

Article

The Complementary Role of Motor Imagery on VO₂max and Lactate in Professional Football Players with Grade II Ankle Sprains During the Return-to-Play Period

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Abstract: Ankle sprains are considered to be the most common musculoskeletal lower limb injury, accounting for a high percentage of all sport injuries in football. Motor imagery (MI) has been widely used for sports performance optimization purposes, suggesting that athletes' ability to reenact a motor action can improve sports performance and rehabilitation. The aim of the present study was to explore the role of MI as an adjunct intervention in VO₂max and lactate in football players with Grade II ankle sprains during the return-to-play period. Fifty-eight professional football players were randomly divided into two groups: first, the MI (n = 29) and second, the placebo (n = 29). The MI group received recorded MI instructions, whereas the placebo group received only relaxation instructions. A one-way ANOVA revealed statistically significant results within the first 4 weeks following the interventions in both groups. Additionally, a *t*-test showed statistically significant differences between the two groups in VO₂max ($t = -6.04$, $p = 0.000$, two-tailed, $p < 0.05$) and lactate ($t = 4.33$, $p = 0.000$, two-tailed, $p < 0.05$). Further research across various sports is needed to better understand the role of MI in the return-to-play period, particularly regarding injury management and sports performance.



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1. Introduction

Football (soccer) is the most popular and commonly played sport around the globe [1], accounting for an increasing number of participants [2]. According to the International Federation of Association Football (FIFA), there are currently approximately 300 million registered football players, coaches and referees worldwide [2]. Additionally, football is an intermittent team sport which involves exercise at a broad range of intensity during match-play [3,4] and places high demands on aerobic endurance, strength and power [5]. Football players need technical, tactical and physical skills in order to succeed and to improve their sports performance [5]. High-intensity intermittent exercises, including sprinting, running and cutting techniques, and low-intensity exercises, including jogging and walking, take place during match-play for different durations and intensities [3–5]. There is a clear link between the work-rate of professional football players and their physical capacities [6]. Football is a sport with high demands on aerobic and anaerobic energy systems [7]. During the game, the intermittent nature of the sport involves alternating periods of high-intensity activity and low-to-moderate intensity recovery [5,7]. Heart rates often peak between 85%

and 98% of maximal values during high-intensity bursts, while recovery phases allow for a reduction in exertion. As a result, the average oxygen uptake remains at approximately 70% $\text{VO}_{2\text{max}}$ [5,7]. This dynamic is driven by the aerobic energy system, which supplies most of the energy during recovery periods, enabling players to sustain performance across repeated high-intensity cycles. Consequently, while 90% of the game is performed at low-to-moderate intensity, these periods are essential for replenishing energy stores between the periods of intense effort [3,7]. High-intensity activities such as jumping, sprinting and accelerating require the use of energy from the anaerobic system, thus resulting in elevated levels of lactate during football match-play [3,5]. Consequently, professional football players have to be adequately prepared with respect to their physical capacities through testing protocols (e.g., the Bruce protocol) before returning to sports activities. As sport participation increases, the high physical demands inevitably result in an increased number of injuries (e.g., ankle sprains) in both professional and amateur football players [2,8].

Ankle sprains are considered to be the most common musculoskeletal lower limb injuries, accounting for 40% of all sports injuries [9,10]. In football, ankle sprains represent between 10% and 36% of all injuries [11], and therefore have been categorized as the fourth most common type of injury [10,11]. Lateral ankle sprains (LAS) can be classified as Grade I, II or III based on the severity of the trauma to the lateral ligamentous complex (Grade I: partial tear of the anterior talofibular ligament (ATFL), Grade II: complete tear of the ATFL and partial tear of the calcaneofibular ligament (CFL), Grade III: complete tear of the ATFL and CFL involving injury of the posterior talofibular ligament (PTFL)) [10,12]. Most incidences of injury involve the ATFL, with a rate of up to 65%, while 20% of injuries involve both the ATFL and the CFL [10,11].

However, LASs can cause various physiological deficits [13] and therefore, it is difficult for sports physiotherapists to predict the precise return-to-play period [11]. Furthermore, inadequate rehabilitation or a premature return to play could cause several long-term complications for the professional football player [11,14]. There are various assessment criteria for deciding when an athlete is ready to return to sports activities: (a) functional limitations should be fully restored, (b) cardiovascular fitness should be equal to or greater than pre-injury levels and (c) the athlete needs to be psychologically prepared to return to play [10,11,15].

Motor imagery (MI) has been defined as the mental representation of an actual movement without any overt body movement [16,17]. It has been widely used for sports performance optimization purposes, suggesting that athletes' ability to represent a motor action can improve motor performance [18–21]. The ability to use MI depends on the type (internal/external) of MI [22]. Internal visual imagery could be defined as a first-person perspective where the athlete feels like performing the action [23,24]. External visual imagery is defined as a third-person perspective where the athlete acts as a spectator watching the movements like a performance [25,26]. Professional football players can benefit from MI application, enhancing self-efficacy, motor learning and sports performance [18]. Sports injuries such as ankle sprains can be a traumatic experiences, causing loss of confidence, depression, anxiety and therefore affecting athletes' performance during the return-to-play period [13,21]. Motor imagery (MI) has increasingly been incorporated into sports rehabilitation as a complementary therapeutic intervention, yet its effectiveness during the return-to-play phase remains underexplored [13,27]. MI triggers autonomic nervous system (ANS) responses that mirror those elicited during physical activity (e.g., football) [13]. Consequently, its effectiveness can be evaluated using ANS responses or validated psychometric tools, such as the Vividness of Movement Imagery Questionnaire (VIMQ-2) [22].

Although the beneficial effects of MI on sports performance are well-documented, limited research has addressed its role in meeting return-to-play criteria following a lateral ankle sprain (LAS) [13,27–30]. Psychological strategies, like MI, during the rehabilitation phase may enhance physical fitness parameters such as VO₂max and lactate levels, thereby shortening the time required to resume sports activities. Investigating the influence of MI on these parameters in professional football players recovering from an ankle sprain is, therefore, a relevant area of inquiry. This highlights the importance of incorporating psychological factors into therapeutic approaches during rehabilitation, as they are closely tied to sports performance outcomes.

The purpose of this study was to assess the complementary role of MI in improving VO₂max and lactate levels in professional football players recovering from Grade II ankle sprains during the return-to-play period.

2. Materials and Methods

2.1. Participants

This study recruited 66 professional football players, aged 18–35 years (mean age = 20.8 ± 3.2), with Grade II lateral ankle sprains (LAS) affecting either the left or right leg. Recruitment was conducted through stratified random sampling in collaboration with the Laboratory of Advanced Physiotherapy (LadPhys) at the University of West Attica. Initial assessments were performed by a sports medicine doctor using clinical tests and diagnostic ultrasound at a private clinic.

Of the original 66 athletes, 5 withdrew voluntarily and 3 were excluded due to a diagnosis of functional ankle instability, resulting in a final cohort of 58 participants. All athletes competed in Greece's Super League 1, Super League 2 or Football League and had been training in football for over five years, with a minimum weekly training load of 10 h. Participants were fully informed of the study's procedures and provided written consent, in accordance with the Declaration of Helsinki. Ethical approval for the study was granted by the University of West Attica's Ethics Committee (approval no. 18030).

The 58 athletes were randomly divided into two groups using a closed-envelope method: the MI intervention group ($n = 29$, mean age = 20.5 ± 3.3 years) and the placebo group ($n = 29$, mean age = 21.2 ± 3.1 years). Anthropometric data showed an average height of 1.76 ± 0.06 m, weight of 69.6 ± 7.8 kg, BMI of 22.3 ± 1.9 , sport participation spanning 11.1 ± 2.7 years and training hours of 12.1 ± 1.5 per week. Dominance analysis revealed 46 right-leg dominant and 12 left-leg dominant athletes, while injury analysis showed 39 right-leg LAS cases and 19 left-leg LAS cases.

Regarding injury history, 38 athletes had experienced a previous LAS in the right leg, 12 in the left leg and 8 in both legs. Of these, 30 had one prior LAS, 22 had two and 7 had three. To be eligible, participants required a Grade II LAS diagnosis by a sports medicine doctor with at least 5 years of experience and had to be in the return-to-play rehabilitation phase.

Exclusion criteria included the presence of visual, vestibular or neurological impairments; fractures or musculoskeletal injuries in the lower extremities within the last 6 months; functional ankle instability [31]; surgical procedures on the lower extremities within the past year; or concussions within the previous 6 months.

2.2. Procedures

This study employed an experimental design to compare two groups: the MI intervention group and the placebo group. The testing protocol was divided into two phases—before and after the MI intervention—over a total period of 4 weeks.

In Phase 1, athletes were introduced to the Bruce Protocol (BP) and ergospirometry procedures [32,33] and trained in the process of measuring lactate levels using capillary blood samples collected from the index finger [5]. A sports physiotherapist with 5 years of experience briefed the athletes about the equipment and testing procedures one week prior. Body mass was recorded to the nearest 0.1 kg using the Mi Body Composition Scale 2 (Xiaomi Inc., Beijing, China), while height was measured with a portable stadiometer (SECA Instruments Ltd., Hamburg, Germany) [13,34]. All tests were conducted at the athletes' respective sports facilities to minimize potential psychological stress.

Phase 2 was conducted exactly 4 weeks later, following the completion of the MI intervention. This timeframe was chosen to reflect the standard rehabilitation period for the return-to-play phase after a Grade II LAS and to evaluate changes in VO₂max and lactate levels.

2.3. Main Outcome Measures

2.3.1. Bruce Protocol

The Bruce Protocol (BP) was used in order to evaluate maximal oxygen uptake (VO₂max) as well as the accumulation of lactate in the peripheral blood samples of professional football players. The evaluation of physical capacity using progressive maximum exercises on a treadmill and with the simultaneous use of ergospirometry can further determine aerobic capacity through the athlete's maximal oxygen uptake (VO₂max), which is directly related to strength, endurance, and above all to the indicators of cardiovascular adaptation and sports performance [32,33]. Furthermore, the evaluation of lactate at the anaerobic threshold is another indicator of aerobic capacity for a professional football player that is directly linked to their athletic performance [5]. Therefore, the improvement of aerobic fitness indices in professional football players is directly linked to their sports performance and their return to play after a Grade II LAS.

A treadmill (Excite Run 1000, Technogym, London, UK), a heart rate monitor (Polar Electro Oy, Helsinki, Finland) and an ergospirometry recording system (Quark CPET, COSMED Inc., Rome, Italy) were used to evaluate the maximum oxygen uptake (VO₂max), in addition to a lactate analyzer (Lactate Scout 4, EKF Diagnostics, Penarth, UK) for the evaluation of the accumulation in a peripheral blood sample. Prior to initiating the procedure, each athlete was informed about the BP stages and was asked to perform a 5 min warm-up (speed 5 km/h, incline 0%) on the floor ergometer for familiarization with the equipment and preparation to perform the evaluation. In addition, each professional football player was informed about all safety and communication parameters during BP execution with the researcher.

BP consists of eight stages with a gradual increase in the speed and incline of the treadmill. Specifically, the BP stages change every 3 min and the speed and inclination parameters are as follows: (a) 2.7 km/h, 10%, (b) 4.0 km/h, 12%, (c) 5.5 km/h, 15%, (d) 6.8 km/h, 16%, (e) 8.0 km/h, 18%, (f) 8.9 km/h, 20%, (g) 9.7 km/h, 22% and (h) 10.5 km/h, 25% [32,35]. The test was completed as soon as the athlete requested to stop the procedure due to fatigue, when the maximal oxygen uptake (VO₂max) and lactate values were recorded by taking capillary peripheral blood from the index finger. After recording the maximum oxygen uptake (VO₂max) and lactate levels, the recovery period started as soon as the heart rate decreased <80% (based on the maximum heart rate and the age of the athlete). Subsequently, for the next 10 min, the athlete had to do no physical activity in order to restore his cardiorespiratory function, with a decrease in heart rates of approximately >20% compared to the maximum rate [5,35].

2.3.2. Vividness of Movement Imagery Questionnaire-2

The VMIQ-2 assesses imagery abilities through twelve questions across three distinct perspectives: (a) external visual imagery (EVI), (b) internal visual imagery (IVI) and (c) kinesthetic visual imagery (KVI). Participants are tasked with imagining themselves performing twelve motor actions from these perspectives: (a) observing the movement from a third-person perspective (EVI), (b) experiencing the movement from a first-person perspective (IVI) and (c) feeling the movement as if performing it themselves (KVI). The vividness of the imagined actions is scored on a 5-point scale, where 1 represents “perfectly clear and vivid” and 5 represents “no image at all” [22].

The twelve motor actions included in the VMIQ-2 are:

1. Walking,
2. Running,
3. Kicking a stone,
4. Bending down to pick up a coin,
5. Running upstairs,
6. Jumping sideways,
7. Throwing a stone into water,
8. Kicking a ball in the air,
9. Running downhill,
10. Riding a bike,
11. Swinging on a rope,
12. Jumping off a high wall.

Imagery ability based on VMIQ-2 scores is categorized as follows:

- High imagery ability: VMIQ-2 score < 26
- Low imagery ability: VMIQ-2 score > 36

The Greek version of the VMIQ-2 (VMIQ-2-GR) has demonstrated acceptable factorial and construct validity, with an intraclass correlation coefficient (ICC) > 0.92, establishing it as a reliable and valid psychometric tool [22].

2.3.3. Intervention Protocol

Both the first (MI intervention) group and the second (placebo) group followed a physical therapy balance training protocol starting 2 days after the completion of Phase 1. The intervention spanned 4 weeks, aligning with the return-to-play rehabilitation period, and included a total of 6 sessions per professional football player. The balance training protocol consisted of 3 distinct parts, with a total session duration of 30 min [36–39]. Details of the protocol are presented in Table 1.

Table 1. The physical therapy balance training protocol.

Part 1—8 min *	Part 2—15 min *	Part 3—7 min
Running—60 s	One legged stance—3 × 45 s hold	Static stretching exercises of the lower limbs
Jumping Jacks—40 s	Jump from one leg to the other with control landing for 4 s—3 × 10 reps	
Linear Knee Raise—10 reps	One legged stance on a balance board—2 × 45 s hold	
Squat—10 reps	One legged stance on a balance board with the knee flexed—3 × 10 knee flexions	
Leg Swing—10 reps	Squats on a balance board—3 × 45 s hold	

* 30 s break between each exercise.

At the end of the physical therapy balance training protocol, professional football players in the first MI intervention group individually received the MI intervention protocol. At the beginning of each MI session, athletes in both groups (MI intervention and placebo) had to complete the VMIQ-2-GR. The first MI intervention group and the second placebo group both received 6 sessions of MI and placebo instructions in addition to their physical therapy balance training protocol. The total duration of each session was 50 min including 30 min of the balance training protocol and 20 min of MI or placebo instructions. All professional football players were asked to sit comfortably in a relaxed position with low-light and quiet environmental conditions.

The MI instructions were professionally recorded by a sound engineer in a recording studio to minimize bias. The recordings were produced using Cubase version 10 and WaveLab version 9 software, along with an NT1 fourth generation condenser microphone (Rode, Sydney, Australia). During each session, the recorded MI protocol was played on the same computer (MacBook Pro, M1, Apple Inc., Cupertino, CA, USA) and listened to using the same headphones (Keiji, HD-2400G, Zeroground, Athens, Greece) to ensure consistency.

In the MI intervention group, professional football players first received relaxation instructions, followed by MI instructions replicating their physical therapy balance training protocol. The athletes were guided to mentally rehearse the progression of balance exercises, including the same duration and repetitions as in their physical therapy sessions. They were encouraged to vividly imagine and feel themselves performing the balance training tasks.

By contrast, the placebo group only listened to recorded relaxation instructions without any MI intervention.

2.3.4. Statistical Analysis

Descriptive statistics, including mean values and standard deviations, were calculated for continuous variables. Statistical significance was set at $p < 0.05$. Differences in the demographic characteristics of the professional football players were assessed using the chi-square test (χ^2) and the chi-square trend test (χ^2), as presented in Table 2 [40]. Data normality was evaluated using the Kolmogorov–Smirnov test.

To analyze within-subject effects over time and compare the two groups after the 4-week intervention period, a repeated measures one-way ANOVA was performed [41]. Additionally, t -tests for independent variables were employed to identify statistically significant differences between the two groups [42]. Partial eta squared (η^2) was calculated to quantify group differences and assess clinical relevance, with effect sizes classified as small ($\eta^2 = 0.01$), medium ($\eta^2 = 0.06$) and large ($\eta^2 = 0.14$) [43,44].

All statistical analyses were conducted using SPSS v.26 (Statistical Package for the Social Sciences, SPSS Inc., Chicago, IL, USA).

Table 2. Demographic characteristics of the two groups.

Demographic Characteristics	Total Participants n = 58	First MI Group n = 29	Second Placebo Group n = 29	Statistical Analysis p Value
Age (M $\pm$ SD)	20.5 $\pm$ 3.3	20.5 $\pm$ 3.3	21.2 $\pm$ 3.1	NS, $p = 0.37$ $^{\alpha}$, $p > 0.05$ t -test for independent
BMI (kg/m ²) (M $\pm$ SD)	22.3 $\pm$ 1.9	22.8 $\pm$ 1.7	21.8 $\pm$ 2.1	NS, $p = 0.05$ $^{\alpha}$, $p < 0.05$ t -test for independent
Yrs of training (M $\pm$ SD)	11.1 $\pm$ 2.7	11.0 $\pm$ 2.8	11.2 $\pm$ 2.6	NS, $p = 0.81$ $^{\alpha}$, $p > 0.05$ t -test for independent
Hrs of training/wk (M $\pm$ SD)	12.1 $\pm$ 1.5	11.9 $\pm$ 1.6	12.3 $\pm$ 1.4	NS, $p = 0.26$ $^{\alpha}$, $p > 0.05$ t -test for independent

Table 2. Cont.

Demographic Characteristics	Total Participants n = 58	First MI Group n = 29	Second Placebo Group n = 29	Statistical Analysis p Value
Dominant Leg		Frequencies %	Frequencies %	Chi-square
Right (n, %)	46 (79.3%)	25 (86.2%)	21 (72.4%)	NS, $p = 0.19^{\beta}$, $p > 0.05$
Left (n, %)	12 (20.7%)	4 (13.8%)	8 (27.6%)	
Grade II LAS—Leg				
Right (n, %)	39 (67.2%)	21 (72.4%)	18 (62.1%)	NS, $p = 0.40^{\beta}$, $p > 0.05$
Left (n, %)	19 (32.8%)	8 (27.6%)	11 (37.9%)	
Previous LAS—Leg				<i>t</i> -test for Independent
Right (n, %)	38 (65.5%)	17 (58.6%)	21 (72.4%)	NS, $p = 0.30^{\alpha}$, $p > 0.05$
Left (n, %)	12 (20.7%)	6 (20.7%)	6 (20.7%)	
Both (n, %)	8 (13.8%)	6 (20.7%)	2 (6.9%)	
Total number of previous LAS				Chi-square for Trends
1 (n, %)	30 (51.7%)	17 (58.6%)	13 (44.8%)	NS, $p = 0.35^{\gamma}$, $p > 0.05$
2 (n, %)	21 (36.2%)	9 (31.0%)	12 (41.4%)	
≥ 3 (n, %)	7 (12.1%)	3 (10.3%)	4 (13.8%)	

NS = no significance, M = mean, SD = standard deviation; $^{\alpha}$ *t*-test, $p < 0.05$; $^{\beta}$ χ^2 , $p < 0.05$; $^{\gamma}$ χ^2 for trends, $p < 0.05$.

3. Results

3.1. VO₂max and Lactate

A one-way ANOVA (repeated measures analysis) within subjects for evaluating VO₂max and lactate before and after 4 weeks showed statistically significant results (VO₂max: $F = 48.997$, $S = 0.000$, $p < 0.05$; lactate: $F = 3841.301$, $S = 0.000$, $p < 0.05$), 4 weeks after the interventions for both groups (Table 3). Also, statistically significant differences were observed for VO₂max and lactate between the two groups, 4 weeks after the interventions.

A *t*-test for independent samples revealed statistically significant differences between the two groups for the variables of VO₂max and lactate, respectively (VO₂max: $t = -6.04$, S (two-tailed) = 0.000, $p < 0.05$; lactate: $t = 4.33$, S (two-tailed) = 0.000, $p < 0.05$), Table 4. The mean values of the VO₂max showed a statistically significant increase of 8 mL/kg/min for the first MI intervention group, compared to the second placebo group which showed an increase of 0.6 mL/kg/min, which means that VO₂max improved statistically significantly in the first MI intervention group. The mean values of the lactate in the first MI intervention group revealed statistically significant differences with a value of 6.7 mmol/L, compared to the second placebo group which showed a value of 7.7 mmol/L, which means that there was a statistically significant reduction in lactate in the first MI intervention group compared to the second placebo group.

The partial variance effect size (η^2) for the VO₂max variable showed a large effect size ($\eta^2 = 0.46$) and observed power = 1.00 ($\alpha = 0.05$). Also, the partial variance effect size (η^2) for the lactate variable showed a large effect size ($\eta^2 = 0.98$) and observed power = 1.00 ($\alpha = 0.05$).

Table 3. A one-way ANOVA showed statistically significant results comparing the mean differences in VO2max (mL/kg/min) and lactate (mmol/L) between the two groups (MI intervention and placebo) before and after 4 weeks.

VO2max (mL/kg/min)					
Groups N = 58	M ± SD (mL/kg/min) Pre	M ± SD (mL/kg/min) Post	Mean Difference (MD) (mL/kg/min)	Confidence Interval (CI) 95%	Significance
First—MI Intervention Group (n = 29)	42.53 ± 4.48	50.41 ± 3.17	−2.24	−4.15; −0.33	F = 48.997, S * = 0.000, p < 0.05
Second—Placebo Group (n = 29)	43.86 ± 5.24	44.59 ± 4.09			
Lactate (mmol/L)					
Groups N = 58	M ± SD (mmol/L) Pre	M ± SD (mmol/L) Post	MD (mmol/L)	CI 95%	Sign
First—MI Intervention Group (n = 29)	6.83 ± 1.07	13.73 ± 1.27	0.80	0.28–1.32	F = 3841.301, S * = 0.000, p < 0.05
Second—Placebo Group (n = 29)	7.13 ± 0.96	15.04 ± 1.00			

* S = significant $p < 0.05$; M = mean; SD = standard deviation.

Table 4. A *t*-test for independent samples showed statistically significant differences in the first MI intervention group in VO2max and lactate variables.

VO2max (mL/kg/min)—Post				
Groups N= 58	M ± SD (mL/kg/min) Post	Mean Difference (MD) (mL/kg/min)	Confidence Interval (CI) 95%	Significance (Two-Tailed)
First—MI Intervention Group (n = 29)	50.41 ± 3.17	−5.81	−7.74; −3.89	$t = -6.04$, S * = 0.000, $p < 0.05$
Second—Placebo Group (n = 29)	44.59 ± 4.09			
Lactate (mmol/L)— Post				
Groups N= 58	M ± SD (mmol/L) Post	MD (mmol/L)	CI 95%	Sign (Two-Tailed)
First—MI Intervention Group (n = 29)	13.73 ± 1.27	1.30	0.70–1.91	$t = 4.33$, S * = 0.000, $p < 0.05$
Second—Placebo Group (n = 29)	15.04 ± 1.00			

* S = significant $p < 0.05$; M = mean; SD = standard deviation.

3.2. Vividness of Movement Imagery Questionnaire—2 (VMIQ-2-GR)

A one-way repeated measures ANOVA was conducted to evaluate the effects of the MI intervention on the VMIQ-2-GR after 4 weeks (six sessions) in the two groups (MI and placebo). Statistically significant results were observed for the MI intervention's effect on all three perspectives of the questionnaire: external visual imagery (EVI: $F = 13.697$, $p = 0.000$, $p < 0.05$), internal visual imagery (IVI: $F = 12.191$, $p = 0.000$, $p < 0.05$), and kinesthetic visual imagery (KVI: $F = 6.996$, $p = 0.000$, $p < 0.05$). However, no statistically significant differences were found between the two groups. The changes in VMIQ-2 scores between the two groups were as follows:

- EVI: The MI intervention group showed a decrease of 7.4 points, compared to a decrease of 5.8 points in the placebo group.
- IVI: The MI intervention group showed a decrease of 4.1 points, while the placebo group showed a larger decrease of 6 points.
- KVI: The MI intervention group demonstrated a decrease of 6.5 points, compared to a decrease of 2.3 points in the placebo group.

The partial eta-squared (η^2) values indicated a large effect size for all three perspectives:

- EVI: $\eta^2 = 0.56$, observed power = 1 ($\alpha = 0.05$).
- IVI: $\eta^2 = 0.54$, observed power = 1 ($\alpha = 0.05$).
- KVI: $\eta^2 = 0.40$, observed power = 0.99 ($\alpha = 0.05$).

4. Discussion

The purpose of this study was to investigate the complementary role of MI on VO₂max and lactate levels in professional football players with Grade II ankle sprains during the return-to-play period. The findings demonstrated that the MI intervention had a significant therapeutic effect as a complementary modality alongside conventional physical therapy balance training protocols, particularly on VO₂max and lactate variables. Statistically significant differences were observed between the two groups (MI intervention and placebo) before and after the 4-week intervention period. MI has been proven to be an effective complementary therapeutic modality, in addition to a conventional physical therapy, in sports injury management and rehabilitation [13,27,30,45–47], and also in sports performance optimization [25,48]. However, most of the studies evaluate the effects of MI with respect to sports performance in healthy athletes and not during the return-to-play period after a sports injury, such as a Grade II ankle sprain.

In our study, the results of VO₂max tests, which were performed using BP through ergospirometry showed statistically significant results ‘within subjects’ after 4 weeks of MI interventions between the two groups (first, MI intervention group and second, placebo group). A greater improvement was observed between the two phases in the first MI intervention group compared to the second placebo group. Additionally, statistically significant differences were revealed for the first MI intervention group compared to the second placebo group. To the best of our knowledge, this is the first single-blind randomized clinical trial aimed at exploring the complementary role of MI on VO₂max in professional football players with a Grade II ankle sprain during the return-to-play period. While numerous studies over the past decades have investigated the effects of MI on sports performance, they have generally focused on healthy athletes from diverse sports backgrounds, often with limited sample sizes. Furthermore, these studies typically did not include physical capacity parameters, such as VO₂max [20,26,49,50]. A key study by Decety et al. [49] was among the first to examine the impact of MI on motor performance through measurements of oxygen consumption (VO₂) and pulmonary ventilation (VE) using ergospirometry. The findings of this study revealed a statistically significant improvement in VE and heart rate in the experimental group, along with a modest enhancement in VO₂ within the MI intervention group. Similarly, to our methodological approach, their study explored oxygen uptake as well, but they did not explore the VO₂max variable using BP through ergospirometry to evaluate physical capacity. Also, their study included only eleven healthy amateur athletes from various athletic backgrounds, and therefore their findings could not be generalized with respect to sports performance indices.

In our study, the lactate variable demonstrated statistically significant differences within subjects, comparing pre-intervention and post-intervention (4 weeks) levels between the two groups (first, MI intervention and second, placebo group). These differences were observed in lactate accumulation in peripheral blood samples after completing the Bruce Protocol (BP). Additionally, significant differences were found between the two groups, with the first MI intervention group showing a notable reduction in lactate levels compared to the second placebo group. This finding is consistent with the study by Perciavalle et al. [50], in which motor working memory was evaluated by using a sequence of reproduction tasks in order to investigate whether working memory performance was affected by blood lactate levels. Participants derived from the non-athletic population, and they executed a cycling exercise protocol in addition to a working memory task.

Their findings showed that high levels of blood lactate worsen types of working memory. The results of our study showed that there was a statistically significant reduction in the accumulation of blood lactate in the first MI intervention group compared to the second placebo group, which could be associated with athletes' MI ability and the manageability of the motor task, encompassing the satisfactory use of working memory.

In our study, all professional football players demonstrated improvements in MI ability across all three perspectives—external visual imagery (EVI), internal visual imagery (IVI) and kinesthetic visual imagery (KVI)—after 4 weeks of interventions (six MI sessions). MI ability was assessed using the VMIQ-2-GR, and statistically significant differences were observed within subjects before and after the interventions. However, no statistically significant differences were found between the two groups (first, MI intervention group and second, placebo group). Among the three perspectives, the IVI perspective emerged as the most preferred by professional football players during MI implementation, as it achieved the lowest score, indicating greater vividness. Meanwhile, the EVI perspective showed the highest enhancement over the intervention period. These findings align with the study by Hardy and Callow [48], which explored the relationship between EVI and IVI perspectives in relation to sports performance in professional athletes. Their research similarly concluded that the IVI perspective was the most preferred and effective, particularly for athletes with greater experience in sports performance.

The current study has various practical and clinical applications for many reasons. It is the first study to explore the complementary role of MI on VO₂max and lactate in professional football players with Grade II ankle sprains during the return-to-play period, and is therefore important in terms of sports performance and practical implementation. The findings of our study proved the efficacious complementary role of MI in addition to conventional physical therapy balance exercise protocols, specifically in the sports field for sports practitioners who desire to enhance performance during the return-to-play period. Also, the use of MI intervention could aid sports practitioners to accelerate the return to play of a professional football player and improve sports performance, simultaneously.

Limitations

This study is the first single-blind randomized clinical trial to reveal statistically significant results regarding the complementary therapeutic effect of MI on VO₂max and lactate levels in professional football players with Grade II ankle sprains during the return-to-play period. However, the 4-week intervention period may be considered relatively short, potentially limiting the full effects of MI. Future research could explore the complementary role of MI in athletes from diverse sports backgrounds to compare its impact on sports performance across various mentalities and disciplines. Additionally, the absence of a control group performing only the physical therapy balance training protocol may have influenced the findings of this study. Another consideration is the inclusion of relaxation instructions in the MI content, which may have affected athletes' physical responses. This is particularly relevant given that VO₂max and lactate variables were measured using the Bruce Protocol, which requires maximal physical effort.

5. Conclusions

The purpose of the current study was to explore the complementary role of MI on VO₂max and lactate in professional football players with Grade II ankle sprains during the return-to-play period.

The results of our study indicate that MI has an efficacious complementary role when applied in addition to physical therapy balance training protocols. The statistically significant results of MI on VO₂max and lactate suggest that further research is needed in

different sports in order to establish the role of MI during the return-to-play period with respect to injury management and sports performance.

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