A meta-analysis of mental imagery effects on post-injury functional mobility, perceived pain, and self-efficacy

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ABSTRACT

Objectives: A meta-analysis was employed to examine the effects of mental imagery (MI) on bio-psychological variables, namely *functional mobility*, *perceived pain*, and *self-efficacy*.
Method: Ten studies were included in the meta-analytical review. Cohen's *d* effect sizes (ES) and Hedge's *g* weighted mean ES (WMES) were computed for all dependent variables.
Results: The analysis revealed non-significant effects of imagery interventions that were (1) small and positive for functional mobility ($g = 0.16$), (2) large and negative for perceived pain ($g = -0.86$), and (3) large and positive for self-efficacy ($g = 0.99$). These effects were all non-significant, probably because the interventions administered and populations sampled in the studies were mostly heterogeneous. The observed null results might also reflect that existing studies on injury lack power. Hence, the effects of MI on bio-psychological variables warrant continued empirical investigation.
Conclusions: Given the observed statistical trends, MI interventions might be beneficial for athletes recovering from injury. However, more experimental work in needed before one claims with certainty that MI enhances bio-psychological functioning in injured athletes.

Contents

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Sport injury is a pervasive phenomenon that interferes with athletes' career and overall bio-psycho-social well-being (e.g., Dawson, Hamson-Utley, Hansen, & Olpin, 2014; Evans, Hare, & Mullen, 2006; Knowles, Marshall, & Bowling, 2006; O'Connor, Heil, Harmer, & Zimmerman, 2005). As such, a great deal of research on injury focused on identifying injury recovery strategies aimed at promoting a healthy "return to play" status for various skill-level athletes (e.g., Brewer, 2009; Chan, Hagger, & Spray, 2011). More specifically, extensive research on injury recovery centered on the role of mental skills in injury recovery, particularly the effects of mental imagery (MI) on athletes' rehabilitation process (see Brewer, 2010; Cumming & Williams, 2013; Podlog, Dimmock, & Miller, 2011; Walker, Thatcher, & Lavallee, 2007; Wiese-Bjornstal, 2010). In fact, MI is among the most popular mental techniques used by athletes for both *performance restoration* (e.g., rehabilitation process from sport injury) and *performance optimization* purposes (e.g., increase self-efficacy; see Filho & Tenenbaum, 2015). The popularity of MI is attributed to the minimal space-time constraints, and can be practiced in most places and at different times. As well, once mastered by the athlete, imagery can be practiced independently (Martin, Moritz, & Hall, 1999).

MI refers to the cognitive simulation process by which an individual can represent perceptual information in his/her mind in the absence of sensory input (Munzert, Lorey, & Zentgraf, 2009). Given that different types of perception induce different forms of imagery (Moulton & Kosslyn, 2009), several types of imagery have been identified, such as spatial imagery, visual object imagery, and motor imagery (Hohlefeld, Nikulin, & Curio, 2011). In the current study, we consider the term MI as a dynamic mental state in which the representation of a given motor act or movement is rehearsed in the working memory without an overt motor output (see Guillot & Collet, 2008; Hashimoto, Ushiba, Kimura, Liu, & Tomita, 2010). This operational definition is broad enough to encompass the bulk of research linking MI and injury recovery across scientific disciplines.

To this extent, in the last three decades over 30 qualitative reviews have been conducted with respect to the benefits of MI on bio-psychological outcomes in different disciplines, including medicine, education, music, psychology, and sport and exercise (e.g., Guillot & Collet, 2008; Heremans et al., 2013; Holmes & Calmels, 2008; Martin et al., 1999; Murphy, 1990; Schuster et al., 2011). Collectively, these reviews suggest that MI has a beneficial positive effect on bio-psychological variables (e.g., Schuster et al., 2011; Weinberg, 2008). Although various qualitative reviews of the literature on MI have been published, a meta-analytical review on the effect of MI on injury rehabilitation has not been conducted to date within the sport and exercise psychology domain.

In the field of sport and exercise psychology, Guillot and Collet (2008) reviewed six imagery models designed to (1) explain how MI influences cognitive, affective, and behavioral outcomes (Martin et al., 1999); (2) provide an understanding of what athletes imagine, and where, when, and why they use MI (Munroe, Giacobbi, Hall, & Weinberg, 2000); (3) explore how MI should be implemented by athletes (Moran, Guillot, MacIntyre, & Collet, 2012); (4) describe MI interventions with respect to the individuals' needs, the environment constraints, and the task at hand, as well as the duration, the intended learning outcomes, and the emotions and perspective associated with the imagery exercise (PETTLEP — physical, environment, task, timing, learning, emotion, perspective; see Holmes & Collins, 2001); (5) explain the importance of MI ability regarding vividness, control, duration, ease, and speed (Watt, Morris, & Andersen, 2004); and (6) discuss different imagery outcomes — specifically motor learning and performance, motivation, self-confidence and anxiety, strategies and problem-solving, and injury rehabilitation. From this over-arching analysis, Guillot and Collet (2008) concluded that imagery models have been mostly used to inform MI interventions aimed at promoting performance optimization and restoration in sports.

With respect to performance restoration, sport and exercise psychologists have been reported to use MI to aid athletes recovering from various types of injury (Filho & Tenenbaum, 2015). To this extent, several models have described the sport injuries' phenomenon in general (e.g., Finch & Cook, 2014; Williams & Andersen, 1998; van Tiggelan, Wickes, Stevens, Roosen, & Witvrouw, 2008), and the process of injury rehabilitation in particular (e.g., Brewer, Andersen, & Van Raalte, 2002; Wiese-Bjornstal, 2010; Wiese-Bjornstal, Smith, Shaffer, & Morrey, 1998). Brewer, Andersen, and Raalte (2002) proposed a theoretical framework to describe the process of rehabilitation from sport injury, and presented a bio-psycho-social model that integrated earlier models; this includes seven components: (1) injury characteristics; (2) socio-demographic details; (3) biological components, such as the immune system, nutrition, sleep, and metabolism; (4) psychological aspects, such as personality, emotional behavior, and cognition; (5) social and contextual aspects, such as social relationships, life stressors, and rehabilitation environment; (6) intermediate bio-psychological outcomes, such as range of motion, strength, pain, and endurance; and (7) recovery outcomes, such as functional performance, quality of life, satisfaction from treatment, and readiness to return to sport. In the present meta-analysis, we used this integrative model to orient our search towards the nomological network established between mental injury stimuli and bio-psychological variables.

Most studies on MI and injury recovery have been based on methodological approaches that preclude the development of meta-analytical reviews. In particular, most studies on MI and injury recovery have been qualitative in nature (see Brewer, 2010), or limited to empirical case studies (e.g., Evans, Hardey, & Fleming, 2000; Hare, Evans, & Callow, 2008). Moreover, the correlational studies available are mostly focused on sport actors' (i.e., athletes, coaches, and physical therapists) perception of the recovery process rather than on the relationship between imagery intervention and bio-psychological outcomes (e.g., Albinson & Petrie, 2003). Bearing these limitations in mind, we focused our meta-analytical procedure on experimental studies only. Experimentally-oriented research allows for the establishment of causality links, whereas correlational and qualitative approaches are limited in establishing generalizability.

1. The present study

We assembled all published interventional and experimental studies on this topic. Our overarching aim was to examine the effect of MI use considering Brewer's (2009) conceptualization that biological components, as well as psychological and social aspects, are implicated in injury rehabilitation in sports. In other words, from injury onset to return to play, changes in biological, psychological, and sociological variables are likely to occur. Of note, congruent with recommendations for conducting meta-analytical reviews (see Lipsey & Wilson, 2001), we adopted a conservative approach and expected that the magnitude and direction of MI effects on bio-psychological variables among injured athletes would be null. More specifically, we examined the effects of MI on *functional mobility*, *perceived pain*, and *self-efficacy*.

The first targeted variable, functional mobility, pertains to the extent and quality that a body movement function is operative in daily life. Functional mobility is tied to individual independence and is considered an index of well-being across population cohorts (e.g., Cnossen et al., 2017; Ryff, 1995; Spieth & Harris, 1996), including athletic groups (e.g., Kell, Bell, & Quinney, 2001; Snyder

et al., 2010). Considering Brewer's (2009) model, functional mobility is among the intermediate outcomes of the rehabilitation process. The second variable of interest, perceived pain, is a clinical marker of recovery that has been linked to patients' satisfaction and adherence to a rehabilitation course (e.g., Bergés, Ottenbacher, Smith, Smith, & Ostir, 2006; Tooth et al., 2003). Among patients who underwent surgical procedures, pain is one of the five most undesirable complications (Macario, Winger, Carney, & Kim, 1999). Unrelieved pain affects the individual's daily life and increases recovery duration (e.g., Wu et al., 2003). Relief in pain perception is also among the intermediate outcomes of the rehabilitation process (see Brewer's (2009) model). The third variable examined self-efficacy, is associated with performance and well-being across domains of human performance (Bandura, 1997). Athletes with high self-efficacy are more likely to adhere to a rehabilitation protocol for a given recovery process (e.g. Milne, Hall, & Forwell, 2005). Following full recovery, self-efficacy is essential for athletes aiming to regain their previous level of athletic performance (e.g., Wesch et al., 2012; 2016), and be "ready to return to sport," which is an important sport injury rehabilitation outcome (Brewer, 2009).

2. Method

2.1. Literature search

We searched for studies using computerized databases in sport, psychology, medicine, and multi-domain platforms. Specifically, our literature search included the following databases: SPORTDiscus (with full text), ERIC Full text, ProQuest, Science Direct, PsychINFO, PubMed, and Google Scholar. Furthermore, the indexes of the following journals were searched manually: *Sage Journals, Journal of Sport and Exercise Psychology*, *The Sport Psychologist*, *Medicine & Science in Sports & Exercise*, *International Journal of Sport and Exercise Psychology*, *Research Quarterly for Exercise and Sport*, *Journal of Applied Sport Psychology*, and the *International Journal of Sport and Exercise Psychology*. The reference lists of the articles selected were also examined in order to locate additional suitable articles. Crosschecking of references and scans of journals in sport psychology, psychology, and exercise science ensured an extensive literature search.

The search entries consisted of broad psychological terms such as "recovery", "psychology", "anxiety", and "intervention". The key terms used to locate imagery as a psychological strategy were *relaxation* OR *goal setting* OR *self-talk* OR *biofeedback* OR *imagery, psychological techniques, psychological strategies*, AND *social support*. Key terms for sport injury were *athletic injury* OR *athletic injuries, sports injury* OR *sport injuries* OR *sports injuries, rehabilitation* AND *recovery*.

2.1.1. Inclusion criteria

To be included in the dataset, studies had to meet the following criteria: (1) written in the English-language, (2) use of a quantitative design and provide sufficient information to calculate effect sizes (ES), and (3) include discussion about the rehabilitation process (see Flow Chart in Fig. 1). The literature search initially yielded 13,854 potential studies. Most of the studies ($N = 11,152$) were excluded for failing to include information about the rehabilitation recovery process. The exclusion criteria we used were as follows: the article dealt with injury prevention or being at risk for getting injured, and not injury rehabilitation; it dealt with the athlete's mental condition during recovery; it presented measurements/instrumentations and methods of measurement; or it presented opinions about the rehabilitation process solely from the therapists or physical therapist.

Other studies were excluded for several reasons, as follows: failed to mention rehabilitation and/or the recovery process, mentioned intervention strategies other than imagery, used qualitative research methods, or consisted of reviews of the literature. Altogether, 10 studies were included in the meta-analysis and used to derive outcome variables.

2.1.2. Dependent variables

The following dependent variables were coded: (1) *functional mobility*, (2) *perceived pain*, and (3) *self-efficacy*. Functional mobility pertained to any intermediate outcomes measuring gains in functionality in either the passive or the active locomotor systems due to the administration of an imagery or due to non-imagery rehabilitation intervention. *Perceived pain* referred to outcome variables measuring participants' subjective assessment of pain over the course of the study. *Self-efficacy* pertained to confidence directed at the recovery process as a function of the imagery or non-imagery rehabilitation intervention.
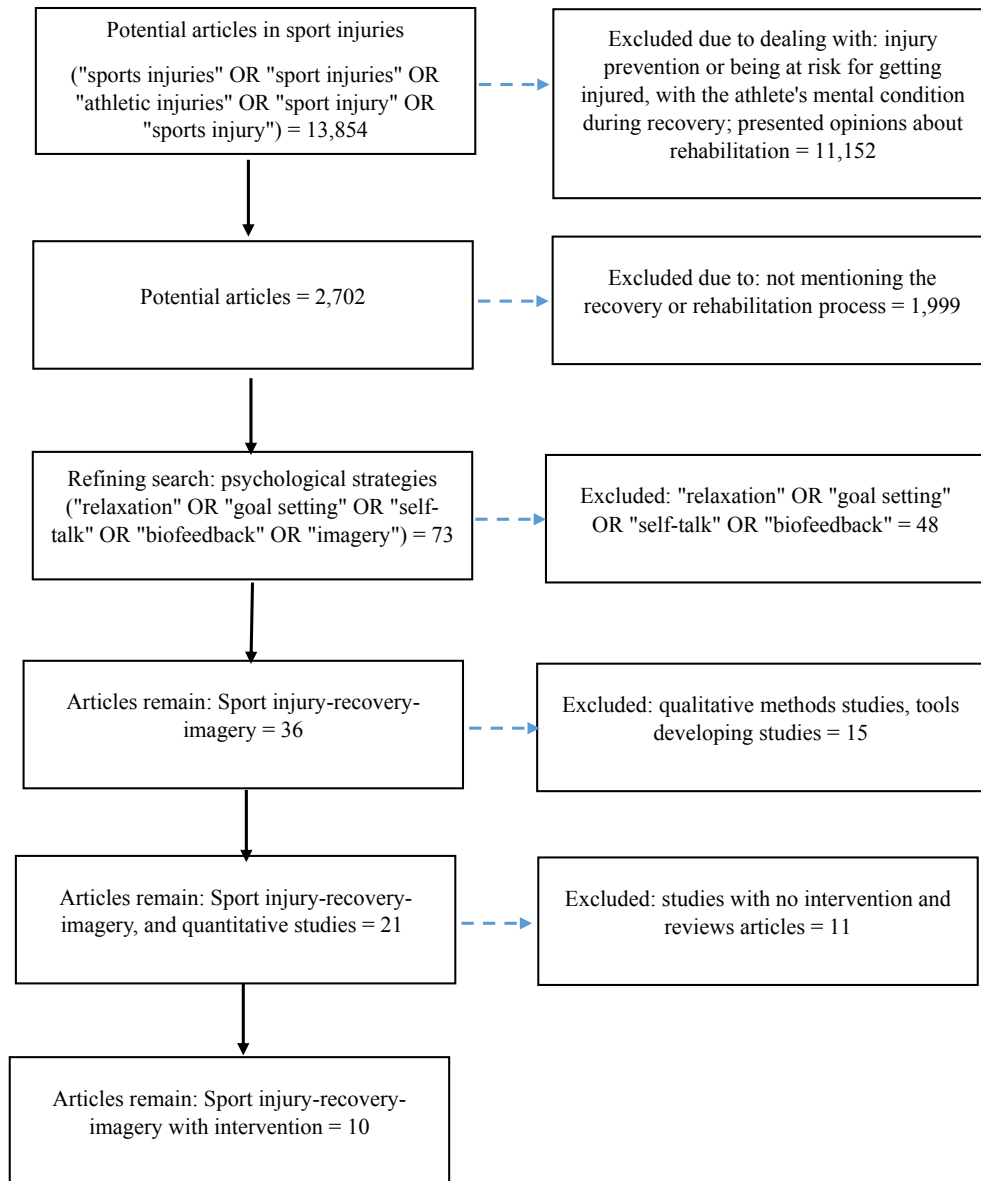
2.1.3. Moderator analysis

The information provided in the reviewed papers about the type of injury, sample, and MI intervention was a-systematic and markedly incomplete. Consequently, we were unable to develop a reliable coding scheme to inform an analysis of moderating variables. It is likely that opportunistic sampling was used in the surveyed studies, as the scholars were unable to manipulate injury severity and type through controlled experimental designs. Furthermore, participants of different genders, ages, and sport types were mixed together and received interventions of varying durations and protocols (e.g., types of imagery); thereby making a reliable coding scheme for moderators pointless. Comparing "apples to oranges interventions," while factoring in the wide variability in the sample characteristics, sport types, and injury types, does not allow for practical or theoretical gains. Referring to this matter, the Campbell Collaboration Group on meta-analysis reviews has posited that the primary objective of a meta-analysis is to draw average effects from comparable data sets (see https://www.campbellcollaboration.org/). Given that no moderator analysis was performed, we computed mean ES analysis.

2.2. Statistical analysis

Each study was independently coded by three authors who have expertise in the field of sport and exercise psychology. Any disagreements regarding the coding were discussed and resolved during peer-debriefing meetings. The quality of the studies included in the analysis was judged by using a self-developed quality scale, which followed the guidelines for reporting research on psychology put forth by the American Psychological Association (see APA Publications and Communications Board, 2008). The quality scale consisted of seven dimensions (i.e., statement of purpose and hypotheses, target population, description of the outcome measures, methodological design, statistical analyses, adequacy of results, and overall quality of the study), and used a 10-point Likert-type scale ranging from 1 (*not acceptable*) to 10 (*excellent*). Three authors rated the studies included in the analysis independently. The first attempt of partial inter-rater agreement among the coders was 80.45%. This estimate was changed to full agreement following a session of elaborations.

The statistical techniques used to compute the estimates of the effect sizes (ES) were adopted from Borenstein, Hedges, Higgins, and Rothstein (2009), Lipsey and Wilson (2001), and Turner and Bernard (2006). We used the d family of ES (i.e., $(M_c - M_e)/S_{pooled}$) (the control group mean minus the intervention mean, divided by the pooled standard deviation) to estimate ES from the studies.

Potential articles in sport injuries ("sports injuries" OR "sport injuries" OR "athletic injuries" OR "sport injury" OR "sports injury") = 13,854	Excluded due to dealing with: injury prevention or being at risk for getting injured, with the athlete's mental condition during recovery; presented opinions about rehabilitation = 11,152
Potential articles = 2,702	Excluded due to: not mentioning the recovery or rehabilitation process = 1,999
Refining search: psychological strategies ("relaxation" OR "goal setting" OR "self-talk" OR "biofeedback" OR "imagery") = 73	Excluded: "relaxation" OR "goal setting" OR "self-talk" OR "biofeedback" = 48
Articles remain: Sport injury-recovery-imagery = 36	Excluded: qualitative methods studies, tools developing studies = 15
Articles remain: Sport injury-recovery-imagery, and quantitative studies = 21	Excluded: studies with no intervention and reviews articles = 11
Articles remain: Sport injury-recovery-imagery with intervention = 10	

Fig. 1. The literature selection process. Numbers indicate references retrieved from the search using the databases: SPORTDiscus (with full text), ERIC Full text, ProQuest, Science Direct, PsychINFO, PubMed, and Google Scholar.

However, Cohen's *d* tends to overestimate the intervention effects in smaller samples sizes (Hedges & Olkin, 1985; Hedges, Shymansky, & Woodworth, 1989). Given that most of the studies included fewer than 20 participants, we corrected for the upward bias in Cohen's *d* by calculating Hedge's *g* using the correction factor (*J*), and applied the formula specified below (see Borenstein et al., 2009; Turner & Bernard, 2006):

$$Hedges's\ g = Cohen's\ d * \left(1 - \frac{3}{4N - 9}\right)$$

We estimated the ES, variance, and inverse variance weight or $w = \frac{1}{v}$ (where v is variance; see Borenstein et al., 2009; Lipsey & Wilson, 2001 for calculations) for each study. By adopting a random-effects model, we calculated the random effects variance component (a constant) and added it to the variance of each ES (v^*). Then, we computed the WMES by multiplying each ES by its inverse variance weight or w^* (includes a random component). The weighted ES estimates were then summed and divided by the sum of the inverse variance weight or w^*. We also computed the confidence intervals for the means and performed a test of homogeneity of distribution (*Q*). It should be noted that several studies presented more than one ES per construct and/or intervention. For example, Hoyek and colleagues (Hoyek, Di Rienzo, Collet, Hoyek, & Guillot, 2014) measured range of motion in the following: flexion, extension, lateral rotation, arm adduction, abduction, and medial rotation. Accordingly, to allow for statistical independence in the data set, we averaged ES that represented the same construct within a given study. This procedure eliminated ES biases, which are otherwise inherent in single studies with multiple ES (see Lipsey & Wilson, 2001). Additionally, many studies measured the outcome variables numerous times during the intervention phase. In such cases, we compared the baseline to the last week of the intervention. Finally, we identified potential outliers using the funnel and forest plots.

3. Results

Ten studies met our inclusion criteria. The overall quality of studies was moderately good ($Q_{uality} = 8.07$; $SD = 0.59$), as measured by our self-developed scale. Table 1 provides information about the type of study, type of injury, imagery intervention protocol, and duration of the intervention. It should be noted that the studies' characteristics were coded only to inform about the scope of generalizability and replicability of the present study. As alluded to previously, the types of injury and the intervention protocol and its duration were inconsistent across studies, such that a moderator analysis was deemed inappropriate. Thus, we saw no clear research paradigms or frameworks that seemed to be guiding the bulk of research on injury rehabilitation. Rather, the research appears to be conducted without a clear underlying framework.

Table 2 includes sample sizes, Hedge's g ES and their associated 95% CI, forest plots, as well as Q heterogeneity statistics for all studies included in the analysis. The tests of homogeneity for functional mobility ($Q = 6.26$, $df = 5$, $p < 0.05$), perceived pain ($Q = 2.33$, $df = 3$, $p < 0.05$), and self-efficacy ($Q = 6.50$, $df = 3$, $p < 0.05$) suggested that the ES were derived from heterogeneous samples; therefore, we adopted a random-effect model. Of note, a funnel plot (see Fig. 2), based on the effect sizes and standard errors, and forest plots (see Table 2) for each dependent variable indicated that publication bias was unlikely in our data pool, except for the Wesch, Callow, Hall, and Pope (2016) study (see Egger, Smith, Schneider, & Minder, 1997).

The analysis of the six ES for functional mobility revealed a small non-significant positive effect ($g = 0.16$, $CI_{0.95} = -0.49, 0.18$) for injury interventions, compared to the control. The four ES for perceived pain revealed a large non-significant negative effect ($g = -0.86$, $CI_{0.95} = -1.93, 0.22$). Lastly, the four ES for self-efficacy revealed a large non-significant positive effect ($g = 0.99$, $CI_{0.95} = -0.38, 2.37$). Altogether, albeit non-significant, imagery use in the rehabilitation from injury was found to have a small positive effect on functional mobility and a large effect in reducing pain perceptions. A large non-significant effect was also observed for self-efficacy. However, these results must be taken with particular caution because of their positive skewness (see Table 2; Fig. 2) in Wesch et al.'s (2016) study.

4. Discussion

In this paper, we sought to clarify the putative effects of MI on bio-psychological variables among injured athletes. Specifically, we examined the effects of MI on three bio-psychological intermediate outcomes, and sport injury rehabilitation outcomes; namely, *functional mobility*, *perceived pain*, and *self-efficacy*. In our analysis, we adopted broad inclusion criteria by assessing any type of imagery intervention directed at athletes of any sport modality with any type of physical injury. No significant effects for any of the three bio-psychological variables were observed. The lack of statistically reliable effects reflects the small power and the fact that the interventions administered and populations sampled in the literature are mostly heterogeneous. Notwithstanding, a positive trend was observed, thereby suggesting that MI might have a minor positive effect on *functional mobility* and a large impact on *perceived pain* and *self-efficacy*. The intricacies of these findings are elaborated upon next.

4.1. Functional mobility

A small non-significant positive effect was observed for the linkage between MI and *functional mobility*. The lack of significant effects is likely due to a wide variability in the meta-analysis data

Table 1
Summary of the studies included in the meta-analysis.

Study	Type of study	Intervention	Duration^	Type of injury	Overview
Christakou and Zervas (2007)	Randomized experimental design	Relaxation and imagery	12 45-min individual sessions over 4 weeks	Grade II ankle sprain	Experimental group was compared to the control group
Christakou, Zervas, and Lavallee (2007)	Randomized experimental design	Movement imagery	12 45-min individual session over 4 weeks	Grade II ankle sprain	Experimental group was compared to the control group
Cressman and Dawson (2011)	Quota sampling, blind experimental design	Cognitive, motivational, and healing imagery	At least 3 sessions per week for 3 weeks	Grade II ankle sprain or sprain	Experimental group was compared to the control group
Cupal and Brewer (2001)	Randomized block design experiment	Relaxation and guided imagery	10 individual sessions 2 weeks apart over 6 months	Anterior cruciate ligament injury	Experimental group was compared to the control group
Gagnon, Grilli, Friedman, and Iverson (2016)	Experimental design with no control group	Visualization and imagery	6-week intervention	Concussion	Balance measures were averaged and compared from pre- to post-intervention
Hoyek et al. (2014)	Randomized experimental design	Motor imagery	10 60-min individual sessions; 3 times per week	Stage II shoulder impingement syndrome	Range of motion measures were averaged; experimental group was compared to the control group
Law, Driediger, Hall, and Forwell (2006)	Correlational study	Cognitive, motivational, and healing imagery*	1 to 288 weeks	Lower limb injury	Group using pain imagery was compared to the group not using pain imagery
Maddison et al. (2012)	Single blind parallel arm randomized-controlled pilot trial	Cognitive, motivational, and healing imagery	9 individual sessions over 24 weeks	Anterior cruciate ligament injury	Intervention/experimental group at 12 weeks was compared to the control group
Wesch et al. (2012)	Prospective observational study	Cognitive, motivational, and healing imagery*	8-week rehabilitation	Shoulder, knee, ankle injury	Assessment at 8 weeks was compared to the baseline
Wesch et al. (2016)	Experimental design with no control group	Cognitive, motivational, and healing imagery	Encouraged daily imagery practice for 6 weeks	Type B malleolar fracture	Task and coping efficacy were averaged; assessment at 6 weeks was compared to the baseline

Note. *no intervention; ^includes standard rehabilitation.

Table 2
Sample sizes, Hedge's g, mean Hedge's g, CIs, Q, and forest plots for the studies included in the analyses.

Study	N_C	N_E	N_{Total}	Hedges' g [95% CI]	Mean Hedges' g [95% CI]	Q
Functional mobility						
Christakou & Zervas (2007)	9	9	18	0.85 [-0.63, 2.33]		
Christakou et al. (2007)	10	10	20	-0.04 [-2.07, 1.99]		
Cupal & Brewer (2001)	10	10	20	1.29 [-0.32, 2.91]		
Gangnon et al. (2016)	10	10	10*	0.51 [-1.06, 2.08]		
Hoyek et al. (2014)	8	8	16	-1.41 [-3.10, 0.27]		
Law et al. (2006)	35	48	83	0.02 [-1.37, 1.41]		
					0.16 [-0.49, 0.81]	6.26
Perceived pain						
Christakou & Zervas (2007)	9	9	18	-0.84 [-2.94, 1.26]		
Cupal & Brewer (2001)	10	10	20	-1.88 [-4.04, 0.43]		
Hoyek et al. (2014)	8	8	16	-1.41 [-3.67, 0.84]		
Law et al. (2006)	35	48	83	0.38 [-1.66, 2.42]		
					-0.86 [-1.93, 0.22]	2.33
Self-Efficacy						
Cressman & Dawson (2011)	4	5	9	0.98 [-1.77, 3.73]		
Maddison et al. (2012)	8	13	21	0.14 [-2.45, 2.73]		
Wesch et al. (2012)	89	89	89	-0.22 [-2.68, 2.24]		
Wesch et al. (2016)	5	5	5*	5.02 [1.54, 8.50]		
					0.99 [-0.38, 2.37]	6.50

Note. N_C = N of individuals in the control group; N_E = N of individuals in the experimental group; N_{Total} = Total number of participants ; CI = 95% Confidence Intervals for Hedge's g; *within-subject analysis.
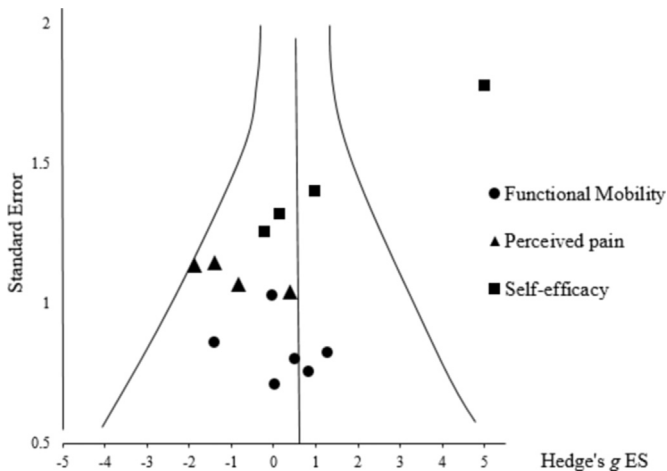

Fig. 2. Funnel plot for the ESs and associated standard errors.

set, which in turn reflects the heterogeneous samples, intervention protocols, and outcome measures that have been used in the experimental research pertained to the effects of imagery on injury recovery. To advance the knowledge on the benefits of MI on *functional mobility*, much clearer input-output relations should be defined, operationalized, and tested. Although we concede that studies on injured athletes are bounded to convenience sampling, as scholars are unable to control for the type and severity of injury, MI intervention parameters (inputs) and the *functional mobility* variables (outputs) must be accurately specified if research is to be advanced in this area. Although the observed findings do not carry inferential predictive power, they still provide descriptive value. The small descriptive difference observed suggests that the most important mechanism in injury rehabilitation is not linked to MI. For instance, athletes with a serious knee injury will not recover through MI exercises only. Proper physical treatment is most likely the major predictor in injury recovery. Put differently, an injured athlete will probably not recover by sitting in his/her room and visualizing the recovery process. In effect, this argument derives from previous research suggesting that physical practice is the most important factor in motor learning and re-learning (see Robertson, Pascual-Leone, & Miall, 2004; Ruffino, Papaxanthis, & Lebon, 2017). Thus, based on our findings, we suggest that the benefits of MI are additive to those of physical recovery. Therefore, we recommend that athletes, in addition to physical rehabilitation exercises, engage in MI to enhance the recovery of their active and passive locomotor systems, even if it is only to a slight degree.

4.2. Perceived pain

There was no significant effect for the linkage between injury-related imagery and *perceived pain*. Power was lacking, as our

analysis was based on three effect sizes only. Again, assessment of input-output relations in injury research might have been established by convenience sampling rather than theory, which in turn leads to scattered and unfocused empirical studies. Accordingly, to advance knowledge on the linkage between MI and *perceived pain*, we recommend testing for the influence of MI on specific bio-psycho-social variables. Despite the non-significant effects observed, a meta-analysis, by definition, represents an increase of power over single studies (Turner & Bernard, 2006). On these grounds, we suggest that the use of MI is more likely to reduce *perceived pain* than not using MI. In fact, previous research suggests that pain is a higher-order psychological process that is ultimately regulated by central inputs (see Marcora, 2009). MI activates multiple neural circuits and thereby might also implicate the neural substrates of *perceived pain*. Put simply, MI is thought to alter ones' psycho-physiological responses (e.g., quiescence of the cortex, reduced heart rate variability), which in turn contributes to positive changes in the perception of pain (for a review, see Strack, Linden, & Wilson, 2011). Clearly, this putative mechanism needs additional research. It follows that MI interventions linking subjective rates of *perceived pain* with objective biological markers (e.g., hormonal markers, peripheral and central physiological variables) are paramount for moving research forward.

4.3. Self-efficacy

Our analysis suggests that MI failed to yield significant changes in *self-efficacy* beliefs. As noted for *functional mobility* and *perceived pain*, this non-significant effect was constrained by the variability in the data set (e.g., interventions, outcome measures, sample characteristics) and lack of power. We highlight that the mean effect size observed is positive and strong. Indeed, it is well established that MI — either through vicarious experiences, verbal persuasion, or its interactive compound effects (see Bandura, 1997; Feltz, Short, & Sullivan, 2008) — is a major source of self-efficacy beliefs. Generally, individuals feel more confident if they can visualize positive cognitive-affective states in their minds. However, more scientific evidence is required before we can determine whether MI leads to statistically reliable effects on self-efficacy. In the present study, we averaged different measures of injury self-efficacy (e.g., task and coping) to derive ES estimates. Hence, to advance research, we advocate studies that commit to Bandura's recommendations on self-efficacy measurement (see Bandura, 2006). Self-efficacy is part of the complex human self (e.g., self-awareness, self-worth, self-esteem, self-confidence), and its assessment should abide by theory and measurement guidelines.

4.4. Limitations and future research

The main limitations of this meta-analysis relate to the small power and absence of moderator analysis. These limitations, however, were beyond our control. First, the lack of power reflects the current state of the literature. Scholars must conduct an a priori power analysis to ensure that a proper number of participants are recruited in accord with the number of hypotheses being tested and the number of independent and dependent variables being considered (see APA Publications and Communications Board Working Group, 2008). To date, there are only few experimental studies published on this topic, and the ones currently available, for the most part, do not target the same outcome variables. Second, the wide range of variability in the MI interventions, sample characteristics (types of injury and sports), and outcome variables did not allow us to evolve a reliable coding scheme to inform analysis of moderators. Moreover, the information provided in the reviewed papers about the type of injury, sample, and MI

intervention was often incomplete. To prevent these problems from affecting future systematic reviews, it is important that scholars: (1) clarify the nomological network linking MI interventions and changes in bio-psycho-social variables, and (2) report detailed information about all aspects of their studies; thus, allowing for replication studies as well as the computation of census-like analysis. Also, in the present study we did not analyze any social variables related to injury rehabilitation. Accordingly, more research into the social factors and outcomes of injury rehabilitation is warranted.

In addition, we recommend that scholars clearly specify the MI intervention protocols administered in their experimental studies. The length of the intervention, duration of each session, and MI script must be provided in complete form to allow meta-analysts to explore moderating effects involving MI and changes in bio-psycho-social variables.

Additional research on the underlying mechanisms accounting for MI effects on neural circuitry in the brain is also warranted. There remains a paucity of experimental studies in sport psychology research related to this theme. Further research is needed to advance knowledge on whether and how MI changes the functional and structural networks in the brain. Studies on concussion-related injuries are also ripe for future research.

5. Conclusions: Implications for theory and practice

Non-significant effects of MI on *functional mobility*, *perceived pain*, and *self-efficacy* measures were observed. Notwithstanding, a small positive trend for *functional mobility*, and a large positive trend for *perceived pain* and *self-efficacy*, were observed. From a theoretical standpoint, the observed non-significant trends are in line with Brewer's (2010) overarching thesis that psychological interventions may improve rehabilitation outcomes through different pathways. In theoretical principle, changes in psychological states prompted by mental interventions may enhance injury recovery by altering physical outcomes, such as functional mobility, while also triggering positive changes in cognitive-affective states such as self-efficacy and perceived pain. However, from an evidence-based applied standpoint, the observed null results indicate that much caution and more experimental work is needed before one claims with certainty that MI enhances bio-psychological functioning in injured athletes. Additional theoretically grounded experimental work with appropriate statistical power is needed to advance best practice guidelines on the linkage between MI and injury recovery.

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