

A Systematic Review of the Effect of Cognitive Strategies on Strength Performance

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## Abstract

### Background

Researchers have tested sportspeople's and sports medicine specialists' beliefs that cognitive strategies influence strength performance. Few investigators have synthesized the literature.

### Objectives

The specific objectives were to review evidence regarding (a) the cognitive strategy-strength performance relationship, (b) participant skill level as a moderator, and (c) cognitive, motivational, biomechanical/physiological, and emotional mediators.

### Method

Studies were sourced via electronic databases, retrieved articles' reference lists, and manual searches of relevant journals. Studies had to be randomised or counterbalanced experiments with a control group or condition, repeated measures, and a quality control score of above .5 (out of 1). Cognitive strategies included goal setting, imagery, self-talk, preparatory arousal, and free choice. Dependent variables included maximal strength, local muscular endurance, or muscular power.

### Results

Globally, cognitive strategies were reliability associated with increased strength performance (results ranged from 61-65%). Results were mixed when examining specific strategies' effects on particular dependent variables, although no intervention had an overall negative influence. Indeterminate relationships emerged regarding hypothesised mediators (except cognitive variables) and participant skill level as a moderator.

### Conclusion

Although cognitive strategies influence strength performance, there are knowledge gaps regarding specific types of strength, especially muscular power. Cognitive variables, such as concentration, show promise as possible mediators.

**Key points:**

1. Cognitive strategies of various types influence muscular strength performance
2. Participant skill level does not appear to moderate the cognitive strategy and strength performance relationship
3. No explanation for why cognitive strategies enhance muscular strength has substantial support, but initial evidence supports continued examination of cognitive variables.

## A Systematic Review of the Effect of Cognitive Strategies on Strength Performance

### 1.0 Introduction

Many strength athletes engage in one or more cognitive strategies prior to or during performance in training and competition, with typical examples including imagery, self-talk, and goal setting [1]. These strategies are designed to increase physical and mental activation, focus attention, and build self-efficacy [2]. Although athletes believe the result will be enhanced strength performance, scientists have tested the hypothesis empirically, and they have reported both (a) significant and non-significant and (b) positive and negative results [3-5]. In addition, scientists have examined the influence of cognitive strategies on strength performance in the injury rehabilitation context [6]. The possibility that cognitive strategies may assist performance and recovery from injury has potential psychological and performance benefits. If cognitive strategies could assist performance and recovery from injury, then athletes might experience greater training gains, enhanced competitive performance, and shortened periods of time away from sport when injured.

Researchers have identified typical cognitive strategies athletes use prior to performing strength-based tasks (e.g., imagery, self-talk, goal setting), and the reasons why they employ them, with typical motives including increasing arousal, confidence, and self-belief [7]. These reasons can be interpreted via the activation set hypothesis [8]. According to the hypothesis, a specific internal state is associated with optimal task execution (e.g. level of activation, attentional focus, and confidence). Cognitive strategies may facilitate performance by enabling athletes to adjust their internal state to one that is desirable for the upcoming task [2]. The activation set hypothesis implies that athletes use cognitive strategies to marshal their psychological and physical resources to bear on the strength-task at hand. In the absence of cognitive strategies, there is the perception that task performance will suffer

1 because athletes are not making use their psychological and physical assets (c.f., with  
2 Steiner's [9] model of group productivity where actual performance equals possible  
3 performance minus coordination and motivational losses).  
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7 The purpose of this article was to conduct a systematic review of the experimental  
8 literature examining the influence of cognitive strategies on muscular strength. There are a  
9 number of reasons why a systematic review will advance current understanding. First, there  
10 have been few attempts to synthesis literature on the topic, and authors have published  
11 narrative reviews only [2, 1]. In these narrative reviews, clear inclusion and exclusion  
12 criteria, detailed search strategies, and transparent data extraction and analysis procedures  
13 were absent. It is not clear if the body of research was adequately represented or examined.  
14 Also, by relying on a subjective interpretation to synthesis knowledge, there is the possibility  
15 of reviewer bias. A systematic review offers a more objective and transparent way of  
16 synthesising the knowledge. Second, the most comprehensive review is more than 10 years  
17 old and a number of studies have been published since [1]. A systematic review will provide  
18 an up-to-date understanding of the topic. Third, the previous reviews did not examine the  
19 quality or rigour of the research. Assessing research rigour is an established component of  
20 systematic reviews [10], and allows insights regarding the confidence that may be placed in  
21 current knowledge and any derived implications.  
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24 For the current review, cognitive strategies were defined as self-directed mental  
25 interventions used prior to or during skill execution to enhance physical performance [1].  
26 Related interventions such as music, external verbal encouragement, or instructor-led guided  
27 imagery were not considered for this review. The current review focused on imagery, goal  
28 setting, self-talk, preparatory arousal, and free choice. These strategies were included  
29 because they are the common interventions participants have identified as being related to  
30 enhanced muscular strength [7]. Research under the imagery heading included studies where  
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1 participants had been asked to visualise or imagine performing the movement [11]. Goal  
2 setting research included investigations in which participants had been given specific  
3 attainment levels to achieve, as opposed to being asked to “do your best” [12]. Self-talk  
4 studies included those in which participants had been asked to use a cue phrase to assist  
5 performance [13]. Preparatory arousal involved self-directed strategies aimed to increase  
6 participants’ activation levels [14]. In free-choice strategies, participants had selected a  
7 preferred cognitive method [7].

16 The major dependent variables measured in the research included maximal strength,  
17 local muscular strength-endurance, and muscular power. Maximal strength has been defined  
18 as the maximal force generated by a muscle or group of muscles at a specified speed [15, 16].  
19 Research under the maximal strength label included studies that measured strength  
20 performance during a low number of repetitions, such as a one-repetition maximum (RM).  
21 Investigations under the local muscular strength-endurance umbrella included studies that  
22 assessed a high number of repetitions performed at a specified resistance level during a  
23 particular time period, such as the number of sit-ups performed during one minute [16].  
24 Tasks included in this research emphasised muscular strength-based movements (e.g.,  
25 handgrip, squats), typically for 1 to 2 minutes, rather than tasks such as cycling or running.  
26 Muscular power-related research included studies that measured explosive muscular strength,  
27 and has been defined as the rate at which work can be performed under a given set of  
28 circumstances [16, 17]. Maximal strength and muscular power were separated because  
29 research has revealed they may predict sporting performance differently [18].

50 As a second way to advance literature, we examined the evidence concerning the  
51 degree to which participant skill level moderated the cognitive strategy-muscular strength  
52 relationship. Moderators influence relationships by altering the direction (positive or  
53 negative) and/or magnitude. The moderator’s influence may then affect the consistency of

1 the relationship within the sampled literature. Although we acknowledge we were unable to  
2 test directly whether a moderating effect exists, because researchers have not conducted the  
3 types of studies needed, examining the overall direction and consistency of findings for  
4 different categories of participant skill level generates meaningful, albeit initial, information  
5 concerning the presence of a moderating effect. These initial findings then provide direction  
6 to help researchers design studies to test moderating effects.  
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8 Participant skill level was selected because researchers have hypothesised it as a  
9 meaningful moderator with regards to strength performance [3], and Fitts and Posner's [19]  
10 stages of skill learning framework provides a theoretical rationale [14]. During early stages  
11 of learning, novices use explicit instruction and talk themselves through the phases of a  
12 movement, whereas during later stages of learning, individuals engage in less cognitive  
13 activity and their performances are more automatic. Further deliberate use of cognitive  
14 strategies may hinder the display of strength in advanced learners if they disrupt attentional or  
15 other movement-related resources [14]. As such, novice performers may benefit more  
16 frequently from the use of cognitive strategies compared with their skilled counterparts.  
17 Recently, Zourbanos and colleagues [20] observed that the influence of instructional self-talk  
18 on motor skill performance was greater in a novel rather than well-learned movement.  
19 Although the task was not a strength-based movement, the study provides initial evidence to  
20 support the hypothesis advanced in the current review. Equally, however, some practitioners  
21 might suggest that during well-learned movements, performers have had greater opportunities  
22 to practice helpful cognitive strategies and may benefit more from their use than novices. As  
23 such we acknowledge that our hypothesis is that, our conjecture based on our interpretation  
24 of existing empirical evidence.  
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26 Regarding a third way the current systematic review may further knowledge, we  
27 considered potential mechanisms that might explain the relationship. Adopting a throughput  
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perspective, as illustrated in Figure 1, we identified four possible mechanisms: cognitive, motivational, biomechanical/physiological, and affective. These four mechanisms were derived from Hardy, Oliver and Tod's [13] work on self-talk with one change. Their behavioural category was modified to become a biomechanical/physiological category. This change represented the research being reviewed better than a behavioural category because researchers had sometimes examined biomechanical and physiological variables, but they had not engaged in behavioural observations. We also considered a separate neurophysiological category, apart from the biomechanical/physiological umbrella, but decided against doing so because the research that emerged from our search had typically not measured neurophysiological variables as mediators of the cognitive strategy-strength performance relationship. Figure 1 reflects the emphasis given by researchers to the various types of mediators. The four categories were also derived from current understanding of how cognitive strategies might influence strength. The force resulting from voluntary skeletal muscle contraction is determined by several factors starting with input from the higher motor centres and terminating with the energy-dependent interaction of actin and myosin [21, 22]. These factors may be categorised as central, peripheral, and mechanical influences [21]. Central components include motor unit recruitment, synchronisation, and firing rate [23]. Peripheral factors include processes intrinsic to the muscle such as muscle membrane excitation, calcium release, sarcomere length, and myosin adenosine triphosphatase activity [23]. Mechanical factors include the length of muscle, velocity of contraction, and the physical arrangement of muscle fibres [23]. Cognitive strategies may influence any of the factors mentioned. It is likely that cognitive strategies influence the central nervous system, given the cerebral cortex is the first and highest level of muscular contraction control. Self-directed cognitive strategies occur in the cerebral cortex and may stimulate changes in central nervous system activity, resulting in changes in motor unit recruitment, synchronisation,



and/or firing rate. Changes in the central nervous system may modify sympathetic nervous system activity, which may result in alterations in peripheral factors such as muscle contractility. These changes at the muscle level could occur in the primary muscles responsible for the movement, the antagonist muscles, and/or any additional muscles contributing to movement [3]. It is likely that the interactions among these variables mediate the cognitive strategy-strength relationship.

Similar to the focus on moderators, researchers have not adopted the research designs needed to assess possible mechanisms in the cognitive strategy and strength performance relationship. By collating the existing findings, however, where the conceptualized mechanisms have been examined as dependent, but not mediating variables, the current review represents an initial step towards identifying possible mechanisms worthy of further inquiry. In the current review cognitive mechanisms encompass informational processing and attentional control. Motivational mechanisms focused on self-efficacy [24], perceived effort, and persistence or long-term goal commitment. Biomechanical/physiological mechanisms refer to changes in physiological, kinematic, or kinetic variables that may underlie performance improvements from cognitive strategies. Affective mechanisms include changes in emotional states, such as increased arousal or decreased anxiety.

The purpose of the current article was to review the experimental cognitive strategy-muscular strength literature employing a transparent systematic approach. The first specific aim was to review the evidence concerning whether cognitive strategies influence muscular strength. The second specific aim was to review the evidence regarding participant skill level as a possible moderator. The third specific aim was to review the evidence regarding four types of mediators: cognitive, motivational, biomechanical/physiological, and emotional. Understanding the evidence for specific techniques, along with knowledge regarding

mechanisms and moderators involved in the cognitive strategy-strength relationship, may assist in optimising interventions to secure maximal performance.

## 2.0 Method

### 2.1 Search Strategy

The search strategy included: (a) an online search of the following electronic databases: SPORTDiscus, PsycINFO, PsycARTICLES, PubMed, Annual Reviews, Science Direct, Taylor and Francis Journals, Sage Journals, and Web of Science; (b) a manual review of reference lists within retrieved articles; and (c) a manual search of journals, including those that had yielded three or more retrieved articles and included: *British Journal of Sports Medicine*, *Journal of Clinical Sport Psychology*, *Journal of Sport and Exercise Psychology*, *Journal of Sports Medicine and Physical Fitness*, *Journal of Sports Sciences*, *Journal of Strength and Conditioning Research*, *Medicine and Science in Sports and Exercise*, *Psychology of Sport and Exercise*, *Research Quarterly for Exercise and Sport*, *The Sport Psychologist*, *International Journal of Sport Psychology*, *International Journal of Sport and Exercise Psychology*, *Journal of Applied Sport Psychology*, and *Journal of Sport Behavior*. Keywords used during the search included combinations and variants of strength, muscle, power, muscular endurance, imagery, visualisation, self-talk, inner dialogue, preparatory arousal, goal setting, and psyching-up. Studies published anytime up until the last day of searching were considered (including in press articles made available online). The last day of searching was November 19, 2014.

Figure 2 presents a Prisma Figure summarizing the search results. These search strategies generated an initial pool of a 13, 746 possible articles. After removing duplicates and documents that did not meet the inclusion criteria after a title and abstract review, the available pool was reduced to 103 documents. After a full-text assessment of the remaining documents against the inclusion criteria, data was extracted from 53 studies and are identified

in the reference list with an “\*”. To assess the adequacy of the search, prior to implementing the protocol, the relevant 36 studies cited in the previous narrative review in the area [2] were identified as a test pool. All 36 articles surfaced during the search protocol. Reasons that studies were excluded at the full text review stage included unsuitable interventions (17% of rejected studies), inadequate strength assessment (32%), lack of sufficient details, with none forthcoming from authors (6%), or the research design was outside the inclusion criteria (e.g., lack of control group, 45%).

## 2.2 Inclusion and Exclusion Criteria

Studies had to have: (a) been experimental in design with randomisation or counterbalancing, (b) compared the use of a cognitive strategy against a control condition, (c) measured maximal strength, local muscular strength-endurance, or muscular power as a dependent variable, (d) scored over .5 in the quality assessment (discussed below), and (e) been written in English. Regarding the moderation and mediation analysis, studies also needed to have described the participant skill level or have measured a variable that fell within one of the four mediator categories (cognitive, motivational, biomechanical/physiological, or affective).

Each study was subject to a quality assessment, as suggested by the Cochrane guidelines [10]. Studies underwent a quality assessment procedure and were graded with respect to their methodological strength. Although quality assessment has limitations, such as articles receiving low scores because of poor report writing rather than deficiencies in experimental design, the grading assists in study interpretation. For example, assessment assists readers in placing greater confidence in articles with better, rather than lower, quality scores. In the current study Timmer, Sutherland, and Hilsden’s [25] checklist was applied, because it has good construct validity and has been found acceptable by expert reviewers. The checklist contains 21 items on which studies can receive 2 (yes), 1 (partial), or 0 (no)

points. Two additional items refer to study design (scored 2, 3, or 4), and randomisation reporting (score 1 or 0). Two items were not applied in the current study, because they referred to the strategy of blinding participants and researchers, which was not a realistic expectation in the current literature. Studies were scored out of a possible 39 and we calculated a ratio of actual score divided by possible score, leading to a quality score of between 0 and 1. For studies to be included in the current review, they had to have at least a ratio of .5. Scores lower than .5 indicates a lack of several necessary details, such as the absence of participant description, descriptive and statistical results, or information about how measurements were operationalized. The score of .5 is relatively low and leads to the exclusion of few studies. We kept the ratio for exclusion low, because a high quality ratio exclusion criterion would have disadvantaged older studies published when there was less agreement regarding the necessary details to report in experimental research.

### 2.3 Procedure

Retrieved papers were scrutinized using the aforementioned inclusion and exclusion criteria. Once these criteria had been satisfied, we used procedures described by Sallis, Prochaska, and Taylor [26] to analyse the papers' content in a quantitative fashion. We selected these procedures because they provide a transparent way to organise literature that results in identifying the major trends and answering the review questions [27-30]. Each study was listed alphabetically according to author; however, as independent effects (*k*) were employed as the unit of analysis, coding also reflected papers that reported multiple studies and/or effects on multiple dependent variables (e.g., Theodorakis et al., 2000, Study 1; Theodorakis et al., 2000, Study 2). Data tables were developed to reflect sample characteristics (e.g., sex, age, skill level), research designs (e.g., presence of manipulation check, random allocation, random selection), and the effects of each specific cognitive strategy on muscular strength and hypothesized mediating variables.

## 2.4 Analysis

The data tables mentioned above were analysed to create summary tables presented in the results section, which involved a number of stages. First, sample and design characteristics were summarized by a tally count. Second, the effects of cognitive strategy on strength performance and hypothesized mediators were examined. For each dependent variable, the numbers of significant and non-significant results were tallied. Positive and negative significant findings were tallied separately, because potentially a cognitive strategy could enhance or hinder performance. Consistent with similar reviews, the direction of each effect was subsequently coded as positive (+), negative (–), no effect (0), or inconsistent (?) if the effect was ambiguous. The summarizing of the research surrounding each consequence was performed by the calculation of the percentage of support offered by the relevant studies. We employed Sallis et al.'s [26] coding system: 0–33% = no effect, 34–59% = inconsistent effect, 60–100% = positive or negative effect. Although potential moderator-related research findings were examined using the same classification system, a slightly altered version was employed for mediator findings.

Researchers had often used different measures of the same potential mediator concurrently which may have exaggerated the study's influence on the results (e.g., they may have used two or more anxiety questionnaires). Mediation results were categorised as “+” (measures of the same construct in a study yielded the same significant positive result), “0” (measures yielded a non-significant result), or “?” (measures yielded mixed results).

Two researchers familiar with the field of cognitive strategies extracted the data. Through discussion, a consensus and final coding of the data were agreed between the two researchers, allowing the individuals to form an in-depth appreciation of the searched literature and ensure that only eligible studies were included in the final analysis stage.

## 3.0 Results

### 3.1 Descriptive Characteristics of Included Studies

The analysis of the literature allowed a clear understanding of the samples and designs researchers have employed. As a result, we were able to highlight gaps in these descriptive aspects. The present review was based on a total population size of 3,762 participants (2,071 male, 1,334 female, and 357 not specified). Regarding sample size, 60% of studies had used less than 60 participants. As presented in Table 1, 53% of studies employed mixed gender samples, with 86% of eligible studies using individuals aged between 17 and 39 years. Students and novices, as opposed to competitive athletes, were recruited most frequently (75%).

As seen in Table 2, the majority of the research has used a between participant design (79%). Local muscular strength-endurance was the most frequently tested muscular strength variable (59%), with goal setting (50%) and imagery (26%) being the most common interventions. The most frequently employed control conditions (85%) included asking participants to “do your best,” engaging them in a distraction task, or providing no instructions. Of the studies, 59% had employed a manipulation check of some type to assess the successful formation of experimental and control groups.

### 3.2 Effects of Cognitive Strategies on Muscular Strength Performance

Table 3 presents a summary of the results regarding the effectiveness of cognitive strategies on muscular strength. Overall, 129 observations (*ks*) satisfied the inclusion criteria of which 84 (65%) indicated a positive relationship between cognitive strategies and muscular strength and 44 (34%) indicated no influence, with 1 (<1%) negative result. The following sections provide a more detailed explanation based on each specific intervention.

#### 3.2.1 Imagery

Overall, imagery was reliably associated with increased muscular strength (63%). According to the criteria we used, the strategy was found to reliably increase maximal

1 strength (69%), had an inconsistent relationship with muscular endurance (55%), and no  
2 relationship with muscular power (67%). Across the observations, 24 had been made during  
3 training studies that had lasted between 10 days and 6 months. The remaining observations  
4 came from non-training studies. In non-training studies, imagery had been found to reliably  
5 influence muscular strength performance (74%), but had an inconsistent relationship in the  
6 training studies (54%).

### 14 3.2.2 Goal-setting

16 Goal setting was reliably associated with increased strength performance (65%). The  
17 strategy was found to increase maximal strength (100%), muscular endurance (63%), and  
18 power (100%). Across the observations, 30 had been made during training studies that had  
19 lasted between 3 and 10 weeks. The remaining observations came from non-training studies.  
20 In both types of studies, goal setting had been reliably associated with increased muscular  
21 strength (75% in training studies and 60% in non-training studies).

### 31 3.2.3 Self-talk

33 Generally, self-talk was associated with increased muscular strength (61%). A fine-  
34 grained examination indicated that the strategy was consistently found to increase maximal  
35 strength (60%) and power (67%), but not local muscular endurance (50%). Self-talk  
36 interventions were further subdivided into motivational self-talk, instructional self-talk, and  
37 cognitive restructuring. Some researchers had used positive self-talk and this was subsumed  
38 within the motivational self-talk umbrella. The description of positive self-talk presented in  
39 the relevant papers indicated it was equivalent to the motivational type. Motivational self-  
40 talk was consistently found to increase muscular strength (70%), whereas the instructional  
41 (57%) and cognitive restructuring (0%) variants were not observed to reliably enhance  
42 strength performance.

### 58 3.2.4 Preparatory arousal

Overall, preparatory arousal was associated with increased muscular strength (63%). More specifically, the strategy was found to increase muscular endurance (100%) and power (100%), but had an inconsistent relationship with maximal strength (55%).

### 3.2.5 Free-choice psych-up

A free choice strategy was associated with increased strength (75%). More specifically, the strategy was found to increase maximal strength (63%), muscular endurance (100%), and power (100%).

### 3.3 Participant Skill Level

Table 4 presents results stratified by participant skill level. Samples were classified as consisting of either untrained novices or trained individuals with regards to the assessed strength task. A consistent pattern emerged that regardless of participant skill level, cognitive strategies were associated with enhanced maximal strength (novices = 65% and trained = 71%). Two anomalous results included the effect of self-talk on maximal strength in novices (an inconsistent relationship, 58%) and the influence of preparatory arousal in trained individuals (no relationship, 100%).

### 3.4 Potential Mediators

Table 5 presents the results from the assessment of mediators. Examples of variables included in the cognitive mediator rubric included attention, concentration, and absence of interfering thoughts. Examples of variables included under the motivation mediator label included perception of effort, confidence, and self-efficacy. Variables such as anxiety, arousal, and various mood states were examples included in the affective category. Within the biomechanical/physiological category were variables such as joint rotation, hormone concentration, and heart rate. In the reviewed research, only cognitive variables had a consistent relationship with cognitive strategies (100%, although this was based on a  $k = 4$ ). There was insufficient evidence for the remaining three categories that they had consistent



relationships with cognitive strategies (motivation = 35%, affective = 17%, and biomechanical/physiological = 47%).

#### 4.0 Discussion

Globally, the current results indicate that cognitive strategies enhance the display of muscular strength. These results are based on research testing different types of cognitive strategies across the various dimensions of strength: maximal strength, strength-endurance, and power. The adoption of systematic review principles represents an advance over previous reviews in the area that have been narrative [1, 2]. Compared with previous reviews, the current article was based on a transparent method with clear inclusion/exclusion criteria, a detailed literature search strategy, and accepted data extraction and analysis procedures. Also, the most comprehensive existing review is more than a decade old (and the other review was not focused on reviewing the literature for knowledge synthesis, but rather to identify applied implications for a professional audience) and the current article is based on more than double the number of studies cited by the 2003 publication. These two reasons imply that the current review represents the most up to date and objective synthesis of the experimental cognitive strategy and muscular strength performance research.

Although the broad findings suggests that cognitive strategies enhance strength, when drilling down into the results, the evidence begins to fragment and is less clear for the effect of some types of mental interventions on specific strength dimensions, particularly muscular power. There are alternate explanations for this observation. First, there might be a strategy by type of strength matching principle, such as imagery being useful for maximal strength, but not for muscular endurance. Such a conjecture echoes the hypothesis that motivational, but not instructional, self-talk enhances strength [31]. The challenge for researchers adopting a matching hypothesis is to develop plausible explanations in the absence of clear data, as indicated by the largely inconsistent results emerging from the examination of the potential

mediators. Any hypothesized explanations would require testing. Second, where null or inconsistent relationships arose, the cell sizes were relatively small. In addition, investigators had typically based their studies on smaller, rather than larger, sample sizes. It is possible that insufficient research has been published to allow an accurate understanding to emerge. Small sample sizes may be underpowered to identify relationships. The influence of cognitive strategies on muscular power provides a clear illustration. Generally, more research is needed to uncover the effect of specific strategies on particular types of muscular force.

With specific reference to the self-talk matching hypothesis mentioned above, the current findings found that motivational self-talk had a consistent relationship with strength, whereas instructional self-talk had an indeterminate relationship. The self-talk matching hypothesis helps explain the observation that motivational self-talk had a consistent relationship with strength because it is conjectured to increase effort and energy expenditure, two attributes that assist strength performance. The findings regarding instructional self-talk may also be understandable within the matching hypothesis. According to the matching hypothesis, instructional self-talk is considered better suited for tasks involving technique, timing, and coordination than those needing effort and energy expenditure. Strength tasks, however, vary on their need for timing, technique, and coordination. Some strength and power tasks, such as a squat or clean and jerk require considerable skill and practice and instructional self-talk might be useful for them. Other tasks, such as a maximal hand grip may require less skill and coordination. The value of instructional self-talk may vary according to the type of strength task being measured and could account for the indeterminate relationship observed in the current review. Implications advanced in the literature that motivational self-talk is better for strength tasks than instructional self-talk may be simplistic

and reflect a practitioner's lack of understanding of the requirements for a strength task.

Future research is needed to explore the issue.

Although we differentiated between motivational and instructional self-talk, it was not possible to identify subtypes among the other strategies, because researchers have not always provided clear descriptions. Such subtypes might exist, however, and represent possible future research, because it cannot be assumed different strategy subtypes are equally useful. For example, research reveals that diverse combinations of outcome, performance, and process goals influence performance differently [32]. Outcome goals assess performance relative to another person (e.g., winning a weight lifting tournament), performance goals measure performance against a personal standard (e.g., lifting a new personal best), and process goals refer to implementing particular processes that underpin performance (e.g., athletes may set a goal to "drive the bar above the eyes" in the bench press exercise). Drawing on Wulf and Prince's [33] research regarding the focus of attention (where an external focus is regarded as better for performance than an internal focus), we hypothesize that performance goals may influence strength performance more positively than process goals. Performance goals may be aligned with an external focus, whereas process goals may be associated with an internal focus.

Furthermore, investigators have typically measured maximal strength more often than local muscular endurance and power (aside from goal setting where local muscular endurance has been the most common dependent variable). In many situations, however, maximal strength may be less helpful to individuals than either local muscular endurance or power. For example, athletes' absolute strength may have less predictive power in many sporting situations than their ability to generate force in a short time period [18]. Similarly, in the rehabilitation context, muscular endurance may be more prized than maximal strength. The strength measures used in the research may help explain the profile of results. Common

1 measures have included sit-ups, hand-grip, and leg extensions, and these are convenient tasks  
2 to use in research, because they are easily measured and do not require participants to engage  
3 in extensive motor skill learning or to attend multiple familiarization sessions. Researchers  
4 could extend current knowledge by employing strength measures that have relevance to the  
5 populations under study, for example, the competitive lifts Olympic weightlifters perform,  
6 the rehabilitation exercises therapists prescribe to patients, or the exercises strength and  
7 conditioning professionals teach their clients.  
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17         Given the presence of non-significant and (occasional) negative relationships across  
18 the results, it appears that cognitive strategies do not help all people enhance the display of  
19 strength. Paralleling other psychological interventions, cognitive strategies help some people,  
20 have no effect in others, and may hinder the performance of a few individuals [34]. The  
21 challenge for researchers is to identify the reasons why there may be various effects. The  
22 possible individual difference moderator examined in the current review was participant skill  
23 level. Results, however, provided limited evidence that skill level may act as a moderator.  
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Researchers, however, have not made direct comparisons between participants with different levels of expertise in a movement. The current results are only suggestive of the likely findings that would emerge from direct comparisons. Whelan, Epkins, and Meyers [35] classified their participants according to level of athletic competitive experience, but given the individuals were from various sports it is unclear the degree to which they were trained in the task assessed as the dependent variable. The vast majority of the research, however, has used novices as participants. Much less attention has been paid to trained individuals. When a small number of studies have been undertaken, trends across the results may not be robust. As outlined in the introduction, arguments can be constructed explaining why cognitive strategies might be more or less effective for trained rather than novice participants. Although the current review indicates trained and untrained individuals may benefit, more

research is needed to build confidence in the result, especially studies that make direct comparisons.

A related observation was the relationship between strength and cognitive strategy in training versus non-training studies. The influence of goal setting appeared stronger during training studies than in non-training studies. In contrast, the influence of imagery was stronger in non-training studies than training studies. The difference between the two strategies may be due to the relative ease with which participants can adjust them to suit the task at hand. Goals can be adjusted relatively easily to ensure they focus participants' attention towards the task in many strength contexts, because of the immediate numerical feedback gained from performance, and with experience athletes can identify realistic increments (e.g., if an athlete squats 210 kgs in their last session for 5 reps, then they can easily set a new target of 215 kgs for when they next train). The same level of flexibility may take more time to develop with regards to imagery, because it may be less clear how to adjust imagery scripts to help athletes coordinate their resources for a new level of performance. The notion, however, that cognitive strategy effectiveness on strength performance may vary with intervention familiarity represents an avenue of future research.

As a limitation with the existing research, there was evidence that individuals in control groups spontaneously engaged in cognitive strategies [36, 37, 31], and such actions weaken experimental control, blurring distinctions between groups. According to the American Psychological Association these groups would be more accurately labelled "contrast groups" because of the inability to control their cognitive actions [38]. One solution is the use of manipulation checks to assess the degree to which participants have adhered to their instructions and the success of experimental and control group formation, but researchers have not always employed these measures. Another solution might be to discard control groups and focus on comparing cognitive strategies on the assumption that most

1 people who attempt muscular strength-related tasks probably engage in some type of mental  
2 preparation technique (e.g., it seems unlikely that many people prepare for a movement by  
3 distracting themselves with a mathematical activity, a common control group strategy across  
4 the research). Although comparative studies would not let investigators assess if cognitive  
5 strategies caused observed changes in dependent variables, they would shed light on dosage-  
6 response questions, and the identification of the most beneficial interventions [36].  
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14         Aside from cognitive variables, typically those associated with concentration, the  
15 mediation results were characterised by inconsistent results. Given that the scientists who  
16 have typically studied the area have track records in psychological research, it is  
17 understandable that they have most often postulated changes in mental states as the reasons  
18 why cognitive strategies may enhance strength, and have focused their attention on  
19 motivational, cognitive, and emotional mediators [e.g., 39]. A limitation with this research  
20 could be the reliance on self-report data. Participants may not be capable of accurately  
21 reporting their higher order cognitive processes, perhaps due to a lack of self-awareness or  
22 their responses being biased by their beliefs regarding why cognitive strategies should  
23 influence strength [40]. It is difficult to blind participants in these studies. When researchers  
24 ask people to engage in imagery, repeat a self-talk statement, or to achieve a specific goal,  
25 participants are likely to guess at the research question and have perceptions about what they  
26 expect the investigator is hoping to find. As such, issues regarding social desirability or  
27 demand characteristics are likely to be present in the reviewed studies. Two possible  
28 solutions may help address these concerns. First, assessing characteristics in novel ways  
29 other than self-report may help to uncover the psychological mediators underpinning the  
30 influence of cognitive strategies on strength performance. For example, perhaps the use of  
31 eye tracking equipment may reveal differences in attention concentration or the use of body  
32 language and posture may reveal changes in self-efficacy. Second, researchers could make  
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greater use of placebo control conditions in which participants are given the expectation they will perform well but other psychological states are unchanged [5, 35, 41].

Also equivocal are the results regarding physiological and behavioural variables. An advantage that physiological and biomechanical variables have is that they can be measured directly rather than indirectly, as is often the case with psychological variables. The challenge may be the selection of suitable measures. Arousal, for example, is a multidimensional construct consisting of various psychological and physiological components, some of which may be relevant, and others irrelevant to strength. Investigators who measure multiple physiological variables may contribute to understanding possible mediators. To illustrate, heart rate may be unsuitable as a measure of arousal when examining strength. Heart rate can increase from both enhanced sympathetic nervous system activity or from reduced parasympathetic nerve activity [42].

Another possible explanation for the inconsistent mediator-related findings is that the various cognitive strategies work for different reasons, such as preparatory arousal helping to increase participants' activation levels and goal setting helping to increase attention concentration. At present there are too few studies, relative to the number of cognitive strategies and possible mediators, to have confidence in any strategy specific mediator conclusions.

Although the examination of the mechanisms underlying the cognitive strategy and strength performance relationship may yield useful knowledge (e.g., such research might help coaches, athletes, trainers, sports medicine staff tailor cognitive strategies to specific ends), investigators need to employ data collection and analysis designs allowing adequate investigation. For example, one possible mechanism that has been studied and we classified under the motivation category is perception of effort, defined by Marcora [43] (p. 380) as the "conscious sensation of how hard, heavy, and strenuous a physical task is," and similar to the

1 other mechanisms, results were inconsistent with regards to the cognitive strategies and  
2 strength performance relationship. Authors, however, have not used analysis techniques  
3 capable of treating perception of effort as a mediator in this body of knowledge. Studies that  
4 have shown that perception of effort regulates endurance performance provide justification  
5 for further examination regarding the cognitive strategy-strength relationship [44, 43], as long  
6 as suitable analysis procedures are used. Hayes [45], for instance, has recently published  
7 regression-based procedures that allow the examination of mediators and mechanisms using  
8 samples sizes smaller than those needed for structural equation modelling.  
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Related to perception of effort, but as yet unexplored sufficiently in the cognitive  
strategy-strength performance research is the role of mental fatigue, defined by Marcora and  
colleagues [46] (p. 857) as “a psychobiological state caused by prolonged periods of  
demanding cognitive activity and characterized by subjective feelings of “tiredness” and  
“lack of energy.” Marcora and colleagues [46] revealed that mental fatigue limited  
performance in a cycling endurance task of 90 minutes through higher perception of effort.  
Evidence reveals engagement in cognitive strategies, such as imagery, leads to mental fatigue  
[47]. Perhaps the inconsistent findings related to mechanisms involved in the cognitive  
strategy-strength performance relationship may be partly attributable to mental fatigue.  
Novices have been used as participants for much of the research, and they might become  
mentally fatigued when asked to engage in both a cognitive strategy and a novel strength task.

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Cognitive strategies may help performers select and adjust the suitable generalized motor program so they can achieve the desired outcome. As a second example, according to attention-control theory, cognitive strategies help trainers organize their attention resources so they can focus on relevant cues and avoid distractions [49]. A third possible explanation is provided by the activation set hypothesis [8]. An activation set refers to an internal state associated with optimal task execution (e.g., level of arousal, attentional focus, etc.). Cognitive strategies may allow performers to adjust their activation set so that it is relevant for the upcoming task. One theme common among these various explanations is that cognitive strategies help individuals prepare for the upcoming exercise or movement. People adjust their physiological, neurophysiological, biomechanical, and psychological states so that these facets of performance are adequate to ensure successful completion. Research would benefit from multidisciplinary studies assessing neurophysiological, psychological, physiological, and biomechanical variables in the same study. Such knowledge would give rise to a psychobiological understanding of the area.

The inclusion/exclusion criteria used in the current review ensured that the findings were based on experimental research that had employed sound design principles such as randomization or counterbalancing and suitable control groups or conditions. A review of the research rigor, however, still points to possible future research that will help advance knowledge, in addition to those suggestions already mentioned (e.g., an enhanced range of meaningful and ecologically valid tasks, further examination of moderators and mediators). For example, the majority of the research has used students and people aged between 17 and 39 years as participants. Notwithstanding that students and individuals in their twenties and thirties are worthy of examination (e.g., they represent a significant segment of the population in the countries where the research has been undertaken); such individuals may be different from other people in numerous psychological, physiological, biomechanical, or sociological

ways. These differences may influence the cognitive strategy and strength performance relationship. Researchers will provide useful knowledge advances through examination of a diverse range of people, such as children, older adults, and the elderly. These types of individuals participate in strength-based sports, receive rehabilitation and surgery for accidents and injuries, and have a desire to function throughout life autonomously and independently. Being able to guide these folks on how cognitive strategies may assist them may contribute to improved happiness, performance, and functioning.

There have been a limited number of studies examining the influence of self-directed cognitive strategies on muscular strength in injured individuals or people recovering from musculoskeletal surgery. Existing related research has examined different types of interventions, such as instructor-led strategies, and measured other types of variables, such as flexibility or quality of life [50, 51]. Given the potential economic, physical, social, and psychological benefits from the implementation of low cost, relatively simple cognitive strategies, such as those included in the current review, it appears justifiable to suggest research in this direction.

## 5.0 Conclusion and Implications

Based on the results of the current systematic review, although cognitive strategies generally enhance the display of muscular strength, during dynamic tasks requiring maximal strength, local muscular endurance, or muscular power, the results are not unanimous. At a more specific level, that is, the examination of specific strategies on particular types of strength, there sometimes exist small numbers of observations, especially with regards to muscular power. The potential implications help to justify additional research.

As one implication, the use of cognitive strategies may contribute to the reliability of testing protocols. If cognitive activity influences strength then providing patients, athletes, and other test takers with a prescribed cognitive strategy to follow may help to standardise

1 psychological factors that might otherwise contribute to unreliability [52]. As a second  
2 implication, cognitive strategies might help patients rehabilitating from muscular injuries  
3 recover as quickly as possible. As a third implication, individuals wishing to maximise  
4 training or competitive performance may be advised to employ a psychological technique.  
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9 Cognitive strategies refer to self-directed mental interventions used prior to or during  
10 skill execution to enhance physical performance. The current article has systematically  
11 reviewed the research investigating the influence that such interventions have on muscular  
12 strength performance. Although the evidence generally suggests that cognitive strategies  
13 enhance strength, muscular endurance, and local muscular power, additional research is  
14 needed to investigate the applicability of these studies beyond the tasks and people currently  
15 examined. Research is also needed to investigate the possible reasons why cognitive  
16 strategies may be effective. Given the possible implications and importance that many  
17 athletes and coaches place on mental preparation immediately prior to performance additional  
18 empirical attention is justifiable.  
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**References [\* relevant studies]**

1. Tod D, Iredale F, Gill N. 'Psyching-up' and muscular force production. *Sport Medicine*. 2003;33:47-58.
2. Mellalieu SD, Shearer DA. Mental skills training and strength and conditioning. In: Tod D, Lavallee D, editors. *Psychology of Strength and Conditioning*. London, England: Routledge; 2012. p. 1-37.
- \*3. Brody EB, Hatfield BD, Spalding TW, Frazer MB, Caherty FJ. The effect of a psyching strategy on neuromuscular activation and force production in strength-trained men. *Research Quarterly for Exercise and Sport*. 2000;71:162-70.
- \*4. Tenenbaum G, Bar-Eli M, Hoffman JR, Jablonovski R, Sade S, Shitrit D. The effect of cognitive and somatic psyching-up techniques on isokinetic leg strength performance. *Journal of Strength and Conditioning Research*. 1995;9:3-7.
- \*5. Tod DA, Iredale KF, McGuigan MR, Strange DEO, Gill N. "Psyching-up" enhances force production during the bench press exercise. *Journal of Strength and Conditioning Research*. 2005;19:599-603.
6. Cupal DD, Brewer BW. Effects of relaxation and guided imagery on knee strength, reinjury anxiety, and pain following anterior cruciate ligament reconstruction. *Rehabilitation Psychology*. 2001;46:28-43.
- \*7. Shelton TO, Mahoney MJ. The content and effect of "psyching-up" strategies in weight lifters. *Cognitive Therapy and Research*. 1978;2:275-84.
8. Schmidt RA, Lee TD. *Motor control and learning: A behavioral emphasis*. Champaign, IL: Human Kinetics; 2005.
9. Steiner ID. *Group process and productivity*. New York: Academic Press; 1972.
10. Higgins JPT, Green S. *Cochrane handbook for systematic reviews of interventions: version 5.1.0 [updated March 2011]*. The Cochrane Collaboration; 2011.

11. Murphy S, Nordin S, Cumming J. Imagery in sport, exercise, and dance. In: Horn TS, editor. *Advances in sport psychology*. 3rd ed. Champaign, IL: Human Kinetics; 2008. p. 297-324.
12. Locke EA, Latham GP. Building a practically useful theory of goal setting and task motivation: A 35-year odyssey. *American Psychologist*. 2002;57:705-17.
13. Hardy J, Oliver E, Tod D. A framework for the study and application of self-talk within sport. In: Mellalieu SD, Hanton S, editors. *Advances in applied sport psychology: A review*. London: Routledge; 2009. p. 37-74.
14. Tod D, McGuigan M. The efficacy of psyching-up on strength performance. In: Selkirk TB, editor. *Focus on exercise and health research*. New York: Nova Science; 2006. p. 163-79.
15. Kraemer WJ, Ratamess NA, Fry AC, French DN. Strength training: Development and evaluation of methodology. In: Maud PJ, Foster C, editors. *Physiological Assessment of Human Fitness*. Champaign, IL: Human Kinetics; 2006. p. 119-50.
16. Harman E, Garhammer J. Administration, scoring, and interpretation of selected tests. In: Baechle TR, Earle RW, editors. *Essentials of strength training and conditioning*. 3rd ed. Champaign, IL: Human Kinetics; 2008.
17. Abernethy P, Wilson G, Logan P. Strength and power assessment: Issues, controversies and challenges. *Sports Medicine*. 1995;19:401-17.
18. McGuigan MR, Wright GA, Fleck SJ. Strength training for athletes: Does it really help sports performance? *International Journal of Sports Physiology and Performance*. 2012;7:2-5.
19. Fitts PM, Posner MI. *Human Performance. Basic concepts in psychology series*. Belmont, Ca.: Brooks/Cole; 1967.
20. Zourbanos N, Hatzigeorgiadis A, Bardas D, Theodorakis Y. The effects of self-talk on dominant and non-dominant arm performance on a handball task in primary physical education students. *The Sport Psychologist*. 2013;27:171-6.

21. Carrol TJ, Riek S, Carson RG. Neural adaptations to resistance training. *Sports Medicine*. 2001;31:829-40.
22. Bigland-Ritichie R. EMG/force relations and fatigue of human voluntary contractions. *Exercise and Sport Science Reviews*. 1981;9:75-117.
23. Latash ML. *Neurophysiological basis of movement*. 2nd ed. Champaign, IL: Human Kinetics; 2008.
24. Bandura A. *Self-efficacy: The exercise of control*. New York: Freeman; 1997.
25. Timmer A, Sutherland LR, Hilsden RJ. Development and evaluation of a quality score for abstracts. *BMC Medical Research Methodology*. 2003;3(2).
26. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. *Medicine & Science in Sports & Exercise*. 2000;32:963-75.
27. Edwards C, Tod D, Molnar G. A systematic review of the drive for muscularity research area. *International Review of Sport and Exercise Psychology*. 2014;7:18-41.  
doi:10.1080/1750984X.2013.847113.
28. Tod D, Hardy J, Oliver E. Effects of self-talk: A systematic review. *Journal of Sport & Exercise Psychology*. 2011;33:666-87.
29. Goodger K, Gorely T, Lavallee D, Harwood C. Burnout in sport: A systematic review. *The Sport Psychologist*. 2007;21:127-51.
30. Park S, Lavallee D, Tod D. Athletes' career transition out of sport: A systematic review. *International Review of Sport and Exercise Psychology*. 2013;6:22-53.  
doi:10.1080/1750984X.2012.687053.
- \*31. Theodorakis Y, Weinberg R, Natsis P, Douma I, Kazakas P. The effects of motivational versus instructional self-talk on improving motor performance. *The Sport Psychologist*. 2000;14:253-72.

32. Filby WCD, Maynard IW, Graydon JK. The effect of multiple-goal strategies on performance outcomes in training and competition. *Journal of Applied Sport Psychology*. 1999;11:230-46.
33. Wulf G, Prinz W. Directing attention to movement effects enhances learning: A review. *Psychonomic Bulletin & Review*. 2001;8:648–60.
34. Paul GL. Strategy of outcome research in psychotherapy. *Journal of Consulting Psychology*. 1967;31:109-18.
35. Whelan JP, Epkins CC, Meyers AW. Arousal interventions for athletic performance: Influence of mental preparation and competitive experience. *Anxiety Research*. 1990;2:293-307.
36. Hardy J, Hall CR, Gibbs C, Greenslade C. Self-talk and gross motor skill performance: An experimental approach? In: *Athletic Insight: The Online Journal of Sport Psychology*, 7, 2. 2005. <http://www.athleticinsight.com/Vol7Iss2/SelfTalkPerformance.htm>. Accessed 26 August 2005.
- \*37. Bar-Eli M, Tenenbaum G, Pie JS, Btresh Y, Almog A. Effect of goal difficulty, goal specificity and duration of practice time intervals on muscular endurance performance. *Journal of Sports Sciences*. 1997;15:125-35.
38. Wilkinson L, Task Force On Statistical Inference. Statistical methods in psychology journals: Guidelines and explanations. *American Psychologist*. 1999;54:594-604.
- \*39. Wilkes RL, Summers JJ. Cognitions, mediating variables, and strength performance. *Journal of Sport Psychology*. 1984;6:351-9.
40. Nisbett RE, Wilson TD. Telling more than we can know: Verbal reports on mental processes. *Psychological Review*. 1977;84:231-59.
41. Caudill D, Weinberg R, Jackson A. Psyching-up and track athletes: A preliminary investigation. *Journal of Sport Psychology*. 1983;5:231-5.

42. Berntson GG, Cacioppo JT, Quigley KS. Respiratory sinus arrhythmia: Autonomic origins, physiological mechanisms, and psychophysiological implications. *Psychophysiology*. 1993;30:183-96.
43. Marcora SM. Effort: perception of. In: Goldstein EB, editor. *Encyclopedia of Perception*. Thousand Oaks: Sage; 2010. p. 380-3.
44. Pageaux B. The psychobiological model of endurance performance: an effort-based decision-making theory to explain self-paced endurance performance. *Sports Medicine*. 2014;44:1319-20.
45. Hayes AF. *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach*. New York, NY: Guildford; 2013.
46. Marcora SM, Staiano W, Manning V. Mental fatigue impairs physical performance in humans. *Journal of Applied Physiology*. 2009;106:857–64.
47. Rozand V, Lebon F, Papaxanthis C, Lepers R. Does a mental training session induce neuromuscular fatigue. *Medicine and Science in Sports and Exercise*. 2014;45:1981-9.
48. Schmidt RA. A schema theory of discrete motor skill learning. *Psychological Review*. 1975;82:225-60.
49. Boutcher SH. The role of performance routines in sport. In: Jones JG, Hardy L, editors. *Stress and performance in sport*. New York: Wiley; 1990. p. 231-45.
50. Lan C, Chen SY, Lai JS, Wong MK. The effect of Tai Chi on cardiorespiratory function in patients with coronary artery bypass surgery. *Medicine and Science in Sports and Exercise*. 1999;31:634-8.
51. Maddison R, Prapavessis H, Clatworthy M, Hall C, Foley L, Harper T et al. Guided imagery to improve functional outcomes post-anterior cruciate ligament repair: Randomized-controlled pilot trial. *Scandinavian Journal of Medicine & Science in Sports*. 2012;22:816-21.



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- \*52. Edwards C, Tod D, McGuigan M. Self-talk influences vertical jump performance and kinematics in male rugby union players. *Journal of Sports Sciences*. 2008;26:1459-65.
- \*53. Boyce BA, Wayda VK. The effects of assigned and self-set goals on task performance. *Journal of Sport & Exercise Psychology*. 1994;16:258-69.
- \*54. Caudill D, Weinberg RS. The effects of varying the length of the psych-up interval on motor performance. *Journal of Sport Behavior*. 1983;6:86-91.
- \*55. Cornwall MW, Bruscatto MP, Barry S. Effect of mental practice on isometric muscular strength. *Journal of Orthopaedic and Sports Physical Therapy*. 1991;13:231-4.
- \*56. De Ruiter CJ, Hutter V, Icke C, Groen B, Gemmink A, Smilde H et al. The effects of imagery training on fast isometric knee extensor torque development. *Journal of Sports Sciences*. 2012;30:166-74.
- \*57. Elko K, Ostrow AC. The effects of three mental preparation strategies on strength performance of young and older adults. *Journal of Sport Behavior*. 1992;15:34-41.
- \*58. Ford KR, Myer GD, Smith RL, Byrnes RN, Dopirak SE, Hewett TE. Use of an overhead goal alters vertical jump performance and biomechanics. *Journal of Strength and Conditioning Research*. 2005;19:394-9.
- \*59. Gould D, Weinberg R, Jackson A. Mental preparation strategies, cognitions, and strength performance. *Journal of Sport Psychology*. 1980;2:329-39.
- \*60. Hall HK, Byrne ATJ. Goal setting in sport: Clarifying recent anomalies. *Journal of Sport & Exercise Psychology*. 1988;10:184-98.
- \*61. Hall HK, Weinberg RS, Jackson A. Effects of goal specificity, goal difficulty, and information feedback on endurance performance. *Journal of Sport & Exercise Psychology*. 1987;9:43-54.

- \*62. Hatzigeorgiadis A, Theodorakis Y, Zourbanos N. Self-talk in the swimming pool: The effects of self-talk on thought content and performance on water-polo tasks. *Journal of Applied Sport Psychology*. 2004;16:138-50.
- \*63. Herbert RD, Dean C, Gandevia SC. Effects of real and imagined training on voluntary muscle activation during maximal isometric contractions. *Acta Physiologica Scandinavica*. 1998;163:361-8.
- \*64. Howard WL, Reardon JP. Changes in the self-concept and athletic performance of weight lifters through a cognitive-hypnotic approach: An empirical study. *American Journal of Clinical Hypnosis*. 1986;28:248-57.
- \*65. Kelsey IB. Effects of mental practice and physical practice upon muscular endurance. *Research Quarterly for Exercise and Sport*. 1961;32:47-54.
- \*66. Kolovelonis A, Goudas M, Dermitzaki I. The effects of instructional and motivational self-talk on students' motor task performance in physical education. *Psychology of Sport and Exercise*. 2011;12:153-8.
- \*67. Lebon F, Collet C, Guillot A. Benefits of motor imagery training on muscle strength. *Journal of Strength & Conditioning Research*. 2010;24:1680-7.
- \*68. Lee C. Psyching up for a muscular endurance task: Effects of image content on performance and mood state. *Journal of Sport & Exercise Psychology*. 1990;12:66-73.
- \*69. Lerner BS, Locke EA. The effects of goal setting, self-efficacy, competition, and personal traits on the performance of an endurance task. *Journal of Sport & Exercise Psychology*. 1995;17:138-52.
- \*70. Li S, Latash ML, Zatsiorsky VM. Effects of motor imagery on finger force responses to transcranial magnetic stimulation. *Cognitive Brain Research*. 2004;20:273-80.
- \*71. McGuigan MR, Ghiagiarelli J, Tod D. Maximal strength and cortisol responses to psyching-up during the squat exercise. *Journal of Sports Sciences*. 2005;23:687-92.

\*72. Nelson JK. Motivating effects of the use of norms and goals with endurance testing.

Research Quarterly for Exercise and Sport. 1978;49:317-21.

\*73. Newsom J, Knight P, Balnave R. Use of mental imagery to limit strength loss after

immobilization. Journal of Sport Rehabilitation. 2003;12:249-58.

\*74. Perkins D, Wilson GV, Kerr JH. The effects of elevated arousal and mood on maximal

strength performance in athletes. Journal of Applied Sport Psychology. 2001;13:239-59.

\*75. Peynircioglu ZF, Thompson JLW, Tanielian TB. Improvement strategies in free-throw

shooting and grip-strength tasks. The Journal of General Psychology. 2000;127:145-56.

\*76. Shackell EM, Standing LG. Mind over matter: mental training increases physical

strength. North American Journal of Psychology. 2007;9:189-200.

\*77. Sidaway B, Trzaska AR. Can Mental Practice Increase Ankle Dorsiflexor Torque?

Physical Therapy. 2005;85(10):1053-60.

\*78. Smith D, Collins D, Holmes P. Impact and mechanism of mental practice effects on

strength. International Journal of Sport and Exercise Psychology. 2003;1:293-306.

\*79. Tenenbaum G, Pinchas S, Elbaz G, Bar-Eli M, Weinberg R. Effect of goal proximity

and goal specificity on muscular endurance performance: A replication and extension.

Journal of Sport & Exercise Psychology. 1991;13:174-87.

\*80. Theodorakis Y, Maliou P, Papaioannou A, Beneca A, Filactakidou A. The effect of

personal goal, self-efficacy, and self-satisfaction on injury rehabilitation. Journal of Sport

Rehabilitation. 1996;5:173-83.

\*81. Tod DA, Thatcher R, McGuigan M, Thatcher J. Effects of instructional and motivational

self-talk on the vertical jump. Journal of Strength and Conditioning Research. 2009;23:196-

202.

- \*82. Weinberg RS, Gould D, Jackson A. Cognition and motor performance: Effect of psyching-up strategies on three motor tasks. *Cognitive Therapy and Research*. 1980;4:239-45.
- \*83. Weinberg R, Jackson A, Seaboune T. The effects of specific vs nonspecific mental preparation strategies on strength and endurance performance. *Journal of Sport Behavior*. 1985;8:175-80.
- \*84. Weinberg R, Bruya L, Jackson A, Garland H. Goal difficulty and endurance performance: A challenge to the goal attainability assumption. *Journal of Sport Behavior*. 1987;10:82-92.
- \*85. Weinberg R, Bruya L, Longino J, Jackson A. Effect of goal proximity and specificity on endurance performance of primary-grade children. *Journal of Sport & Exercise Psychology*. 1988;10:81-91.
- \*86. Weinberg R, Bruya L, Garland H, Jackson A. Effect of goal difficulty and positive reinforcement on endurance performance. *Journal of Sport & Exercise Psychology*. 1990;12:144-56.
- \*87. Wright CJ, Smith D. The effect of PETTLEP imagery on strength performance. *International Journal of Sport and Exercise Psychology*. 2009;7:18-31.
- \*88. Yue G, Cole KJ. Strength increases from the motor program: Comparison of training with maximal voluntary and imagined muscle contractions. *Journal of Neurophysiology*. 1992;67:1114-23.
- \*89. Zijdewind I, Toering ST, Bessem B, van der Laan O, Diercks RL. Effects of imagery motor training on torque production of ankle plantar flexor muscles. *Muscle & Nerve*. 2003;28:168-73.

\*90. Yue GH, Wilson SL, Cole KJ, Darling WG, Yuh WTC. Imagined muscle contraction training increases voluntary neural drive to muscle. *Journal of Psychophysiology*. 1996;10:198-208.

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Table 1

*Sample Characteristics of Participants employed in the Reviewed Research*

Characteristic	Number of studies
Gender	
Male only	18
Female only	3
Combined	27
Not stated	5
Sample size	
< 20	6
20-39	18
40-59	8
60-79	7
80-99	3
100+	11
Mean age	
<17	7
17-39	45
40+	1
Participant label	
Primary school student	3
High school student	4
University student	29
Novice	5
Weight trained	8
Other	4

Note: total participants = 3695, male participants = 2042, female participants = 1212, not disclosed = 341

Table 2

*Design Characteristics of the Reviewed Research*

Characteristic	Total
Between versus within participant	
Between	41
Within	12
Dependent variable	
Maximal strength	56
Local muscular endurance	58
Muscular Power	15
Cognitive strategy (Ks)	
Imagery	43
Goal-setting	40
Self-talk	18
Preparatory arousal	16
Free choice	12
Control	
Do your best/task	43
Distraction	37
No instruction/intervention	30
Rest	8
Usual care/training	4
Placebo	7
Strategy manipulation check employed	
Manipulation check employed	76
Manipulation check not employed	53

Table 3

*Effects of Each Cognitive Strategy on Muscular Strength*

		Number of Ks supporting the effect			
	<i>K</i>	+	-	0	Sum Code (%)
Imagery					
Strength	29	20	0	9	+ (69%)
Endurance	11	6	0	5	? (55%)
Power	3	1	0	2	0 (67%)
Total	43	27	0	16	+ (63%)
Goal setting					
Strength	3	3	0	0	+ (100%)
Endurance	36	22	0	14	+ (61%)
Power	1	1	0	0	+ (100%)
Total	40	26	0	14	+ (65%)
Self-talk					
Motivational ST	10	7	1	2	+ (70%)
Instructional ST	7	4	0	3	? (57%)
CR	1	0	0	1	0 (100%)
Strength	5	3	1	1	+ (60%)
Endurance	4	2	0	2	? (50%)
Power	9	6	0	3	+ (67%)
Total	18	11	1	6	+ (61%)
Preparatory arousal					
Strength	11	6	0	5	? (55%)
Endurance	4	4	0	0	+ (100%)
Power	1	1	0	0	+ (100%)
Total	16	11	0	5	+ (63%)
Free Choice					
Strength	8	5	0	3	+ (63%)
Endurance	3	3	0	0	+ (100%)
Power	1	1	0	0	+ (100%)
Total	12	9	0	3	+ (75%)
Total	129	84	1	44	+ (65%)

Note: ST = Self-talk, CR = Cognitive Restructuring, *K* = number of comparisons with a control condition



Table 4

*Results Stratified According to Participant Skill Level*

Number of Ks supporting the effect					
	<i>K</i>	+	0	-	Sum Code (%)
<b>Imagery</b>					
Novice	40	24	16	0	+ (60%)
Trained	3	3	0	0	+ (100%)
<b>Goal setting</b>					
Novice	39	25	14	0	+ (64%)
Trained	1	1	0	0	+ (100%)
<b>Self-talk</b>					
Novice	11	6	4	1	? (58)
Trained	7	5	2	0	+ (71)
<b>Preparatory arousal</b>					
Novice	14	11	3	0	+ (79%)
Trained	2	0	2	0	0 (100%)
<b>Free Choice</b>					
Novice	8	6	2	0	+ (75%)
Trained	4	3	1	0	+ (75%)
<b>Total</b>					
Novice	112	72	39	1	+ (65%)
Trained	17	12	5	0	+ (71%)

*K* = number of comparisons with a control condition

Table 5

*Results from Mediation Analysis*

Number of <i>K</i> s supporting the effect					
	<i>K</i>	+	0	M	Sum Code (%)
Cognitive	4	4	0	0	+ (100%)
Motivation	17	6	8	3	? (47%)
Emotional	18	6	3	9	? (50%)
Biomechanical/physiological	15	7	5	3	? (47%)

*K* = number of comparisons with a control condition

### Acknowledgements

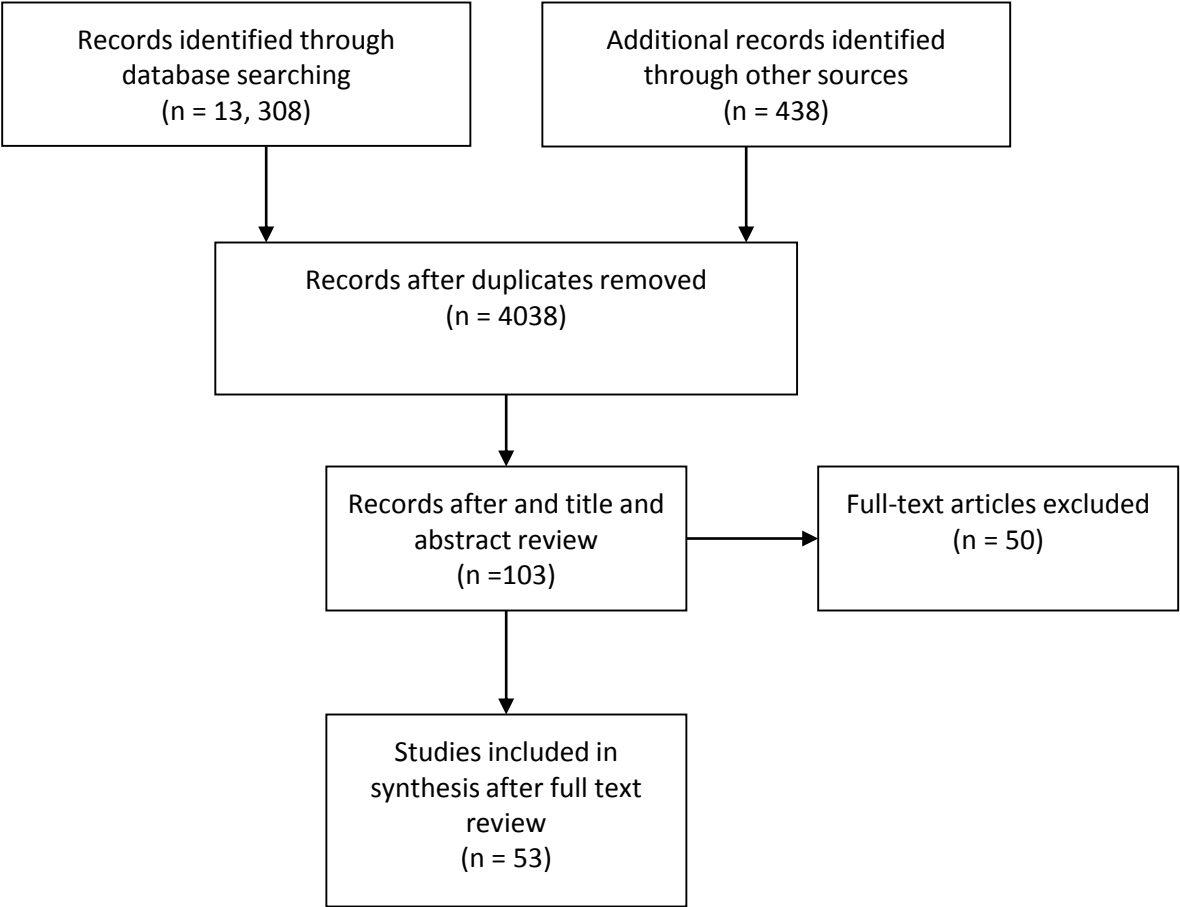
David Tod, Christian Edwards, Mike McGuigan and Geoff Lovell declare that they have no conflict of interest. No financial support was received for the conduct of this study or preparation of this manuscript.

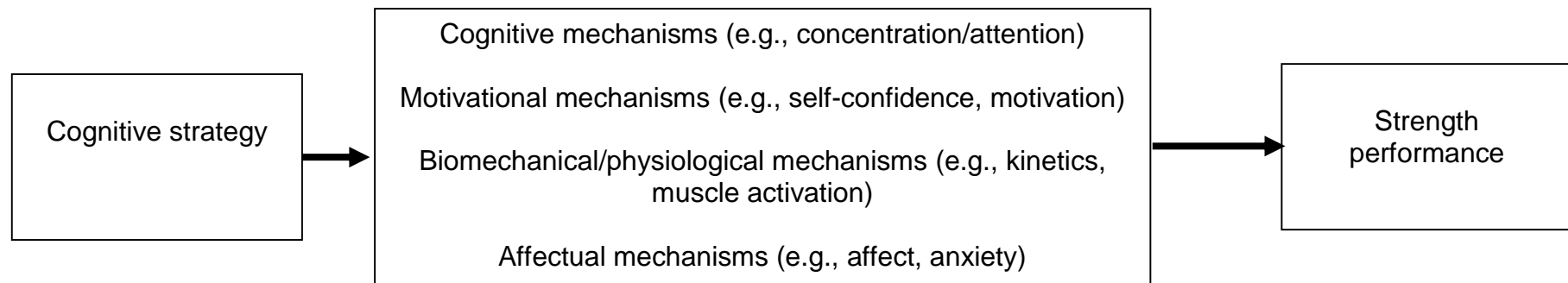
Figure 1

*Proposed Mediators Studied in the Cognitive Strategy-Muscular Strength Relationship*

Figure 2

*PRISMA Flowchart Illustrating the Literature Search at each Stage*





## **Supplementary material: Search strategy used for each database**

### **Article title**

A Systematic Review of the Effect of Cognitive Strategies on Strength Performance

### **Journal**

Sports Medicine

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### **Search strategy used for each database**

streng\* and imagery

streng\* and visualisation

streng\* and visualization

streng\* and self-talk

streng\* and inner dialogue

streng\* and preparatory arousal

streng\* and preparatory activation

streng\* and goal-setting

streng\* and goal setting

streng\* and goal-set\*

streng\* and goal set\*

streng\* and psych-up

streng\* and psyching-up

musc\* and imagery

musc\* and visualisation

musc\* and visualization

musc\* and self-talk

musc\* and inner dialogue

musc\* and preparatory arousal

musc\* and preparatory activation

musc\* and goal-setting

musc\* and goal setting

musc\* and goal-set\*

musc\* and goal set\*

musc\* and psych-up

musc\* and psyching-up

power and imagery

power and visualisation

power and visualization

power and self-talk

power and inner dialogue

power and preparatory arousal

power and preparatory activation  
power and goal-setting  
power and goal setting  
power and goal-set\*  
power and goal set\*  
power and psych-up  
power and psyching-up  
muscular endurance and imagery  
muscular endurance and visualisation  
muscular endurance and visualization  
muscular endurance and self-talk  
muscular endurance and inner dialogue  
muscular endurance and preparatory arousal  
muscular endurance and preparatory activation  
muscular endurance and goal-setting  
muscular endurance and goal setting  
muscular endurance and goal-set\*  
muscular endurance and goal set\*  
muscular endurance and psych-up  
muscular endurance and psyching-up