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SHORT-TERM CREATINE SUPPLEMENTATION AND REPEATED SPRINT ABILITY – A SYSTEMATIC REVIEW AND META-ANALYSIS

RUNNING HEAD TITLE: Creatine and repeated sprint ability

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ABSTRACT

The aim of this study was to conduct a systematic review and meta-analysis of the effects of short-term creatine supplementation on repeated sprint ability. Fourteen studies met the inclusion criteria of adopting double-blind randomized placebo-controlled designs in which participants (age: 18 – 60 years) completed a repeated sprint test (number of sprints: $4 < n \leq 20$; sprint duration: ≤ 10 s; recovery duration: ≤ 90 s) before and after supplementing with creatine or placebo for 3 – 7 days in a dose of ~ 20 $g \cdot d^{-1}$. No exclusion restrictions were placed on the mode of exercise. Meta-analyses were completed using random-effects models, with effects on measures of peak power output, mean power output, and fatigue (performance decline) during each repeated sprint test presented as standardized mean difference (δ); and with effects on body mass and post-test blood lactate concentration presented as raw mean difference (D). Relative to placebo, creatine resulted in a significant increase in body mass ($D = 0.79$ kg; $p < 0.00001$) and mean power output ($\delta = 0.61$; $p = 0.002$). However, there was no effect of creatine on measures of peak power ($\delta = 0.41$; $p = 0.10$), fatigue ($\delta = 0.08$; $p = 0.61$), or post-test blood lactate concentration ($D = 0.22$ $L \cdot min^{-1}$; $p = 0.60$). In conclusion, creatine supplementation may increase mean power output during repeated sprint tests; though the absence of corresponding effects on peak power and fatigue means that more research, with measurements of intramuscular creatine content, is necessary to confirm.

Key words: Sprinting; multiple sprint; ergogenic; phosphocreatine

INTRODUCTION

Creatine supplementation, often in the form of creatine monohydrate, is a popular performance aid used by athletes. During intense, short duration exercise, the rate of adenosine trisphosphate (ATP) regeneration is largely dependent upon intramuscular phosphocreatine (PCr) availability (Buford et al., 2007). To maintain energy and allow maximal effort activity to be continued, ATP regeneration must be close to the rate of ATP hydrolysis (Maughan, 1995). Transfer of the phosphate group from PCr to adenosine diphosphate restores ATP, providing a short-term energy buffer. As PCr stores are limited, depletion results in a diminished ability to resynthesise ATP at the rate required to maintain high-intensity activity. Consequently, increasing muscle creatine content via creatine supplementation is proposed to increase PCr availability, thus accelerating the rate of ATP restoration and allowing a greater amount of work to be completed (Buford et al., 2007; Glaister et al., 2006; Maughan, 1995).

Studies have examined the potential beneficial effects of creatine supplementation on sport and exercise performance (Bemben & Lamont, 2005), with the greatest benefits being suggested for field and court sports (multiple sprint sports) due to their intermittent activity patterns (Kreider et al., 2017; Wax et al., 2021). One of the reasons given for this suggested benefit is that creatine supplementation results in an increased muscle creatine concentration, which possibly enhances the rate of between-sprint PCr resynthesis by potentiating the rate of flux through the creatine kinase reaction at the mitochondrial membrane (Casey & Greenhaff, 2000). Since the rate of PCr resynthesis is related to the recovery of power output (Bergström & Hultman, 1991; Bogdanis et al., 1995; Hitchcock, 1989; Sahlin & Ren, 1989), it is reasoned that creatine supplementation could enable better recovery between successive sprints, resulting in an overall improvement in performance (or repeated sprint ability) (Glaister et al., 2006; Yquel et al., 2002). However, the results of studies examining the effects of creatine supplementation on post-exercise PCr resynthesis rates are inconsistent (Delecluse et al., 2003; Francaux et al., 2000; Greenhaff et al., 1994; Kreis et al., 1999; Preen et al., 2001; Smith et al., 1999; Vandenberghe et al., 1999; Yquel et al., 2002); with most showing either no effect (Delecluse et al., 2003; Francaux et al., 2000; Kreis et al., 1999; Smith et al., 1999; Vandenberghe et al., 1999), or an effect after the first minute of recovery only (Greenhaff et al., 1994; Preen et al., 2001). Furthermore, investigations into the efficacy of creatine supplementation on eliciting improvements in repeated sprint ability, typical of that experienced in multiple sprint sports, present conflicting findings (see Glaister et al., 2006). Therefore, although creatine is often recommended to multi-sprint sport (soccer, rugby, basketball, volleyball, etc.) athletes as a performance aid, its ergogenic effect remains unclear. The aim of this systematic review and meta-analysis was therefore to examine the effects of short-term creatine supplementation on the repeated sprint ability typical of that experienced in multiple sprint sports.

MATERIALS AND METHODS

Systematic review

This systematic review was conducted according to the guidelines proposed in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement (Moher et al., 2009). The study was registered with Open Science Framework (10.17605/OSF.IO/NT734). The databases of Pubmed, SPORTDiscus, and Web of Science were searched for peer-reviewed publications (prior to June 2022) containing 'creatine' (but not 'creatine kinase') and 'sprint' in the title or the abstract, along with the words 'repeated' or 'multiple', or 'intermittent'. Reference lists of those studies that passed the initial screening for potential inclusion in the analysis were also examined for publications which may have eluded the online database search.

Inclusion and exclusion criteria

Studies considered for inclusion in this investigation were limited to those conducted on adult (18 – 60 years of age) humans using randomized, double-blind, placebo-controlled designs (an exception to the age restriction was made for the study by Deminice et al. (2013) on under-20 soccer players, as the mean age was 17.4 ± 1.2 years for the placebo group and 17.1 ± 1.4 years for the creatine group, and there is no evidence that this margin of age difference influences the acute responses to creatine supplementation). Although the four-week washout period for creatine, following supplementation, favors between-group designs, there are several crossover studies and, as such, both approaches were included in the analysis. The method of creatine supplementation was restricted to the standard short-term loading dose of at least 20 g of creatine per day for 3 – 7 days. To qualify as a test of repeated sprint ability, protocols were restricted to those consisting of a series ($4 < n \leq 20$) of short ($\leq$ 10 s) maximal sprints interspersed with fixed-duration rest periods of $\leq$ 90 s (Girard et al., 2011). Performance responses were limited to those used typically to determine repeated sprint ability, namely: peak power output/fastest sprint time, mean power output/sprint time, and fatigue (Glaister, 2008). Research quality (risk of bias) was evaluated by means of the Physiotherapy Evidence Database (PEDro) scale, which ranks the quality of research, via a series of questions, on a 10-point scale (Verhagen et al., 1998). The scale evaluates aspects relating to eligibility criteria, treatment blinding and randomisation, participant matching at baseline, participant completion rate, method of statistical comparison, and the magnitude of any effects. Publications achieving a PEDro score < 6 were considered to lack sufficient quality to be included in the meta-analysis (Ganio et al., 2009).

Data extraction

Data were extracted independently by two reviewers from relevant publications as means, standard deviations (SD), and sample sizes. In instances where data were presented in a graphical format, images were enlarged to improve the precision of the data estimates. Given that the intramuscular uptake of creatine following supplementation is reflected in an increase in body mass (Branch, 2003), data on the effects of creatine on body mass were extracted. In addition, since there is some evidence that an increased availability of PCr in a repeated sprint test may lead to a reduction in anaerobic glycolysis (Balsom et al., 1993), data on the effects of creatine supplementation on post-test blood lactate concentration [BLa] were also collated. For all study designs, data were extracted for baseline (T_{base}) and post-supplementation (T_{post}) responses for both creatine and placebo groups/conditions. Data from sprint running tests of repeated sprint ability were converted to power outputs in line with previous research (Zagatto et al., 2009) using Equation 1.

$$\text{Equation 1. power output} = (\text{body mass (kg)} \times \text{distance (m)}^2)/\text{time (s)}^3.$$

Meta-analysis

The database search (Figure 1) returned 172 articles (Pubmed, n = 55; SPORTDiscus, n = 57; Web of Science, n = 60), which, after the removal of duplicates (n = 93), the addition of articles acquired from the search of reference lists (n = 1), and the removal of studies which failed to meet the inclusion criteria (n = 66), left 14 studies for the meta-analysis (Table 1). Meta-analyses were conducted using specialist software (Review Manager Version 5.3. The Nordic Cochrane Centre, Copenhagen: The Cochrane Collaboration, 2014). Meta-analyses were completed using random-effects models, with effects on measures of peak power output, mean power output, and fatigue during each repeated sprint test presented as standardized mean difference (δ) and with effects on body mass and post-test [BLa] presented as raw mean difference (D) (i.e. the difference between the raw mean values of the creatine and placebo conditions). 95% confidence limits (CL_{95}) were calculated for all estimates. Given the failure of studies using between-group designs to report $T_{base} – T_{post}$ change scores, mean changes from baseline in placebo and creatine groups for each dependent variable were calculated using Equation 2, with standard deviations of those changes (SDΔ) imputed using Equation 3 (Higgins et al., 2008). The same approach was used for studies adopting crossover designs to allow between- and within-study designs to be included in the same analyses.

$$\text{Equation 2. mean difference} = \text{mean post} – \text{mean baseline}$$

$$\text{Equation 3. } SD\Delta = [(SD_{base})^2 + (SD_{post})^2 – 2 \times \text{corr}(T_{base}, T_{post}) \times SD_{base} \times SD_{post}]^{0.5}$$

Note: $\text{corr}(T_{base}, T_{post})$ is the correlation between T_{base} and T_{post} values and was calculated for all dependent variables, apart from post-test [Bla], using the raw data of Glaister et al. (2006) (see Table 2). In contrast, for post-test [Bla], SDΔ was imputed using a conservative $\text{corr}(T_{base}, T_{post})$ estimate of 0.5 for both creatine and placebo responses (Higgins & Green, 2008).

Heterogeneity between studies was examined using the I^2 statistic, which describes the percentage of variability in mean difference estimates due to heterogeneity rather than chance. When I^2

was > 25% (25 – 50% represents moderate heterogeneity (Higgins et al., 2003)), a subgroup meta-analysis was completed to investigate the source of heterogeneity. In line with recommendations regarding tests for heterogeneity (Ioannidis et al., 2007), CL_{95} for I^2 were calculated using the method outlined by Higgins and Thompson (2002). Subgroup meta-analyses were performed, when appropriate, to investigate the influence of exercise mode as a potential moderator variable. In contrast, no subgroup analyses were conducted to investigate the effects of either: 1) sex – since most studies used male participants; or 2) training status – since between-study inconsistences in the way that this variable was reported/measured did not allow quantification with adequate precision. Heterogeneity between subgroups was also evaluated using the I^2 statistic. Publication bias was evaluated through visual inspection of funnel plots. Statistical significance was accepted at $p < 0.05$ for all analyses.

FIGURE 1. ABOUT HERE.

RESULTS

A summary of the findings from each of the studies that met the inclusion criteria, including the risk-of-bias assessment, is presented in Table 1. All the studies that met the inclusion criteria passed the risk-of-bias assessment (Table 1) and there was no evidence of asymmetry (publication bias) in any of the funnel plots. The mean age of participants in each of the studies was < 30 years, with the oldest being 28.4 ± 0.7 years (Kamber et al., 1999). Seven of the studies stated that participants were non-vegetarian with the remainder providing no comment. Apart from the studies by Ahmun et al. (2005), Deminice et al. (2013), and Mujika et al. (2000), creatine was ingested with carbohydrate to increase the insulin response and facilitate a greater intramuscular uptake of creatine (Casey & Greenhaff, 2000). However, none of the studies measured $T_{base} – T_{post}$ changes in muscle creatine content.

TABLE 1. ABOUT HERE.

TABLE 2. ABOUT HERE.

Body mass

Relative to placebo, there was a significant increase in body mass following creatine supplementation (Figure 2) (D = 0.79 kg; CL_{95}[0.55, 1.03]; $p < 0.00001$). There was also evidence of a moderate degree of heterogeneity between the studies (I^2 = 40%; CL_{95}[0, 70]).

FIGURE 2. ABOUT HERE.

Peak power output

The effect of supplementation on peak power output during the repeated sprint tests is presented in Figure 3. Relative to placebo, creatine had no effect on peak power output (δ = 0.41; CL_{95}[-0.08, 0.90]; p = 0.10). Despite a large degree of heterogeneity between studies (I^2 = 75%; CL_{95}[58, 85]), subgroup analyses were unable to attribute that heterogeneity to between-study differences in mode of exercise (I^2 = 0%; p = 0.80). Large degrees of heterogeneity in peak power output remained in cycling (I^2 = 71%; CL_{95}[32, 88]) and running (I^2 = 79%; CL_{95}[59, 89]) based studies, and the absence of any significant effects of creatine on peak power output remained in both sprint cycling (δ = 0.34; CL_{95}[-0.40, 1.08]; p = 0.37) and sprint running (δ = 0.47; CL_{95}[-0.22, 1.15]; p = 0.18) protocols.

FIGURE 3. ABOUT HERE.

Mean power output

Seven of the studies included in this review reported mean power output in their analysis (Figure 4). Relative to placebo, creatine supplementation increased mean power output by 27 ± 20 W (δ = 0.61; CL_{95}[0.23, 1.00]; p = 0.002), with a moderate degree of between-study heterogeneity (I^2 = 27%; CL_{95}[0, 68]). Subgroup comparisons revealed significant effects of creatine on mean power output in sprint cycling (δ = 0.82; CL_{95}[0.19, 1.45]; p = 0.01) but not in sprint running (δ = 0.49; CL_{95}[-0.01, 0.99]; $p = 0.06$) protocols. Despite moderate degrees of heterogeneity in the cycling- ($I^2 = 27\%$; $CL_{95}[0, 95]$) and running-based ($I^2 = 33\%$; $CL_{95}[0, 76]$) studies, there was no evidence of heterogeneity between those subgroups ($I^2 = 0\%$; $p = 0.43$).

FIGURE 4. ABOUT HERE.

Fatigue

The effects of supplementation on measures of fatigue during the repeated sprint tests are presented in Figure 5. Relative to placebo, there was no effect of creatine on fatigue ($\delta = 0.08$; $CL_{95}[-0.22, 0.37]$; $p = 0.61$) and there was no evidence of heterogeneity between the studies ($I^2 = 0\%$; $CL_{95}[0, 71]$).

FIGURE 5. ABOUT HERE.

Blood lactate

Seven studies reported a measure of post-test [BLa] (Figure 6). Relative to placebo, there was no effect of creatine on post-test [BLa] ($D = 0.22\ L \cdot min^{-1}$; $CL_{95}[-0.59, 1.03]$; $p = 0.60$) and no evidence of between-study heterogeneity ($I^2 = 0\%$; $CL_{95}[0, 71]$).

FIGURE 6. ABOUT HERE.

DISCUSSION

The aim of this systematic review and meta-analysis was to examine the effects of creatine supplementation on repeated sprint ability. The key findings were that creatine increased body mass and mean power output, but had no effect on peak power output, fatigue, or post-test [BLa]. Moreover, the effect of creatine on mean power output appeared to be constrained to those studies which used cycling as the mode of exercise.

The increase in body mass following short-term creatine supplementation is similar to that reported previously (Branch, 2003) and is attributed mostly to an increase in fluid retention resulting from the osmotic pressure caused by the intramuscular uptake of creatine (Casey & Greenhaff, 2000; Juhn & Tarnopolsky, 1998; Ziegenfuss et al., 2002). Nevertheless, there was considerable between-study heterogeneity in the magnitude of the response, with five of the studies reporting no significant effect of creatine on body mass (see Table 1). The large degree of heterogeneity is most likely the result of considerable between-subject variability in creatine uptake following supplementation, with reports that approximately 20 – 30% of individuals experience an increase in intramuscular creatine content of less than 10 mmol.kg dm^{-1}, and are classified, therefore, as 'non-responders' (Greenhaff, 1997; Greenhaff et al., 1994; Syrotuik & Bell, 2004). However, it is difficult to draw any firm conclusions about the cause of the variability in body mass changes since none of the studies measured $T_{base} – T_{post}$ change scores in muscle creatine content.

The absence of any significant effect of creatine supplementation on peak power output during the repeated sprint tests is not surprising given that peak power output occurs within the first few sprints (often in the first sprint), and that PCr stores are not considered to be limited at that time (Gaitanos et al., 1993). Indeed, PCr is reported to contribute approximately 50% to ATP resynthesis in the first of 10 × 6 s sprints (30 s rest periods), depleting stores by approximately 50% (Gaitanos et al., 1993). In contrast, the significant effect of creatine supplementation on mean power output suggests that the increased availability of creatine is able to offset partially the shortfall in PCr as sprints are repeated, and/or that increased creatine availability is facilitating faster recovery of PCr between successive sprints. As highlighted earlier, if the response on mean power output is due to faster PCr recovery between sprints, it is strange that most studies investigating the effects of creatine supplementation on PCr recovery kinetics have failed to show any effect; particularly in the relatively short recovery time-frame typical of tests of repeated sprint ability (Glaister et al., 2006). Nevertheless, the increase in mean power output in the absence of any significant change in post-exercise [BLa] supports the idea that the increase in mean power output was due to an increased contribution from PCr to ATP resynthesis as the repeated sprint tests progressed.

Although the results of the meta-analysis revealed a significant effect of creatine on mean power output, it seems strange that there was no corresponding effect on the fatigue response; particularly given the absence of any effect of creatine on peak power output during the repeated sprint tests. Then again, there are many ways to quantify fatigue in repeated sprint tests and all show relatively poor test-retest reliability (Glaister et al., 2008). In effect, it may be that the fatigue calculations used by the studies included in this review lacked sufficient sensitivity to detect changes in repeated sprint ability of the magnitude possible from creatine supplementation.

It would be easy to attribute the results of the subgroup analysis on mean power output to the effects of body mass changes on weight-bearing (running) versus non-weightbearing (cycling) protocols; particularly if the gain in body mass is due to fluid retention. However, there are some problems with that argument. First, the analysis showed that the moderate degree of heterogeneity remained regardless of whether studies were cycling- or running-based; secondly, there were no differences in heterogeneity between the subgroups; and thirdly, there was no corresponding effect on peak power output. As such, while it is possible that a creatine-induced increase in body mass may have counteracted any positive effect on sprint running performance, further research is required to clarify.

Limitations

There are a few limitations associated with this review which should be highlighted. First, despite a reasonable number of studies meeting the inclusion criteria, the number measuring mean power output, fatigue, and [BLa] in the repeated sprint tests was relatively small, making it difficult to form clear conclusions about those responses (particularly when investigating subgroup differences); secondly, the measurement of data from graphical representations for each meta- analysis may have introduced some error into the precision of the estimates; thirdly, the failure of studies to report the standard deviations of $T_{base} - T_{post}$ change scores, a common problem in meta-analyses of between-group designs (Pearson & Smart, 2018), meant that values had to be imputed, thereby introducing a potential source of error into each analysis; ~~thirdly~~fourthly, Tarnopolsky and MacLennan (2000) proposed that independent groups should contain at least 20 participants in each to avoid the potential for making a Type II statistical error. However, most of the independent group design studies included in this review failed to meet that recommendation; and lastly, given the difficulties of accurately quantifying muscle creatine content, the failure of studies to measure $T_{base} - T_{post}$ change scores in muscle creatine content means that the true effects of creatine supplementation on repeated sprint ability remain largely uncertain.

Conclusions

The results of this analysis show that short-term creatine supplementation increases mean power output in a repeated sprint test, though the absence of a corresponding effect on fatigue means that more research is required to confirm. The effect on mean power output also appears to be dependent on the mode of exercise, with the positive effect on sprint running protocols possibly being offset by the gain in body mass associated with creatine supplementation. In contrast, creatine had no effect on peak power output. Research into the effects of creatine supplementation continues to be blighted by the failure of studies to measure $T_{base} - T_{post}$ change scores in muscle creatine content and, until this issue is addressed, it is difficult to draw any firm conclusions about the effects of creatine on repeated sprint ability.

Author contributions

Mark Glaister (MG) and Lauren Rhodes (LR) wrote the introduction and performed the literature search. Both authors independently checked the literature for relevant papers. MG extracted the data on all the key variables and LR checked those data for accuracy. MG and LR conducted the review of research quality of included articles. MG converted all the performance data to power outputs and wrote the corresponding sections in the paper. MG conducted the meta-analyses on the key variables and wrote the corresponding methods and results sections. MG and LR wrote the discussion section of the review. All authors read and approved the final version of the manuscript.

Conflicts of interest

The authors declare no conflicts of interest. The authors alone are responsible for the content and writing of the article.

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Table 1. The effects of short-term creatine supplementation (~20 g·d^{-1} for 3 – 7 days) on repeated sprint ability (number of sprints: 4 < n ≤ 20; sprint duration: ≤ 10 s; recovery duration: ≤ 90 s) and associated physiological responses.

Author(s)	n (CR)	n (PL)	Sex	Design	Training status (as described)	Exercise mode	Sprint protocol	Dose (per day)	Dose duration (days)	Results	PEDro score
Ahmun et al. 2005	14	14	M	R, DB, XO[a]	Rugby players	Cycling	10 × 6 s; 24 s rest	4 × 5 g	5	No Δ in BM, PPO, or fatigue	10
Ahmun et al. 2005	14	14	M	R, DB, XO[a]	Rugby players	Running (Indoor)	10 × 40 m; 24 s rest	4 × 5 g	5	No Δ in BM, FST, or fatigue	10
Barnett et al. 1996	9	8	M	R, DB, IG, Md	Recreationally active	Cycling	5 × 10 s; 30 s rest	4 × ~5 g	4	No Δ in BM, PPO, MPO, or [BLa]	10
Bogdanis et al. 2022	8	8	M	R, DB, IG	Recreationally active	Running (NMT)	6 × 10 s; 30 s rest	4 × ~5 g	5	↑ BM & MPO; No Δ in PPO, or [BLa]; ↓ fatigue	10
Dawson et al. 1995	11	11	M	R, DB, IG	Healthy active	Cycling	6 × 6 s; 24 s rest	4 × 5 g	5	No Δ in BM or [BLa], or fatigue; ↑ PPO & MPO	10
Delecluse et al. 2003	9	9	4F; 5M	R, DB, XO[b]	Sprinters	Running (Indoor)	7 × 40 m; 30 s rest	5 × ~4.6 g	7	No Δ in BM, FST, or fatigue	9
Deminice et al. 2013	13	12	M	R, DB, IG	Soccer players	Running (Field)	6 × 35 m; 10 s rest	~21.5 g	7	No Δ in BM, [BLa], or fatigue; ↑ PPO & MPO	10
Glaister et al. 2006	21	21	M	R, DB, IG, Md	Physically active	Running (Indoor)	15 × 30 m; ~30 s rest	4 × 5 g	5	↑ BM; No Δ in FST, MST, [BLa], or fatigue	10
Griffen et al. 2015	9	9	M	R, DB, XO[c]	Well-trained	Cycling	6 × 10 s; 60 s rest	4 × 5 g	7	No Δ in PPO or MPO; ↑ fatigue	10
Izquierdo et al. 2002	9	10	M	R, DB, IG	Handball players	Running (Indoor)	6 × 15 m; 60 s rest	4 × 5 g	5	↑ BM; No Δ in MST	10
Kamber et al. 1999	10	10	M	R, DB, XO[a]	Well-trained	Cycling	10 × 6 s; 30 s rest	4 × 5 g	5	↑ BM and MPO; ↓ [BLa]	10
Kinugasa et al. 2004	6	6	M	R, DB, IG, Md	Healthy	Cycling	10 × 6 s; 30 s rest	4 × 5 g	5	↑ BM; No Δ in PPO, MPO, or [BLa]	10
Mujika et al. 2000	8	9	M	R, DB, IG, Md	Soccer players	Running (Unsure)	6 × 15 m; 30 s rest	4 × 5 g	6	↑ BM, No Δ in [BLa]; unclear for FST and MST	10
Skare et al. 2001	9	9	M	R, SB*, IG, Md	Sprinters	Running (Indoor)	6 × 60 m; ~42 s rest	4 × 5 g	5	↑ BM & [BLa]; ↓ MST	10
Ziegenfuss et al. 2002	10	10	10F; 10M	R, DB, IG, Md	Athletes (Collegiate)	Cycling	6 × 10 s; 60 s rest	5 × ~4.3 g	3	↑ BM, PPO, and MPO	10

Note: ↑, significant ($p < 0.05$) increase relative to placebo; ↓, significant ($p < 0.05$) decrease relative to placebo; [BLa], end test blood lactate concentration; BM, body mass; CR, creatine; DB, double-blind; F, female; FST, fastest sprint time; IG, independent groups; M, male; Md, matched at baseline; MST, mean sprint time; NMT, non-motorized treadmill; no Δ, no significant ($p \geq 0.05$) change relative to placebo; PEDro, Physiotherapy evidence database scale; Phys Ed, physical education; PL, placebo; PPO, peak power output; R, randomized; XO, crossover; [a]28 day washout; [b]49 day washout; [c]35 day washout.

Table 2. Pre – post correlation coefficients for the short-term effects of creatine and placebo supplementation on repeated sprint ability.

Supplement	Body mass	Peak power	Mean power	Fatigue	Post-test [BLa]
Creatine	0.996	0.971	0.960	0.551	0.500*
Placebo	0.994	0.891	0.677	0.558	0.500*

Note: [BLa] = blood lactate concentration. Unless otherwise indicated, values were evaluated from the raw data of Glaister et al. (2006). *Estimated value.

Figure Legends

Figure 1. Flow chart of the search strategy used to identify studies examining the effects of short-term creatine supplementation (~20 g·d^{-1} for 3 – 7 days) on repeated sprint ability (number of sprints: 4 < n ≤ 20; sprint duration: ≤ 10 s; recovery duration: ≤ 90 s) and associated physiological responses.

Figure 2. A forest plot of studies that have investigated the effects of short-term creatine supplementation on body mass. Squares represent the mean difference in change scores (post supplementation – baseline), relative to placebo, with associated 95% confidence limits. The size of each square reflects the weighting given to each response. The diamond at the base of the plot represents the overall effect calculated from a random effects model; the width of the diamond representing the 95% confidence interval.

Figure 3. A forest plot of studies that have investigated the effects of short-term creatine supplementation on peak power output during a repeated sprint test. Squares represent the standardized mean difference in change scores (post supplementation – baseline), relative to placebo, with associated 95% confidence limits. The plot includes subgroup analyses of studies that used cycling versus running as the mode of exercise. The size of each square reflects the weighting given to each response. The diamond at the base of the plot (and at the base of each subgroup analysis) represents the overall effect calculated from a random effects model; the width of the diamond representing the 95% confidence interval.

Figure 4. A forest plot of studies that have investigated the effects of short-term creatine supplementation on mean power output during a repeated sprint test. Squares represent the standardized mean difference in change scores (post supplementation – baseline), relative to placebo, with associated 95% confidence limits. The plot includes subgroup analyses of studies that used cycling versus running

as the mode of exercise. The size of each square reflects the weighting given to each response. The diamond at the base of the plot (and at the base of each subgroup analysis) represents the overall effect calculated from a random effects model; the width of the diamond representing the 95% confidence interval.

Figure 5. A forest plot of studies that have investigated the effects of short-term creatine supplementation on fatigue percentage during a repeated sprint test. Squares represent the standardized mean difference in change scores (post supplementation – baseline), relative to placebo, with associated 95% confidence limits. The size of each square reflects the weighting given to each response. The diamond at the base of the plot represents the overall effect calculated from a random effects model; the width of the diamond representing the 95% confidence interval.

Figure 6. A forest plot of studies that have investigated the effects of short-term creatine supplementation on blood lactate concentration at the end of a repeated sprint test. Squares represent the mean difference in change scores (post supplementation – baseline), relative to placebo, with associated 95% confidence limits. The size of each square reflects the weighting given to each response. The diamond at the base of the plot represents the overall effect calculated from a random effects model; the width of the diamond representing the 95% confidence interval.

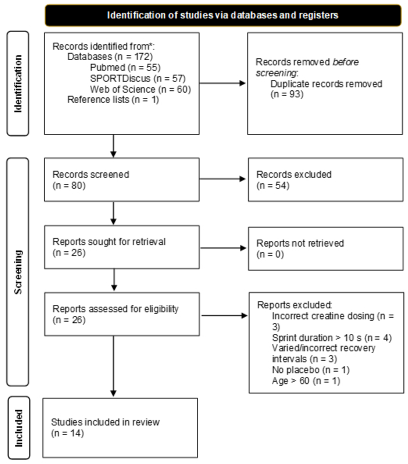

Figure 1. Flow chart of the search strategy used to identify studies examining the effects of short-term creatine supplementation (~20 $g \cdot d^{-1}$ for 3 – 7 days) on repeated sprint ability (number of sprints: $4 < n \leq 20$; sprint duration: ≤ 10 s; recovery duration: ≤ 90 s) and associated physiological responses.

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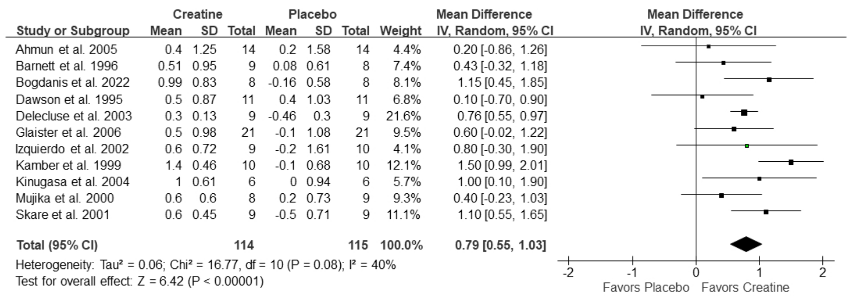

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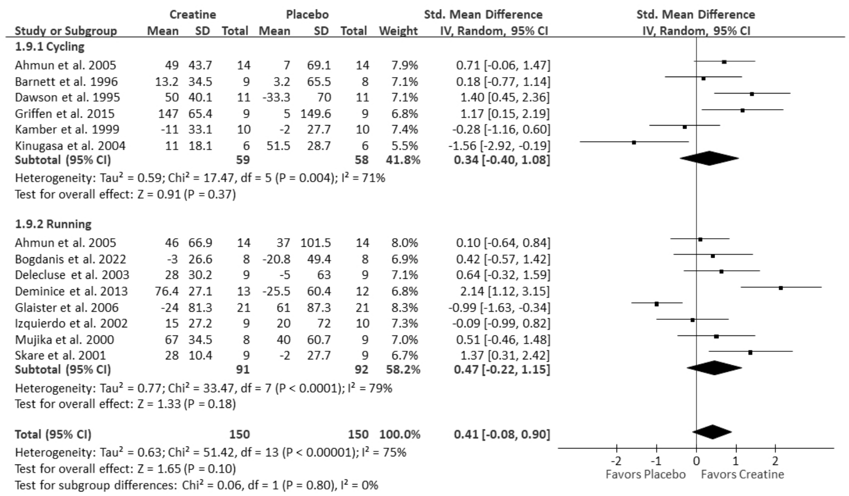

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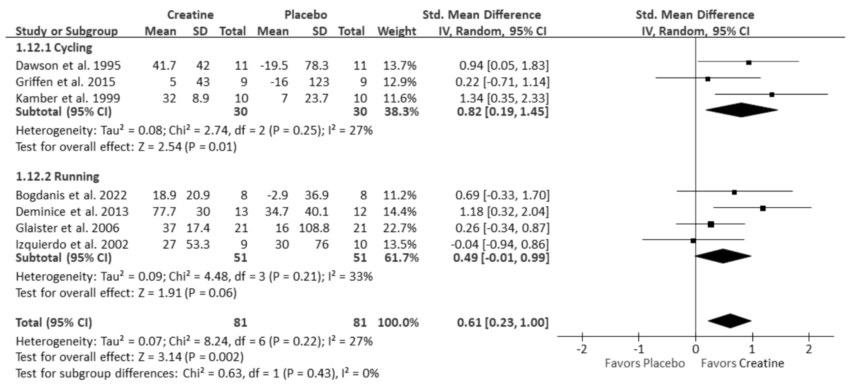

Figure 4. A forest plot of studies that have investigated the effects of short-term creatine supplementation on mean power output during a repeated sprint test. Squares represent the standardized mean difference in change scores (post supplementation – baseline), relative to placebo, with associated 95% confidence limits. The plot includes subgroup analyses of studies that used cycling versus running as the mode of exercise. The size of each square reflects the weighting given to each response. The diamond at the base of the plot (and at the base of each subgroup analysis) represents the overall effect calculated from a random effects model; the width of the diamond representing the 95% confidence interval.

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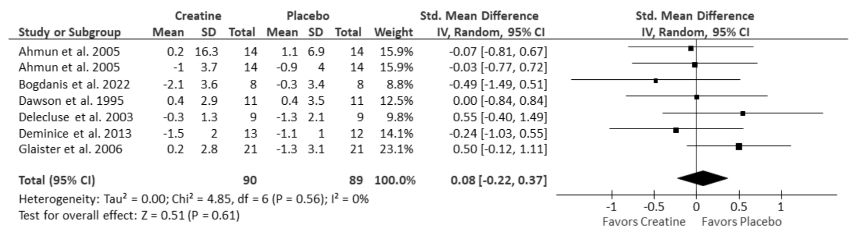

Figure 5. A forest plot of studies that have investigated the effects of short-term creatine supplementation on fatigue percentage during a repeated sprint test. Squares represent the standardized mean difference in change scores (post supplementation – baseline), relative to placebo, with associated 95% confidence limits. The size of each square reflects the weighting given to each response. The diamond at the base of the plot represents the overall effect calculated from a random effects model; the width of the diamond representing the 95% confidence interval.

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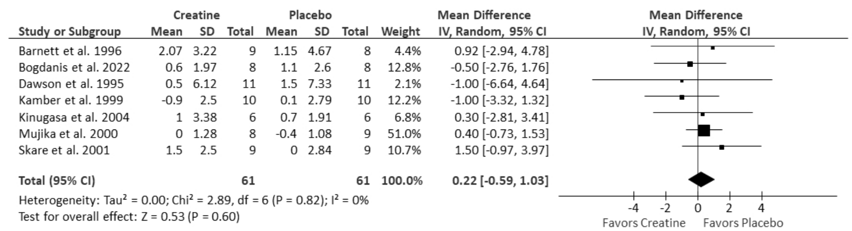

Figure 6. A forest plot of studies that have investigated the effects of short-term creatine supplementation on blood lactate concentration at the end of a repeated sprint test. Squares represent the mean difference in change scores (post supplementation – baseline), relative to placebo, with associated 95% confidence limits. The size of each square reflects the weighting given to each response. The diamond at the base of the plot represents the overall effect calculated from a random effects model; the width of the diamond representing the 95% confidence interval.

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