

Evidence Built on Men? Sports Drinks and Performance in Female Athletes: A Scoping Review

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Research Article

Keywords:

Posted Date: October 6th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11060531/v1>

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Abstract

Introduction:

Sports drinks (SD) are widely consumed by athletes across all levels of competition to support hydration, energy provision and performance. However, research examining the efficacy of SD consumption in female athletes remains limited. The objective of this review was to systematically identify and summarise existing literature that examined performance-related outcomes after the consumption of a SD in female athletes.

Methods

The databases MEDLINE, SPORTDiscus, CINAHL, Scopus, Web of Science, Embase, and the Cochrane Library were searched up to 14th August 2026. Eligible studies included female athletes classified as Tier 1 or above according to the Participant Classification Framework and investigated the effect of ingestion of carbohydrate–electrolyte solutions or carbohydrate only solutions (hereafter referred to as SD), as defined by Commission Regulations (EU), before, during, or after any sport or exercise activity, on physiological and/or cognitive performance outcomes. Searches were conducted in English; however, peer-reviewed articles published in any language were eligible. Data were synthesised using a narrative approach, consistent with scoping review methodology.

Results

A total of 12,686 studies were identified, with 21 included. A total of 211 participants were identified across all studies (2–43 participants per study). Tier 1 to Tier 5 athletes were represented, with the majority classified as Tier 1 (n = 78) or Tier 3 (n = 77). With the exception of two studies (carbohydrate only beverage), all SDs contained a combination of carbohydrate (4-7.6%) and electrolytes. The most common comparators were artificially sweetened placebos and water. While narrative synthesis was possible, substantial heterogeneity in exercise protocols, SD profiles and ingestion rates limited comparability across studies. Time trials (n = 3 studies) and time to exhaustion performance tests (n = 4 studies) were typically enhanced with SD consumption. Studies that investigated performance outcomes related to power output (n = 5) did not find any benefits from the consumption of SD before or during exercise. Studies that assessed aspects of cognitive function (n = 2) reported conflicting results. Sport specific performance assessments (n = 3 studies) showed mixed results, with tennis specific sprint test outcomes enhanced with SD consumption, but no performance benefits were identified in collegiate volleyball and football athletes following SD consumption.

Conclusion

Marked variability in study designs, athlete tier, and outcomes limited synthesis and hindered the ability to draw definitive conclusions regarding the benefits, or not, of SD consumption to enhance performance in female athletes. There is a clear need for adequately powered research in female athletes to evaluate whether SDs and the carbohydrate and electrolyte content of commercially available SD is suitable for female athletes considering the current evidence base.

Key Points

- Although sports drinks are widely consumed by athletes, scientific evidence regarding their performance benefits specifically in female athletes remains limited.
- Current evidence suggests that sports drink consumption prior to and during endurance exercise enhances performance, however data supporting comparable ergogenic effects on strength, power, intermittent sport activities, and cognitive function are limited in female athletes.
- Preliminary evidence indicates sex-based differences in fluid balance and thermoregulation during endurance exercise, however further research is needed to characterize these differences.

1. Introduction

The use of nutritional supplements is widespread among athletes and physically active individuals, with sports drinks (SD) consistently ranking amongst the most consumed products [1, 2]. The global SD market was valued at USD 38.42 billion in 2023 and is projected to reach over USD 69 billion by 2030 [3], therefore understanding the benefits of SD consumption (or not) for all athletes is warranted based on the widespread use and projected increases over time. Carbohydrate–electrolyte (CE) and carbohydrate only solutions are included on the European Commission’s list of authorised health claims, based on the established cause-and-effect relationship between consuming carbohydrate solutions and improved physical performance during high-intensity (at least 65% of VO_2 max) and prolonged (at least 60 minutes) exercise in healthy, trained adults [4]. To bear the health claim for maintenance of endurance performance and enhancing water absorption during exercise, CE solutions must contain 80–350 kcal/L of carbohydrate, with at least 75% of the energy coming from carbohydrate. In addition, CE solutions must contain between 20 mmol/L and 50 mmol/L of sodium and have an osmolality between 200–330 mOsm/kg water [5].

At face value, the body of evidence appears compelling, with numerous original studies and systematic reviews demonstrating that SD enhance performance, particularly endurance-based activities [6–10]. However, this apparent consensus warrants greater scrutiny. In 2023, Paul et al. reported that only 8.8% of studies published between 2017–2021 in the leading sports medicine journals examined females exclusively [11]. An audit of the representation of females versus male athlete in sport science and sports medicine research for performance-based supplements in 2022, identified a clear lack of female athlete representation in nutritional supplement research that underpinned sports nutrition guidelines to promote evidence-based practice for beta-alanine, caffeine, creatine, glycerol, nitrate/beetroot juice and

sodium bicarbonate [12]. In addition, Kuikman et al. (2022) highlighted that much of the literature underpinning current carbohydrate intake guidelines for the acute periods around exercise lacks high-quality research specific to female athletes [13]. This raises an important question. Are current SD claims and recommendations truly based on evidence from all adults, or just some adults?

It is widely acknowledged that recommendations and nutritional considerations for female athletes, in relation to both health and performance, must be sex-specific to the female athlete [14]. However, current sports nutrition literature remains insufficient to support these tailored guidelines [13, 15, 16]. Consequently, it is unclear whether existing SD guidelines reflect genuine sex difference or represent an unvalidated extrapolation from male cohorts, where potential differences in sex-specific physiology are not accounted for. Despite the growing interest in SD, no review has specifically synthesized evidence on their efficacy in female athletes. The primary aim of this scoping review was therefore to map the current evidence on SD and athletic performance in this population.

2. Methods

Reporting of this scoping review follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) extension for scoping review guidelines, following the guidelines of the Arskey & O'Malley framework [17]. The protocol for this scoping review is registered at Open Science Framework (<https://osf.io/scx36/overview>).

2.1 Eligibility Criteria

Experimental, observational, and case study designs in any language were eligible for inclusion. Review papers, abstracts, white papers, and grey literature were not. Studies included in the review encompassed biological female participants classified as Tier 1 or above according to the Participant Classification Framework [18], who ingested a SD (CE or carbohydrate only solution) as defined by the Commission Regulations (EU) for permitted health claims made on foods [4, 5], before, during or after any sport or exercise activity, that had a physiological or cognitive performance outcome. Searches were completed in English from inception to 14th August 2026, however peer-reviewed articles in any language were eligible for inclusion. Studies where female data could not be isolated or sex was not reported, involving biological males only or sedentary individuals (Tier = 0), involving consumption of drinks that did not meet the definition of a SD, and/or that were related to the prevalence of SD consumption, and SD applied in medical circumstances such as vomiting and diarrhoea were excluded.

2.2 Search Strategy

The search strategy was developed by two researchers (KP and JKA) with the assistance of an experienced Librarian (DS) and further refined through consultation with a fourth author (KH). The initial search to identify studies was completed by two researchers (KP and JKA) from inception to 29th of May 2025. Databases searched included Medline via Ovid, SPORTDiscus via EBSCOhost, CINAHL via EBSCOhost, Scopus via Elsevier, Web of Science via Clarivate, Embase via Elsevier and Cochrane via

Cochrane Library. To ensure currency of the evidence, the search was re-run on the 14th of August 2026, using the same search strategy, and records published between the 30th of May 2025, and 14th of August 2026 were screened for inclusion using the same eligibility criteria. The search used key words and controlled vocabulary in the following combination (Female* OR Wom*n OR Girl* OR Lady OR Ladies) AND (Sport* drink* OR Sport* Beverage* OR Electrolyte* drink* OR Hydration Drink* OR Fluid Replacement* OR Isotonic drink* OR carbohydrate-electrolyte* OR oral rehydration OR hydration strategies OR fluid* intake OR Rehydration solution* OR carbohydrate drink* OR carbohydrate solution* OR Glucose drink* OR glucose beverage* OR glucose solution* OR hypertonic drink* OR hypotonic drink* OR hypertonic solution OR hypotonic solution OR isotonic solution OR isotonic drink* OR hypertonic beverage OR hypotonic beverage OR isotonic beverage OR Hydro-electrolytic beverage) AND (sport* OR exercis* OR Athlet* OR Physical activit* OR aerobic* OR Fitness OR Train* OR Perform* OR Kinesiology OR Physical condition* OR Play* OR exertion OR endurance exerc*). The full electronic search strategy is presented in Supplementary File 1.

2.3 Selection of Studies and Data Extraction

After the search was conducted and duplicates removed, manuscripts were screened by title and abstract by two researchers (KP and JKA). Full texts of potentially eligible manuscripts were independently screened by two researchers (KP and JKA). Disagreements were resolved by discussion between screening authors. When a resolution could not be achieved, a third author (KH) made the final decision. All screening and data extraction steps were conducted using Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia). Data extraction was completed by two researchers independently (KP and JKA). Extracted data included year of publication, country in which the study was conducted, primary and secondary aims of the study, study design, number and demographics of female participants, SD compositions and the control or comparative drinks, volume and timing of beverage consumed, exercise intervention, performance outcome measures and the key findings of the study. The data extraction tool was piloted for the first 3 articles to ensure accuracy, with conflicts resolved through discussions between the extractors (KP and JKA).

2.4 Assessment of Reporting Quality

Although assessment of methodological quality is not required for scoping reviews, the research team deemed it appropriate to provide context to the overview of the literature on the topic. The methodological quality of all included publications was assessed using the Physiotherapy Evidence Database (PEDro) scale [19]. Total PEDro scores are reached based on the satisfaction of criterion measures relating to participant allocation, allocation concealment, blinding of participants, researchers and assessors, and the provision of statistical information. A total of 11 criterion measures were assessed. Scoring of each publication was completed by two researchers independently (KP and JKA), with discrepancies resolved by discussion.

2.5 Data Synthesis

A narrative approach to data synthesis was undertaken, consistent with scoping review methodology. Studies were categorised according to the primary performance outcomes assessed, with evidence grouped into endurance performance, cognitive performance, intermittent activities, and strength and power outcome measures.

3. Results

3.1 Study Selection and Characteristics

The initial search identified a total of 10,167 citations. Following the removal of duplicates ($n = 3,097$), title and abstract screening of the remaining citations was completed ($n = 7070$). 6,924 studies were excluded, leaving 146 citations to be reviewed in full, of which two full text articles were unable to be located. A total of 126 articles were excluded after full text screening, leaving 18 articles meeting the inclusion criteria [20–37]. The search was updated on the 14th of August 2026 to capture literature published since the 30th of May 2025, when the initial search was conducted, identifying a further 2,519 citations. After the removal of duplicates in the updated search ($n = 482$), 2,038 citations underwent title and abstract screening, with 2,028 articles excluded, leaving 10 articles for full text review. Of these, 7 were excluded after full text screening, leaving 3 additional articles meeting the inclusion criteria [38–40]. In total, 21 articles were included in this review. Figure 1 outlines the study identification and selection process for both the initial and updated searches.

Details of the characteristics and assessment methods of the included studies are provided in **Table 1**. The included studies were published between 1995 and 2026, with publications originating from eight different countries (Fig. 2). Athletes included participants across all five Tiers of the Participant Classification Framework. The majority of the participants were determined to be recreationally active (Tier 1), ($n = 78$) [20, 21, 25, 26, 34, 36–38, 40], closely followed by highly trained/national level athletes (Tier 3), ($n = 77$) [22, 23, 28, 31, 35, 39]. Six studies reported the inclusion of trained/developmental athletes (Tier 2), [24, 27, 29–31, 33] ($n = 45$), and one study included Tier 3, 4 and 5 athletes, highly trained/national level, elite/international level and world class level athletes respectively ($n = 11$) [32] (Fig. 2). Fourteen studies included both male and female participants [20, 21, 23, 24, 26, 28, 29, 31–35, 37, 40], and 7 studies were conducted exclusively on female athlete [22, 25, 27, 30, 36, 38, 39].

In total, 12 studies included a primary outcome measure of endurance performance [20, 21, 24, 25, 28–33, 35, 36], five had a primary outcome of strength and/or power [26, 27, 34, 38, 40], three studies were based on intermittent activities: tennis [23], volleyball [22], and soccer [39], and one study focused on cognitive function outcomes [37]. Of the 21 studies, 19 were randomised controlled trials [20–30, 32–37, 39, 40], one an observational study [31], and one a double-blinded, non-randomised controlled trial [38]. The total number of female participants across all studies was 211, with a sample size ranging from 2 [28] to 43 [39] participants. See Table 1.

The carbohydrate concentration of SD included in the studies ranged from 3-7.6%, with varying combinations and concentrations of sodium, potassium, calcium, chloride, and magnesium featuring in all but two of the studies, which included carbohydrate only beverages [38, 40]. The majority of the studies utilised a commercially available SD, which provided carbohydrates in isolation or in combination of glucose, sucrose, dextrose, fructose, and galactose. Two studies investigated SD with non-electrolyte added ingredients, including betaine [34] and caffeine [39].

Comparison beverages, of which some studies includes multiple comparison beverages included artificially sweetened placebos (n = 8 studies) [21, 23, 24, 32, 33, 36, 39], water (n = 4) [20, 26, 37, 40], chocolate milk (n = 2) [22, 35], low carbohydrate beverages (n = 1) [28], sweetened placebo (n = 1) [38], water with electrolytes (n = 1) [29], combined carbohydrate and protein beverage (n = 2) [25, 30], an artificially sweetened beverage with caffeine (n = 1) [23], a carbohydrate beverage with betaine (n = 1) [34], and lemon tea (n = 1) [37] (Fig. 2). Two studies used no fluid as a control [20, 31].

The majority of studies encompassed the consumption of the SD during exercise (n = 14) [20, 21, 23–25, 27, 28, 30–32, 36, 38–40], or post exercise (n = 5) [22, 26, 29, 35, 37]. In one study, a SD bolus equivalent to 8 mL/kg body mass was consumed 15 min before a 20 km TT [33], and one study requested participants consume the SD in the morning and afternoon, but not specifically around exercise [34]. The volume of the SD consumed was individualised to the participants body mass in 10 studies [21, 22, 24, 26–28, 32, 33, 36, 37], with 9 studies reporting that participants consumed absolute volumes of the SD or comparison beverage, irrespective of body mass [20, 23, 25, 30, 31, 34, 38–40]. The final two studies allowed participants to consume as much or as little as they desired of the assigned beverage (n = 2) [29, 35].

Endurance based performance outcomes

Thirteen studies included primary or secondary outcomes related to endurance performance [20–22, 24, 25, 28–33, 35, 36]. Seven of these studies involved participants cycling [20, 21, 24, 28–30, 33], five running [22, 25, 31, 35, 36], and one swimming [32]. The performance outcome measures included time trials (TT) (n = 3) [25, 28, 33], time to exhaustion (TTE) (n = 4) [21, 24, 30, 36], highest power output (PO) produced during endurance cycling (n = 2) [20, 29], shuttle runs (n = 2) [22, 35], marathon performance times (n = 1) [31], and swim velocity during a graded swimming exercise test (n = 1) [32].

Of the three studies that utilised TT as the primary performance outcome, all reported SD consumption improved TT performance, with Gui et al. (2010) reporting SD consumption contributed to a 3.7% faster TT compared to the placebo over a 16km treadmill run [25], and Jeukendrup et al. (1997) reporting the two female participants in their study completed the set work faster and at a higher average workload when consuming the SD compared to the placebo, though no formal statistical analysis was completed due to low participant numbers [28]. The third study reported two-thirds of the female athletes performed faster after SD consumption, though the data were again not statistically analysed due to the low female participant numbers (n = 3) [33]. When reviewing studies that implemented a TTE assessment, two of the four studies reported the consumption of a SD improved performance. Davis et

al. (1997) identified that the TTE was delayed when the 7 participants consumed a SD compared to the placebo beverage (84.9 ± 18.4 v 62.0 ± 9.4 min) [21], and Sun et al. (2015) reported the participants TTE was 16% longer when consuming the SD compared to the placebo beverage [36].

Glance et al, reported no significant difference in TTE, TT and isometric quadriceps strength between the SD and placebo beverage after 2 hours of cycling at ventilatory threshold [24], with one final study reporting that a combined carbohydrate and protein beverage (3% glucose, maltodextrin and fructose plus 1.2% protein) to be more efficacious than the traditional 6% carbohydrate (dextrose) only beverage [30].

Where the maintenance of PO was the primary performance outcome measure during endurance exercise (n = 1 study), 1.2 L of a 6% CE SD consumed *ad libitum* did not appear to be more effective than distilled water or no fluid consumption during 60 min of cycling at the highest possible PO [20]. In this study, individual data for all participants was provided graphically, however statistical analysis was only completed on all participants as a group (females n = 6 and males n = 4). However, from the figures presented, individual female participant data did not suggest better performance with SD consumption compared to the water or no fluid trial.

Two studies focused on peak power output (PPO) after endurance exercise. In one study, the efficacy of consuming a 7% SD throughout exercise relative to a placebo on PPO after endurance exercise, was assessed via a Wingate test following 50 minutes of cycling at 80% VO_2 max in 10 Tier 2 female athletes. No significant differences in PPO, rate of perceived exertion (RPE), lactate, or respiratory exchange ratio were observed [27]. McCartney et al. (2019) assessed PPO during a maximal exercise test following an initial 60-minute-high intensity interval cycling bout and subsequent 4-hour post-exercise recovery period, during which participants consumed either a 5.8% CE SD or water, alongside food *ad libitum*. Participants then completed an additional 45 min cycle at 50% PPO, before a 1 W increase every 6 sec to volitional exhaustion and PPO was assessed. Despite greater energy and carbohydrate intake in the SD condition, no significant differences in PPO were observed, suggesting that SD ingestion during the recovery period did confer a meaningful benefit to PPO performance, when fluid and food were available *ad libitum* [29].

Two studies incorporated shuttle runs to fatigue as part of their performance outcome measures [22, 35], with both studies finding no significant difference between the SD and the comparative beverages of chocolate milk. In an isolated study investigating marathon performance times, it was reported that a 7% CE SD consumed during exercise did not enhance a simulated 40 km run time, compared to career best performance times, however it was unclear if participants had consumed SD or any form of carbohydrates during those career best times [31]. In highly trained swimmers, blood lactate was significantly higher during an intermittent 5 stage incremental interval swim test (27% to 50% higher during the first and second swim stages) after SD ingestion compared to placebo, but no differences in heart rate, swim velocity or RPE were observed [32].

3.3 Cognitive Performance

Two studies evaluated the efficacy of SD consumption during endurance exercise on cognitive function and reported different outcomes. Wong et al. (2014) reporting improved accuracy for working memory when a SD was consumed compared to distilled water or lemon tea after treadmill running for 60 min in the heat [37]. In contrast, Gui et al. reported no difference across a wide range of cognitive function assessments after 11 Tier 1 female athletes ran for 21 km on a treadmill, despite participants completing the TT faster when consuming a SD [25].

3.4 Intermittent activities

Three studies involved intermittent activities: tennis, volleyball and football (soccer). The efficacy of SD consumption in female athletes during a competitive tennis game was evaluated in eight Tier 3 females. Though no differences in participant readiness to perform, a ball throw task, hitting precision and games won were reported, the tennis sprint test time was significantly faster in athletes consuming the SD beverage compared to the placebo (3.29 ± 0.20 v 3.34 ± 0.18 seconds) [23]. Ten Tier 3 collegiate volleyball athletes completed a battery of physiological assessments including a vertical jump, 2-step vertical jump, L-run and Yo-Yo Intermittent Recovery Test Level 1, after consuming either a 6% CE SD or a low-fat chocolate milk during a 2-hour recovery after a tournament style exercise session. The authors reported no significant differences between the two beverages at any timepoint [22]. Most recently, Jagim et al. investigated the efficacy of a CE SD with 250 mg of added caffeine for improving distance covered (as measured by global positioning systems) during simulated matchplay, against a non-carbohydrate sweetened solution in 43 Tier 3 female collegiate football athletes. No significant differences in total distance covered, average velocities, heart rate or training impulses were observed between conditions [39].

3.5 Strength and Power Performance Outcomes

Five studies investigated the effect of SD consumption on performance outcomes of strength and power [26, 27, 34, 38, 40]. One study evaluated PPO on a cycle ergometer (without prior endurance exercise), evaluating the PPO achieved during 4 x 12 sec sprints [34]. No significant improvements in PPO after consuming a SD was identified. It should be noted that this study compared a commercially available SD to a commercially available SD with added 2.5g of betaine. Statistical analysis was not completed independently for females for all metrics, however the authors reported the females that consumed the SD with betaine had a higher mean PO compared to their baseline values collected prior to 7 days consumption of SD and betaine consumption, or SD only consumption. As mentioned above, Jarvis et al. (1999) assessed PPO via a Wingate anaerobic test after 50 min of cycling, with no significant differences in PPO observed [27].

Three studies investigated outcome measures of strength after SD consumption. Peak torque of the knee extensors was assessed before and after exercise in the heat, with a 6% CE SD compared to mineral water and spring water [26]. No differences in peak torque were identified between beverages. Aoki et al. (2003) evaluated the efficacy of a carbohydrate only SD compared to a sweet placebo on 1 repetition max (RM) leg press, and strength endurance as assessed by the number of leg press

repetitions completed at 70% of the participants 1RM. No difference in any outcome measure was identified [38]. The most recent study to evaluate strength related outcomes was conducted by Morenas-Aguiler et al. (2025). The number of bench press, bench pull and squats at a 12RM load, and the mean velocity of these repetitions, was assessed in 15 Tier 1 participants. Participants consumed a 250 mL bolus of a 6% carbohydrate only beverage (highly branched cyclic dextrin) during exercise (50 mL before each set), with no significant differences found for any performance metric [40].

3.6 Menstrual Cycle Monitoring

Seven studies reported information on participants menstrual phase [21, 25, 29, 31, 36, 37, 40], with one study reporting all participants were using oral contraceptive pills [21], three studies reporting all participants were assessed during the same menstrual cycle phase [25, 29, 36], one reporting all bar one athlete was assessed during the mid-luteal phase [31], one reporting all participants were eumenorrheic, with trials separated by 30 days [37], and one study asked participants to self monitor menstrual cycle, and not to complete testing in the follicular phase [40].

3.7 Sex Differences

Of the 21 included studies, 14 included male participants, with 132 male participants across those 14 studies. Findings from studies that compared females to males (statistically or descriptively) are discussed below. Several studies that included both male and female participants did not formally analyse outcomes by sex.

Davis et al. (1997) found no main effects of sex or sex-by-treatment interactions and pooled the data for more detailed statistical analysis when comparing the SD and placebo [21]. Bachle et al. (2001), Jeukendrup et al. (1997), and Palmer et al. (1998) reported demographic and outcome data for both sexes but did not conduct statistical comparisons, the latter two due to small female samples ($n = 2$ and $n = 3$, respectively) [20, 28, 33]. Neither found a treatment effect on performance. Pryor et al. (2012) presented sex-separated data graphically with within-sex analyses only, with improvements in cycling sprint mean and peak power observed in both males and females [34].

Across several studies, females consistently showed smaller fluid losses and thermoregulatory challenges than males. Millard-Stafford et al. (1995) found that, despite comparable run times and fluid intake, women had smaller plasma volume losses, higher serum sodium and potassium, and lower rectal temperatures than men during a 40-km run [31]. Harris et al. (2019) similarly reported faster dehydration and higher sweat rates in males [26], and McCartney et al. (2019) found males lost a greater proportion of body mass than females across both water and SD trials, with females showing lower plasma osmolality after a 4-hour recovery period [29]. Wong et al. (2014) found no sex difference in the primary cognitive outcome, but the CE SD restored hydration more effectively in females than lemon tea or water, and females lost less body mass during exercise (1.4% vs. 2.0%) [37]. Similarly, during a 240 min singles tennis match, Ferrauti et al. found that body weight remained constant during both placebo and SD trials for females, compared to a mean 0.9 kg weight loss in males across all trials, despite an average

additional voluntary water supplementation of 1.8 L in males. This finding was reported in the follow-up paper to the original study [41].

Sex differences in glucose and lactate responses were also apparent. Glace et al. (2019) found blood glucose was higher in the SD trial versus placebo for both sexes but significantly higher in females at every time point ($p = 0.017$) [24]. Millard-Stafford et al. (2010) reported lower swim velocity and lower blood lactate in females across all time points compared to males, with females showing higher lactate during SD versus placebo in the first two swim stages [32]. Conversely, Ferrauti and Weber (1997) found that males had higher lactate and post-exercise urinary epinephrine than females during the SD trial, with no other sex differences [23]. However, these sex differences were similar in the SD and placebo trials, suggesting no interaction between sex and beverage type.

Sex differences emerged most consistently in the effect of SD ingestion on performance and strength outcomes. Glace et al. (2019) found that although both sexes lost voluntary strength with no peripheral fatigue, only males showed attenuated decline in central activation ratio with SD, and only males improved 3 km time-trial performance with SD ($p = 0.005$ vs. $p = 0.173$ in females) [24]. Harris et al. (2019) found that although males generated greater peak torque before and after exercise, the exercise-induced loss of torque was significant only in males with SD consumption ($9.6 \pm 7.4\%$, $p = 0.0117$) and not females ($10.6 \pm 8.1\%$, $p = 0.1999$) [26]. Spaccarotella and Andzel (2011) found a trend toward increased time to fatigue with chocolate milk versus SD in males only ($p = 0.03$), with no difference in females [35], and Morenas-Aguilar et al. (2025) found SD improved resistance-exercise repetition velocity in men but not women [40].

3.8 Assessment of Reporting Quality

PEDro scale appraisal of all 21 included studies indicated high overall methodological quality, with scores ranging from 6 to 11 (mean = 9.2). The majority of studies ($n = 14$, 66.7%) were classified as excellent quality (score ≥ 9), with the remaining seven (33.3%) rated as good quality (score 6–8). No studies fell below a score of 6. Individual PEDro scores are reported in Supplementary File 2.

4. Discussion

This study aimed to systematically identify and summarise existing literature that examined performance-related outcomes with the consumption of a SD before, during or after exercise in female athletes. Despite the global SD market being valued at USD 38.42 billion in 2023 and projected to exceed USD 69 billion by 2030 [3], only 21 studies met the inclusion criteria from a pool of 12,686 citations, collectively enrolling just 211 female participants. This stark disparity between commercial ubiquity and commercial scrutiny, is perhaps the most telling finding of this review, and mirrors the broader pattern of female athlete underrepresentation in research across sport science and sports nutrition research [11, 13, 15, 16].

4.1 Performance Outcomes

Of the 21 included studies, the majority evaluated the efficacy of SD for enhancing endurance performance, with a smaller number examining strength, power, intermittent activities and cognitive function. Across these domains, the balance of evidence offers limited support for SD consumption as a performance-enhancing intervention in female athletes, though the heterogeneity of study designs, SD compositions, and outcome measures substantially constrain the conclusions that can be drawn.

Endurance-based outcomes were the most frequently examined domain across the included studies, with 13 of the 21 studies incorporating at least one outcome measure of endurance performance. The most consistent evidence for a beneficial effect of SD consumption was observed in TT and TTE protocols, where five studies reported improved performance compared to placebo or water. This finding is broadly consistent with the established mechanistic rationale underpinning current EU health claims that carbohydrate delivery during prolonged, high-intensity exercise sustains exogenous fuel oxidation, attenuates glycogen depletion, and delays the onset of fatigue [4, 5]. On the surface, this might suggest that the performance benefits of SD consumption observed in predominantly male cohorts extend to female athletes. However, the confidence that can be placed in this conclusion is severely undermined by the varying characteristics of the studies from which it is drawn.

Sample sizes across the included endurance studies ranged from 2 to 14 participants. These figures fall substantially short of what would be required to adequately power a female-specific analysis, detect meaningful effect sizes, or account for the physiological variability inherent in a female cohort including menstrual cycle phase, hormonal contraceptive use, and reproductive status [42].

Where PO was the primary endurance performance outcome, the picture was notably different. Across studies examining the maintenance of power output during sustained cycling, and PPO assessed following endurance exercise, SD ingestion did not appear to confer a meaningful advantage over water or placebo. This pattern of null findings for power-based metrics, in contrast to the more favourable TT and TTE results, may reflect meaningful differences in the physiological demands and fuel requirements of these distinct performance contexts. Time trials and TTE tasks are typically of sufficient duration to deplete endogenous carbohydrate stores, creating conditions under which exogenous carbohydrate delivery becomes performance-limiting [43, 44]. In contrast, assessments of PPO, often of shorter duration and higher intensity, may rely more heavily on phosphocreatine and anaerobic glycolytic pathways, where the provision of additional exogenous carbohydrate offers less marginal benefit. The results from PO assessments post endurance based exercise also held true for those studies that investigated PO, PPO, peak torque and sprint performance without prior endurance exercise, where across multiple study designs, SD consumption did not improve these outcomes, most likely due to the above mentioned differences in metabolic pathways. Whether this pattern holds specifically in female athletes or simply reflects well-established exercise physiology that has yet to be adequately tested in female cohorts, cannot be determined from the current evidence base.

Long distance running performance and effects of incremental swimming on blood lactate were each examined in single studies, with no effect on 40km run time and an increase in blood lactate reported

with SD consumption. However, both studies had methodological limitations including comparing to career best times with no comparator condition [31], and the lack of a performance test (swimming study) [32]. Taken together, the endurance performance findings suggest positive results for SD consumption in TT and TTE contexts, but one that is insufficiently supported by the volume, quality, and female-specific rigour of the existing literature to justify confident, sex-specific recommendations.

Only two studies examined cognitive outcomes [25, 37], with opposing results. Given the growing interest in sport cognition and the potential effects of carbohydrate on brain function [45], this represents an important gap in the literature. This is particularly relevant for intermittent sports, where performance requires repeated high-intensity efforts alongside complex sport-specific skills and perceptual cognitive processes, including rapid decision making and anticipation [46]. Though the study by Ferrauti and Webber (1997) did not identify any benefits to SD consumption on mental drive and concentration [23], over the last 30 years, approaches to assessing cognitive function and decision-making in sport have evolved considerably, with increasing emphasis on sport-specific and ecologically valid assessments that better capture the perceptual, cognitive and decision making demands of competitive performance [47].

Considering the need for female-informed study designs that account for sex-specific physiological and hormonal factors that may influence mood, perceptual responses, and cognitive performance [48, 49], future research should prioritise the investigation of cognitive outcomes alongside sport-specific physical performance.

4.2 Menstrual Cycle Monitoring

Only seven studies reported information on participants menstrual phase [21, 25, 29, 31, 36, 37, 40]. None of these studies objectively verified the menstrual cycle phase or the participants reproductive status. The seven studies that reported menstrual cycle phase were based on participant self-report rather than hormonal confirmation, which limits the precision with which hormonal influences on the observed outcomes can be excluded or accounted for. As hormonal fluctuations across the menstrual cycle may influence substrate utilisation [50], fluid regulation [51], and thermoregulatory responses during exercise [52], each of which are directly relevant to the proposed mechanisms by which SD are thought to enhance endurance performance. The absence of confirmatory menstrual cycle phase and reproductive status from the included studies means that even the most consistently positive findings in this review must be interpreted as hypothesis-generating rather than conclusive. These findings suggest that not only is female-only research necessary, but should also be female-informed, including, but not limited to controlling for menstrual cycle phase and reproductive status [13, 14, 53].

4.3 Sex Differences and Performance

Several of the included studies enrolled mixed-sex populations, and where sex-disaggregated data were reported, notable differences emerged in fluid balance and thermoregulation. Millard-Stafford et al. (1995), reported that despite comparable run times and fluid intake between sexes during a 40 km run, women experienced smaller plasma volume losses, higher serum sodium and potassium

concentrations, and lower rectal temperatures than men, pointing to underlying sex-based differences in fluid regulation and heat dissipation [31]. A similar result was also found by McCartney et al. (2019), where males lost a greater percent body mass during exercise compared to female participants, though plasma osmolality was lower in female participants at the end of a 4-hour recovery period compared to males [29]. Harris et al. (2019) similarly observed that males dehydrated more rapidly and had a significantly higher sweat rate (25.2 ± 7.8 mL/min v 15.3 ± 3.2 mL/min) than females during a stationary cycling in the heat. Though males generated greater peak torque at baseline and post the exercise dehydration protocol, the loss of peak torque after exercise only reached significance in males and not females ($9.6 \pm 7.4\%$, $p = 0.0117$ v $10.6 \pm 8.1\%$, $p = 0.19989$) [26]. In contrast to Millard-Stafford's 1995 paper above, no significant difference in core temperature were identified between sexes. In the context of rehydration efficacy specifically, Wong et al. (2014), reported that a CE SD was more effective for restoring hydration status in female participants relative to lemon tea or water, whereas cognitive performance benefits were seen in both sexes [37]. Collectively these findings suggest that sex-specific physiological differences in fluid regulation and thermoregulation may warrant consideration when developing hydration strategies and SD formulations, though most of these studies were not designed a priori to test for sex-based interactions.

Sex differences were also apparent in performance and neuromuscular responses to SD consumption. Glace et al. (2019) reported that SD ingestion preserved central neuromuscular activation and improved TT performance in men, but conferred no measurable benefit in women, suggesting a possible sex-specific central fatigue response to SD during prolonged cycling [24]. Consistent with this pattern Morenas-Aguilar et al. (2025) reported that SD consumption improved repetition velocity during resistance exercise in men but not women [40]. In the context of SD as a recovery beverage, Spaccarotella and Andzel (2011) observed a trend towards improved time to fatigue with chocolate milk compared to a SD in male athletes only, with no corresponding effect in females [35]. Taken together, these findings raise the possibility that males and females may respond differently to SD consumption across a range of exercise modalities, from endurance cycling to resistance training. However, these comparisons should be interpreted cautiously as none of the studies were powered specifically to detect sex-based differences, and female sub-group sample sizes were often small. As such, these findings are best considered as hypothesis generating and highlight a need for future research that is adequately powered to examine sex as a biological variable in sports nutrition research.

The EU health claims framework authorises CE solutions for endurance performance based on evidence from *healthy, trained adults* [4], yet this review demonstrates that female athletes are barely represented in the evidence base utilised to confirm these claims. This raises a regulatory and ethical question: are female athletes being implicitly covered by claims built on predominantly male data? The findings of this review highlight a clear evidence-to-policy gap, whereby regulatory approval has outpaced the availability of sex-specific evidence. Without adequate inclusion of female athletes in the studies underpinning health claims, practitioners and athletes are left to apply recommendations whose efficacy in females remains uncertain. This represents an important opportunity for regulators, funding bodies, and industry

to prioritise the generation of high-quality female-specific evidence that better reflects the intended end users of these products.

4.4 Strengths and Limitations

This review had several strengths, including a systematic search strategy, and a focus on an under-researched population, which allowed for a comprehensive synthesis of the available female-specific SD literature. However, a number of limitations should be considered when interpreting these findings. The quality of the included research varied considerably, and this variability, combined with substantial methodological heterogeneity across the included studies, limited and comparison of outcomes. Although all studies rated good to excellent on the PEDro scale, some ($n = 3$) only reported descriptive outcomes for the female participants, due to the limited females within the study population [20, 28, 33]. Considerable variation existed in SD composition (3–7.6% carbohydrate), comparator beverages (water, placebo, chocolate milk, and lemon tea), timing of ingestion (pre-, during-, or post-exercise), fluid volumes (absolute versus body mass-indexed), and exercise protocols. While this heterogeneity limited direct comparison between studies and an associated meta-analysis, it also highlights a broader issue within the literature, the absence of methodological consensus in female-specific SD research. Without greater standardisation of intervention protocols and outcome measures, the evidence base will remain fragmented, hindering the ability to draw robust conclusions or conduct meaningful meta-analyses. Establishing minimum reporting standards and standardised protocols for future female-specific SD trials, including consistent reporting of beverage composition, dosing strategies, exercise protocols, participant menstrual status, and core performance outcomes, would improve study comparability, facilitate evidence synthesis, and accelerate the development of evidence-based recommendations for female athletes.

5. Conclusion

Marked variability in study designs, athlete tier, and outcomes limited synthesis and hindered the ability to draw definitive conclusions regarding the benefits, or not, of SD consumption to enhance performance in female athletes. The current limited evidence suggests some benefits in TT and TTE endurance contexts in Tier 1 to 3 athletes, however, no studies have examined endurance performance outcomes in international level and elite athletes (Tier 4 and 5) and there is little evidence currently to support SD consumption for other performance related outcomes. There is a clear need for adequately powered research in female athletes to evaluate whether SD and the carbohydrate and electrolyte content of commercially available SD is suitable for female athletes considering the current evidence base.

Abbreviations

CE Carbohydrate-electrolyte

EU European Union

FFA Free fatty acids

HR Heart rate

PEDro Physiotherapy Evidence Database

PO Power output

PPO Peak power output

PRISMA Preferred Reporting Items for Systematic Reviews and Meta-Analysis

RPE Rate of perceived exertion

RM Repetition maximum

SD Sports drink

TTE Time to exhaustion

TT Time trial

VO₂ Volume of oxygen consumed

Declarations

Ethics approval and consent to participate – Not applicable.

Consent for publication – All authors consent to the publication of this article.

Availability of data and materials – Not applicable.

Competing interest Kate Pumpa, Diarmuid Stokes, and Katy Horner declare that they have no conflicts of interest relevant to the content of this review. James Kitoto Anyange was completing a University internship at Britvic Ireland when the original search for this paper was conducted (May 2025). His internship finished mid-2025.

Funding At no point was funding received by any of the authors for the writing of this manuscript.

Author Contributions The search strategy was developed by KP, JKA and DK. KP and JKA conducted the search. KP and JKA screened the selected studies, with KH the third reviewer in resolving conflicts. KP and JKA conducted the quality appraisal of the studies, with KP, JKA, and KH writing the manuscript. All authors reviewed, refined, and approved the final version of the manuscript.

Acknowledgements – No acknowledgements to note.

Supplementary information The online version contains supplementary material available at [insert weblink].

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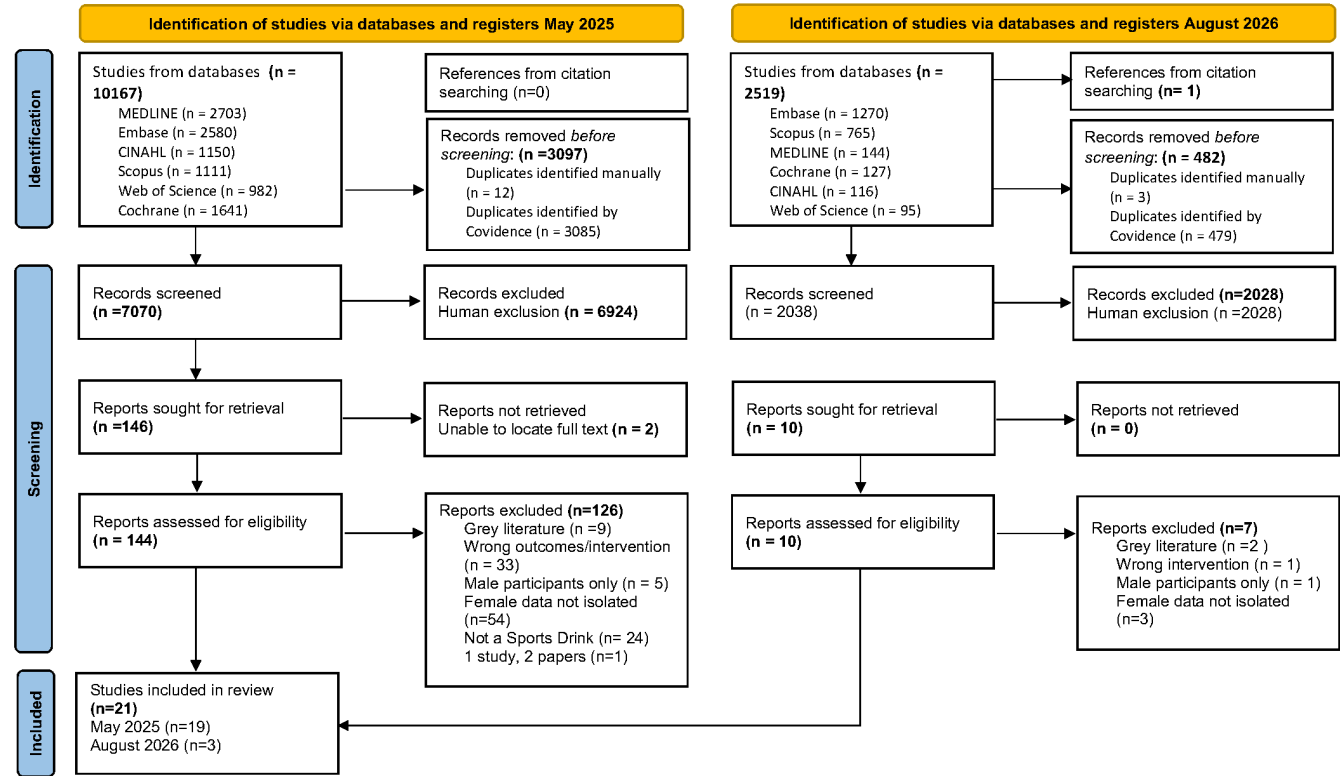
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Figures

Figure 1. PRISMA flow diagram



Source: Page MJ, et al. BMJ 2021;372:n71. doi: 10.1136/bmj.n71.

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Figure 1

See image above for figure legend

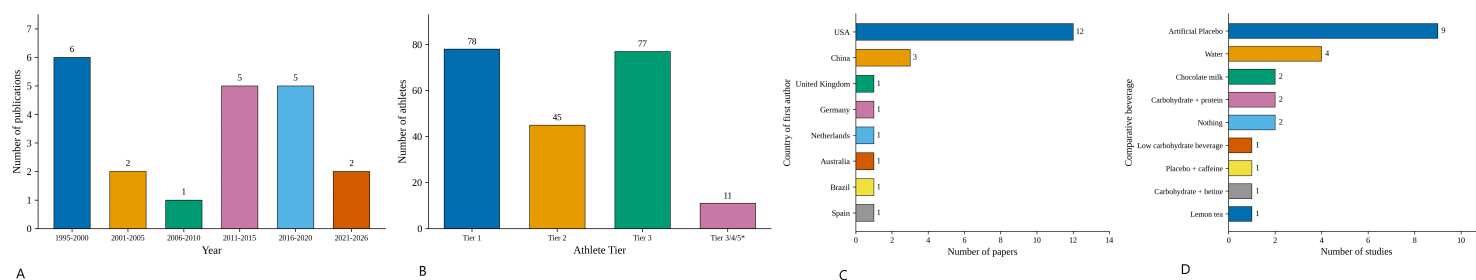


Figure 2

a. Distribution of sports drink research studies involving female athletes across five-year intervals (1995–2026); **b.** Number of participating athletes by athlete tier. * one study combined athletes of Tiers 3, 4 and 5 without a specific breakdown. **c.** Geographic distribution of first authors across included studies; **d.** Comparative beverages used against sports drinks across included studies

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