




Motor Imagery and Sport Performance: A Systematic Review on the PETTLEP Model

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Featured Application: The reviewed studies reported evidence supporting the effectiveness of motor imagery based on the PETTLEP model for strength increase and pain management, suggesting implementation of this practice into physical training routines.

Abstract: The aim of this review is to critically analyze the evidence provided throughout the years regarding the application of motor imagery (MI) in sport performance, focusing on the PETTLEP approach. Among the different MI approaches, in fact, the PETTLEP model takes into account many different domains for increasing the performance of athletes. These domains include physical features, the environment, task-related aspects, timing, learning, emotion, and perspective.

Keywords: motor imagery; PETTLEP model; strength; sport; psychology; training



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1. Introduction

Motor imagery (MI) is the act of mentally rehearsing voluntary movements without engaging in the actual corresponding motor actions, as described by cognitive neuroscientists [1]. The overlapping of many neural substrates of motor imagery and motor execution involves cortical and subcortical areas such as the primary motor cortex [2–5], the premotor cortex, the supplementary motor area, the anterior cingulate cortex, the parietal lobule and the cerebellum [6–8], and even some vegetative indices [9–11]. This is at the basis of the “functional equivalence theory” [6,12,13], which relies on three factors: the same duration for the executed and imagined task [14], more time required for more complex movements [15], and correlation between the force required for the motor task execution and the mental effort during its imagination [16]. Consequently, MI practice could hence facilitate the successive motor execution [2,13] and could lead to increased brain plasticity fundamental for motor-skill learning [17,18]. Furthermore, MI is supposed to result in increased excitability of spinal motor neurons [19,20], which leads to a greater neural impulse reaching the agonist muscle [21], eventually increasing the activity of such a muscle [22–25]. Moreover, MI may modify movement-related cortical potentials, which are comparable to those observed with physical practice (PP) [26].

This can result in a better synchronization of the muscle fibers and inhibition of the antagonist muscle [22], eventually increasing strength [22,26]. These findings suggest that such common neural circuitry might underpin an increased performance efficacy induced by MI in athletes [27,28]. Motor imagery can be distinguished depending on the strategy adopted by the subject that is asked to mentally recite a motor task. Visual motor imagery consists in producing a visual representation of one's moving limbs. Kinetic motor imagery requires the subject to use the physical feeling of the movement to rehearse it [29,30]. At

the neural level, it has been demonstrated that the associative parietal cortex processes information necessary for MI. Indeed, this area is not only in charge of controlling posture and strength in the course of the executed movement, but it also plays a role in forming the body image and its relation to the outer world [31].

Several models propose that motor imagery, movement execution, and action observation recruit the same brain regions, but recent observations have suggested that the functional equivalence in subcortical areas is related to the first two acts, whereas action observation did not consistently recruit any subcortical areas [32]. Among the motor imagery models that could have a practical application, the most interesting seems to be the PETTLEP model, which takes into account many different domains related to motor imagery: physical features, environment, task-related aspects, timing equivalence, learning, emotion, and perspective.

This mixed review, reporting qualitative and quantitative results, aims to critically analyze the evidence provided throughout the years regarding the application of motor imagery (MI) in sport performance, conducted in agreement with the criteria of the PETTLEP approach.

Athletes typically adopt this method when attempting to enhance their performance [33]. Furthermore, following sport injury, MI is endorsed either concomitant to physical practice or as a temporary back-up during immobilization periods [34]. MI is particularly useful in conditions where practical limitations inhibit physical training, including biomechanical rigidity, poor physical strength, fatigue, injury risk, and limited access to equipment. In the present review, we focused on the application of motor imaging in the enhancement of sport performance and in sport rehabilitation of athletes.

Motor Imagery in Sport Training

The effectiveness of imagery in sport performance is attested by the reports of various athletes [35]. Such cases can be found in a variety of sports, such as swimming [36], baseball [37], basketball [38], and Australian-rules football [39]. Additionally, as well as the players, there is evidence showing that coaches have made use of imagery; the majority of US Olympic sport psychology consultants adopted this technique in their mental training programs with athletes [40]. Several meta-analyses shed light on the validity of imagery in enhancing sports performance amongst elite and aspiring athletes. Its use gives rise to a number of benefits: an increase of self-awareness, facilitation of the acquisition and maintenance of skills, self-confidence enhancement, emotion regulation, pain alleviation, arousal control, and improvement of preparation strategies [35]. The administration of the Sport Imagery Questionnaire confirmed the extensive use of imagery by elite athletes along with their belief in the positive impact it has on performance [41]. Generally, it is practiced by athletes during the training phases in order to subsequently benefit competition. However, it may also be used during actual competition. To capitalize the most on the various kinds of imagery, it is fundamental to practice it in a persistent and systematic way, which should be the closest to reality as possible [35].

2. Materials and Methods

2.1. Search Strategy and Study Selection

In order to systematically collect empirical studies regarding the application of PETTLEP imagery protocol in sport performance, a search strategy was made through psycINFO (<https://www.apa.org>), pubMED (<https://pubmed.ncbi.nlm.nih.gov/>), Cochrane Library (<https://www.cochranelibrary.com/>), and Scopus (<https://www.scopus.com/>) electronic database for English-language publications with human participants (accessed on 20 January 2022).

One single search was conducted for the following key words: PETTLEP AND sport. No restrictions were made regarding year of publication or age of the study population. Wherever possible, a research restriction was applied to research articles only. Manuscripts were included in the present systematic review if the following inclusion criteria were

met: (a) studies including athletes or participants engaging in sports from any discipline and (b) studies applying the PETTLEP protocol. Reasons for exclusions were based upon the follow exclusion criteria: (a) review or metanalytic articles, (b) non-English-language studies, (c) case reports, (d) grey literature, and (e) studies not applying PETTLEP imagery protocol in any kind of sportive discipline. Each study was included just once in the present review. The selection process was based upon PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines and PRISMA checklist [42].

2.2. Data Extraction

The following data were gathered from each of the included studies (see Table 1): (a) study's author and publication year, (b) size of the group performing PETTLEP imagery protocol, (c) participants' characteristics such as age and sex, (d) sport or athletic discipline played, (e) methodological quality, (f) description of how the PETTLEP model was applied, (g) setting information such as imagery programs and training duration, (h) conclusions regarding the application of the PETTLEP model.

2.3. Evaluation of Methodological Quality

Methodological quality of each study was assessed using the PEDro Scale [43] (see Table 2). The score is calculated by summing the scores from criteria 2 to 11. Scores below 3 are considered indices of low methodological quality, while scores ranging from 4 to 6 represent a medium methodological quality, and finally, scores equal or higher than 7 mean that the examined study has a high methodological quality.

Table 1. Extracted Articles.

	Authors	N. Subjects	Age	Sport	PEDRO Quality Score (0–10)	PETTLEP Description	PETTLEP Setting	Results
1	Afrouzeh et al., 2013 [44]	12	13.5 ± 0.55	Volleyball	6	Participants were instructed to perform their imagery standing in the volleyball court (environment), dressed in their volleyball clothing, and holding a ball. The physiological responses and emotions associated with performance were incorporated into the imagery (task and emotion). The participants were also instructed to perform the imagery in real time from an internal perspective (timing and perspective).	During a 7-week program, participants had to perform imagery training for 15 min followed by 13 min of “passing” practice 3 times per week.	The PETTLEP training is greatly effective in enhancing performance of passing skill in volleyball when combined with physical practice.
2	Battaglia et al., 2014 [45]	36 Females	13.8 ± 1.3	Rhythmic gymnastic	6	Athletes had to image themselves (internal perspective) or see themselves from the outside (external perspective) while performing a specific skill (task) online (timing) in the place where they normally train (environment) focusing on their proprioceptive feelings and sensations, including any emotions associated with that specific performance (emotion).	Two–three-hour training sessions per day for 6 weeks, in the morning, with one rest day per week.	Improvement of the jumping performance, preserving the elite athlete’s energy for other tasks.
3	Björkstrand and Jern, 2013 [46]	14 Females	15.74 ± 0.89	Soccer	6	PETTLEP-based imagery intervention on penalty taking ability in soccer. The imagery script was an adaptation of the imagery scripts used in the study by Ramsey et al. (2010). The script includes both stimulus and response propositions.	One week of imaging task 10 times a day for 5 days (50 visualized scenarios in total).	Players who evaluate themselves peaking under pressure more easily benefit from the imagery intervention.
4	O and Munroe-Chandler, 2008 [47]	102 (69 Females)	18.10 ± 1.88	Soccer	7	Tested the timing element of the PETTLEP approach by investigating the effects of three imagery practice conditions—real-time imagery, slow-motion imagery, and slow motion concluded with real-time imagery—on the performance of a serial motor task (soccer dribbling around a set of cones).	Participants were asked to image themselves executing the soccer task in real time, slow motion or both, for 7 trials.	Improvements of error performance from pre- to post-intervention.
5	Post, Young and Simpson 2018 [48]	56 Females	20.61 ± 2.48	Table tennis	7	Participants were instructed to stand at the end of the anticipation-timing track holding the table tennis paddle (physical and environmental). They were told to image the movement (task) in real time (timing) and were told to include any emotions (i.e., be confident and positive) consistent with a successful execution (emotion). They were instructed to image each trial from an internal perspective (perspective).	Six blocks of nine trials (54 total) of the anticipation-timing task.	Imagery combined with physical practice can benefit the learning of a coincident anticipation timing (CAT) task.

Table 1. Cont.

	Authors	N. Subjects	Age	Sport	PEDRO Quality Score (0–10)	PETTLEP Description	PETTLEP Setting	Results
6	Ramsey et al., 2010 [49]	22 (12 Females)	19.87 ± 1.36	Soccer	5	Examined the PETTLEP model using penalty kicks in soccer. Each imagery session consisted of either hearing their 18 imagery script (read by a member of the investigative team) or reading the script themselves and then mentally taking 10 successful penalties into a corner of the net.	Four weekly sessions for 6 weeks + independent sessions + weekly evaluation form, which assessed the imagery performed that week.	Physical and environment elements of PETTLEP-based imagery interventions appear to be key factors to enhance performance in sport.
7	Smeeton et al., 2013 [50]	8	14.9 ± 0.75	Cricket	5	Participants were instructed to imagine the ball flight in their mind (stimulus information). The physical and perspective components of the PETTLEP model were then manipulated by asking participants to mentally face the delivery (internal visual imagery perspective), holding their cricket bat and adopting a typical batting stance. The timing and emotion components were manipulated by instructing the participants to see the ball's flight and play the shot as they would in a real-life situation. They were told to feel confident and positive in the decision of how to play the shot and that making this decision would make them feel mentally calm and in control.	Participants received a 4-week, film-based training intervention.	Improvements in the kinesthetic imagery abilities.
8	Smith, Wright, Allsopp, 2007 [51]	Study 1: 12 (Females and Males) in a sport-specific imagery group condition Study 2: 10 Females in PÉTTLÉP group	Study 1: 20.37 ± 3.26 Study 2: 10.1 ± 1.81	Study 1: Hockey Study 2: gymnastic	6	Study 1: participants had to stand on their team's hockey pitch, imagine the goalkeeper standing in the center of the goal, and image their penalty flicks while wearing their hockey uniforms; strong emphasis was given on the physical and environment components. Study 2: The gymnasts performed their imagery while standing on the beam in the gym (task and environment components) while dressed in their normal gymnastics clothing (physical component) and were instructed to image the perfect full turning jump in real time (timing component) from an internal perspective (perspective component). Participants were encouraged to alter the kinesthetic responses they felt during their imagery as they became more experienced (the learning component).	Study 1: imagery training daily for 6 weeks, with each imagery session consisting of 10 imagined penalty flicks and lasting around 5 min. Study 2: imagery training 3 times per week, imaging the jump twice on each occasion, with interventions lasting around 3–5 min.	Both studies provide support for the efficacy of PETTLEP-based imagery over more traditional imagery interventions.

Table 1. Cont.

Authors	N. Subjects	Age	Sport	PEDRO Quality Score (0–10)	PETTLEP Description	PETTLEP Setting	Results
9 Smith, Wright and Cantwell, 2008 [51]	8	//	Golf	6	Participants had to perform their imagery in real time from an internal perspective (timing and perspective) while standing in a tray of sand or a sand pit (environment), dressed in their golf clothing and holding a sand wedge. They were instructed not to inhibit any small movements if they helped to make the imagery more realistic (physical). The physiological responses and emotions associated with performance were incorporated into the imagery (task and emotion). The golfers were consulted regarding the imagery effectiveness and any changes or additions they gave were incorporated in the following imagery sessions (learning).	Participants had to image 15 bunker shots twice per week for 6 weeks.	PETTLEP model is effective in enhancing golf performance, especially when used in combination with physical practice.
10 Wakefield and Smith, 2009 [35]	24 Females	20 ± 2	Netball	6	Participants had to complete the imagery on the netball court (environment), holding the netball (physical) and imaging the specific task (task) from an internal perspective (perspective), in real time (timing), and include any emotions that they experienced in the pre-test (emotion). They were instructed to image themselves performing twenty shots at the net, with a short rest in between.	Four-week intervention, once, twice, or three times per week, with each session consisting of 20 imaged shots at the target, 4 from each of 5 different angles, with a short break in between each shot.	PETTLEP imagery may be more effective if completed at least three times per week.
11 Winter and Collins, 2013 [52]	18 (9 Females)	16.5 ± 7.49	Field hockey	5	The PETTLEP approach of Holmes and Collins (2001) was used to guide participants' motor imagery.	Participants were able to mentally practice their actual hockey-dribbling task, adopting a characteristic posture, wearing their typical hockey attire, all within the environment the task was taking place.	The imagery condition was effective in enhancing performance, based on both time and accuracy measurements; the PETTLEP model, specifically, should be considered to be an important piece of effective preparation for physical and mental performance.
12 Wright and Smith, 2009 [51]	10	20.74 ± 3.71	Gym	6	Participants imaged two sets of curls while sitting at the machine in the gym (task and environment components) watching an internal perspective video (perspective component) in real time (timing component). Participants were also encouraged to include any emotions that they experienced during the actual performance (emotion component).	During a 6-week intervention period, participants performed their imagery twice per week while sitting at the bicep curl machine, in the gym.	PETTLEP is effective at improving muscle strength, especially when combined with physical practice.

Table 2. PEDro scale scores for the selected studies.

Study	Random Allocation	Concealed Allocation	Groups Similar at Baseline	Participant Blinding	Therapist Blinding	Assessor Blinding	<15% Dropouts	Intention to Treat Analysis	Between Group Differences Reported	Point Estimate and Variability Reported	Total Score (0–10)
Afrouzeh et al., 2013 [44]	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6
Battaglia et al., 2014 [45]	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6
Björkstrand and Jern, 2013 [46]	Yes	No	Yes	Yes	No	No	No	Yes	Yes	Yes	6
Jenny and Munroe-Chandler, 2008 [47]	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	7
Post, Young, and Simpson, 2018 [48]	Yes	No	Yes	Yes	No	No	Yes	Yes	Yes	Yes	7
Ramsey et al., 2010 [49]	Yes	No	Yes	No	No	No	No	Yes	Yes	Yes	5
Smeeton et al., 2013 [50]	No	No	Yes	No	No	No	Yes	Yes	Yes	Yes	5
Smith, Wright, and Cantwell, 2008 [51]	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6
Smith, Wright, and Allsopp, 2007 [53]	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6
Wakefield and Smith, 2009 [35]	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6
Winter and Collins, 2013 [52]	No	No	Yes	No	No	No	Yes	Yes	Yes	Yes	5
Wright and Smith, 2009 [54]	Yes	No	Yes	No	No	No	Yes	Yes	Yes	Yes	6

3. Results

3.1. Study Selection and Characteristics

The PRISMA flow diagram (Figure 1) shows the study selection process. The initial search strategy provided an initial pool of 48 potential studies. After removing duplicates, the abstracts of 42 studies were screened for further evaluation. Following the application of exclusion and inclusion criteria, a total of 23 articles were retrieved, and a full-text assessment was made. Thus, the current review is based upon data provided from 12 studies that met the inclusion criteria. The included studies were published over a period spanning from 2007 to 2018. Sample sizes ranged from 8 to 102 participants, totaling a final sample of 332 participants performing the PETTLEP imagery protocol while playing individual or team sports. One-third of the samples included only male participants [44,50,51,54], one-third was composed only of females [35,45–47], and one-third included both males and females [48,49,52,53]. The mean age of participants among included studies ranged from 10 to 22 years; most of them were underage boys and girls. All the included participants were healthy.

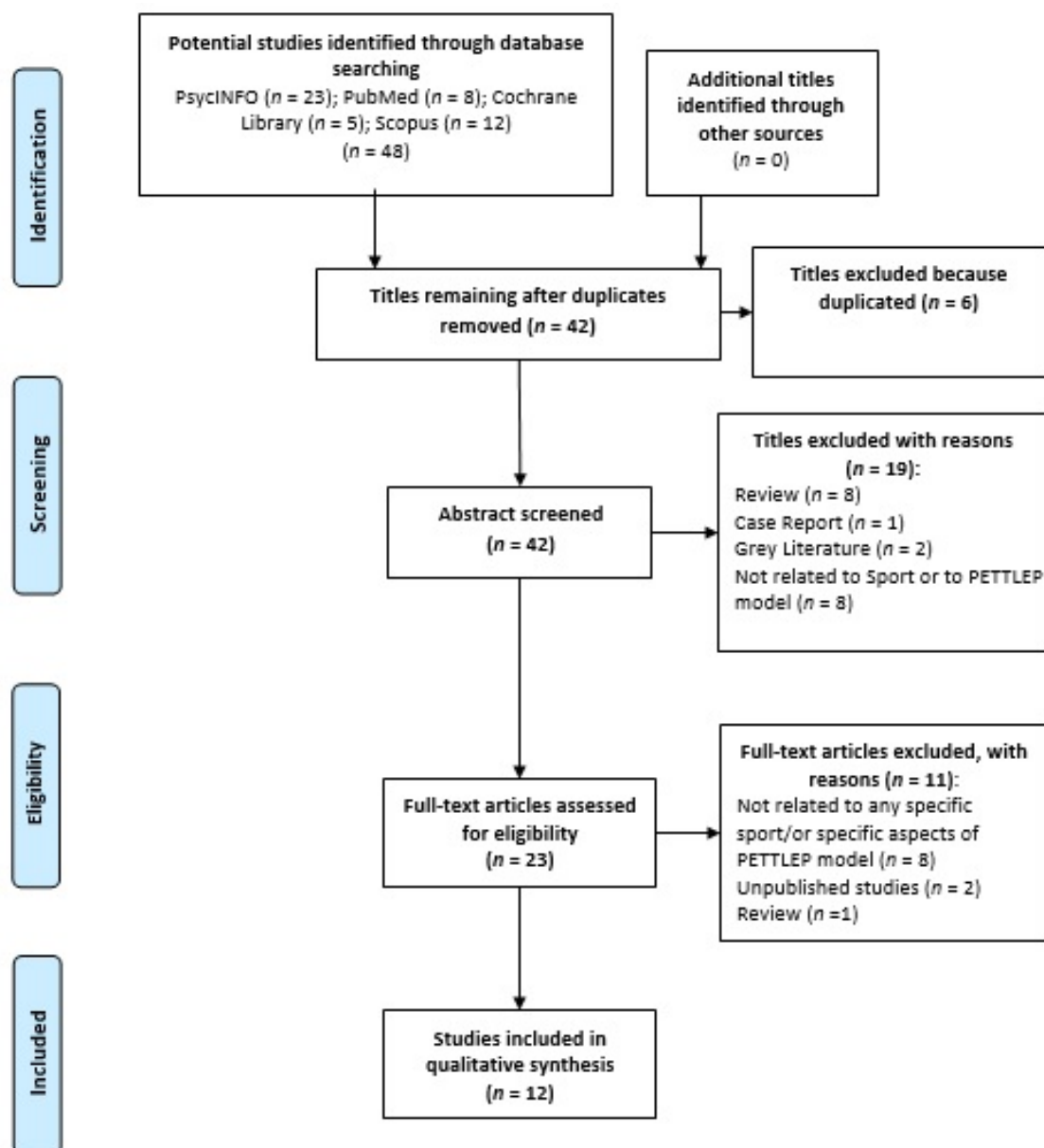


Figure 1. Flow chart of the review performed in accordance with PRISMA statement.

The majority of the 12 studies included in the present review applied imaging protocols during team sports such as soccer, netball, volleyball, field hockey, or cricket [35,44,46,47,49,50,52,53], while only 5 studies out of 12 involved individual sports such as gymnastic or table tennis [45,47,51,53,54]. Most of the included motor imagery interventions took place over a period of 4 to 6 weeks [35,44,45,50,51,53,54]. Most of the included studies adopted imagery sessions consisting of participants either hearing a motor imagery script read by someone or reading the script themselves [44,46,49–53]. Detailed instructions regarding imagery training were used in four studies [35,47,48,54], while in only one study the mental training protocol was provided by video-guided motor imagery [48]. In all the reported studies, the PETTLEP imagery protocol was effective in enhancing sport performance, especially when combined with physical practice, even when compared to traditional imagery interventions.

3.2. Methodological Quality

According to the PEDro scale criteria [43], the mean score of the included studies' methodological quality is 5.9 (SD 0.66). Munroe-Chandler (2008) [50] and Post et al. (2018) [51] studies were classified as high-quality studies, having 7 as their score. The majority of the studies ranged from scores of 5 to 6, thus being regarded as medium-quality studies [35,44–46,49–54]. None of the included studies was classified as being low-quality. The less satisfied criteria were the ones regarding blinding process, while the best satisfied criteria were the ones regarding randomization and statistical information.

4. Discussion

4.1. PETTLEP Model

The PETTLEP model of imagery was developed by Holmes and Collins [55] based on the notion of functional equivalence; the same neurophysiological processes underlie imagery and the actual executed movement. Such functional equivalence possibly accounts for the performance-enhancing effects of imagery. The PETTLEP intervention is supposed to resemble as much as possible all relevant features of the situation in which the execution occurs. Of particular importance are the movement-related sensations and the effect of these from an emotional point of view. PETTLEP is an acronym that stands for the relevant components to be acknowledged when applying motor imagery: physical, environment, task, timing, learning, emotion, and perspective [53]. Functional equivalence is found also in the physiological mechanisms underpinning imagined and executed movement; autonomic responses linked to voluntary motor activity, such as heart rate and blood pressure, have been reported to vary similarly during kinesthetic motor imagery [11]. Some authors in the sport psychology field initially suggested that the athlete's ideal situation to imagine a movement vividly would be in complete relaxation and tranquility [56,57]. However, the majority of studies do not support such a view and demonstrate a greater improvement in performance when all the senses experienced in the actual execution are included, despite sources of external distractions [55,58–60]. In the next sections, all the components of the PETTLEP model are briefly reviewed.

4.1.1. P—Physical Component

To make the experience as realistic as possible, interventions should incorporate elements such as the correct posture, possible implements, and appropriate clothing for the practiced sport. For example, in a study by Wang et al. [61], expert badminton players reported better motor imaging when holding a particular implement. Other studies demonstrated that long-term physical training with a specific implement can alter the structure and function of multiple neural areas in athletes [62]. Hence, given that the presence of implements is a crucial component of certain sports, one may infer that they may vehicle integration of internal and external MI components at specific cortical areas. Other studies found not only a facilitation effect of a sport-specific implement but also an interference effect when holding a non-specific implement [63].

4.1.2. E—Environment Component

Smith et al. [53] have proven that PETTLEP intervention is beneficial for all types of tasks, of populations, and of age groups. Although the distinct components of the model have an effect taken one by one, a greater benefit is obtained by including more of them. For example, the authors found that the group that was wearing hockey clothing and performed imagery on the hockey pitch improved more compared to both the clothing-only and traditional imagery group and also more than the group performing imagery at home with everyday clothing.

One of the limitations of this method is the struggle faced when conducting experimental imagery in the field. As a matter of fact, research is mostly carried out in labs or based on case studies. Guillot et al. [64] showed how implementing MI during specific aerobic training sessions in young elite tennis players helped with developing their physical fitness, leading to optimal outcomes and to optimization of training time. Hence, it is clear that performing MI in an ecological context is beneficial and, when possible, it should be applied.

4.1.3. T—Task Component

The imagined task should resemble the real performance of such a task and should be altered according to the skill of the athlete [55]. Motor imagery is typically used as an integration of physical training [40,65]. Indeed, imagery interventions have been demonstrated to improve strength tasks especially when in combination with physical practice [54]. Combining mental training protocol with physical practice for several weeks in rhythmic gymnastics significantly improved their jumping skills. This training protocol can potentially reduce injuries caused by excessive physical workload and decrease tiredness during strength training [45]. Such a finding is crucial for those performers who are required to train at a very intense pace to reach a competitive level. Nonetheless, even using MI as a replacement of physical practice has led to significant improvements [66]. Preparatory imagery, for example, occurring just prior to performance, can improve the actual execution of the movements. Blair et al. [67] examined the effects of imagery on the performance of skilled and novice soccer players, finding better response time in both when compared to the control group, which developed a strategy lacking a clear relation with the task.

4.1.4. T—Timing Component

Timing is an important aspect to consider in terms of functional equivalence; the action should be imaged at the correct speed. However, it may only be appropriate when the athletes are experts in the skills that they are mentally rehearsing [68]. Voluntary increases in MI speed have proven to increase the speed of the subsequent motor performance, whereas voluntarily decreasing MI speed exerts the opposite effect [69]. Louis et al. [69] suggested that instructions regarding the duration of the imagery process must be made explicit in order to regulate mental work according to the performer's goal. When the time needed to complete an activity and the time required to imagine it were compared, they have been found to show quite a significant positive correlation. Moran and MacIntyre [70], for example, investigated motor imagery experiences of elite canoe-slalom athletes who had to mentally visualize themselves whilst concluding a race. Indeed, the time it took to image the race was positively correlated with the actual race completion time. Hence, various studies show that preserving the temporal characteristics of movement during MI represents a reliable index of its efficiency. Varying the speed of imagery may unexpectedly cause rapid alterations of actual speed in both elite and amateur athletes [69].

4.1.5. L—Learning Component

The use of MI has been extensively investigated in the sports field because of its potential in promoting learning [71,72]. The PETTLEP model is beneficial in terms of sport performance not only for athletes but for enhancing the exercise experience in general.

Indeed, for this reason, the learning component is important and needs to be taken into consideration: imagery content should be adapted to the stage of learning. There is a shift in skills that go from being cognitive to being more autonomous; the associated motor representation and responses change accordingly. Extensive research supports the notion that PETTLEP, especially when combined with physical practice, enhances learning and skill performance in novice athletes [44,53,73]. Recently, it has been proven that internal and external motor imagery can have differential impacts on performance improvement in complex skills (such as tennis strokes) among novices in early learning stages [28].

4.1.6. E—Emotion

Another influential component to be included in an optimal imagery-based intervention is certainly the performer's emotional responses and his own personal interpretation of the scenario [74]. Using video observation combined with PETTLEP imagery and physical practice can enhance not only physical abilities and skills but can also exert an effect on psychological aspects such as motivation [75]. For MI to be efficient in improving sport performance, it has been shown that it should be based on positive images. Hence, the athlete should imagine himself performing the movement in a successful and rewarding way [76,77]. Regarding the direction of MI's effects on performance, some have differentiated them depending on whether they were more "facilitative" or "debilitative" [78,79]. However, athletes often report imagining negative situations because of the intention to cope with worst case scenarios [80].

4.1.7. P—Perspective Component

Perspective refers to the way imagery is viewed. Kinesthetic imagery is characterized by an internal and first-person view of the performer. Visual imagery can be internal (first person) or external (third person), depending on if the athlete is imagining himself performing the task from his eye perspective or as from a distance [53]. Different studies support the view that it may be beneficial for athletes to combine alternative perspectives together instead of using preferentially only one [21,81]. Visual and kinesthetic imagery share common neural areas; for this reason, it seems that using the two perspectives independently from each other may require the brain of the athlete to perform an extra effort because it would be necessary to inhibit regions of the same network shared by the two modalities [82]. However, the two perspectives have been suggested to be differently useful and to rely on the level of experience, therefore of expertise, in order to boost the potentiality of imagery-based interventions. Indeed, it is suggested to be easier to use internal imagery when one's ability in a task is high [81,83]. During motor skill learning, instead, athletes are more likely to use external imagery [21,81]. Furthermore, while some authors provided evidence for a higher efficacy of visual MI whilst learning form-based skills such as gymnastic moves [31,81], others found instead kinesthetic imagery to be more effective for this kind of learning [53]. Moreover, it was assumed that the most experienced performers are able to switch between different perspectives to benefit equally from both and ultimately optimize the imagery experience [53]. Recently, scholars have shown that first-person kinesthetic internal perspective can be used to develop and improve performance of an already internalized movement [30]. On the other hand, an external perspective has proved to be useful in learning, and subsequently improving, a movement sequence of recent acquisition [84]. Such data provide novel and valuable insights into the use of motor imagery techniques, particularly in the field of sport performance.

There is growing evidence suggesting the combination of MI and action observation (AO) could be the optimal practice, especially when there is no possibility to engage in physical training. Research on mirror neurons [85], as well as the study of Borroni et al. [86], found a tight temporal coupling between an observed action and its mental representation. However, temporal coupling between AO and MI still requires further investigation. The first studies assessing the validity of applying MI+AO in sport found such a combination to be effective in increasing performance on a golf putting task [87] and biceps strength [54].

Moreover, Bek et al. [88] found that when imitating hand movements, subjects performing MI+AO or paying close attention to the observed kinematics were significantly better in imitating the movements. Two studies support the hypothesis of a greater corticospinal excitability [89] and larger BOLD activity [90] in the left hemisphere when performing MI. Since MI ability declines with age [91], implementing AO to MI training could also be useful to support the degraded imagery abilities of elderly or neurological patients [92]. In conclusion, it seems preferable to implement AO in MI training in order to decrease the mental load of the MI task. Having a visual support to the imagery could help subjects focus on the imagery task and obtain better results. This could help athletes who are still learning how to perform some movements, as well as both the elderly and children, which are characterized by limited imagery abilities in terms of reproducing real performances [91].

4.2. The Role of Expertise

A number of studies in the past years have investigated differences in brain activation during motor imagery in novices with respect to experts. Some claimed that novices have difficulty in filtering out irrelevant information, whereas experts have a greater impact on performance because they manage to be more focused [93]. There are other aspects that clearly differ when dealing with imagery in more expert players, such as the strategies and tactics adopted. Indeed, elite athletes are more focused on using more pertinent skills, whereas novices' main concern is how properly they perform the basic movements required for the task [30]. Hence, the content of imagery should differ between expert performers and novices, because the level of the skill mastered will also be different [55]. Indeed, the use of MI also differs in expert athletes and novices depending on the type of sport, i.e., open sports athletes (for example rugby and martial arts) are supposedly more prone to MI than those specialized in closed sports (for example, golf and figure skating [94]). Action anticipation behavior has also been shown to be enhanced throughout motor imagery in basketball athletes compared to novices in observing a free-throw task [95]. The level of expertise influences the degree of awareness of the technical complexity of a movement. Indeed, elite performers are usually more accurate at mentally representing a movement because of the positive relationship between the amount of physical training and the decreased discrepancy between imagined and executed performance [96]. The importance for athletes of exploring their own meta-imagery processes has been demonstrated. Specifically, expert performers should exploit the level of expertise and knowledge mastered in order to gain control over their own imagery skills [97,98].

4.3. Motor Imagery and Strength Increase

Strength-based disciplines, such as weightlifting or powerlifting, can benefit from MI to reduce anxiety and improve the execution of movements. However, increasing performance in these disciplines could also be achieved by increasing strength output. Furthermore, during the rehabilitation period following an injury, it is crucial to prevent excessive strength loss, and MI has been revealed to be particularly helpful in this regard. The so-called psyching-up strategies (which include MI) were found to be effective in increasing strength output in weightlifters [99]. However, some studies did not find any improvement in strength-based tasks after MI training [100,101]. The ineffectiveness of this kind of training could be related to differences in the experimental design or imagery instructions [24]. Indeed, most of the studies that investigated this issue did not use a PETTLEP approach in all of its components but rather focused on the physical and task components. Reiser [102] found an increase in strength after imagined maximal voluntary isometric contraction (MViC) on a task which involved isometric bench pressing. However, this increase was restricted to the first training session.

Another study [103] compared the effects of MViC on isometric bench press, leg press, triceps extension, and calf raise. In this study, different ratios of imagined-to-actual muscle contraction were compared. The 100% physical training group was the one with the higher strength increase. However, replacing part of the physical training with MI did not

result in significant strength loss [103]. However, Paravlic et al. [104] suggested that, in order to have greater results from MI practice, more repetitions and time devoted to MI are required.

Larger strength gains are observed when imagining MVIC compared to submaximal dynamic contractions [105]. Furthermore, muscles with larger cortical representation (more distal muscles) seem to benefit the most from MI [24,38], but this hypothesis requires further investigations.

4.4. Combining MI with Physical Practice

Physical practice (PP) is more effective in increasing strength compared to MI alone and comparison between MI+PP vs. PP alone leads to unclear results [104]. However, Wright and Smith [54] found that when using a PETTLEP approach, the strength gains were similar to those acquired by the PP-alone group.

When making a comparison between MI and PP, it must be noted that PP activates both the muscles and the neural circuit controlling the motor action, resulting in an optimal training of both the peripheral and central system by the PP [1,106]. Furthermore, although similar, the neural networks underlying MI and PP are not identical, probably due to the inhibition of efferent sensorimotor output, which is required during MI [6,107].

The different ability of individuals to perform the MI task could lead to suboptimal activation of the control network, leading to increased variability in the results [30,108–110]. Cerebral activity in motor-related areas was found to be elicited more by the combination of MI and PP than by either one of the two alone [111,112]. Accordingly, greater benefits were experienced after MI+PP than after PP alone, both in healthy subjects [54,113] and symptomatic populations [114,115]. The study of Lebon et al. [113] was particularly interesting because it introduced MI training during rest periods. Over a 6-week program, subjects performed both the bench press and sled leg press. The MI group experienced a higher increase in strength for the sled leg press but not for the bench press. These results could be explained by findings showing that closed kinetic chain exercises (such as the sled leg press) resulted in increased strength gains when compared with open kinetic chain exercises such as the bench press [116].

Nonetheless, there are other factors that could have affected the results. First of all, subjects were all involved in different sports but had no experience with resistance training. Additionally, contrarily to how subjects were instructed in the study [113], the bench press must be considered a compound movement that involves more than lowering the barbell to the chest and pushing it back up. A correct execution of the bench press requires scapula retraction, involvement of the legs, and the execution of a specific barbell path [117].

To avoid issues related to proper execution of exercises, for research purposes, it is preferable to use isometric contractions in order to limit variability in the results. A study which used a similar protocol of Lebon et al. [113] was conducted by Di Rienzo et al. [118], resulting in the highest strength gains, and MI of muscle relaxation was also better than passive recovery [118]. Wriessnegger et al. [119] showed that sport practice enhances MI brain patterns, probably because vividness of the imagery is a strong variable affecting the results of a MI intervention and suggesting that MI could be more effective when performed after PP.

These findings suggest that a combination of MI and PP could be the optimal method for increasing strength. However, more studies in which MI is performed in addition to PP (without reducing time devoted to PP) are required. A crucial problem in this field of research is that imagery abilities play a key role in the effectiveness of this practice: if participants are not able to clearly imagine the motor task, their benefits will certainly be limited [109,110]. Nonetheless, during MI, greater activity of motor-related areas is associated to the experience of the subject in performing the motor task [120] and to the adoption of a first-person perspective during the imagined task [121]. With this in mind, implementation of MI protocols in strength training is suggested. However, in

some cases, its effectiveness could be limited to technical improvements and increased motivation [113,122].

4.5. Motor Imagery and Pain Management

MI during relaxation was found to be helpful in reducing the feeling of pain [102,123], both by maintaining a positive attitude and by promoting recovery [124,125]. Furthermore, performing relaxation alone was found to be helpful in reducing musculoskeletal pain [126] and reducing anxiety [127]. In fact, studies that involved relaxation before motor imagery [128] found a significant reduction in pain, while the study of Moseley et al. [129], which did not use relaxation, found increased levels of pain in participants. Yue et al. [130] found that participants who performed MI during immobilization maintained their strength and experienced an increased EMG signal despite muscle atrophy. In another study, subjects performing MI during immobilization attenuated strength loss by 50% [131].

A meta-analysis of these findings suggested that MI training could help athletes to preserve their strength when they are unable to engage in physical exercises [104]. Gildea et al. [132] studied the effects of MI in dancers with a history of low back pain (LBP). Individuals with recurrent LBP exhibit greater stiffness and less damping in their trunk dynamics [133], and this could be the result of an altered recruitment and morphology of trunk muscles, which are associated with LBP [134]. In the study of Gildea et al. [132], dancers with LBP exhibited less damping but the same trunk stiffness compared to dancers without LBP. When dancers responded to trunk perturbations with imagined fluid and gentle movements, those with LBP performed the same amount of damping as those without, demonstrating their ability to improve trunk control [132]. The study from Craje et al. [135] found that motor imagery improved reaching and grasping abilities but not dexterity, suggesting that gross tasks could benefit more from MI than complex tasks. However, more research is needed to confirm this hypothesis. Harris and Hebert [136] suggested that research about MI in rehabilitation should focus on the type of tasks and aspects of physical practice such as timing and intensity. Furthermore, it is crucial for studies to report the specific content of interventions, allowing replication and better comparison between studies. From pure static motor imagery to dynamic motor imagery, MI is conceptually defined as being performed in the absence of any movement [137], but if the aim is not to study MI but to increase the performance, MI could be coupled with actual movements as simplified versions of the real movements to perform during the task. This practice is referred to as dynamic motor imagery (dMI) [97]. Furthermore, there is evidence showing that, during MI, a subliminal muscular activity is possible, suggesting that the motor control is not completely inhibited [105,138], and some motor output should be included during MI [139]. Fusco et al. [140] found that dMI, such as performed coupling imagery and stepping in place, was more accurate than “static” motor imagery (sMI) for running or lateral walking toward a target. Another study by the same authors was the first in defining the application of the PETTLEP model to dMI, finding dMI more spatially and temporally accurate than sMI in both young and older adults [141].

5. Conclusions

Throughout the years, various scholars have engaged in the study of MI and of its application in various fields. Furthermore, motor imagery is a term used for delivering different kinds of protocols, and this leads to difficulties when comparing different studies, highlighting the need for defining specific protocols and relevant features [136]. One of the most debated and studied models of MI intervention is the PETTLEP approach, which aims at reproducing more realistically as possible all the relevant aspects of the situation in which the execution takes place [55], in line with the functional equivalence notion. The reported studies suggested that the components of the PETTLEP model are those that may potentially increase the efficacy of MI in sport performance. On the other hand, the PETTLEP approach has been poorly used for strength increase and rehabilitation [142–144],

and future research should be focused on assessing the effectiveness of MI based on this model in the above fields.

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Evidence Acquisition: Research papers were searched using the following databases: psycINFO (<https://www.apa.org>), pubMED (<https://pubmed.ncbi.nlm.nih.gov/>), Cochrane Library (<https://www.cochranelibrary.com/>), and the Scopus (<https://www.scopus.com/>) electronic database for English-language publications with human participants (accessed on 20 January 2022). The search identified 48 potential articles across all databases. After the application of inclusion criteria, a total of 12 articles (including 332 total participants) was included in this mixed review that reports quantitative and qualitative results. Manuscripts were included in the present systematic review if the following inclusion criteria were met: (a) Studies including athletes or participants engaging in sports from any discipline and (b) studies applying the PETTLEP protocol.

Evidence Synthesis: The reviewed studies reported evidence supporting the effectiveness of motor imagery based on the PETTLEP model for strength increase and pain management, suggesting implementation of this practice into physical training routines. Conclusions: mental imagery protocols based on PETTLEP were effective in enhancing sport performance, especially when combined with physical practice.

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