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SYSTEMATIC REVIEW

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

David Tod[1] · Christian Edwards[2] · Mike McGuigan[3] · Geoff Lovell[4]

Abstract
Background Researchers have tested the beliefs of sportspeople and sports medicine specialists that cognitive strategies influence strength performance. Few investigators have synthesised 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, reference lists of retrieved articles, 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 above 0.5 (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 to 65 %). Results were mixed when examining the effects of specific strategies 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.
Conclusions 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

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

1 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,

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✉ David Tod
d.a.tod@ljmu.ac.uk

[1] School of Sport and Exercise Sciences, Tom Reilly Building, Byrom Street Campus, Liverpool John Moores University, Liverpool L3 3AF, UK

[2] Institute of Sport and Exercise Science, University of Worcester, Worcester, UK

[3] Sports Performance Research Institute New Zealand, Auckland University of Technology, Auckland, New Zealand

[4] School of Social Sciences, University of the Sunshine Coast, Sippy Downs, QLD, Australia

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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 have reported both (a) significant and nonsignificant results, 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 because athletes are not making use of their psychological and physical assets (c.f. with Steiner's [9] model of group productivity where actual performance equals possible performance minus coordination and motivational losses).

The purpose of this article was to conduct a systematic review of the experimental literature examining the influence of cognitive strategies on muscular strength. There are a number of reasons why a systematic review will advance current understanding. First, there have been few attempts to synthesize literature on the topic, and authors have published narrative reviews only [1, 2]. In these narrative reviews, clear inclusion and exclusion criteria, detailed search strategies, and transparent data extraction and analysis procedures were absent. It is not clear if the body of research was adequately represented or examined. Also, by relying on a subjective interpretation to synthesis knowledge, there is the possibility of reviewer bias. A systematic review offers a more objective and transparent way of synthesising the knowledge. Second, the most comprehensive review is more than 10 years old and a number of studies have been published since [1]. A systematic review will provide an up-to-date understanding of the topic. Third, the previous reviews did not examine the quality or rigour of the research. Assessing research rigour is an established component of systematic reviews [10], and allows insights regarding the confidence that may be placed in current knowledge and any derived implications.

For the current review, cognitive strategies were defined as self-directed mental interventions used prior to or during skill execution to enhance physical performance [1]. Related interventions such as music, external verbal encouragement, or instructor-led guided imagery were not considered for this review. The current review focused on imagery, goal setting, self-talk, preparatory arousal, and free choice. These strategies were included because they are the common interventions participants have identified as being related to enhanced muscular strength [7]. Research under the imagery heading included studies where participants had been asked to visualise or imagine performing the movement [11]. Goal-setting research included investigations in which participants had been given specific attainment levels to achieve, as opposed to being asked to 'do your best' [12]. Self-talk studies included those in which participants had been asked to use a cue phrase to assist performance [13]. Preparatory arousal involved self-directed strategies aimed at increasing the activation levels of participants [14]. In free-choice strategies, participants had selected a preferred cognitive method [7].

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

As a second way to advance literature, we examined the evidence concerning the degree to which participant skill level moderated the cognitive strategy–muscular strength relationship. Moderators influence relationships by altering the direction (positive or negative) and/or magnitude. The moderator's influence may then affect the consistency of the relationship within the sampled literature. Although we acknowledge we were unable to test directly whether a moderating effect exists, because researchers have not conducted the types of studies needed, examining the overall direction and consistency of findings for different categories of participant skill level generates meaningful, albeit initial, information concerning the presence of a moderating effect. These initial findings then provide direction to help researchers design studies to test moderating effects.

Participant skill level was selected because researchers have hypothesised it as a meaningful moderator with regard to strength performance [3], and Fitts and Posner's [19] stages of skill learning framework provides a theoretical rationale [14]. During the early stages of learning, novices use explicit instruction and talk themselves through the phases of a movement, whereas during the later stages of learning, individuals engage in less cognitive activity and their performances are more automatic. Further deliberate use of cognitive strategies may hinder the display of strength in advanced learners if they disrupt attentional or other movement-related resources [14]. As such, novice performers may benefit more frequently from the use of cognitive strategies compared with their skilled counterparts. Recently, Zourbanos and colleauges [20] observed that the influence of instructional self-talk on motor skill performance was greater in a novel rather than well-learned movement. Although the task was not a strength-based movement, the study provides initial evidence to support the hypothesis advanced in the current review. Equally, however, some practitioners might suggest that during well-learned movements, performers have had greater opportunities to practice helpful cognitive strategies and may benefit more from their use than novices. As such, we acknowledge that our hypothesis represents our conjecture based on our interpretation of existing empirical evidence.

Regarding a third way the current systematic review may further knowledge, we considered potential mechanisms that might explain the relationship. Adopting a throughput perspective, as illustrated in Fig. 1, we identified four possible mechanisms: cognitive, motivational, biomechanical/physiological, and affective. These four mechanisms were derived from the work of Hardy et al. [13] 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 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

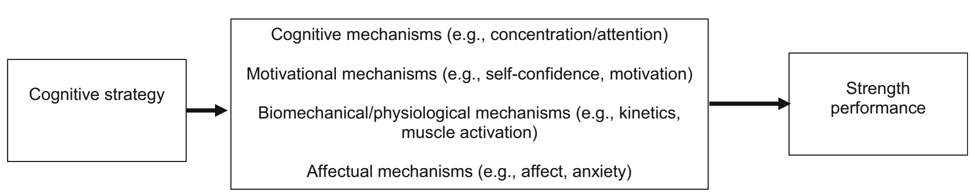

Fig. 1 Proposed mediators studied in the cognitive strategy–muscular strength relationship

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. However, by collating the existing findings, where the conceptualised 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; and 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 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 search was conducted on 19 November 2014.

Figure 2 presents a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram summarising the search results. These search strategies generated an initial pool of 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 were extracted from 53 studies, which are identified in the reference list with an asterisk [3–5, 7, 25–66, 76]. 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 endurance, or power as a dependent variable; (d) scored over 0.5 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

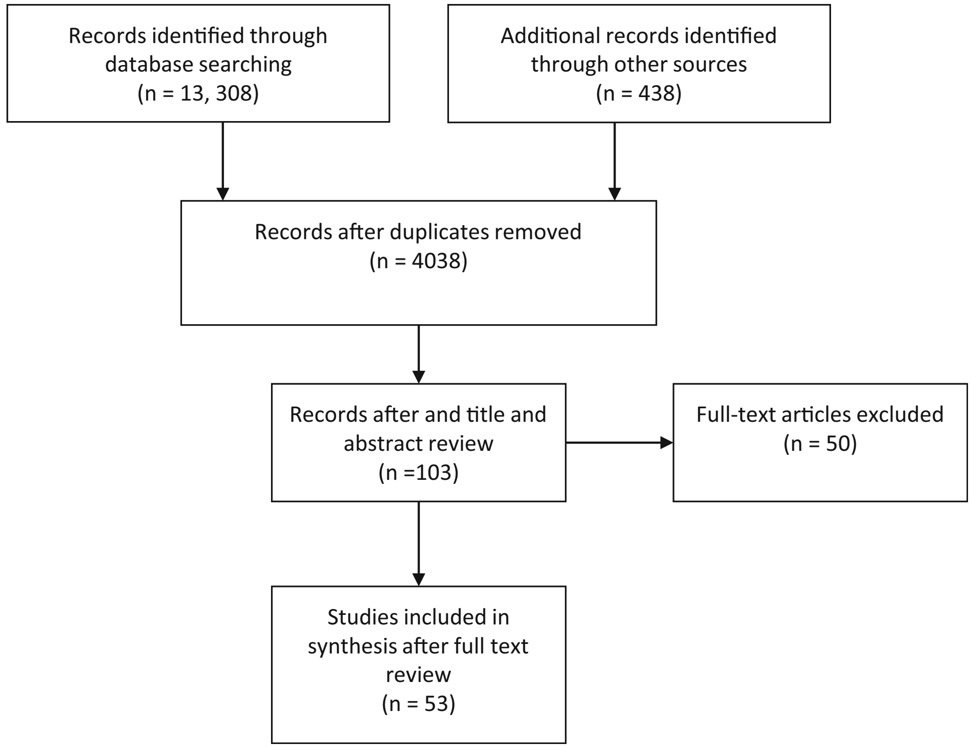

Fig. 2 PRISMA flowchart illustrating the literature search at each stage. *PRISMA* Preferred Reporting Items for Systematic Reviews and Meta-Analyses

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, the checklist of Timmer et al. [67] was applied because it had good construct validity and had 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 0.5. Scores lower than 0.5 indicate a lack of several necessary details, such as the absence of participant description, descriptive and statistical results, or information about how measurements were operationalised. The score of 0.5 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 scrutinised using the aforementioned inclusion and exclusion criteria. Once these criteria had been satisfied, we used procedures described by Sallis et al. [68] to analyse the content of the papers in a quantitative fashion. We selected these procedures because they provided a transparent way to organise literature that results in identifying the major trends and answering the review questions [69–72]. 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., study 1; Theodorakis et al., study 2 [25]). 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 hypothesised mediating variables.

2.4 Analysis

The data tables mentioned above were analysed to create summary tables presented in the Sect. 3, which involved a number of stages. First, sample and design characteristics were summarised by a tally count; and, second, the effects of cognitive strategy on strength performance and hypothesised mediators were examined. For each dependent variable, the numbers of significant and nonsignificant results were tallied. Positive and negative significant findings were tallied separately because a cognitive strategy could potentially 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. Summarising of the research surrounding each consequence was performed by the calculation of the percentage of support offered by the relevant studies. We employed the coding system of Sallis et al. [68]: 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 nonsignificant 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 indepth appreciation of the searched literature and ensure that only eligible studies were included in the final analysis stage.

3 Results

3.1 Descriptive Characteristics of Included Studies

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 3762 participants (2071 male, 1334 female, and 357 not specified). Regarding sample size, 60 % of studies used less than 60 participants. As presented in Table 1, 53 % of studies employed mixed-sex 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 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 (*k*s) satisfied the inclusion criteria, of which 84 (65 %) indicated a positive relationship

Table 1 Sample characteristics of participants employed in the reviewed research

Characteristic	No. 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 (years)	
<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

Total participants = 3762; male participants = 2071, female participants = 1334, not disclosed = 357

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 (*K*s)	
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

	K	Number of *K*s supporting the effect			Sum code (%)
		+	−	0	
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)

ST self-talk, *CR* cognitive restructuring, *K* number of comparisons with a control condition, + indicates positive, − indicates negative, 0 indicates no effect, ? indicates inconsistent

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

3.2.2 Goal Setting

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

3.2.3 Self-Talk

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

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 regard 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 value of $k = 4$). For the remaining three categories, there was insufficient evidence that they had consistent relationships with cognitive strategies (motivation = 35 %, affective = 17 %, and biomechanical/physiological = 47 %).

Table 4 Results stratified according to participant skill level

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

K number of comparisons with a control condition, + indicates positive, − indicates negative, 0 indicates no effect, ? indicates inconsistent

Table 5 Results from mediation analysis

	K	Number of *K*s supporting the effect			Sum code (%)
		+	0	M	
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, + indicates positive, 0 indicates no effect, ? indicates inconsistent, M indicates mixed results

4 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 suggest 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 [25]. 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 hypothesised 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. However, strength tasks 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. However, such subtypes might exist, 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 [73]. Outcome goals assess performance relative to another person (e.g. winning a weightlifting 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 the research of Wulf and Prinz [74] regarding the focus of attention (where an external focus is regarded as better for performance than an internal focus), we hypothesise 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). However, in many situations maximal strength may be less helpful to individuals than either local muscular endurance or power. For example, absolute strength of athletes 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 measures have included sit-ups, hand grip, and leg extensions, and these are convenient tasks to use in research because they are easily measured and do not require participants to engage in extensive motor skill learning or to attend multiple familiarisation sessions. Researchers could extend current knowledge by employing strength measures that have relevance to the populations under study, e.g. the competitive lifts Olympic weightlifters perform, the rehabilitation exercises therapists prescribe to patients, or the exercises strength and conditioning professionals teach their clients.

Given the presence of nonsignificant and (occasional) negative relationships across the results, it appears that cognitive strategies do not help all people enhance the display of strength. Paralleling other psychological interventions, cognitive strategies help some people, have no effect in others, and may hinder the performance of a few individuals [75]. The challenge for researchers is to identify the reasons why there may be various effects. The possible individual difference moderator examined in the current review was participant skill level. However, results provided limited evidence that skill level may act as a moderator. Moreover, researchers 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 et al. [76] 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. However, the vast majority of the research 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 five repetitions, 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 regard 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. However, the notion 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 [25, 26, 77], 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 [78]. 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 people who attempt muscular strength-related tasks probably engage in some type of mental preparation technique (e.g. it seems unlikely that many people prepare for a movement by distracting themselves with a mathematical activity, a common control group strategy across the research). Although comparative studies would not let investigators assess if cognitive strategies caused observed changes in dependent variables, they would shed light on dosage-response questions and identification of the most beneficial interventions [77].

Aside from cognitive variables, typically those associated with concentration, the mediation results were characterised by inconsistent results. Given that scientists who have typically studied the area have track records in psychological research, it is understandable that they have most often postulated changes in mental states as the reasons why cognitive strategies may enhance strength, and have focused their attention on motivational, cognitive, and emotional mediators (e.g. Wilkes and Summers [27]). A limitation with this research could be the reliance on self-report data. Participants may not be capable of accurately reporting their higher-order cognitive processes, perhaps due to a lack of self-awareness or their responses being biased by their beliefs regarding why cognitive strategies should influence strength [79]. It is difficult to blind participants in these studies. When researchers ask people to engage in imagery, repeat a self-talk statement, or to achieve a specific goal, participants are likely to guess at the research question and have perceptions about what they expect the investigator is hoping to find. As such, issues regarding social desirability or demand characteristics are likely to be present in the reviewed studies. Two possible solutions may help address these concerns. First, assessing characteristics in novel ways other than self-report may help to uncover the psychological mediators underpinning the influence of cognitive strategies on strength performance. For example, perhaps the use of eye-tracking equipment may reveal differences in attention concentration, or the use of body language and posture may reveal changes in self-efficacy. Second, researchers could make greater use of placebo control conditions in which participants are given the expectation they will perform well but other psychological states are unchanged [5, 76, 80].

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. For example, arousal 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; it can increase from both enhanced sympathetic nervous system activity or from reduced parasympathetic nerve activity [81].

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 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, and sports medicine staff to 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 that we classified under the motivation category, is perception of effort, defined by Marcora [82] (p. 380) as the "conscious sensation of how hard, heavy, and strenuous a physical task is" and, similar to the other mechanisms, results were inconsistent with regard to the cognitive strategies and strength performance relationship. However, authors have not used analysis techniques capable of treating perception of effort as a mediator in this body of knowledge. Studies that have shown that perception of effort regulates endurance performance provide justification for further examination regarding the cognitive strategy–strength relationship [82, 83], as long as suitable analysis procedures are used. For instance, Hayes [84] has recently published regression-based procedures that allow the examination of mediators and mechanisms using sample sizes smaller than those needed for structural equation modelling.

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 [85] (p. 857) as "a psychobiological state caused by prolonged periods of demanding cognitive activity and characterised by subjective feelings of "tiredness" and "lack of energy". Marcora and colleagues [85] revealed that mental fatigue limited performance in a cycling endurance task of 90 min through higher perception of effort. Evidence reveals that engagement in cognitive strategies, such as imagery, leads to mental fatigue [86]. 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.

In the absence of empirical data, one way to drive knowledge forward may be to identify suitable theory from which testable hypotheses can be derived. One example is the schema theory [87]. According to the schema theory, the instructions for a task, such as the squat, are represented in the nervous system by a generalised motor programme. There is also a motor response schema allowing people to adjust the generalised motor programme so they are able to produce the desired action (e.g. generate sufficient force to squat a particular weight). Cognitive strategies may help performers select and adjust the suitable generalised motor programme so they can achieve the desired outcome. As a second example, according to the attention-control theory, cognitive strategies help trainers organise their attention resources so they can focus on relevant cues and avoid distractions [88]. 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 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 randomisation or counterbalancing and suitable control groups or conditions. However, a review of the research rigor 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 20s and 30s are worthy of examination (e.g. they represent a significant segment of the population in 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 [89, 90]. 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 Conclusions 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, i.e. the examination of specific strategies on particular types of strength, there sometimes exist small numbers of observations, especially with regard 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 psychological factors that might otherwise contribute to unreliability [28]. As a second implication, cognitive strategies might help patients rehabilitating from muscular injuries recover as quickly as possible. As a third implication, individuals wishing to maximise training or competitive performance may be advised to employ a psychological technique.

Cognitive strategies refer to self-directed mental interventions used prior to or during skill execution to enhance physical performance. The current article has systematically reviewed the research investigating the influence that such interventions have on muscular strength performance. Although the evidence generally suggests that cognitive strategies enhance strength, muscular endurance, and local muscular power, additional research is needed to investigate the applicability of these studies beyond the tasks and people currently examined. Research is also needed to investigate the possible reasons why cognitive strategies may be effective. Given the possible implications and importance that many athletes and coaches place on mental preparation immediately prior to performance, additional empirical attention is justifiable.

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