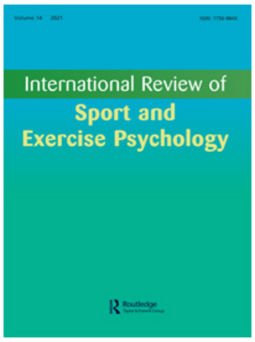

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The mechanisms underpinning the effects of self-control exertion on subsequent physical performance: a meta-analysis

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ABSTRACT

Prior self-control exertion is consistently reported to cause decrements in subsequent physical performance. However, research into the explanatory mechanisms underpinning the effect is limited and has not been assessed under a meta-analytical lens. Therefore, the present study reports a meta-analysis examining the effects of self-control exertion on subsequent physical performance, as well as the mechanisms underpinning the effect.

A systematic search of relevant databases was conducted to identify studies that utilized the sequential task paradigm, involving self-control manipulations lasting 30 minutes or less, and examined an aspect of physical performance. Random effects meta-analysis demonstrated that the prior exertion of self-control resulted in a statistically significant medium sized negative effect of prior self-control exertion on subsequent physical performance ($g = -0.55$). Further analysis revealed a small increase in initial perceptions of pain ($g = 0.18$) and a medium sized reduction in self-efficacy ($g = -0.48$), while motivation and RPE were unaffected following the exertion of self-control.

The present study provides a novel insight into the mechanisms underpinning the effects of prior self-control exertion on subsequent physical performance. Initial perceptions of pain and self-efficacy appear important mechanisms and thus could be targeted in future interventions aimed at attenuating the effects of self-control exertion to enhance subsequent physical performance.

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KEYWORDS
Self-control; cognitive exertion; mechanisms; pain; self-efficacy; motivation

1.0. Introduction

Self-control is defined as the ability to override and manage dominant response tendencies to regulate one's emotions and behaviours (Vohs & Baumeister, 2004). Exhibiting

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high levels of self-control is beneficial for a large range of adaptive behaviours; including those related to achievement, task performance, interpersonal functioning, and health (de Ridder et al., 2012). Self-control has also been shown to be important in a magnitude of sport-settings, including athletic performance (Englert, 2016, 2017), whereby athletes are required to control their impulses and behavioural tendencies to optimize sporting performance. For example, athletes need to force themselves to work persistently during strenuous physical exercise despite the desire to reduce effort to relieve the discomfort associated with achieving optimal performance (Wagstaff, 2014). A further example of the importance of self-control in an exercise setting is where individuals must routinely exert their self-control to persevere at gym work-out routines to achieve personal physical fitness goals (Bandura, 2005; Gillebaart & Adriaanse, 2017). It is however important to distinguish between self-control and self-regulation; self-regulation is considered an umbrella term that captures automatic and nonconscious regulatory processes, whereas self-control has been categorized as a specific form of self-regulation in which an individual exerts deliberate and conscious effort to control the self (Baumeister et al., 2007).

The ability to exert self-control has been shown to differ between individuals (i.e. trait self-control; Tangney et al., 2004), as well as across situations within the same individual (i.e. state self-control; Gailliot et al., 2012). High levels of trait self-control have been associated with various favourable behaviours important for optimal athletic performance, including training adherence (Englert, 2017). Regarding the state perspective of self-control, contemporary meta-analytical research has supported the notion that the initial exertion of self-control on one task impairs performance on a subsequent, seemingly unrelated task, also requiring self-control (Dang, 2017; Hagger et al., 2010). Referred to as the 'ego-depletion' effect, this phenomenon has generated a substantial amount of debate within the literature. While such meta-analytical evidence provides support (Dang, 2017; Hagger et al., 2010), the existence and/or true size of the effect has been questioned with Registered Replication Reports and meta-analyses failing to demonstrate support for the ego-depletion effect (e.g. Carter et al., 2015; Dang, 2018; Hagger et al., 2016; Vohs et al., 2021). Furthermore, while some of the meta-analyses (e.g. Carter et al., 2015; Hagger et al., 2010) included studies with physical outcomes, they did not carry out a sub-group analysis that explored the size of the depletion effect on different types of physical tasks, which has recently been suggested to influence the size of the effect (Graham & Brown, 2021). In addition, the multi-lab replication studies (e.g. Dang et al., 2021; Hagger et al., 2016) did not involve a physical task as the outcome measure. As a result, domain-specific carryover effects on subsequent physical performance cannot be ruled out. Therefore, more domain specific research is necessary to understand the true effect that prior self-control exertion has on subsequent physical task performance, and how this may be different across different physical performance task types.

Despite the ongoing controversy surrounding the ego-depletion effect, several theoretical models have been established to explain why self-control failures are seen in a multitude of performance contexts, including sport and exercise settings. The first of these, *the strength model of self-control,* implies that individuals possess a limited central resource of self-control, which can become depleted following a period of self-control exertion (Baumeister et al., 2007). Although this 'limited resource' perspective has received empirical and meta-analytical support (e.g. Dang, 2017; Hagger et al., 2010), it has also been challenged by evidence demonstrating that performance decrements following prior self-control exertion are not observable when participants were adequately motivated, using techniques such as providing monetary incentives (Brown & Bray, 2017a; Muraven & Slessareva, 2003) and offering choice (Moller et al., 2006). Consequently, doubts have arisen that self-control failure can be attributed to a single universal resource that becomes depleted (Inzlicht & Friese, 2019).

An alternative explanation is the *shifting priorities model* (Inzlicht & Schmeichel, 2016; Milyavskaya & Inzlicht, 2017); which suggests that initial self-control exertion results in a shift in attentional and motivational foci, whereby the desire to exert additional self-control to achieve distal goals (i.e. optimal performance) is reduced, while the desire to concede to the tempting proximal goal (i.e. reducing discomfort) is increased (Taylor et al., 2020). These tenets are also consistent with the *opportunity-cost conceptualizations* of self-control, whereby individuals weigh the benefits of pursuing a specific task against its costs (Kurzban et al., 2013; Wolff & Martarelli, 2020).

To provide empirical support for the theoretical models of self-control researchers have typically implemented the 'sequential-task paradigm' to examine the effects of self-control exertion on a subsequent, assumedly unrelated task, also requiring self-control (Baumeister et al., 2007). Within this paradigm, the experimental (self-control exertion) condition requires participants to complete two tasks necessitating self-control. Conversely, the control (non-self-control exertion) condition requires participants to exert self-control only during the second performance task. The self-control tasks that are frequently employed require participants to resist impulses or temptations created by instinctive and well-learned responses (Arber et al., 2017; Baumeister et al., 2007). For example, self-control is often manipulated using a Stroop task (e.g. Boat & Taylor, 2017; Englert & Wolff, 2015). In the self-control exertion condition, participants complete an incongruent Stroop task where the aim of the task is to select the font colour (requiring well-learned responses to be overridden); whereas in the non-self-control exertion condition, participants instead complete a congruent Stroop task (requiring no overriding of well-learned responses). Both versions of the Stroop task involve a central stimulus word (always a colour) being presented to participants. Participants are required to select the font colour instead of the word itself. In the congruent Stroop task, the target word, and the font colour will be matched (e.g. 'blue' written in a blue font). In the incongruent Stroop task, the target word and font colour will be mis-matched (e.g. 'blue' written in red font), thus requiring the inhibition of well-learned dominant responses.

The detrimental effects of self-control exertion on subsequent physical task performance have been substantiated during endurance cycling tasks (Englert & Wolff, 2015; Boat et al., 2017), skill-based tasks (e.g. Darts; McEwan et al., 2013; Basketball; Englert, Bertrams, et al., 2015) and simple physical persistence tasks (e.g. wall-sit task; Boat & Taylor, 2017; handgrip task; Bray et al., 2012; sit-up task; Dorris et al., 2012). This has been corroborated by recent meta-analytical evidence demonstrating that prior self-control exertion impairs subsequent physical performance (Brown et al., 2020; Giboin & Wolff, 2019). However, it is important to note that these previous meta-analyses have combined studies examining the effects of self-control exertion and mental fatigue on subsequent physical performance, despite suggestions that there are clear differences between these two constructs (Englert, 2016, 2019). For example, tasks that are utilized to induce mental fatigue typically last considerably longer (e.g. 90 minutes AX-continuous performance task; Marcora et al., 2009) than the tasks that are employed in self-control exertion research (e.g. 4-minute Stroop task; Boat et al., 2021). Therefore, it has been argued that typical self-control depletion tasks are not long enough to induce subjective feelings of effort and mental fatigue (Pageaux et al., 2013). However, other researchers have suggested that ego-depletion may be a brief manifestation of mental fatigue (Inzlicht & Berkman, 2015) and shorter, yet more effortful cognitive manipulations can promote equivalent levels of mental fatigue to the traditional longer manipulations (Brown & Bray, 2017a; Brown & Bray, 2019). Moreover, self-control exertion and mental fatigue both evidently lead to performance decrements, which may be a result of an unwillingness to employ further effort rather than incapacity (Englert, 2017; Hockey, 2013; Inzlicht & Schmeichel, 2012) and may be overcome with adequate task-motivation (Muraven & Slessareva, 2003). There may also be similarities in the mechanistic underpinnings of self-control and mental fatigue. For example, theories of self-control (e.g. Inzlicht & Schmeichel, 2016; Kurzban et al., 2013; Milyavskaya & Inzlicht, 2017) and the *psychobiological model of fatigue* (Marcora, 2008; Marcora et al., 2008; Marcora et al., 2009; Marcora & Staiano, 2010) highlight aspects of motivation as a key mechanism underpinning exercise tolerance. However, the mechanisms specific to self-control, or mental fatigue, have never been collated and analyzed under a meta-analytical lens.

Understanding the mechanisms underpinning the effects of self-control exertion on subsequent physical performance is important to allow for a more complete understanding of *how* and *why* self-control exertion affects performance, and to allow the development of specific targeted interventions aimed at attenuating the effects. The mechanisms that have been proposed to date derive from the two key theories of self-control previously mentioned, yet evidence for these mechanisms is limited and discordant. For instance, support for the *shifting priorities model* has been demonstrated with suggestions that differences in initial perceptions of pain and motivation provide quantifiable shifts in motivational and attentional foci to explain self-control failures (e.g. Boat et al., 2020). Conversely, measurements of motivation, emotion, and attention did not mediate the relationship between self-control exertion and physical task performance (e.g. Stocker et al., 2020). Using a meta-analytical lens to provide a consensus regarding which proposed mechanisms of self-control failure appear to be associated with subsequent reductions in physical performance after completing a self-control exertion task lasting 30 minutes or less, would provide some clarity on this important issue.

Therefore, the aim of this present study is two-fold. Firstly, we will provide a comprehensive meta-analysis of the effects of self-control exertion on subsequent physical performance. This will include an examination of key moderating variables such as study design and physical performance task type, to explore methodological factors that may influence the reported effects of self-control exertion on physical performance. Secondly, we will adopt a meta-analytical approach to examine the mechanisms underpinning the effects of self-control exertion on subsequent physical performance.

2.0. Methods

The PRISMA guidelines on protocols and reporting in systematic reviews and meta-analyses were followed (Moher et al., 2009). A full overview of the checklist can be found with the additional material (see Electronic Supplementary Material: Table S1).

2.1. Eligibility criteria

Studies published prior to June 2021 (the month selected to conclude the systematic search) were considered for review. Studies had to be performed on healthy humans and written in English. Studies also had to utilize the sequential task paradigm in which participants engaged in two consecutive tasks (Baumeister et al., 2007). In the self-control exertion condition, there was the necessity that studies included a cognitive exertion task that has been shown to deplete self-control by requiring well-learned responses to be overridden (e.g. incongruent Stroop task, transcription task with instruction to omit letters). In the control condition, it was essential that self-control was not exerted in the first task, with tasks employed not requiring any overriding of well-learned responses (e.g. congruent Stroop task, transcription task with no additional instructions). For clarity, the common cognitive exertion tasks that were employed in the included studies were: (i) incongruent Stroop task; (ii) transcribing tasks; (iii) solving hard labyrinths; (iv) regulating emotions while watching an emotion-based video clip. In an attempt to focus solely on studies examining self-control exertion, the duration of the initial exertion task was required to be less than 30 minutes, as this duration is typically associated with self-control exertion studies (e.g. Boat et al., 2020; Englert & Wolff, 2015; Wagstaff, 2014), whereas cognitive manipulations exceeding 30 minutes in duration are suggested to elicit mental fatigue (e.g. Marcora et al., 2009). Therefore, in the present meta-analysis we focused only on self-control tasks 30 minutes or less in duration.

In accordance with the sequential-task paradigm, performance tasks had to require self-control and be objective measures of physical performance (e.g. handgrip task, cycling time trial). Outcome performance tasks were split into four categories: (i) isometric: outcomes included holding a posture or producing maximal force for as long as possible; (ii) aerobic: outcomes involved any type of endurance activity, namely covering a given distance in as short a time as possible, or covering as much distance or generating as much work as possible until volitional exhaustion; (iii) dynamic: outcomes involved completing as many repetitions of a particular movement, in a given time or until volitional exhaustion/failure; (iv) motor skill performance: outcomes involved measures such as number of false starts and reaction times/accuracy on skill-based tasks. Once studies met the above criteria, they were also assessed to see if they measured any potential mechanisms underpinning the effects of self-control exertion on subsequent physical performance.

All relevant statistical information to calculate effect sizes was required for all studies. The Cochrane Handbook (Higgins et al., 2019) was used to follow protocols surrounding missing data (e.g. using data from previous studies to impute missing standard deviations; Furukawa et al., 2006). A full breakdown of methods used can be found in the Data Synthesis section. In addition, missing data from eligible studies was also requested by contacting the corresponding authors. If these protocols could not be implemented or missing data was not received from authors, studies were excluded.

2.2. Search strategy and study selection

A systematic review of the literature was carried out using Science Direct ($n = 213$), Web of Science ($n = 749$), PubMed ($n = 119$) and SPORTDiscuss ($n = 576$). To find relevant publications, searches were conducted with the following keywords search: '(self-control OR ego-depletion) AND (physical OR task OR activity OR endurance OR exercise OR skill OR exert)'. This search resulted in 1,682 publications which was reduced to 1,411 once duplicates were removed (search concluded June 2021). Publications were screened for eligibility from their title and abstract, resulting in 55 papers being selected for a full text review. An additional reverse citation search produced 5 additional papers to be included. The full text review led to an additional 16 papers being excluded due to not fully meeting the eligibility criteria. Forty-four articles were included in the meta-analysis, producing 50 comparisons for the effects of self-control exertion on subsequent physical performance. Furthermore, these studies provided 61 comparisons for the exploration of the mechanisms underpinning the effects of self-control exertion on subsequent physical performance (see Figure 1 for PRISMA flow diagram).

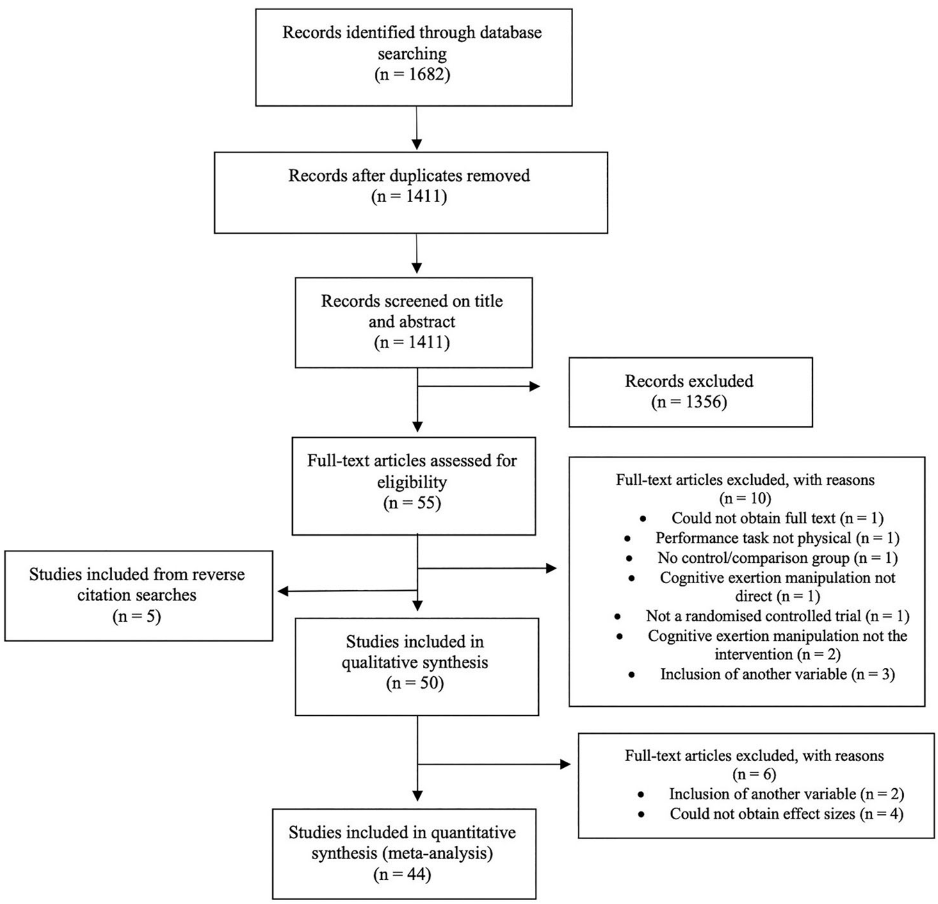

Figure 1. PRISMA study selection flowchart (Moher et al., 2009).

2.3. Data extraction

Data including sample characteristics (e.g. participant demographic and number) and study characteristics (e.g. depletion task used, study design) were collated, alongside means and standard deviations for measures of physical performance and the underpinning mechanisms. The mechanisms that provided a substantial amount of data (at least 3 effect sizes; Valentine et al., 2010) were pain (split by overall pain, pain at the start of the physical performance task, and pain at the end of the physical performance task), motivation, self-efficacy, and ratings of perceived exertion (RPE). For all variables, if the data were presented graphically, numerical data were attained using ImageJ (ImageJ 1.53v, NIH, Bethesda, MD, USA).

2.4. Risk of bias

The risk of bias for each publication was assessed by three reviewers independently, using the risk bias tool in Review Manager (RevMan 5.4; The Cochrane Collaboration, 2020) (https://tech.cochrane.org/revman) software. Across five domains (selection bias, performance bias, detection bias, attrition bias and reporting bias) publications were labelled as 'low risk', 'unclear risk' or 'high risk'. Where there was disagreement, a consensus was achieved through discussions (see Figure 2 for risk of bias assessment).

2.5. Data synthesis

Hedge's *g* effect sizes were calculated to summarize estimates of effect, calculated using standard procedures ($M_1 - M_2 / SD_{\text{pooled}}$) (Higgins et al., 2019). For the handful of studies that used handgrip tasks as a performance outcome, Hedge's *g* was calculated using provided change scores (i.e. effect sizes were calculated using the difference of performance before and after the cognitive manipulation was administered) to enhance the precision of effect size estimation (Higgins et al., 2019). Two studies (Graham et al., 2017; McEwan et al., 2013) provided multiple effect sizes for one physical performance outcome; following the Cochrane Handbook recommendations (Higgins et al., 2019) these outcomes were combined using the RevMan 5.4 calculator to produce a single pair-wise comparison. Two studies (Boat et al., 2020; Brown & Bray, 2017b) provided multiple effect sizes over several time points. To avoid a unit-of-analysis error (i.e. double counting), the control group participant sample was shared across the pairwise comparisons (Higgins et al., 2019). Two studies (Brown & Bray, 2017b; Ciarocco et al., 2001) did not provide sufficient standard deviation data to calculate the necessary effect sizes; as per recommendations (Furukawa et al., 2006; Higgins et al., 2019) an average of standard deviations was taken from similar handgrip studies included in the meta-analysis (Alberts et al., 2007; Bray et al., 2008; Bray et al., 2013; Graham & Bray, 2012; Graham & Bray, 2015) to impute estimated standard deviations (*SD self-control depletion condition* = 17.49 s; *SD control condition* = 23.71 s). Five studies (Alberts et al., 2007; Brown & Bray, 2017a, 2019; Shaabani et al., 2020; Yusainy & Lawrence, 2015) included a secondary experimental manipulation (e.g. persistence priming vs. neutral priming; mindfulness intervention vs. no mindfulness intervention), in this instance only the data from the condition that did not involve the secondary

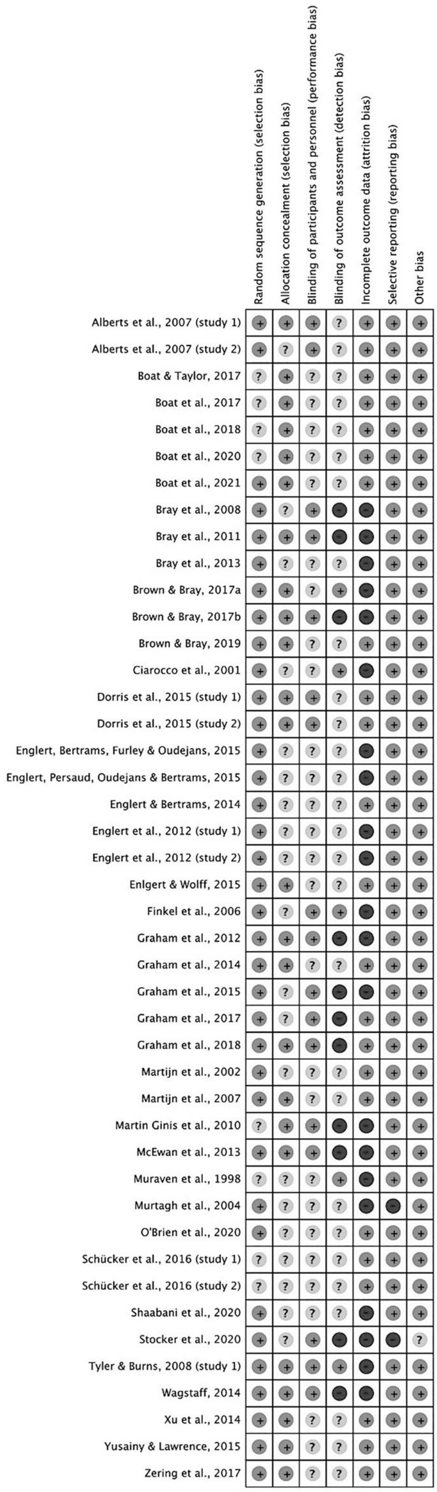

Figure 2. Summary of risk of bias assessment of the included studies. Key: '+' low risk, '–' high risk, '?' unclear risk.

manipulation were included (i.e. high self-control exertion & neutral condition compared to low self-control exertion & neutral condition). Similar protocols were followed for the investigation into the mechanisms. To calculate one single effect size for the 'overall pain' subgroup, the start of task pain and end of task pain effect sizes provided in four studies were combined (Boat & Taylor, 2017; Boat et al., 2018, 2020, 2021). These effect sizes were also analyzed independently. Seven studies provided two or more effect sizes for measures of motivation (Boat et al., 2018, 2020, 2021; Brown & Bray, 2017b; Brown & Bray, 2019; Graham & Bray, 2015; Stocker et al., 2020). Similarly, these were combined to align with recommendations (Higgins et al., 2019).

2.6. Meta-analysis

All analyses were conducted using RevMan 5.4. Due to the varied methods of data collection, a random effects model was used. Firstly, a comprehensive meta-analysis of the effects of self-control exertion on subsequent physical performance was performed, including an examination of key moderating variables such as study design and physical performance task type. Heterogeneity was explored using the Cochrane Q (x^2) test and summarized with the I^2 statistic. Sensitivity analysis was conducted by removing one study at a time to analyse its influence on the overall effect size (see Electronic Supplementary Material: Table S2). Subsequently, a separate meta-analysis was conducted to examine the mechanisms underpinning the effects of self-control exertion on subsequent physical performance.

3.0. Results

3.1. Included studies

Forty-four articles provided a total of 50 comparisons with 2315 participants (not adjusted for within-subject designs) (see Figure 3). Study characteristics and outcomes are outlined in Table 1.

3.2. Risk of bias

A summary of the risk of bias for each included study is presented in Figure 2. All studies were rated as low risk for selective reporting as all relevant information was considered present. Twenty-three out of 44 were rated high-risk in at least one domain. A rating of high risk or unclear risk was commonly a result of a lack of allocation concealment (selection bias) and blinding protocols (performance and detection bias) being employed. In addition, studies often reported incomplete outcome data (attrition bias).

3.3. Meta-analyses

3.3.1. Overall effect

Results showed that 44 of the 50 comparisons resulted in a negative effect of self-control exertion on physical task performance (see Figure 3). Overall, a significant medium

Study or Subgroup	Std. Mean Difference IV, Random, 95% CI	Year
Muraven et al., 1998	−0.15 [−0.77, 0.47]	1998
Ciarocco et al., 2001	−0.93 [−1.77, −0.10]	2001
Martijn et al., 2002	−0.70 [−1.41, 0.01]	2002
Murtagh et al., 2004	−0.07 [−0.55, 0.42]	2004
Finkel et al., 2006	−0.63 [−1.43, 0.16]	2006
Alberts et al., 2007 (study 1)	−0.86 [−1.53, −0.19]	2007
Alberts et al., 2007 (study 2)	−1.58 [−2.32, −0.84]	2007
Martijn et al., 2007	−0.68 [−1.15, −0.20]	2007
Bray et al., 2008	−0.51 [−1.08, 0.06]	2008
Tyler & Burns, 2008 (study 1)	−0.92 [−1.86, 0.01]	2008
Martin Ginis et al., 2010	−0.32 [−0.83, 0.18]	2010
Bray et al., 2011	−0.69 [−1.20, −0.17]	2011
Englert et al., 2012 (study 1)	−0.25 [−0.74, 0.24]	2012
Englert et al., 2012 (study 2)	−0.23 [−0.86, 0.39]	2012
Graham et al., 2012	−0.19 [−1.02, 0.64]	2012
Bray et al., 2013	−0.36 [−0.93, 0.21]	2013
McEwan et al., 2013	−0.12 [−0.59, 0.36]	2013
Englert & Bertrams, 2014	−0.54 [−1.20, 0.12]	2014
Graham et al., 2014	−0.86 [−1.44, −0.28]	2014
Wagstaff, 2014	−0.53 [−1.16, 0.10]	2014
Xu et al., 2014	0.19 [−0.20, 0.58]	2014
Dorris et al., 2015 (study 1)	−0.48 [−1.06, 0.09]	2015
Dorris et al., 2015 (study 2)	−0.26 [−0.83, 0.31]	2015
Englert, Bertrams, Furley & Oudejans, 2015	−0.83 [−1.57, −0.09]	2015
Englert, Persaud, Oudejans & Bertrams, 2015	−1.10 [−1.79, −0.41]	2015
Enlgert & Wolff, 2015	−0.36 [−0.98, 0.27]	2015
Graham et al., 2015	−0.78 [−1.46, −0.11]	2015
Yusainy & Lawrence, 2015	−0.37 [−0.90, 0.17]	2015
Schücker et al., 2016 (study 1)	−0.04 [−0.84, 0.76]	2016
Schücker et al., 2016 (study 2)	0.01 [−0.73, 0.75]	2016
Boat & Taylor, 2017	−1.83 [−2.25, −1.42]	2017
Boat et al., 2017	−0.26 [−1.00, 0.49]	2017
Brown & Bray, 2017a	−0.86 [−1.50, −0.21]	2017
Brown & Bray, 2017b	0.02 [−0.96, 1.00]	2017
Brown & Bray, 2017b	0.26 [−0.82, 1.33]	2017
Brown & Bray, 2017b	−0.57 [−1.65, 0.51]	2017
Brown & Bray, 2017b	−0.31 [−1.38, 0.76]	2017
Brown & Bray, 2017b	−0.42 [−1.50, 0.66]	2017
Graham et al., 2017	−1.10 [−1.70, −0.50]	2017
Zering et al., 2017	−0.11 [−0.83, 0.61]	2017
Boat et al., 2018	−1.83 [−2.27, −1.38]	2018
Graham et al., 2018	−1.02 [−1.52, −0.52]	2018
Brown & Bray, 2019	−0.73 [−1.21, −0.26]	2019
Boat et al., 2020	−0.36 [−1.09, 0.36]	2020
Boat et al., 2020	−0.52 [−1.25, 0.21]	2020
Boat et al., 2020	−1.15 [−1.95, −0.36]	2020
O'Brien et al., 2020	−0.15 [−0.67, 0.37]	2020
Shaabani et al., 2020	−0.83 [−1.51, −0.14]	2020
Stocker et al., 2020	0.18 [−0.29, 0.65]	2020
Boat et al., 2021	−0.07 [−0.79, 0.64]	2021
Total (95% CI)	**−0.55 [−0.70, −0.39]**	

Heterogeneity: $Tau^2 = 0.19$; $Chi^2 = 145.40$, df = 49 (P < 0.00001); $I^2 = 66\%$
Test for overall effect: Z = 7.01 (P < 0.00001)

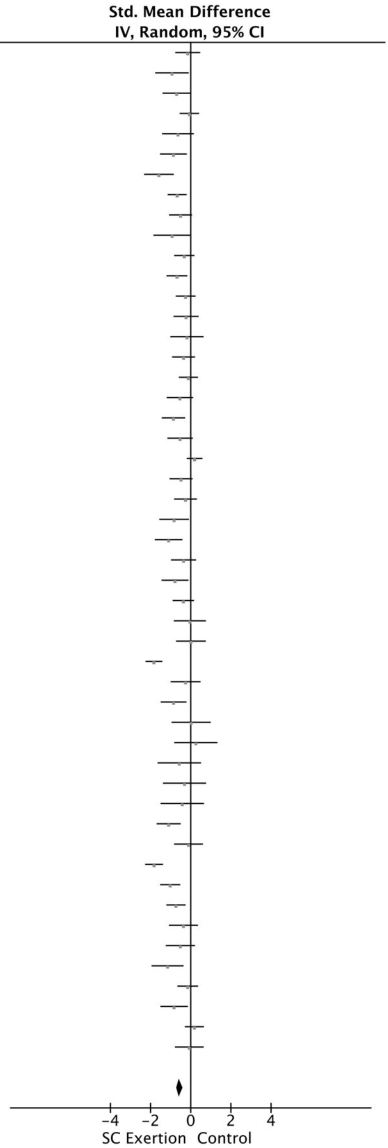

Figure 3. Forest plot of the studies examining the effects of prior self-control exertion on physical task performance.

negative effect of prior self-control exertion on physical task performance was found ($g = -0.55$ [−0.70, −0.39], $Z = 7.01$, $p < 0.001$). Heterogeneity analysis demonstrated significant heterogeneity for the overall effect ($Q(49) = 145.40$, $p < 0.001$, $T^2 = 0.19$, $I^2 = 66$), therefore, the decision to conduct subgroup analyses examining the factors that could impact the effect was justified (see Figure 3).

Results of the sensitivity analyses (see Electronic Supplementary Material: Table S2) revealed a stable significant effect size ranging from $g = -0.53$ [−0.67, −0.40] (when excluding the study by Boat & Taylor, 2017) to $g = -0.59$ [−0.74, −0.44] (when excluding the study by Xu et al., 2014).

Table 1. Study characteristics and outcomes.

Study	Participants	*N*	*N* (control)	Design	Cognitive task	Control task	Cognitive task duration	Performance task	Main effect on performance	Mechanism(s) assessed
Muraven et al. (1998) study 1	University students	20	20	Between	Regulate emotions while watching emotion-based video clip	Watching the same video clip with no emotion regulation instructions	3 min	Handgrip TTE	Time to failure decreased	–
Ciarocco et al. (2001)	University students (recreationally active)	12	12	Between	Ostracism condition	Conversation condition	3 min	Handgrip TTE	Time to failure decreased	–
Martijn et al. (2002)	University students	17	16	Between	Regulate emotions while watching emotion-based video clip	Watching the same video clip with no emotion regulation instructions	3 min	Handgrip TTE	Time to failure decreased	–
Murtagh and Todd (2004)	University students	42	27	Between	Incongruent Stroop task	Congruent Stroop task	15 min	Handgrip TTE	No significant difference in time to failure	–
Finkel et al. (2006)	University students	13	13	Between	Inefficient social coordination	Efficient social coordination	6 min	Handgrip TTE	Time to failure decreased	–
Alberts et al. (2007) study 1	University students (recreationally active)	19	19	Between	Solving hard labyrinths	Solving easy labyrinths	10 min	Handgrip TTE	Time to failure decreased	–
Alberts et al. (2007) study 2	University students (recreationally active)	19	19	Between	Calculating difficult sums + video distraction	Calculating easy sums + no video distraction	8 min	Holding a 1.5-kg weight TTE	Time to failure decreased	–
Martijn et al. (2007)	University Students	37	36	Between	Solving hard labyrinths	Solving easy labyrinths	10 min	Handgrip TTE	Time to failure decreased	–
Bray et al. (2008)	University students (sedentary)	26	23	Between	Incongruent Stroop task	Congruent Stroop task	3 min 40 sec	Handgrip TTE (isometric) + Handgrip maximum voluntary contraction (anaerobic)	Time to failure decreased (Isometric) No significant change in peak force (anaerobic)	EMG activation; RPE

(*Continued*)

Table 1. Continued.

Study	Participants	*N*	*N* (control)	Design	Cognitive task	Control task	Cognitive task duration	Performance task	Main effect on performance	Mechanism(s) assessed
Tyler and Burns (2008)	University students	10	10	Between	Arithmetic while standing on one leg	Counting backwards from 2000 in 5's while standing on both feet	6 min	Handgrip TTE	Time to failure decreased	–
Martin Ginis and Bray (2010)	University students (recreationally active)	31	30	Between	Incongruent Stroop task	Congruent Stroop task	3 min 40 sec	10 min cycling	Decrease in exercise work output (kilojoules)	–
Bray et al. (2011)	Older adults	33	28	Between	Incongruent Stroop task	Congruent Stroop task	3 min 40 sec	Handgrip TTE	Time to failure decreased	–
Dorris et al. (2012) study 1	Highly trained and experienced college athletes	24		Within	Counting backwards from 1000 in 7's + holding a spirit level	Counting backwards from 1000 in 5's	Not standardized (till counting finished)	Press Ups	Less press up reps completed	–
Dorris et al. (2012) study 2	Highly trained and experienced college athletes	24		Within	Counting backwards from 1000 in 7's + holding a spirit level	Counting backwards from 1000 in 5's	Not standardized (till counting finished)	Sit Ups	Less sit up reps completed	–
Englert and Bertrams (2012) study 1	Experienced male basketball players	32	32	Between	Transcribing task	Transcribing task (no instructions to omit letters)	6 min	Basketball Free throws	No significant difference in free throw success rate /10	–
Englert and Bertrams (2012) study 2	Experienced male basketball players	21	19	Between	Transcribing task (instructions to omit letters)	Transcribing task (no instructions to omit letters)	6 min	Dart Throwing	No significant difference in throwing accuracy	–
Graham & Bray (2012)	University students (recreationally active)	15	9	Between	Guided imagery	Quite rest	6 min	Handgrip TTE	No significant difference in time to failure	–
Bray et al. (2013)	University students (recreationally active)	24	24	Between	Incongruent Stroop task	Congruent Stroop task	5 min	Handgrip TTE	Time to failure decreased	–

McEwan et al. (2013)	Young adults, inexperienced dart players	31	31	Between	Incongruent Stroop task	Congruent Stroop task	5 min	Dart Throwing	Reduced throwing accuracy No significant difference in reaction time	–
Englert and Bertrams (2014)	University students (with sprinting experience)	18	19	Between	Transcribing task (instructions to omit letters)	Transcribing task (no instructions to omit letters)	6 min	Sprint start (reaction time recorded)	Increased reaction time	–
Graham et al. (2014)	University students	25	25	Between	Imagery	Quiet rest	3 min	Handgrip TTE	Time to failure decreased	–
Wagstaff (2014)	Experienced cyclists	20		Within	Regulate emotions while watching emotion-based video clip	Watching the same video clip with no emotion regulation instructions	3 min	Cycling 10 km	Increased completion time	RPE
Xu et al. (2014)	Community adults and young adults	51		Within	Transcribing task (crossing out letters task)	Transcribing task (only ask to omit the letter 'e')	8 min	Handgrip TTE	No significant difference in time to failure	–
Englert, Bertrams, et al. (2015)	Experienced male basketball players	16	15	Between	Transcribing task (instructions to omit letters)	Transcribing task (no instructions to omit letters)	6 min	Basketball free throws	Decrease in free throw success rate	–
Englert, Persaud, et al. (2015)	Experienced female soccer players	19	19	Between	Transcribing task (instructions to omit letters)	Transcribing task (no instructions to omit letters)	6 min	Sprint starts	Increase in false starts	–
Englert and Wolff (2015)	University students	20		Within	Incongruent Stroop task	Congruent Stroop task	Time to complete 80 trials (time not reported)	Cycle as fast as possible for 18 min at fixed workload	Reduced bpm and rpm	RPE
Graham and Bray (2015)	University students (recreationally active)	19	18	Between	Incongruent Stroop task	Congruent Stroop task	5 min	Handgrip TTE	Time to failure decreased	Motivation; Self-efficacy; RPE; Arousal
Yusainy and Lawrence (2015)	Young adults	27	28	Between	Attentional control task	Attentional control task (with no instructions)	6 min	Handgrip TTE	Time to failure decreased	–

(*Continued*)

Table 1. Continued.

Study	Participants	*N*	*N* (control)	Design	Cognitive task	Control task	Cognitive task duration	Performance task	Main effect on performance	Mechanism(s) assessed
Schücker and MacMahon (2016) study 1	Trained athletes	12		Within	Incongruent Stroop task	Congruent Stroop task	10 min	Beep test	No significant difference in completion time	–
Schücker and MacMahon (2016) study 2	Trained athletes	14		Within	Incongruent Stroop task	Congruent Stroop task	10 min	Beep test	No significant difference in completion time	–
Boat and Taylor (2017)	Young people (recreationally active)	63		Within	Incongruent Stroop task	Congruent Stroop task	4 min	Wall-sit	Time to failure decreased	Perceptions of Pain
Boat et al. (2017)	Experienced cyclists	14		Within	Incongruent Stroop task	Congruent Stroop task	4 min	Cycling 16 km	Increased completion time	Glucose
Brown and Bray (2017a)	University students (recreationally active)	20	21	Between	Incongruent Stroop task	Documentary	10 min	Handgrip TTE	Reduced time to failure	Motivation, EMG activation, RPE
Brown and Bray (2017b)	University students (recreationally active)	123	21/20, 20,21,21,21	Between	Incongruent Stroop task	Documentary	0,2,4,6,8,10 min	Handgrip TTE	Reduced time to failure	Motivation; Self-efficacy; RPE
Graham et al. (2017)	University students (recreationally active)	25	25	Between	Incongruent Stroop task	Congruent Stroop task	5 min	Bench Press & Leg Extension	Reduced repetitions for both bench press & leg extensions	Motivation; Self-efficacy; RPE
Zering et al. (2017)	Young people (recreationally active)	15		Within	Stop-signal task	Documentary	10 min	Cycling (graded exercise test)	Reduced peak power (Watts)	RPE
Boat et al. (2018)	Young people (recreationally active)	55		Within	Incongruent Stroop task	Congruent Stroop task	4 min	Wall-sit	Reduced time to failure	Perceptions of Motivation and Pain
Graham et al. (2018)	Children	33	37	Between	Incongruent Stroop task	Congruent Stroop task	1 min	Handgrip TTE	Reduced time to failure	Motivation
Brown and Bray (2019)	University students	36		Within	Incongruent Stroop task	Documentary	10 min	Cycling (work completed in 20 min)	Decrease in total work	Motivation, RPE, Goal commitment, Heart rate biofeedback

Boat et al. (2020)	University students (recreationally active)	29		Within	Incongruent Stroop task	Congruent Stroop task	4, 8, 16 min	Wall-sit	Reduced time to failure	Perceptions of Motivation and Pain
O'Brien et al. (2020)	University students (recreationally active)	29		Within	Transcribing task (instructions to omit letters)	Transcribing task (no instructions to omit letters)	6 min	Handgrip TTE	No significant difference in time to failure	Challenge and threat states; Cerebral perfusion
Shaabani et al. (2020)	Male basketball players	18	18	Between	Modified Stroop Task	No intervention/ task	15 min	Basketball free throws	Decrease in free throw success rate	–
Stocker et al. (2020)	University students	34	34	Between	Transcribing task (instructions to omit letters)	Transcribing task (no instructions to omit letters)	6 min	Bicep Endurance task	No significant difference in time to failure	Motivation, Emotion, Attention
Boat et al. (2021)	Male cyclists (recreationally trained)	15		Within	Incongruent Stroop task	Congruent Stroop task	4 min	10 km cycling time-trials	No significant difference in overall performance time	Perceptions of Motivation and Pain, RPE

TTE time to exhaustion, km kilometres, EMG electromyography, RPE rating of perceived exertion, BPM beats per minute, RPM revolutions per minute a '–' in the 'mechanism(s) assessed' column indicates that no mechanisms were assessed in the relevant study.

3.3.2. Study design

Studies that implemented a within-subject design demonstrated a similar significant medium negative effect of self-control exertion on physical task performance ($g = -0.53$ [−0.87, −0.20], $Z = 3.13$, $p = 0.002$), when compared to studies that implemented a between-subject design ($g = -0.54$ [−0.68, −0.40], $Z = 7.40$, $p < 0.001$) (see Figure 4a).

There was significant heterogeneity in terms of study design for publications that employed a within-subjects design ($Q(17) = 95.50$, $p < 0.001$, $T^2 = 0.42$, $I^2 = 82$), and between-subjects design ($Q(31) = 48.85$, $p = 0.02$, $T^2 = 0.06$, $I^2 = 37$).

3.3.3. Type of physical performance task

The subgroup analysis demonstrated a significant negative effect of self-control exertion on physical task performance for all physical task types. The largest negative effect was found for isometric physical tasks ($g = -0.62$ [−0.84, −0.39], $Z = 5.32$, $p < 0.001$). A large negative effect size was also found for dynamic physical tasks ($g = -0.61$ [−1.09, −0.12], $Z = 2.44$, $p = 0.01$), while smaller negative effect sizes were found for studies that implemented aerobic ($g = -0.36$ [−0.58, −0.14], $Z = 3.19$, $p = 0.001$) and motor skill ($g = -0.45$ [−0.71, −0.20], $Z = 3.47$, $p < 0.001$) tasks (see Figure 4b).

There was significant heterogeneity in terms of type of physical performance task for studies that employed an isometric physical performance task ($Q(30) = 120.33$, $p < 0.001$, $T^2 = 0.29$, $I^2 = 75$). Heterogeneity was not observed in studies that employed aerobic ($Q(7) = 4.92$, $p = 0.67$, $T^2 = 0.00$, $I^2 = 0$), motor skill ($Q(7) = 9.50$, $p = 0.22$, $T^2 =$

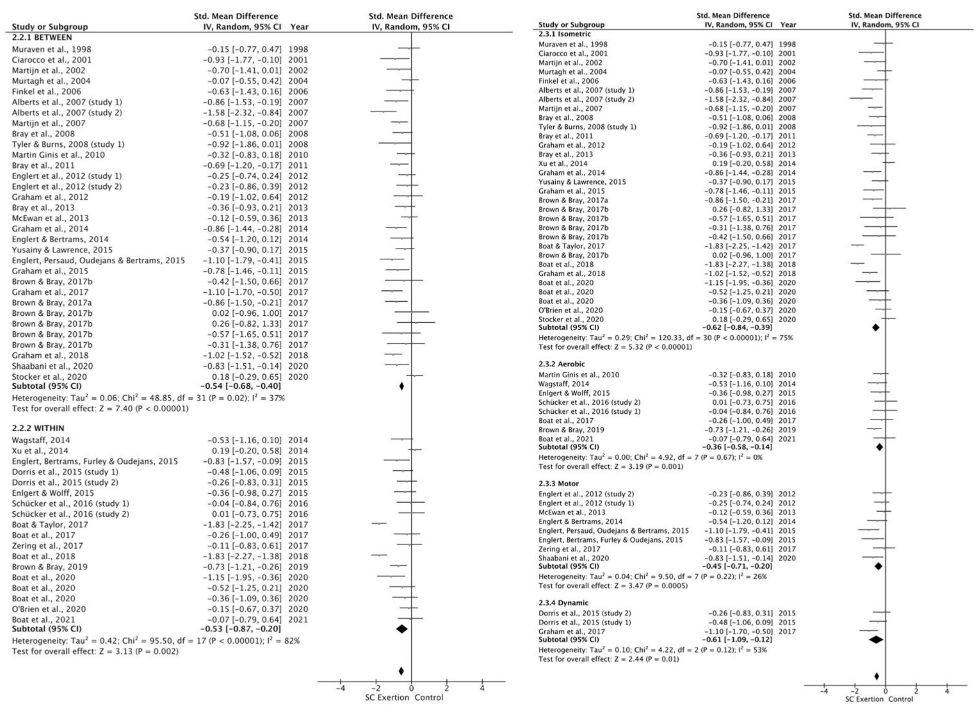

Figure 4. Forest plots displaying the results of the subgroup analysis of the effects of prior self-control exertion on physical performance (Figure 4a: Study design; Figure 4b: Performance task type).

0.04, $I^2 = 26$) or dynamic ($Q(2) = 4.22$, $p = 0.12$, $T^2 = 0.10$, $I^2 = 53$) physical performance tasks.

3.4. Mechanisms analyses

3.4.1. Pain

There was no statistically significant effect of self-control exertion on participants' overall perceptions of pain ($g = 0.08$ [−0.08, 0.24], $Z = 1.01$, $p = 0.31$) (see Figure 5a). However, there was a statistically significant small effect of self-control exertion on participants' initial perceptions of pain ($g = 0.18$ [0.02, 0.34], $Z = 2.18$, $p = 0.03$), whereby initial perceptions of pain tended to be higher following self-control exertion (see Figure 5b). There was no statistically significant effect of self-control exertion on participants' perceptions of pain at the end of the physical task ($g = -0.03$ [−0.19, 0.13], $Z = 0.31$, $p = 0.75$) (see Figure 5c). Heterogeneity was not observed for any of the pain subgroups (overall pain, $p = 1.00$; initial pain, $p = 0.56$; end pain, $p = 0.45$).

3.4.2. Motivation

There was no statistically significant effect of self-control exertion on participants' motivation ($g = -0.03$ [−0.36, 0.29], $Z = 0.20$, $p = 0.84$). Significant heterogeneity was observed for the effects on motivation ($Q(15) = 56.46$, $p < 0.001$, $T^2 = 0.30$, $I^2 = 73$).

3.4.3. Self-efficacy

There was a statistically significant medium negative effect of self-control exertion on self-efficacy ($g = -0.48$ [−0.86, −0.10], $Z = 2.47$, $p = 0.01$), whereby participants displayed lower levels of self-efficacy following self-control exertion, compared to the control group/condition (see Figure 5e). Significant heterogeneity was observed for the effects on self-efficacy ($Q(8) = 15.64$, $p = 0.05$, $T^2 = 0.16$, $I^2 = 49$).

3.4.4. RPE

There was no statistically significant effect of self-control exertion on participants' RPE ($g = 0.03$ [−0.25, 0.32], $Z = 0.21$, $p = 0.83$) (see Figure 5f). Significant heterogeneity was observed for the effects on RPE ($Q(11) = 19.59$, $p = 0.05$, $T^2 = 0.10$, $I^2 = 44$).

4.0. Discussion

The findings of the present study suggest that the prior exertion of self-control resulted in a statistically significant medium sized negative effect on subsequent physical task performance ($g = -0.55$). Subgroup analyses revealed a statistically significant medium sized negative effect for studies employing both a within-subject design ($g = -0.53$) and a between-subject design ($g = -0.54$). Furthermore, the type of physical performance task also influenced the results, with prior self-control exertion demonstrating a medium-to-large sized negative effect on isometric ($g = -0.62$) and dynamic ($g = -0.61$) based physical tasks, while a small-to-medium sized negative effect was found for studies that utilized aerobic ($g = -0.36$) and motor skill ($g = -0.45$) tasks. In addition, the present study is the first to meta-analytically examine the mechanisms underpinning the effects of self-control exertion on subsequent physical performance. The findings demonstrated

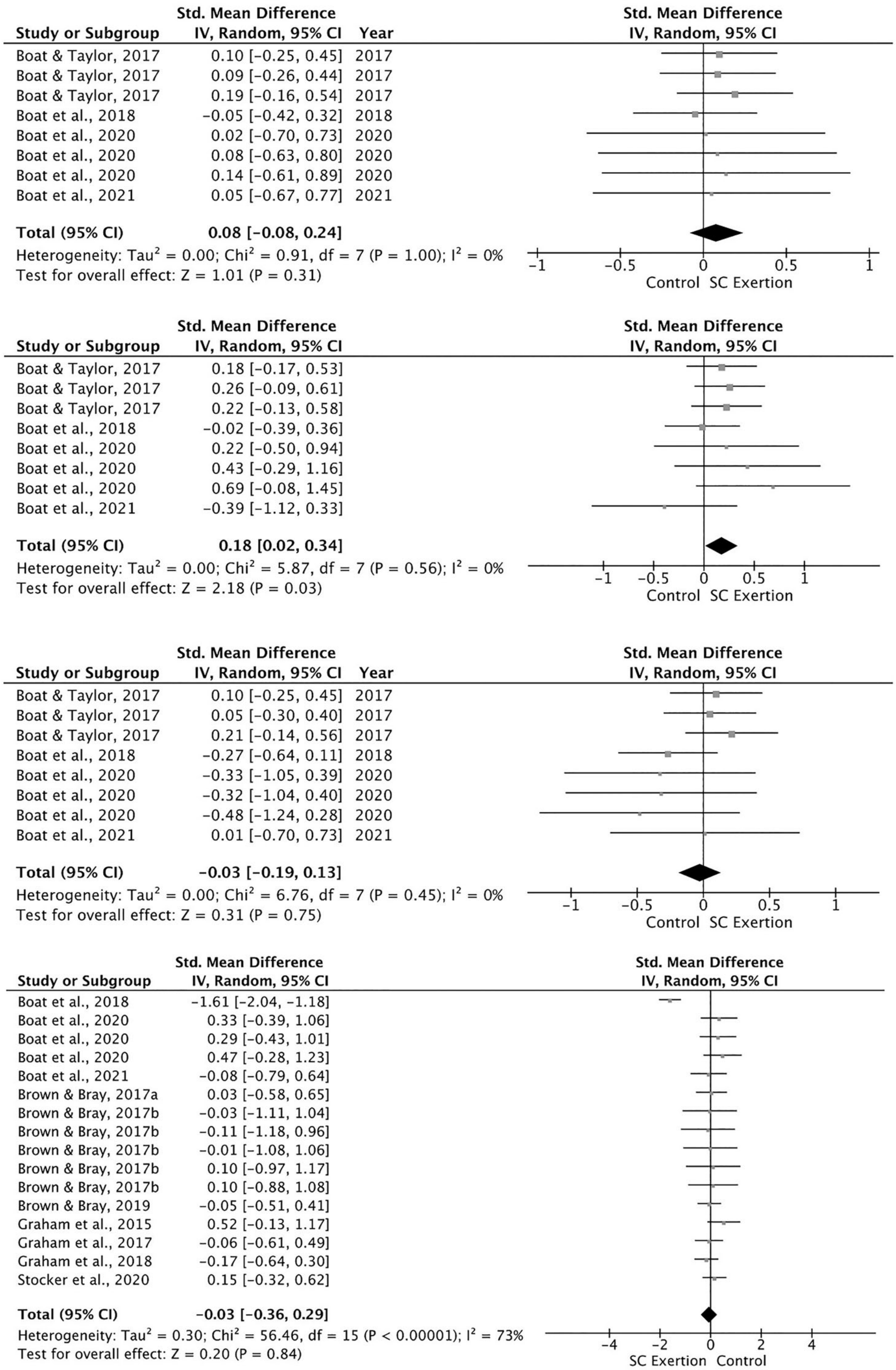

Figure 5. Forest plots examining the mechanisms for the effects of prior self-control exertion on physical performance (Figure 5a: Overall pain; Figure 5b: Start pain; Figure 5c: End pain; Figure 5d: Motivation; Figure 5e: Self-efficacy; Figure 5f: RPE).

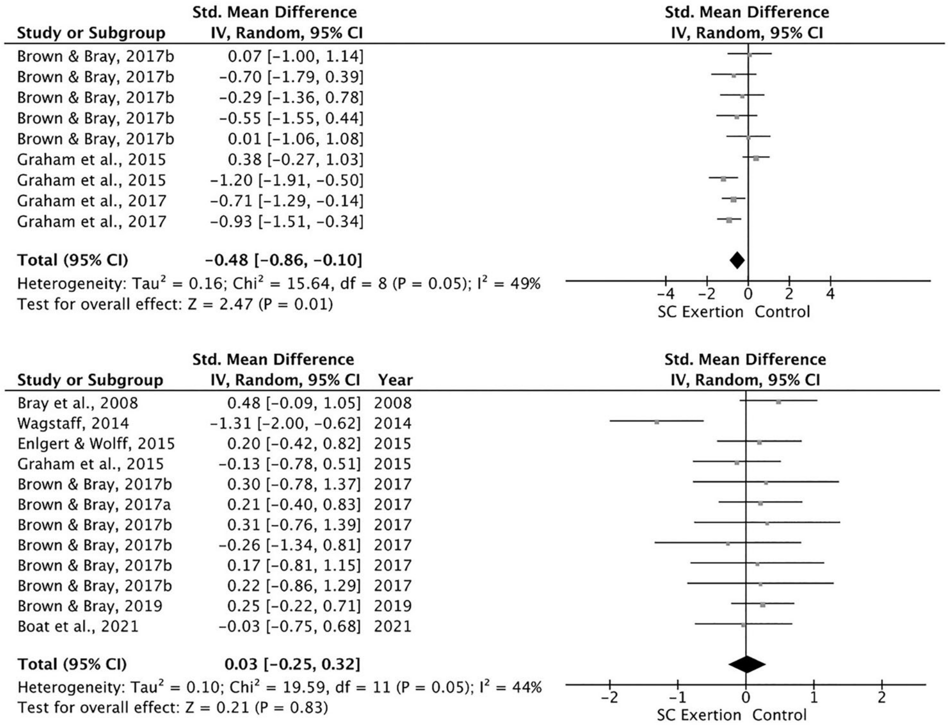

Figure 5. *Continued*

that the prior exertion of self-control had a medium-sized negative effect on self-efficacy (*g* = −0.48), and a small effect on initial perceptions of pain during the subsequent physical task (*g* = 0.18); while there was no statistically significant effect of prior self-control exertion on perceptions of pain overall (*g* = 0.08), pain in the latter stages of the physical performance task (*g* = −0.03), motivation (*g* = −0.03) or RPE (*g* = 0.03). The findings provide novel evidence for self-efficacy and initial perceptions of pain to be recognized as the mechanisms by which prior self-control exertion affects subsequent physical performance.

An important finding of the present study is that prior self-control exertion had a statistically significant medium sized negative effect on subsequent physical performance (*g* = −0.55). This finding extends a recent meta-analysis which combined studies examining both prior self-control exertion and mental fatigue studies, which yielded an effect size of *g* = −0.38 (Brown et al., 2020). Furthermore, when considering studies within initial cognitive task with a duration of less than 30 minutes, Brown et al. (2020) reported an effect size of *g* = −0.45. The differences between the effect sizes could be attributed to the inclusion of unpublished studies in the meta-analysis of Brown et al. (2020), therefore, greater influence of the 'file drawer effect', in which null effect sizes may reduce the overall effect size.

Another key finding of the present study was that studies that employed a within-subject design produced a similar medium negative effect size (*g* = −0.53) to studies employing a between-subject design (*g* = −0.54). Previous meta-analytical evidence has displayed larger effect sizes for studies that have employed a between-subjects design

(Brown et al., 2020). Subsequently, the inclusion of more recent studies in the present meta-analysis, most of which employ a within-subjects design, could explain the discrepancy with previous findings.

The findings of the present study also suggest that the type of physical task used is another important factor to consider when interpreting studies examining the effects of prior self-control exertion on subsequent physical performance. Specifically, the present meta-analysis demonstrated a medium-to-large negative effect for isometric ($g = -0.62$) and dynamic ($g = -0.61$) physical tasks, while small-to-medium negative effect sizes were found for aerobic ($g = -0.36$) and motor skill ($g = -0.45$) physical tasks. However, the discrepancies between physical task type subgroups may be confounded by study design. For example, 20 out of 31 studies that employed an isometric task utilized between-subject study designs, which typically yield larger effect sizes (e.g. Alberts et al., 2007; Brown & Bray, 2017a). Furthermore, some effect sizes in the present meta-analysis are derived from a low number of studies (e.g. dynamic subgroup $n = 3$). Nonetheless, these findings support the notion that prior cognitive exertion has a greater detrimental effect on subsequent physical performance in isolated tasks (e.g. wall-sit), compared to whole-body endurance tasks (e.g. cycling) (Giboin & Wolff, 2019). The varying physiological and psychological demands of different performance tasks could explain the differences in effects seen in the present study. For instance, isometric performance tasks such as a wall-sit may demand greater levels of attentional control for optimal performance compared to whole-body endurance tasks, such as cycling, that rely on more automatic motor processes (Dimitrijevic et al., 1998; Giboin & Wolff, 2019). Therefore, future research should continue to investigate the effects of self-control exertion on differing physical performance tasks to advance this debate; and consider examining sport-specific performance tasks with ecological validity for real-world sporting performance.

A key novel aspect of the present study is the meta-analytical investigation of the mechanisms that underpin the effects of self-control exertion on subsequent physical performance. The largest effect size was found for self-efficacy, with a statistically significant medium-sized negative effect ($g = -0.48$). As a result of initial self-control exertion, individuals may have reduced belief that they possess the capabilities to mobilize the resources required to exert further self-control, which would be required to achieve optimal performance on a subsequent physical task (Bandura, 1977; Graham & Bray, 2015). In accordance with the *opportunity-cost conceptualization* of self-control (Kurzban et al., 2013; Wolff & Martarelli, 2020), following prior self-control exertion individuals may be less motivated to exert further self-control if they do not feel confident that they can persevere at the task and if they do not see any additional benefit in investing further self-control and effort. This will result in the cons of persisting at the task (i.e. feelings of pain and discomfort) outweighing the benefits (i.e. optimal performance), and could lead to reduced physical performance and/or the termination of effort (Inzlicht et al., 2018; Kool & Botvinick, 2014; Kurzban et al., 2013). Acknowledging self-efficacy as a key mechanism for physical task performance could have valuable implications for sport and exercise practitioners. Specifically, athletes and those in their support network should be aware of the impact that prior self-control exertion can have on the athlete's self-efficacy for a subsequent physical task. Moreover, researchers should develop specific interventions that aim to increase self-efficacy to combat the negative effects of prior self-control exertion on subsequent performance.

Prior self-control exertion was also discovered to have a small-sized negative effect on individuals' initial perception of pain during a physical performance task ($g = 0.18$). However, there was no effect on overall pain ($g = 0.08$) or pain towards the end of a physical performance task ($g = -0.03$). These findings are in accordance with previous research suggesting that the prior exertion of self-control results in elevated perceptions of pain, but only during the early stages of a physical task (e.g. Boat & Taylor, 2017; Boat et al., 2020). Theoretically, the importance of perceptions of pain can be explained by the *shifting priorities model* (Inzlicht & Schmeichel, 2016; Milyavskaya & Inzlicht, 2017) and *opportunity-cost conceptualization* (Kurzban et al., 2013; Wolff & Martarelli, 2020) of self-control. Specifically, it is suggested that the prior exertion of self-control causes increased perceptions of pain during the early stages of a subsequent physical performance task, causing an individuals' attention during the task to shift to the proximal goal (e.g. ceasing exercise to alleviate pain) and away from the distal goal (e.g. optimal physical performance); ultimately causing a reduction in subsequent physical performance. The present study has investigated this using a meta-analytical approach for the first time.

In the present study, there was no effect of prior self-control exertion on individual's motivation ($g = -0.03$). This finding is in accordance with previous research showing motivation did not change in response to cognitive exertion (e.g. Brown & Bray, 2017b, 2019; Graham & Bray, 2015). The current findings present challenges for the motivational aspect of the *shifting priorities model* (Inzlicht & Schmeichel, 2016; Milyavskaya & Inzlicht, 2017), as this meta-analysis suggests that there is no effect of prior self-control exertion on subsequent motivation during the subsequent physical task. Interestingly, changes in other more nuanced aspects of motivation, such as goal commitment and exercise intentions, have been suggested to decrease following prior self-control exertion (Brown & Bray, 2019). However, the evidence base is very limited and thus requires further investigation. Such research is necessary to examine multiple aspects of motivation to provide a more detailed explanation of an individual's motivational intentions, than the more commonly used broad measures of task and intrinsic motivation. In addition, it has been suggested that future research should aim to investigate more complex motivational processes through qualitative methods (i.e. think aloud) to record the reasons behind changes to individuals' intentions or commitment (Brown & Bray, 2019; Marcora, 2008; Marcora et al., 2008, 2009; Marcora & Staiano, 2010). Moreover, an explanation for the findings of the present study could be a result of motivation being measured at varied time-points in the included studies. Some research has measured motivation at pre-selected intervals throughout the physical task (e.g. Boat et al., 2018), while other studies have acquired a singular measurement prior to the physical task (e.g. Graham et al., 2018). These inconsistencies could explain the discrepant findings of previous research, and future studies should continue to examine the time course of the changes in multiple aspects of motivation as a result of the prior exertion of self-control.

The findings of this meta-analysis provide very limited evidence for RPE to be considered a mechanism that could underpin the effects of prior self-control exertion on subsequent physical performance ($g = 0.03$). RPE, however, has been considered as the main explanatory mechanism underpinning the effects of mental fatigue on subsequent physical performance (Pageaux & Lepers, 2018; Van Cutsem et al., 2017). Taken together, these findings allude to there being key differences between the constructs of self-control exertion and mental fatigue. Our findings support the notion that typical self-control depletion tasks are not long enough to induce subjective feelings of effort (Pageaux, Marcora, & Lepers, 2013), and thus self-control depletion tasks may not invoke the same mechanistic responses that underpin the effects of mental fatigue on subsequent physical performance. Therefore, caution should be taken when combining both research streams for future investigation as results may not be attributed to the same mechanisms. Furthermore, RPE findings are difficult to interpret as both self-control exertion and mental fatigue result in individuals reducing the absolute intensity that they are exercising at. Thus, RPE measurements may be comparable to participants in a non-depleted/non-fatigued state, while the absolute exercise intensity would be different, resulting in differences in performance but no differences in RPE (Pageaux, 2014; Van Cutsem et al., 2017). Further research is required to fully uncouple the relationship between RPE following cognitive exertion and physical performance and how this may be different for studies that induce mental fatigue and those that require self-control exertion.

4.1. Limitations and future direction

Although yielding novel findings surrounding the effects of self-control exertion on physical task performance, some limitations must be addressed. It must be acknowledged that the findings of this study only relied on published literature and no research teams were contacted regarding unpublished papers. We decided to base our meta-analysis on published literature only, that was accessible to the scientific community, and that we were confident had been through the peer-review process. However, we acknowledge that the omission of unpublished work may skew the present effect sizes and conceal the impact of the 'file-drawer' effect, with the omission of studies that reported null effects. Moreover, the risk of bias assessment could not identify any study included in the meta-analysis as completely low risk. Factors associated with higher risks were namely associated with detection bias and attrition bias. For example, several studies did not provide information surrounding the blinding of researchers, and thus future studies should encourage and explicitly state the use of double-blind techniques. In addition, researchers must openly report the reasons and handling of incomplete data outcomes to safeguard the internal validity of studies.

Furthermore, while the present study has provided the first meta-analysis on the mechanisms that are affected by prior self-control exertion, it must be noted that some findings were interpreted from a low number of effect sizes due to the limited evidence base. The significance level of an effect size can be influenced considerably by the inclusion of an additional publication when dealing with effect sizes calculated from a relatively small number of comparisons. Therefore, further research into the mechanisms identified in this meta-analysis is required to create an extensive and stronger evidence base. Finally, future mediational research is required to investigate the relationship of the 'causal chain' between self-control exertion, the mechanisms identified in this meta-analysis, and subsequent physical performance. This will develop our understanding of how these mechanisms are impacted by prior self-control exertion, and as a result how they impact subsequent physical performance. Building upon the findings of this meta-analysis, future research should aim to create interventions that target the suggested mechanisms, to identify strategies to attenuate the effects of self-control exertion on subsequent physical performance. For example, researchers could develop strategies to alter perceptions of pain in the initial stages of a physical task. Such strategies could reduce the initial perception of pain, resulting in individuals being able to continue exerting the self-control required to achieve optimal performance.

Moreover, some additional mechanisms could not be included in the meta-analysis due to a lack of empirical evidence. For example, state anxiety could not be included as a potential mechanism because the studies that have examined this have included an additional direct manipulation of state-anxiety and thus have not solely measured the effects on self-control exertion on state anxiety in isolation (Englert & Bertrams, 2012; Englert, Zwemmer, Bertrams, & Oudejans, 2015). Similarly, motivational incentives (Brown & Bray, 2017a), biofeedback (Brown & Bray, 2019) and autonomy supportive instructions (Graham et al., 2014) have been employed to attenuate the depletion effect, and should be further investigated to provide valuable insight into the potential role of specific aspects of motivation. Furthermore, more recently, it has been hypothesized that feelings of boredom may be provoked once self-control has been exerted (Wolff & Martarelli, 2020); yet no empirical studies have investigated this to date. Therefore, task-induced boredom should be examined as a psychological factor that may explain performance reductions on physical tasks following self-control exertion.

5.0. Conclusion

Results from the current meta-analysis showed that 50 comparisons (and over 2200 participants) resulted in a medium negative effect ($g = -0.55$) of prior self-control exertion on subsequent task performance. Explanatory mechanisms that underpin the effect were also established, whereby self-efficacy was lower and initial perceptions of pain were higher, following the prior exertion of self-control. Future research should continue to mechanistically investigate the effects of prior self-control exertion on subsequent physical performance. Ultimately, this knowledge can be used to design and implement interventions aimed at attenuating the effects of self-control exertion, to enhance physical task performance.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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