% (n = 171) male; 21% (n = 45) female	Yes	In person	0%	15
13. Pedroso da Silva et al.	2017	Brazil	402	Young student athletes	16.0 ± 0.8	49% (n = 197) male; 51% (n = 205) female	Yes	In person	75%	12
14. Sekulic et al.	2017	Croatia	130	Kickboxers	Males: 21.4 ± 4.8, Females: 20.3 ± 2.9	71% (n = 92) male; 29% (n = 38) female	Yes	In person	13%	13
15. Devcic et al.	2018	Slovenia	301	National level swimmers	16.4 ± 2.4	49% (n = 148) male; 51% (n = 153) female	Yes	In person	50%	14
16. Hurst et al. (study 1)	2019	United Kingdom	608	Competitive athletes	21.2 ± 4.5	69% (n = 417 male; 31% (n = 191) female	Yes	In person	13%	17
17. Hurst et al. (study 2)	2019	United Kingdom	475	Competitive athletes	20.3 ± 2.2	70% (n = 337) male; 31% (n = 138) female	Yes	In person	13%	17
18. Sajber et al.	2019	Slovenia	242	Elite junior swimmers	15.3 ± 1.1	46% (n = 111) male; 54% (n = 131) female	Yes	In person	38%	18
19. Seifarth et al.	2019	Germany	1,953	Recreational triathletes	39.6 ± 10.7	76% (n = 1491) male; 24% (n = 462) female	Yes	In person	13%	15
20. Barkoukis et al.	2020	Greece	497	Competitive athletes	23.5 ± 5.8	64% (n = 318) males; 36% (n = 179) female	Yes	In person	13%	15
21. García-Grimau et al.	2021	Spain	281	Track and Field athletes	Between 18 and 28	51% (n = 142) males; 49% (n = 139) females	Yes	Online	13%	20
22. Hurst et al.	2021a	United Kingdom	557	Competitive athletes	20.8 ± 2.2	77% (n = 429) male; 23% (n = 128) female	Yes	In person	25%	17
23. Hurst et al.	2021b	United Kingdom	362	Competitive athlete	23.6 ± 10.3	61% (n = 221) male; 39% (n = 141) female	Yes	Online	13%	19
24. Mettler et al.	2021	Switzerland	430	Elite Swiss adolescent athletes	not reported	56% (n = 242) male; 44% (n = 186) female	Yes	In person	25%	17
25. Hurst et al. (study 1)	2022	United Kingdom	366	Competitive athlete	23.8 ± 10.3	61% (n = 223) male; 39% (n = 133) female	Yes	Online	13%	19
26. Hurst et al. (study 1)	2022	United Kingdom	200	Competitive athlete	26.0 ± 12.3	51% (n = 102) male; 49% (n = 98) female	Yes	Online	13%	19

Note: JBI = Joanna Briggs Institute Critical Appraisal Checklist, STROBE = Strengthening the Reporting of Observational Studies in Epidemiology checklist.

Table 2
Prevalence of dietary supplement and doping use.

Study	Dietary supplement		Doping		Doping between dietary supplement users and non-users	
	User	Non-users	User	Non-users	Dietary supplement users	Dietary supplement non-users
1. Mazanov et al. (2008)	61.0% (n = 462)	39.0% (n = 295)	-	-	-	-
2. Kondric et al. (2011)	44.5% (n = 85)	54.5% (n = 102)	-	-	-	-
3. Petróczi et al. (2011)	68.3% (n = 56)	31.7% (n = 26)	13.4% (n = 11)	86.6% (n = 71)	12.5% (n = 7)	15.4% (n = 4)
4. Backhouse et al. (2013)	45.3% (n = 96)	54.7% (n = 116)	12.7% (n = 27)	87.3% (n = 185)	21.9% (n = 21)	5.2% (n = 6)
5. Dietz et al. (2013)	15.2% (n = 455)	80.2% (n = 2,396)	11.8% (n = 351)	67.8% (n = 2,026)	25.3% (n = 115)	11.1% (n = 267)
6. Kondric et al. (2013)	92.2% (n = 59)	6.3% (n = 4)	-	-	-	-
7. Loraschi et al. (2014)	97.5% (n = 39)	2.5% (n = 1)	-	-	-	-
8. Sekulic et al. (2014)	30.5% (n = 32)	43.8% (n = 46)	-	-	-	-
9. Barkoukis et al. (2015)	38.9% (n = 253)	61.1% (n = 397)	4.2% (n = 27)	95.8% (n = 623)	8.3% (n = 21)	1.5% (n = 6)
10. Al Ghobain et al. (2016)	38.4% (n = 439)	61.6% (n = 703)	4.4% (n = 50)	95.6% (n = 1,092)	7.3% (n = 32)	2.6% (n = 18)
11. Balaravi et al. (2017)	74.0% (n = 37)	26.0% (n = 13)	-	-	-	-
12. Lazuras et al. (2017)	74.0% (n = 37)	26.0% (n = 13)	-	-	-	-
13. Pedroso da Silva et al. (2017)	36.1% (n = 78)	62.0% (n = 134)	5.6% (n = 12)	92.6% (n = 200)	7.7% (n = 6)	4.5% (n = 6)
14. Sekulic et al. (2017)	39.1% (n = 157)	60.9% (n = 245)	14.2% (n = 57)	85.8% (n = 345)	21.0% (n = 33)	9.8% (n = 24)
15. Devcic et al. (2018)	100.0% (n = 130)	0.0% (n = 0)	-	-	-	-
16. Hurst et al. (study 1; 2019)	63.8% (n = 192)	36.2% (n = 109)	-	-	-	-
17. Hurst et al. (study 2; 2019)	69.1% (n = 328)	30.9% (n = 147)	-	-	-	-
18. Sajber et al. (2019)	60.3% (n = 146)	39.7% (n = 96)	-	-	-	-
19. Seifarth et al. (2019)	31.5% (n = 574)	68.5% (n = 1,246)	21.0% (n = 382)	79.0% (n = 1,438)	34.0% (n = 130)	20.2% (n = 252)
20. Barkoukis et al. (2020)	64.0% (n = 318)	36.0% (n = 179)	6.8% (n = 34)	93.2% (n = 463)	10.4% (n = 33)	0.6% (n = 1)
21. García-Grimau et al. (2021)	77.2% (n = 217)	22.8% (n = 64)	9.6% (n = 27)	90.4% (n = 254)	10.6% (n = 23)	6.3% (n = 4)
22. Hurst et al. (2021)	53.0% (n = 295)	47.0% (n = 262)	-	-	-	-
23. Hurst et al. (2022a)	55.2% (n = 200)	44.8% (n = 162)	-	-	-	-
24. Mettler et al. (2021)	83.0% (n = 357)	17.0% (n = 73)	-	-	-	-
25. Hurst et al. (study 1; 2022b)	37.4% (n = 137)	62.6% (n = 229)	1.1% (n = 4)	98.9% (n = 362)	2.2% (n = 3)	0.4% (n = 1)
26. Hurst et al. (study 2; 2022b)	46.5% (n = 93)	53.5% (n = 107)	8.5% (n = 17)	91.5% (n = 183)	15.1% (n = 14)	2.8% (n = 3)

Barkoukis, Lazuras, Lucidi, et al., 2015; Dietz et al., 2013; García-Grimau et al., 2021) or was positively associated with dietary supplement use (r range = 0.28 to 0.66; Al Ghobain et al., 2016; Barkoukis et al., 2020; Hurst et al., 2022b; Lazuras et al., 2017). Two studies reported that the prevalence of doping was similar in dietary supplement users and non-users (Petroczi et al., 2011; Seifarth et al., 2019). Overall, most evidence indicates that doping use was greater in dietary supplement users than non-users.

Doping intention

Twelve studies examined dietary supplement use and doping intention (Barkoukis, Lazuras, & Harris, 2015; Barkoukis et al., 2020; Devcic et al., 2018; Hurst et al., 2019; Hurst et al., 2022a; Kondric et al., 2011; Kondric et al., 2013; Lazuras et al., 2017; Mettler et al., 2021; Sajber et al., 2019; Sekulic et al., 2014; Sekulic et al., 2017). Most studies reported that dietary supplement users reported higher intentions to dope than non-users (Barkoukis, Lazuras, Lucidi, et al., 2015; Barkoukis et al., 2020; Devcic et al., 2018; Lazuras et al., 2017; Sekulic et al., 2017). Barkoukis, Lazuras, Lucidi, et al. (2015) and Mettler et al. (2021) found that more dietary supplement users intended to dope than non-users ($p<0.05$), whereas Barkoukis et al. (2020), Lazuras et al. (2017), Hurst et al. (2019) and Hurst et al. (2022a) reported positive relationships between dietary supplement use and doping (r range = 0.15 to 0.35). Sekulic et al. (2017) found that regular dietary supplement users reported greater intentions to dope than those using dietary supplements from time-to-time (OR = 2.6), and Devcic et al. (2018) reported that users expressed higher intentions than non-users (OR = 3.2). In contrast, four studies reported no differences in doping intention between dietary supplement users and non-users (Kondric et al., 2011; Kondric et al., 2013; Sajber et al., 2019; Sekulic et al., 2016). Specifically, Sekulic et al. (2014) and Kondric et al. (2013) reported that doping intention was not related to dietary supplement use (r range = -0.07 and 0.19), and Kondric et al. (2011) and Sajber et al. (2019) found no differences in doping intention between dietary supplements users and non-users ($p >0.05$). Collectively, most evidence suggests that dietary supplement users are more likely to report a higher intention to dope than non-users.

Doping attitudes

Six studies examined dietary supplement use and doping attitudes. Attitudes represent a person's evaluation of an object of thought (i.e., an opinion about something; Bohner & Dickel, 2011). Most studies reported that dietary supplement users expressed more favourable attitudes to dope than non-users (Backhouse et al., 2013; Hurst et al., 2019; Hurst et al., 2021; Lazuras et al., 2017). Backhouse et al. (2013) reported that dietary supplement users expressed more positive attitudes towards doping than non-users (U = 4206.5, $p <0.05$) and Lazuras et al. (2017) and Hurst et al. (2019) found that dietary supplement use was positively associated with doping attitudes ($r = 0.26$ and $r = 0.11$, respectively). Hurst et al. (2021) categorised dietary supplement use into medical (e.g., iron tablets), ergogenic (e.g., creatine), sport food and drink (e.g., electrolytes), and superfoods (e.g., goji berries), and found that users of medical and ergogenic dietary supplements were more likely to report more favourable attitudes than non-users ($p <0.01$), whereas sport food and drink and superfood users and non-users reported similar attitudes ($p >0.05$).

In contrast to the above, García-Grimau et al. (2021) found that dietary supplement use did not predict doping attitudes ($\beta = 0.18$, $p >0.05$) and while Barkoukis, Lazuras, Lucidi, et al. (2015) reported that dietary supplement non-users reported less favourable attitudes than users of doping substances ($p <0.01$), no differences in attitudes towards doping were reported between dietary supplement users and non-users. Despite these null findings, most research indicates that dietary supplement users report more favourable attitudes to doping than non-users.

Doping descriptive norms

Six studies assessed dietary supplement use and doping descriptive norms. Descriptive norms refer to perceptions of what others would do (Rivis & Sheeran, 2003). Backhouse et al. (2013) asked competitive athletes (N = 212) about their perceptions of doping prevalence in their sport and found that dietary supplement users believed there to be a greater percentage of athletes doping than non-users. Mazanov et al. (2008) found that dietary supplement users were more likely to report that doping is more of a problem in their sport compared to non-users (OR = 1.19, $p < 0.05$) and that those who use dietary supplements for both health (e.g., multivitamins) and performance (e.g., creatine) purposes were more likely to believe doping was a problem compared to those that did not use these supplements. In contrast, Lazuras et al. (2017) and Sekulic et al. (2014) found that dietary supplement users and non-users reported similar perceptions of the prevalence of doping, and Barkoukis, Lazuras, Lucidi, et al. (2015) showed that dietary supplement users and non-users reported similar beliefs in the prevalence of doping at the same ability, elite and professional level. Finally, Kondric et al. (2013) found that the relationship between dietary supplement use and doping descriptive norms was positive for males ($r = 0.31$, $p > 0.05$) but negative for females ($r = -0.53$, $p < 0.05$). In short, evidence appears equivocal as to whether dietary supplement use is related to doping descriptive norms.

Dietary supplement beliefs

Six studies examined the role of dietary supplement beliefs in the relationship between dietary supplement use and doping related variables (Hurst et al., 2019; Hurst et al., 2021; Hurst et al., 2022a; Hurst et al., 2022b). All studies were conducted by the same research group who reported that beliefs about the effectiveness of dietary supplements could help explain, at least in part, why dietary supplement use is related to doping. In two separate samples, Hurst et al. (2019) found that dietary supplement use was indirectly related to both doping attitudes and likelihood to dope. These findings were replicated in two further studies (Hurst et al., 2022a; Hurst et al., 2022b), that highlighted dietary supplement users may be more likely to dope due to the belief that dietary supplements improve performance. To examine the relationship further, Hurst et al. (2021) separated dietary supplement use into four categories: 1) medical, 2) ergogenic, 3) sport food and drink, and 4) superfoods. They reported that dietary supplement use was indirectly related to doping attitudes among those who used ergogenic, medical and sport food and drink supplements, but not for those who used superfoods. Collectively, the evidence suggests that dietary supplement beliefs can help explain why a dietary supplement user is more likely to dope, and, moreover, that users of medical, ergogenic, and sport food and drink supplements may be more likely to dope due to the belief supplements improve performance.

Doping knowledge

Four studies assessed dietary supplement users' and non-users' knowledge about doping. Both Loraschi et al. (2014) and Balaravi et al. (2017) reported that dietary supplement use was not related to athletes' knowledge of the types of substances on the prohibited list, whereas Sekulic et al. (2014) found that dietary supplement use was negatively and moderately related to knowledge of anti-doping doping rules ($r = -0.29$, $p < 0.05$). However, Mazanov et al. (2008) noted that those who use dietary supplements had more knowledge of the drug testing procedure than non-users. Accordingly, it is unclear whether dietary supplement use is related to doping knowledge.

Motivation and achievement goals

Two studies assessed motivational regulations and achievement goals in relation to dietary supplement use and doping. Barkoukis et al. (2020) reported that motivational regulation (i.e., autonomous, controlled, and amotivation) and achievement goals (i.e., mastery/performance and approach/avoidance) moderated the relationship between dietary supplement and doping use. That is, compared to dietary supplement non-users, users with higher motivation and achievement goals were more likely to dope. Similar results were found by Hurst et al. (2022a) who reported that high ego orientated athletes (i.e., those motivated to win and beat others) were more likely to dope because of their use of dietary supplements and belief that they are effective at improving performance. This finding was not shown for task orientated (i.e., those motivated to work hard and master a skill) athletes. This preliminary evidence suggests that motivational regulation and achievement goal orientations may play a role in determining whether a dietary supplement user is more likely to dope than a non-user.

Morality

Recent evidence has shown that the relationship between dietary supplement use and doping can be influenced by an athlete's morality. In two studies, Hurst et al. (2022b) reported that the indirect effect of dietary supplement use on doping via dietary supplement beliefs was moderated by moral variables. That is, dietary supplement users, who believed dietary supplements are necessary, were more likely to dope if they had low moral values and believed that being a moral person was not important to their self-image. Athletes may therefore be less likely to dope after they use dietary supplements and believe they are necessary if they have strong moral values and high moral identities.

Results of syntheses

Sufficient data for meta-analyses were available for doping prevalence, intention, and attitudes. While six studies examined dietary supplement use and doping descriptive norms, we decided a meta-analysis would be inappropriate given the disparate measures used in each study.

Prevalence of doping between dietary supplement users and non-users

Twelve studies, including 8,822 participants, reported the prevalence of doping between dietary supplement users and non-users (Fig. 2). The pooled estimate of doping prevalence indicated that doping was 2.74 times more likely in dietary supplement users than non-users. There was low to moderate degree of between-study heterogeneity ($Q = 19.69$, $p = 0.50$, $I^2 = 44.13\%$). No evidence of publication bias contributed to the findings, with Egger's ($p = 0.16$) and Begg's ($p = 0.63$) tests being non-significant and the FSN indicating that 342 studies were needed to reduce this effect. Removal of studies rated with high risk of bias or poor study quality, based on the JBI Critical Appraisal and STROBE checklist respectively, did not change outcomes (Supplementary Table 1), and the same was true after each study was removed one by one (OR range = 2.58 to 3.00; Supplementary Table 2). Moderator analyses revealed no significant differences for any of the observed variables (Supplementary Table 2).

Dietary supplement use and doping intention

Data from 12 studies, including 3,408 participants, reported the relationship between dietary supplement use and doping intention. The pooled effect size showed that dietary supplement use was positively and moderately associated with doping intention (Fig. 3). That is, dietary supplement users were more likely to report a greater intention to dope than non-users. Between-study heterogeneity was substantial ($Q = 62.01$, $p < 0.01$, $I^2 = 82.26\%$). Egger's ($p = 0.91$) and Begg's ($p = 0.63$) tests indicated that publication bias did not influence the results, and FSN reported that 618 studies were needed to bring the meta-analysed effect to a small value. Results remained similar after studies considered having high risk of bias or low quality were removed (Supplementary Table 1) and after each study was removed one-by-one

Study name	Time point	Odds ratio	Lower limit	Upper limit	p-Value
Petroczi et al.,	2011	0.79	0.21	2.99	0.73
Backhouse et al.,	2013	5.13	1.98	13.32	0.00
Dietz et al.,	2013	2.70	2.11	3.45	0.00
Barkoukis et al.,	2015	5.90	2.35	14.83	0.00
Al Ghobain et al.,	2016	2.99	1.66	5.40	0.00
Lazuras et al.,	2017	1.77	0.55	5.68	0.34
Pedroso da Silva et al.,	2017	2.45	1.39	4.33	0.00
Seifarth et al.,	2019	2.04	1.63	2.54	0.00
Barkoukis et al.	2020	20.61	2.79	152.02	0.00
García-Grimau et al.,	2021	1.78	0.59	5.35	0.31
Hurst et al., a	2022	5.10	0.53	49.57	0.16
Hurst, et al., b	2022	6.17	1.71	22.19	0.01
Pooled		2.74	2.10	3.57	0.00
Prediction Interval		2.74	1.43	5.26	

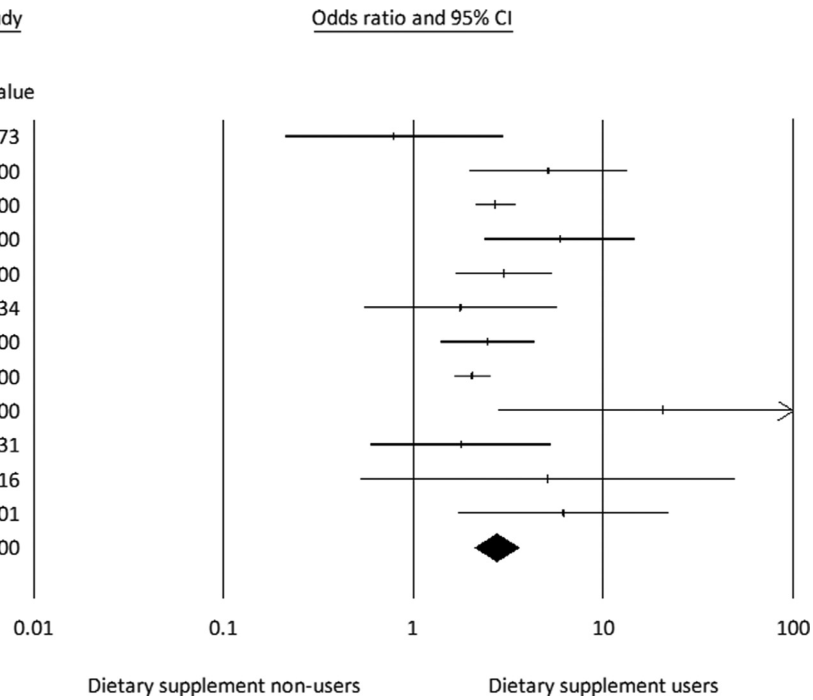

Fig. 2. Forest plot of the pooled prevalence of doping between dietary supplement users and non-users. *Note*. a = data are from Study 1. b = data are from Study 2. Significance was set at p<0.05, and Odds Ratio were derived from a Random Effects Model using Comprehensive Meta-analysis Software.

Study name	Time point	Correlation	Lower limit	Upper limit	Z-Value	p-Value
Kondric et al., a	2013	-0.07	-0.49	0.37	-0.30	0.77
Kondric et al., b	2013	0.12	-0.19	0.41	0.76	0.45
Sekulic et al.,	2014	0.19	0.02	0.35	2.17	0.03
Barkoukis et al.,	2015	0.19	0.12	0.27	5.00	0.00
Sekulic et al.	2017	0.22	0.05	0.38	2.57	0.01
Lazuras et al.,	2017	0.46	0.35	0.56	7.26	0.00
Devcic et al.,	2018	0.34	0.23	0.43	6.02	0.00
Hurst et al.,	2019	0.15	0.06	0.24	3.28	0.00
Sajber et al.,	2019	0.50	0.39	0.58	8.39	0.00
Barkoukis et al.	2020	0.35	0.27	0.43	8.20	0.00
Hurst et al.	2021	0.18	0.08	0.28	3.45	0.00
Mettler et al.,	2021	0.12	0.02	0.21	2.39	0.02
Pooled		0.26	0.18	0.34	6.06	0.00
Prediction Interval		0.26	-0.04	0.51		

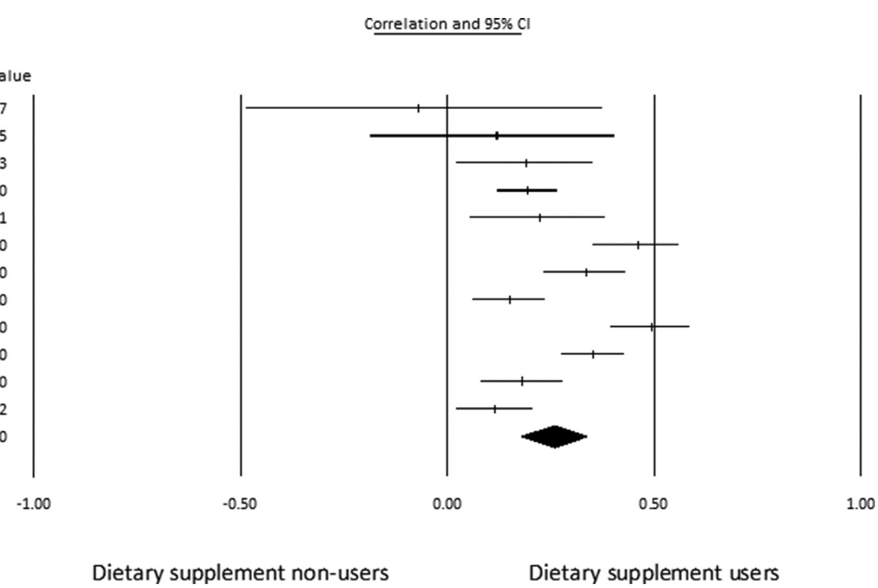

Fig. 3. Forest plot of the pooled prevalence of doping intention between dietary supplement users and non-users. *Note.* a = data are female sub-group. b = data are male sub-group. Significance was set at p<0.05, and correlation coefficients were derived from a Random Effects Model using Comprehensive Meta-analysis Software.

(*r* range = 0.23 to 27; Supplementary Table 2). Meta-regression revealed no moderators for any variables (Supplementary Table 3).

Dietary supplement use and doping attitudes

Six studies reported associations between dietary supplement use and doping attitudes (n = 2,524) and a moderate, positive correlation was shown (Fig. 4). That is dietary supplement use was associated with more favourable doping attitudes. Moderate heterogeneity between-study data was found (Q = 17.76, p = 0.003, I^2 = 71.85%). Publication bias was not present, as shown by both the Egger's (p = 0.71) and Begg's (p = 1.00) tests, and the FSN indicating that 147 studies were needed to yield a non-significant meta-analysed effect.

Effects did not change when studies considered as having high bias and low quality were excluded (Supplementary Table 1). After removing Barkoukis, Lazuras, Lucidi, et al. (2015) from the analysis, heterogeneity substantially reduced (Q = 6.24, p =0.18, I^2 = 35.86%), but the effect size remained unchanged (*r* = 0.17, 95% CI = 0.11 to 0.23, p <0.01; Supplementary Table 2). Simple meta-regression analysis revealed a relationship between age and doping attitude (b = -0.03 ± 0.01, 95% CI = -0.04 to -0.01, Z = -3.76, p <0.001), suggesting that that younger athletes who used dietary supplements were more likely to have positive

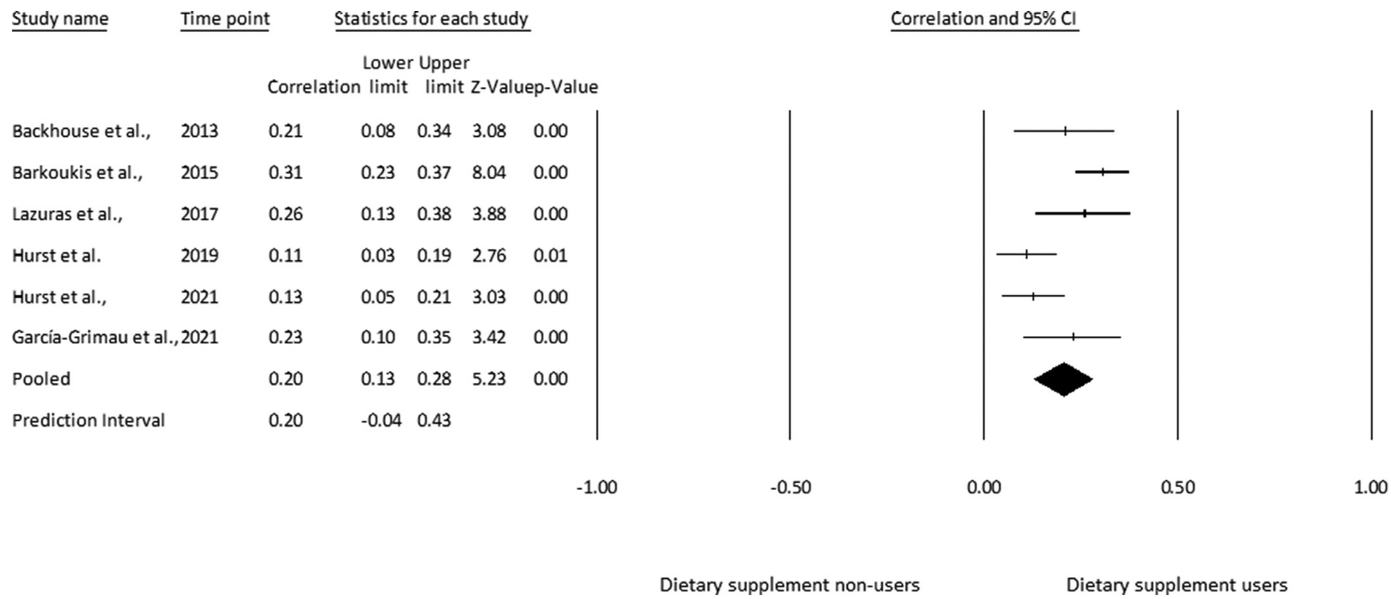

Fig. 4. Forest plot of the pooled prevalence of doping attitudes between dietary supplement users and non-users. Significance was set at $p<0.05$, and correlation coefficients were derived from a Random Effects Model using Comprehensive Meta-analysis Software.

attitudes than older athletes. Similarly, year of publication date (b = -0.02 ± 0.01, 95% CI = -0.04 to -0.01, Z = -2.03, p = 0.04) moderated the meta-analysed effect, with studies published earlier reporting larger effect sizes. No other significant effects were found for the other variables (Supplementary Table 3)

Certainty of evidence

As per the GRADE assessment, we assessed the imprecision, inconsistency, risk of publication bias, indirectness, and risk of bias of the overall quality of evidence amassed here. Overall, results were relatively consistent between studies, most sampled competitive athletes, the confidence intervals of effect sizes were narrow, and there was very low risk of publication bias. However, all studies were cross-sectional and there was high heterogeneity between studies. As a result, it is likely that the overall quality of evidence falls within the low to medium category, suggesting that the estimate of effect is uncertain and future research that employs stronger designs may change this estimate.

Discussion

We systematically reviewed the prevalence of doping in dietary supplement users and non-users and identified social cognitive factors that were related to both dietary supplement use and doping. In short, our results indicate that dietary supplement users were more likely to dope and report stronger doping intentions and favourable attitudes toward doping than non-users. Further, motivations to succeed and beat others, beliefs about the effectiveness of dietary supplements, and personal morality are likely to play key roles in a dietary supplement users' decision to dope.

Doping was 2.74 times more prevalent in dietary supplement users than non-users. This effect size is lower than the one reported in a previous meta-analysis (Ntoumanis et al., 2014), which showed that doping use was 8.24 times more likely in dietary supplement users than non-users. This difference is likely to be due to our eligibility criteria, whereby we only included studies sampling athletes who competed in sports under the World Anti-Doping Code compared to Ntoumanis et al. (2014) who placed no restrictions on participant characteristics. Given that athletes can be banned from sport for using a doping substance, they may be less likely to use or less willing to self-report that they use these substances compared to non-athlete populations. As a result, the data included in our review are likely to be lower than that reported for general population samples. Nevertheless, the direction is consistent with previous evidence that doping use is more prevalent for dietary supplement users than non-users (Nicholls et al., 2017; Ntoumanis et al., 2014).

The pooled evidence indicates moderate associations between dietary supplement use and doping intention (r = 0.26) and attitudes (r = 0.20). Previous reviews have reported that intentions to dope and favourable attitudes toward doping are related to doping use (Blank et al., 2016; Nicholls et al., 2017; Ntoumanis et al., 2014), and highlight that dietary supplement users may be more likely to dope because of a greater intention or favourable attitude towards doping. Similarly, our moderation analysis showed that younger dietary supplement users may be more likely to report favourable attitudes to dope than older users. Reasons for this could be related to the lack of education younger athletes receive about doping than older athletes. That is, as athletes progress through their career, they are more likely to attend anti-doping education programmes and as a result report less favourable attitudes towards doping (Denham, 2017; Gatterer et al., 2020; Gatterer et al., 2021; Hurst, Ring, et al., 2020). This could also explain our other moderation effect, whereby studies published earlier were more likely to report a positive association between dietary supplement use and doping attitudes. Although speculative, it is reasonable to suggest that the greater emphasis on anti-doping education within the past decade (Gatterer et al., 2021), means that athletes sampled today may be less likely to report favourable attitudes to dope than those sampled 10 years ago.

An athlete's motivation plays a key role in determining whether a dietary supplement user is more likely to dope than a non-user. Both Barkoukis et al. (2020) and Hurst et al. (2022a) highlighted the role of motivation in a dietary supplement user's likelihood to dope, and that the reasons underpinning an athlete's decision to use dietary supplement may be important in whether that athlete uses prohibited performance enhancing substances. Similarly, beliefs that dietary supplements are effective was indirectly related to doping use (Hurst et al., 2022b), intention (Hurst et al., 2019; Hurst et al., 2022a), and attitudes (Hurst et al., 2019; Hurst et al., 2021). This shows that athletes who use dietary supplements may develop the belief that performance enhancing substances are effective and thereby become more likely to dope. Collectively, evidence indicates that an athlete's motivation and beliefs are likely to influence a dietary supplement users' decision to dope.

While dietary supplement users may be more likely to dope than non-users, the present data also show that the vast majority of supplement users do not dope. Hurst et al. (2022a) reported that more task-oriented athletes who used dietary supplements were less likely to dope than those who were more ego-oriented, while Hurst et al. (2022b) reported that athletes who used dietary supplements, and believed they were effective, were less likely to dope if they believed morality was important and had a strong sense of moral identity. These preliminary data indicate that dietary supplement users, who define success by focusing on mastering a skill or demonstrating personal improvement and who have strong moral values, may be less likely to dope than supplement users focused on winning and beating others and who perceive morality as less important.

Further research is needed to examine doping descriptive norms in dietary supplement users and non-users. Six studies examined descriptive norms and their relationship to doping, with two reporting positive associations (Backhouse et al., 2013; Mazanov et al., 2008), three reporting null-findings (Barkoukis, Lazuras, Lucidi, et al., 2015; Lazuras et al., 2017; Sekulic et al., 2014), and one reporting positive relationships for males but negative relationships for females (Kondric et al., 2013). While other meta-analyses have reported that doping descriptive norms are related to doping use and intention (Blank et al., 2016; Ntoumanis et al., 2014), more data are needed to determine whether dietary supplement users express greater beliefs that doping is prevalent in other athletes than non-users. Similarly, our review found that doping knowledge is unlikely to be different between dietary supplement users and non-users. Athletes will receive anti-doping education irrespective of their use of dietary supplements, and, therefore, dietary supplement users are likely to share a similar understanding of doping as non-users.

Limitations of the evidence included in the review

A number of limitations with the studies included in this review temper the interpretation of our conclusions. First, all studies were cross-sectional. It is unknown whether dietary supplement use and doping occur simultaneously, or whether doping precedes dietary supplement use. Second, while most studies were considered at low risk of bias and had good study quality, common methodological issues existed across studies including a description of the sample eligibility criteria, reasons for participant exclusion and defining outcome measures. Finally, all studies measured outcomes using self-report measures which could be influenced by social disability bias (Petróczi et al., 2011).

Limitations of the review

A limitation of our review was that we were unable to evaluate potential moderators. While studies reported the prevalence of doping between dietary supplement users and non-users, they did not report differences in, for example, users' doping intentions, and their relationship to doping. Therefore, comparing effect sizes for moderators was not possible. Similarly, preliminary evidence suggests that different types of dietary supplements (e.g., medical and ergogenic) may increase the likelihood of an athlete doping more than others (sport food and drinks) (Hurst et al., 2021). We were unable to differentiate between different types of dietary supplements, and, therefore, it would be fruitful for future research to assess different types of dietary supplements in order to examine whether these influence doping prevalence. Finally, our review is limited to English language studies. It is likely that there are non-English language studies, which were not considered here.

Implications for practice, policy, and future research

Our findings have practical implications for anti-doping organisations and policies. WADA published the International Standard for Education document (WADA, 2020), which outlines mandatory standards for organisations worldwide when developing and delivering anti-doping education programmes. As a result, organisations are required to provide information about the risk of using dietary supplements (see page 13 of WADA, 2020). Given the outcomes of our review, to ensure dietary supplement users are less likely to dope, educational programmes should aim to include content related to the importance of working hard and mastering a skill and highlighting the moral consequences of doping (e.g., unfairly preventing another athlete from succeeding). The interventions developed by Kavussanu and colleagues (Kavussanu et al., 2022; Kavussanu et al., 2021) serve as effective examples of how this can be achieved. Similarly, organisations should highlight that the effectiveness of supplements can often be the result of the belief that they will improve performance (Hurst, Schiphof-Godart, et al., 2020). A large body of evidence has shown that dietary supplements are influenced by the placebo effect (Hurst, Schiphof-Godart, et al., 2020), and, therefore, anti-doping programmes should highlight other methods that allow athletes to improve their performance, such as a food-first approach, a modified training programme, and better sleep and recovery. This approach not only has implications for an athlete using a dietary supplement and progressing to doping, but also in reducing the likelihood of that athlete failing a drug test via cross-contamination of a prohibited substance (Chan et al., 2018; Eichner & Tygart, 2016).

The results of our review highlight the need for better study designs, in particular longitudinal and prospective studies with large sample sizes, which investigate the association between dietary supplement use and doping use and other related factors (e.g., intention, attitudes, morality). Experimental studies should aim to determine if reducing dietary supplement use also reduces doping use. To support future reviews, research studies should clearly identify the eligibility criteria of participants, highlight reasons for exclusion, and clearly define what constitutes use of a dietary supplement or doping substance. Similar to this, it would be fruitful to compare our findings with populations other than athletes, that are focused on performance, such as the military and dancers. Both of these groups have been shown to use dietary supplements and doping substances (Boardley et al., 2016; Knapik, Jean, et al., 2016) and it would be worthwhile to investigate if similar patterns of substance use behaviour exists in these populations and the underlying psychosocial mechanisms. Further, given the potential for social desirability bias with self-report measures, future research should aim to assess doping prevalence via other more objective measurements, such as bioanalysis (Petroczi et al., 2011). Finally, to help understand why dietary supplement users do not dope, future research should aim to extend understanding of the factors that prevent athletes from doping while using dietary supplements.

Registration and protocol

The review protocol was published and registered to Open Science Framework (OSF) Registries (https://osf.io/xvcaq). In the protocol paper, we stated that we would consider studies sampling participants from of all types of sports. However, we only considered papers that sampled participants who competed in sports that are signatories to the World Anti-Doping Code (WADA, 2022). Only one author extracted data from each study instead of two and we used comprehensive meta-analysis instead of RevMan to analyse the data.

Ethics approval

The authors declare that the work reported herein did not require ethics approval because it did not involve animal or human participation.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declarations of Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

Andrea Petróczi is the Chair of the World Anti-Doping Agency's Working Group for Doping Prevalence. All other authors report no conflict of interest.

CRediT authorship contribution statement

Philip Hurst: Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Lieke Schiphof-Godart:** Investigation, Methodology, Writing – review & editing. **Maria Kavussanu:** Writing – original draft, Writing – review & editing. **Vassilis Barkoukis:** Writing – review & editing. **Andrea Petróczi:** Writing – review & editing. **Christopher Ring:** Methodology, Writing – review & editing.

Acknowledgements

The authors would like to thank Dr Wichor Bramer for helping create and conduct the search strategy and all authors who provided data for the analyses

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.drugpo.2023.104077.

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