

Effect of Taurine Supplement on Aerobic and Anaerobic Outcomes: Meta-Analysis of Randomized Controlled Trials

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Abstract

Background: Taurine is a well-known free amino acid that has gained prominence in recent years despite its little or no role in protein formation. Few studies on the ergogenic effect of taurine exist with inconsistent results. The question on whether performance markers show the benefit from the taurine remains open. This study aimed to reach a consensus about whether taurine supplementation is effective on aerobic (time to exhaustion, VO₂max, and rating of perceived exertion) and anaerobic (jumping, blood lactate level) performance outputs.

Methods: Google Scholar, Pubmed databases, clinical trial websites, and grey literature were reviewed until November 2021. Mean differences (MDs) were pooled using random or fixed-effects models according to the heterogeneity degree of related outcomes. Although 17 studies were detected for the meta-analysis between 2001-2021, 15 studies were grouped. Only randomized controlled trials (single or double-blind) were considered.

Results: Taurine supplementation had a significant effect on vertical (MD =3.60; 95% CI 2.32 to 4.89, p <0.00001) and countermovement (MD = 8.50; 95% CI 4.78 to 12.22, p <0.00001) jump performance when compared to a placebo group. Taurine supplementation had no significant effect on VO₂max level and rate of perceived exertion (respectively, MD = -0.54 ml/kg/min; 95% CI -6.84 to 5.75, p=0.87; MD = -0.24; 95% CI -0.74 to 0.27, p=0.35) when compared to a placebo group.

Conclusion: Taurine improves potentially jumping performance and time to exhaustion.

Background

Taurine is a well-known free amino acid that has expanded in popularity in recent years, plays little or no part in protein biosynthesis. It does, however, provide a variety of physiological functions, including interacting with ion channels, membrane stability, and cellular osmoregulation [1, 2]. Taurine has an intracellular concentration range of around 5 to 20 μmol/g in many tissues, notably excitable tissues including skeletal muscle, heart, and brain [3]. Meat, shellfish, sea vegetables, and dairy products are the main sources of dietary taurine. The availability of its precursor cysteine affects taurine biosynthesis [3, 4].

By oxidizing the precursor cysteine, exercise is a critical component that can affect taurine production. For instance, high-intensity-induced redox alteration of cysteine might result in a variety of post-translational modifications that impact taurine production, resulting in either muscular adaptation or tiredness [5]. External taurine sources may be required in this circumstance. Taurine may help to reduce oxidative damage and restore muscle function in people with muscular dystrophy [3-5]. Additionally, taurine-regulated calcium homeostasis can lead to an increase in calcium-binding proteins during muscular contraction, resulting in increased muscle strength and endurance [6-8].

Taurine is commonly used orally in the form of capsules or taurine-rich drinks [9, 10]. Taurine plasma concentrations rise about 10 minutes after consumption and generally peak (0.03 to 0.06 mmol/L) 1 hour later. Taurine's impact on performance is influenced by various aspects, including taurine ingestion timing, administration type, and exercise technique. Taurine levels return to baseline within 6.5 hours after this absorption phase [9]. In published human trials, taurine dosages ranged from 500 mg/d to 10 g/d [11]. The amount of taurine present in muscle is influenced by training status (higher in trained than untrained muscle and fiber type higher in type I than type II) [12, 13]. Taurine has been reported to improve exercise performance [14, 15] and reduce recovery time from damaging and stressful exercise in some but not all studies [16, 17]. According to ISSN's (2018) report, the categories of nutritional supplements vary according to the quality and quantity of scientific studies on supplementation [18]. Taurine is in the "Limited or Mixed Evidence Supporting Efficacy" category according to this ISSN report. It is thought that more scientific studies are needed to prove its efficacy and safety.

Taurine has been reported to improve exercise performance [14, 15] and reduce recovery time from damaging and stressful exercise in some but not all studies [16, 17]. The ergogenic effects of taurine supplementation are still controversial, according to previous studies. M Waldron et al. [19], found that single daily dosages of 1 to 6 g for up to two weeks can considerably increase endurance exercise performance. Two research found that taurine might have its role in recovery from muscular injuries and improving resistance exercise performance [20, 21]. Oral intake of 50 mg/kg 14 days before and 7 days after injury boosted strength along with reducing discomfort and muscle damage indicators [21]. Lastly, taurine has been demonstrated to act as an antioxidant, enhancing the cellular environment ability to endure exercise stress [22, 23]. While more research on taurine is being published, the results of these studies are still equivocal in terms of taurine's ability to improve physical performance [16, 24].

A previous review study with taurine supplementation addressed the dose-response relationship in aerobic and strength exercises [24]. No previous meta-analysis has examined the effects of taurine on aerobic and anaerobic exercise outcomes. Therefore, the purpose of this meta-analysis was twofold: to evaluate the effects of taurine intake on i. aerobic and ii. anaerobic outputs. The results are thought to benefit athletes and practitioners in a variety of sports where aerobic and anaerobic capacity and/or power performance are important determinants.

Methods

Search Strategy and Quality Assessment of Studies

A systematic literature search was conducted utilizing the PubMed and Google Scholar databases, ClinicalTrials.gov website, and grey literature inputs to find studies published from 2001 to November 2021 that looked at the effects of taurine supplementation on aerobic and anaerobic outputs. "taurine" AND "aerobic performance", "taurine" AND "anaerobic performance" were used as keywords. To confirm that all relevant studies were included in the analysis, a thorough search was conducted via the reference lists of identified related documents. Following the eradication of duplicate articles, each study was evaluated in accordance with predetermined inclusion and exclusion criteria, as stated in Figure 1. to determine which articles were eligible. The Cochrane risk of bias tool for randomized controlled trials has been used to assess the quality of each article. Random sequence generation, allocation concealment, blinding, as well as the detection of incomplete outcome data, selective outcome reporting, and other possible reasons for bias are all included in the Cochrane Risk of Bias tool scale [25].

Study Selection Criteria

The study inclusion criteria were: (i) healthy individuals and athletes (ii) reporting aerobic or anaerobic performance markers regardless of the nature of the applied exercises (iii) examining the effect of taurine supplementation (iv) all placebo-controlled single and double-blind experimental studies (v) studies in English or Turkish. Studies in which an (i) co-ingestion with other supplements (ii) individuals with chronic diseases took part (iii) different outcomes from aerobic or anaerobic performance markers and (iv) non-randomized controlled trials were excluded from the meta-analysis.

Data Extraction and Outcome Measures

Extracted data included: (i) information of studies (author's surname, year, study design) (ii) characteristics of the sample (gender, health, and training status, age and weight) (iii) duration of supplementation (iv) dosage and form of taurine supplementation (v) exercise protocols (vi) outcomes of the study (vii) side effects of taurine supplementation. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology was used to retrieve data. Web-PlotDigitizer (<https://automeris.io/WebPlotDigitizer/>) was used to read data that was only provided graphically. The intercoder reliability for WebPlotDigitizer is strong, given the fact that it relies on hand plotting (Drevon, Fursa & Malcolm, 2017). Previous systematic reviews and meta-analyses, including those on various nutritional supplements, have employed WebPlot-Digitizer [19, 26, 27].

In this meta-analysis, aerobic outputs were measured with the following indices: time to exhaustion (min), VO₂max (ml/kg/min), and perceived effort; in the case of anaerobic outputs we retrieved data on blood lactate level (mmol/l) and vertical and countermovement jumping (cm). All data extracted as mean and standard deviation (SD) of taurine and placebo post measurements. Then, it is entered into the excel sheet and transferred into the meta-analysis program.

Statistical Analyses

Time to exhaustion (min), VO₂max (ml/kg/min), and degree of perceived exertion (score) were used to choose results for aerobic performance, while vertical and countermovement jumping (cm) and blood lactate level (mmol/l) were used to select results for anaerobic performance. In the meta-analysis, raw data in the form of a mean, SD, and sample size for taurine and placebo groups were extracted. Unreported values obtain from WebPlotDigitizer (Version 3.12). The meta-analysis of aerobic and anaerobic performance outputs was conducted using Review Manager 5.4 (Cochrane's Software).

The mean differences were used for continuous outcomes to estimate the effects of taurine. The data was analyzed using fixed-effects or random-effects models dependent on the degree of heterogeneity as measured by the I² statistic. The mean differences between taurine and placebo groups were expressed using Hedges' g and 95 percent confidence intervals (CIs) across trials. MDs of ≤0.2, 0.2–0.49, 0.5–0.79, and ≥ 0.8 were considered to represent small, medium, large, and very large effects, respectively [28]. To evaluate the tests for the forest plots, subgroup analysis, and quality assessment, Review Manager version 5.4 was utilized. For all analyses, the statistical significance level was set at p<0.05.

Register

PROSPERO recording of our work titled "Does Taurine Supplementation Affect Aerobic and Anaerobic Outputs? A Meta-Analysis of Randomized Controlled Trials" with ID 291146 has been made. However, the protocol of this review was not registered in PROSPERO since this platform does not accept systematic reviews assessing sports performance as an outcome.

Results

Study Selection

For this meta-analysis, a total of 17,880 studies were identified. Duplications were eliminated and the remaining 169 relevant studies were assessed based on their title and abstract. In total, 153 of studies were excluded due to the following reasons: co-ingestion of other supplements (n=14), relevant measurements not taken (n=124), animal studies (n=7), participants with chronic health status (n=3), not open access study (n=1), meta-analysis (n=2) and systematic review (n=2). Ultimately, the current analysis involves 17 studies. Figure 1. depicts the selection procedure.

Although 17 studies were detected for the meta-analysis between 2001-2021, 15 studies were grouped. Only randomized controlled trials (single or double-blind) were considered.

Characteristics of the Included Studies

There were 202 participants (128 athletes and 74 healthy individuals) from 17 studies included in the present meta-analysis. The studies' sample sizes ranged from 7 [29] to 21 [30] subjects. The participants' ages ranged from 17 [31] to 34.6 [10] years old on average. One of the research [32] included females, whereas the others employed males. The duration of supplementation varied from acute to eight weeks. The daily doses of taurine given vary between 1 and 10 g/d. gram of taurine was the most common dosage. Swimming, running, jumping, cycling performance, and treadmill or cycle ergometer testing were all part of the exercise regimen. In 10 of the 17 studies [10, 14-16, 29, 30, 32-35], found had aerobic outputs, 6 studies [31, 36-40] had anaerobic outputs, and 1 study [41] both aerobic and anaerobic outputs were provided.

Characteristics of included studies concerning aerobic, and anaerobic performance outputs are presented in Tables 1. and 2.

Table 1 Characteristics of Included Studies Related to Aerobic Outputs (n=11)

Table 2 Characteristics of Included Studies Related to Anaerobic Outputs (n=7)

Author, Year	Study design	Sample group and total size	Mean age (yr) and body weight (kg)	Duration	Dosage and form of Taurine	Exercise Protocols	Results	Side Effect
TG Balshaw et al. [16]	RDB	8 male middle-distance runners	19.9 yr / 69.4 kg	Acute	1 g/d Capsule	3-km running performance on the treadmill	VO _{2max} « RPE «	NR
FG De Carvalho et al. [33]	RDB	10 male triathletes	30.9 yr/ 77.45 kg	8 weeks	3 g/d Capsule	A maximal incremental running test	RPE «	NR
BS Galan et al. [34]	RDB	9 male long-distance triathletes	30 yr/ 78.45 kg	8 weeks	3 g/d Capsule	Progressive treadmill test (A constant incline of 1% and an initial speed of 8 km.h ⁻¹)	RPE «	NR
M Kammerer et al. [41]	RDB	14 male soldiers	NR	Acute	1g / d Beverage	A ramp protocol (first speed of 3.5 mile/h + 1% inclination after speed was increased by 0.5 mile/h every minute)	VO _{2max} « TTE «	No
F Milioni et al. [14]	RCT	17 male trainees	26 yr/ 77.8 kg	Acute	6 g/ d Capsule	Incremental treadmill-running test (submaximal intensity (7,5 km.h ⁻¹))	TTE «	NR
NT Torun [30]	RSB	21 non-active males	23.56 yr/ NR	1 week	3g or 6g /d Capsules	Bruce Protocol	VO _{2max} «	NR
JA Rutherford et al. [15]	RCT	11 male athletes	27.2 yr/ 74.3 kg	Acute	1.66 g/d Beverage	Incremental cycle test (~65%)	RPE «	NR

						VO _{2max}) to exhaustion		
M Waldron et al. [32]	RDB	9 female lacrosse players	22 yr/ 65 kg	2 weeks	50 mg/kg/d Capsule	Incremental ramp exercise at isokinetic high (90 r/min) cadence	RPE «	NR
M Waldron et al. [35]	RDB	12 recreationally active males	23 yr/ 75.5 kg	Acute	50 mg/kg/d Capsule	3 minutes all-out test on a cycle ergometer	↑ TTE	NR
R Ward et al. [10]	RDB	11 male cyclists	34.6 yr/ 74,8 kg	Acute	500 ml water containing 1 g of taurine	4 km time trial performance on ergometer	VO _{2max} «	NR
R Warnock et al. [29]	RSB	7 male team sports players	20 yr/ 86.3 kg	Acute	50 mg/kg Capsule	Three Wingate repeated sprint	RPE «	NR

Abbreviations: RCT, randomized controlled trial; RDB: Randomised double-blind; RSB: Randomised single-blind; NR, Not reported; RM: repetition maximum; TT: Time trial; RPE: Rate of Perceived Exertion VO_{2max}: Maximal oxygen uptake; TTE: Time to Exhaustion; g/d: gram/day; ↑: significantly improve; ↓: significantly decrease ; « : No significant difference.

Author, Year	Study design	Sample group and total size	Mean age (yr) and body weight (kg)	Duration	Dosage and form of Taurine	Exercise Protocols	Results	Side Effect
K Akalp [39]	RDB	10 active males	21,4 yr/ 75,2 kg	1 week	0,1 g / kg Powder	Chest press, abdominal crunch, and leg extension exercises (1RM 50%)	Blood Lactate Level « Vertical Jump «	NR
G Batitucci et al. [36]	RDB	14 male swimmers	18-25 yr/ 78.6 kg	8 weeks	3g / d Capsule	400 m front crawl swimming performance	Blood Lactate Level ↑	NR
CC Dato [31]	RDB	10 male swimmers	17-21 yr/ 75 kg	Acute	6g / d Capsule	400 m swimming performance	Blood Lactate Level «	NR
FG De Carvalho et al. [37]	RDB	9 male swimmers	19,8 yr/ 76,3 kg	Acute	6g / d Capsule	400 m front crawl swimming performance	Blood Lactate Level «	NR
M Kammerer et al. [41]	RDB	14 male soldiers	NR	Acute	1g / d Beverage	Three vertical jump trials	Vertical Jump «	No
A Samandari et al. [40]	RDB	10 male elite taekwondo athletes	20,6 yr/ 67,1 kg	10 days	15 mg /kg / d Capsule	Simulation of taekwondo competition day included five exhaustive single competition exercises	Countermovement Jump «	No
E Kowsari et al. [38]	RDB	20 male squash players	25.1 yr / 97.8 kg	Acute	1 g / d Capsule	Bruce Protocol	Blood Lactate Level ↓	NR

Abbreviations: RDB: Randomised double-blind; NR, Not reported; RM: repetition maximum; g/d: gram/day; ↑: significantly improve; ↓: significantly decrease ; « : No significant difference.

Sub-Group Analysis Results of Individual Studies According to the Outputs

Two distinct subgroup analyses of aerobic and anaerobic performance outputs were carried out in this study.

The Effect Of Taurine Supplementation on Aerobic Performance Outputs

11 studies were assessed aerobic performance outputs. 3 studies [14, 35, 41] reported the time to exhaustion (minutes), 2 studies [10, 16] reported VO_{2max} level (ml/kg/min) and 6 studies [15, 16, 29, 32-34] measured rate of perceived exertion using the Borg scale (6 to 20 score). A total of 108 participants were reached with 10 studies.

Abbreviations: Green circle: low risk of bias; Red circle: high risk of bias; Blank space: unclear risk of bias. A: Random sequence generation; B: Allocation concealment bias; C: Blinding of participants and personnel; D: Blinding of outcome assessment; E: Incomplete outcome data; F: Selective reporting; G: Other bias; CI: Confidence interval.

In a fixed effects model, taurine supplementation had no significant effect on VO_{2max} level and rate of perceived exertion (respectively, MD = -0.54 ml/kg/min; 95% CI [-6.84 to 5.75], p=0.87; MD = -0.24; 95% CI [-0.74 to 0.27], p=0.35) when compared to a placebo group. In any case, taurine supplementation had a disposition moderate effect on time to exhaustion (MD = 0.43, 95% CI [-0.31 to 1.16], p= 0.26) in moderate level. Heterogeneity degree (I^2) was calculated as 0% in all subgroups.

The Effect Of Taurine Supplementation on Anaerobic Performance Outputs

3 studies [39-41] analyzed vertical and countermovement jump as total height (cm). 3 studies [31, 36, 37] assessed blood lactate level as post-measure concentration (mmol/L). In total 6 studies (with 67 participants) were evaluated for anaerobic outputs.

Abbreviations: Green circle: low risk of bias; Red circle: high risk of bias; Blank space: unclear risk of bias. A: Random sequence generation; B: Allocation concealment bias; C: Blinding of participants and personnel; D: Blinding of outcome assessment; E: Incomplete outcome data; F: Selective reporting; G: Other bias; CI: Confidence interval.

In a random-effects model, taurine supplementation had a significant effect on vertical (MD =3.60; 95% CI [2.32 to 4.89], p <0.00001) and countermovement (MD = 8.50; 95% CI [4.78 to 12.22], p <0.00001) jump performance when compared to a placebo group. Additionally, it was determined that taurine supplementation had no effect on blood lactate level (MD =-0.56, 95% CI [-1.82 to 0.70], p= 0.38). While the level of heterogeneity for the vertical jump subgroup was 16% and 0% for the blood lactate level.

Risk Of Bias

Most of the studies had a low or unclear risk of bias. In 1 study [10] allocation concealment and blinding; in 2 studies [33, 34] incomplete outcome data, selective reporting, and other biases were unclear. The publication bias analysis is depicted in Figure 4.

The funnel plot of aerobic and anaerobic performance outputs revealed no significant publication bias because of symmetrical distribution except for a few studies.

3.5. Side Effects

In none of the trials, there were any negative consequences.

Discussion

Although various roles of taurine in muscle have been reported, no specific mechanism has been reported for taurine that can increase muscle capacity or strength and reduce muscle damage. Therefore, this study focused on aerobic and anaerobic outputs to evaluate exercise performance. The current meta-analysis study provides up-to-date data for the literature on the effect of taurine intake on aerobic and anaerobic exercise performance. In total, 11 studies were selected for the evaluation of aerobic capacity and 6 studies for the evaluation of anaerobic capacity. Thus, the results of the meta-analysis indicate that taurine can be an effective ergogenic aid, especially on jumping performance, which is a marker of anaerobic output. The pooled effects of taurine on performance appear to be small, medium, and large. It should be noted that even small improvements in performance in some sports can translate into significant differences in competitive results [42, 43].

We found that taurine supplementation does not significantly affect neither aerobic (MD = -0.03; 95% CI [-0.45 to 0.39]; $p=0.89$) nor anaerobic (MD = 2.08; 95% CI [-0.60 to 4.76], $p= 0.13$) performance outputs. However, subgroup analysis showed a significant effect on jumping performance and it has been shown to have a moderate effect disposition on TTE.

To the best of our knowledge, the effects of taurine on aerobic and anaerobic performance have never been pooled in a meta-analysis before. It shows that taurine can cause practically significant improvements in jumping performance. For this reason, it is thought that taurine supplementation will be important in sports branches where jumping performance is at the forefront. In addition, athletes, trainers, and sports nutritionists should be informed about the ergogenic potential of taurine, and the outputs of this study can be used as a source for future scientific research.

Aerobic Outputs

TTE, VO_{2max} , and RPE parameters were used to evaluate aerobic exercise performance. In this study, it was determined that taurine had no effect on total aerobic performance, but showed a moderate effect on TTE. Taurine supplementation did not have a statistically significant effect on VO_{2max} and RPE according to this meta-analysis. Most studies investigating the effect of taurine intake on aerobic performance have generally used the TTE parameter to assess aerobic capacity [22, 44, 45]. Results of individual studies evaluating aerobic performance reported a positive effect of taurine administration [22, 44]. While the effect size of the improvement in taurine status was significant in these studies, it was seen that although there was no significant difference in TTE as a result of the meta-analysis in this study, it had a moderate effect size

The findings of the present meta-analysis are in line with previous research, as taurine intake has not been shown to affect VO_{2max} [8, 16] and RPE [16, 44]. In contrast, maximal oxygen uptake has been shown to increase up to exhaustion following taurine supplementation in individuals in an incremental cycle test [22, 46]. However, the fact that oxygen uptake did not differ between conditions despite the significantly shorter completion time in the taurine intake case in the time trial could be interpreted as a positive effect of taurine uptake on central factors or muscle coordination independent of the metabolic effect. It has previously been suggested that the effect of taurine on exercise metabolism during simulated time trial performance would appear to act through interaction with the muscle. This is particularly important given that acute taurine intake not only increases muscle content but also plasma content [8]. Conversely, it is hypothesized that prior taurine intake may reduce taurine losses from muscle during aerobic exercise. However, a 1 g dose of taurine generally used in the studies included in the current meta-analysis would be sufficient to induce a concentration gradient by preventing muscle loss. Although it has been shown that the taurine content in muscle is decreased following aerobic exercise [13, 47], such studies have not been conducted yet, therefore further research is important to clarify the issue.

The effect of oral taurine on performance versus time has been inconsistent. For example, R Ward et al. [10] reported no effect of taurine on 4-km cycling time-trial performance, but TG Balshaw et al. [16] reported improvement in the 3km time

trial. The energetics of exercise over long distances is largely reliant on capacity in the severe-intensity domain and based on the current findings, we would predict clear effects on closed-loop events of this distance. Indeed, ischemia preconditioning, beet juice, beta-alanine, and caffeine had equal or stronger effects on severe-intensity exercise TTE [48-52]. As a result, although the explanation for the differences in research findings is not known clearly, the doses used and supplementation periods can still be associated with the training status of the individuals.

In an experimental investigation conducted by 11 male cyclists on a bicycle ergometer, it was revealed that 1 g of taurine supplement ingested before the 4 km time trial performance did not influence VO_{2max} [10]. In a double-blind randomized study examining the effects of acute administration of 1 g taurine on the 3 km time trial performance on a treadmill in middle-distance runners, it was stated that taurine supplementation did not influence VO_{2max} [16]. M Zhang et al. [22], in their experimental study conducted with 11 healthy male individuals, exercised on a bicycle ergometer after the participants were given 6 g of taurine daily for 1 week. As a result, it has been reported that daily taurine supplementation of up to 6 g provides a significant improvement on VO_{2max} . NT Torun [30], in his study with 21 healthy men, had the Bruce protocol applied, which is one of the maximally loaded treadmill methods, and after the protocol, the participants were included in a 1 week 3 and 6 g taurine loading process. As a result, it was observed that VO_{2max} increased significantly after 6 g taurine loading. It can be seen that the effects of taurine on the VO_{2max} parameter provide mixed outcomes. However, studies in the literature suggest that high dosages of ≥ 6 g may improve VO_{2max} .

Anaerobic Outputs

Jumping performance (vertical and countermovement jumps) and blood lactate levels were used to assess anaerobic exercise performance. Taurine is known to increase Ca^{2+} transport to the sarcoplasmic reticulum, which aids skeletal muscle activation and muscle strength development [47, 53]. Jumping is a complex action involving multiple joints that require high power and strength generation. Vertical jump distance has an important place among measurement methods in many sports branches [54, 55]. Vertical jump performance is linked to maximal lower-body strength, according to several studies. Additionally, the rapid stretch provided by the countermovement jump, which is one of the most frequently used vertical jump tests, could lead to increased muscle activation and force production [56].

In this meta-analysis, it was observed that taurine intake significantly improved jumping performance. K Akalp [39], compared the measurements by performing the vertical jump test on 10 healthy men who took 0.1 g/kg taurine 1 hour before and 1 hour, 24 hours, 48 hours, and 72 hours after strength exercise. As a result, the ability of taurine to reveal a statistically significant difference in vertical jump performance was determined. When the studies on the jumping performance of taurine intake were examined, no consensus has been reached. On the contrary, in an experimental study involving 10 male taekwondo athletes who were given an exercise protocol in which the taekwondo race day was simulated, it was stated that taurine supplementation of 15 mg/kg per day for 10 days was not effective on the countermovement jump performances of the athletes [40]. In a placebo-controlled double-blind study conducted with 14 healthy individuals, it was reported that 1 g of taurine consumed before 3 vertical jump trials did not have a statistically significant effect on vertical jump performance compared to placebo [41]. Although it was emphasized that taurine did not affect jumping performance due to the individual results of studies with different groups, taurine had a significant effect on jumping performance in this meta-analysis when compared to the placebo group.

The blood lactate-lowering effect of taurine is thought that most likely owing to a potential interaction between taurine and the calcium in mitochondrial buffering [57]. In this study, it was determined that taurine supplementation did not affect blood lactate levels. When the findings obtained from this meta-analysis are compared with the literature, various studies are reporting that taurine both does not [16, 31, 37] and does affect [36, 38] blood lactate levels. It is thought that more studies are needed to examine whether taurine intake affects blood lactate levels.

Conclusion

Taurine supplementation has a considerable significant effect on jumping performance ($p < 0.0001$), according to the results of experimental research conducted over the last 20 years. When compared to placebo, it had no ergogenic effect on aerobic outputs (RPE and VO_{2max}), although it may improve the TTE parameter. More controlled trials with a larger number of people and more diverse groups are needed to develop a consensus on taurine's ergogenic effects on sports performance and to extend these findings.

Limitations

The study's limitations include a lack of research, difficulties grouping due to the use of a wide variety of exercises, different doses and intervention periods, and a small sample size. The analysis of various athletes' competition levels is also another limitation of this study. Exercise protocols were asked to show concordance when aerobic and anaerobic performance were evaluated.

Abbreviations

RCT: randomized controlled trial; RDB: Randomised double-blind; RSB: Randomised single-blind; NR, Not reported; RM: repetition maximum; TT: Time trial; RPE: Rate of Perceived Exertion VO_{2max} : Maximal oxygen uptake; TTE: Time to Exhaustion; g/d: gram/day

Declarations

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Authors' contributions

YB conceived the idea and conceptualized the review. YB, CDE, and ES conducted the study selection, data extraction, and methodological quality assessment. AT, KSZ drafted the initial manuscript. YB, CDE, AT, ES, and KSZ contributed to writing the manuscript. All authors read and approved the final manuscript.

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Availability of data and materials

The tables, figures, and supplemental materials supporting the conclusions of this article are included within the article.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Conflict of Interest

There are no competing interests declared by the authors.

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