BMJ Open Sport & Exercise Medicine

Effectiveness of an On-Field Rehabilitation framework for return to sports in injured male professional football players: a single-blinded, prospective, randomised controlled trial

Ioannis Stathas ,[1,2] Alkiviadis Kalliakmanis,[3] Afxentios Kekelekis,[4] Despoina Danassi Afentaki,[5] Elias Tsepis,[6] Konstantinos Fousekis[7]

To cite: Stathas I, Kalliakmanis A, Kekelekis A, *et al*. Effectiveness of an On-Field Rehabilitation framework for return to sports in injured male professional football players: a single-blinded, prospective, randomised controlled trial. *BMJ Open Sport & Exercise Medicine* 2024;**10**:e001849. doi:10.1136/bmjsem-2023-001849

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/bmjsem-2023-001849).

Accepted 7 December 2023

For numbered affiliations see end of article.

Correspondence to
Mr Ioannis Stathas;
statioan@hotmail.com

ABSTRACT

Objectives In football, on-field rehabilitation (OFR) is critical during injury recovery for a player's safe return to sports (RTS). The study aimed to evaluate the effectiveness of an OFR framework for RTS in injured male professional football players.

Trial design A prospective block-randomised controlled-parallel trial was conducted (level of evidence 1b).

Methods Male professional football players (mean age, 26.3±3.6 years) from Greece diagnosed with an acute, lower limb musculoskeletal (MSK) injury (confirmed clinically and through imaging) participated in the study. During rehabilitation, the participants' OFR was guided by either the On-Field Rehabilitation (On FI.RE.) accelerated framework (experimental group) or a traditional OFR framework for a late injury recovery phase (comparison group). Between July 2021 and January 2022, 76 players were randomly allocated to the experimental group (n=38) and the comparison group (n=38). Participants were blinded during the study regarding intervention therapeutic protocols. The primary outcome measure was the effect of On FI.RE. framework on the time needed to return to team training (RTT) participation. The correlation between the time needed to return to on-field activity and RTT was calculated. Subsequent injuries were registered for a 12-month follow-up period.

Results The intervention protocol, On FI.RE. framework, had a statistically significant effect on the time needed to RTT ($F(1) = 49\,626$, $p<0.001$) with a large effect size (ES; $\eta^2=0.422$) and fewer days (mean=23.8±9.1 days) needed than the comparison group (mean=30.3±9.8 days). There was a strong correlation between return to on-field activity and the time needed to RTT ($r_{(76)} = 0.901$, $p<0001$) with a large ES ($r>0.5$). Six subsequent injuries were registered in the traditional OFR framework group, and one subsequent injury in the On FI.RE. framework group after a follow-up period of 12 months.

Conclusion The On FI.RE., an accelerated OFR framework during injury recovery, is more effective than a traditional OFR framework, reducing the time a player needs to RTS. It entails a very low risk of reinjury.

Trial registration number NCT05163470.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ While existing literature extensively covers high-impact frameworks for on-field rehabilitation (OFR), there is a noticeable lack of original research that focuses on assessing the effectiveness of such programmes.

WHAT THIS STUDY ADDS

⇒ In this randomised controlled trial involving male professional football players, the On FI.RE. framework demonstrated superiority over a traditional OFR framework for moderate and severe lower limb musculoskeletal injuries. This resulted in a significantly faster return to participation in team training ($p=0.001$), with a trend towards the On FI.RE. framework minimising subsequent injuries during a follow-up period of 12 months.

⇒ A statistically significant positive correlation ($r(76)=0.901$, $p<0.001$) was found between «Return to On-filed Activity» and «Return to Participation in team training» for On FI.RE. framework. On this basis, the sooner the player started on-filed rehabilitation during the rehabilitation period, the sooner the player returned to participation in team training.

⇒ The On FI.RE. framework is recommended for daily clinical practice as an accelerated, therapeutic exercise-based OFR framework for male professional football players and most lower limb musculoskeletal injuries. Its purpose is to enhance treatment outcomes, reduce Return to Team Training time and minimise subsequent injuries.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Focus on guiding future research in randomised controlled trials for sports rehabilitation. Emphasise specific protocols, criteria for return to sports and injury prevention strategies, particularly in football, to improve treatment outcomes.

INTRODUCTION

In the highly demanding environment of elite football, injuries pose a critical challenge

as they impact players' availability and significantly affect individual and team performance, thereby jeopardising goal achievement.[1] Effective post-injury rehabilitation is of utmost importance.[2] When delayed or ineffective, rehabilitation can lead to prolonged pain and a delayed return to sports (RTS). RTS is when the player has returned to their defined sport but is not performing at their desired level.[3] During rehabilitation, the focus should be on maintaining the player's football skills, as the injury has the biological time needed to heal.[2 4] According to the ecological theory in sports,[4–7] the player has an increased potential to maintain football-specific skills during on-field rehabilitation (OFR); this is because OFR brings them closer to the sport, using a realistic approach and providing opportunities to interact with their regular sporting environment, thus enabling them to maintain their skills.

However, contrasting opinions about OFR during injury recovery are prevalent among the sports medicine community. The traditional OFR mainly focuses on the latest phase of injury recovery, which is the overlap period between the rehabilitation and RTS; when off-field, initially, the player focuses on restoring baseline preinjury screening or standard values before initiating OFR.[8–13] However, off-field rehabilitation keeps players away from the sporting activity environment, resulting in a prolonged adaptation period to restore physiological and mental capacities to achieve maximum performance.[14] In contrast, the context of ecological theory in sports emphasised the need for a premature accelerated OFR strategy. An accelerated OFR programme is defined as a programme that includes an early initiation of OFR, allowing the player to start OFR as soon as possible during the rehabilitation period.[15] The injured player remains in their regular sporting environment by conducting rehabilitation on the field, enhancing injury recovery and promoting increased cognitive performance while maintaining vital physiological and neuromuscular adaptations.[2 4–7 14]

To our knowledge, high-impact frameworks for OFR are documented in the literature. However, there is a noticeable absence of original research regarding the effectiveness of OFR programmes. Therefore, the overall objective of the proposed research was to evaluate the effectiveness of an accelerated OFR framework—the On FI.RE. (On-Field Rehabilitation) framework—for safe RTS in injured male professional football players.

METHODS

Trial design

A prospective block-randomised controlled parallel trial that included male professional football players from Athens, Greece, was conducted in collaboration with the Department of Physiotherapy of the University of Patras. Both the players and the examiner were blind regarding the group allocation. The University of Patras ethics committee approved the trial (file No.12193), and the trial was registered on clinicaltrials.gov under 'On-field functional rehabilitation'.

Participants

Eligibility criteria

The eligible study population consisted of male football players aged 17 and 40 participating in three professional Greek football categories. The inclusion criteria were (a) the players had played professional football for at least 3 years, (b) had a diagnosed acute low limb musculoskeletal (MSK) injury, (c) participated in the study from the initial time of injury, (d) had a moderate (7–28 day) or a severe (>28 days) injury as defined in the prediction of initial diagnosis.[1] Exclusion criteria were (a) the players had suffered a subsequent injury of a previous injury, (b) had a chronic overuse syndrome or other disorders that would affect the intervention and (c) had not sustained another injury in the 2 months before the index injury.

Data collection

Between July 2021 and January 2022, four teams (two teams from Super League, one team from Super League 1 and one high-level team from Super League 2) participating in Greece's top three professional football leagues, as well as two sports physical therapy clinics, were invited to participate in the study and accepted the invitation. All the players were professional football players who typically played 1–2 weekly matches, accompanied by five training sessions. The study focused on recruiting players who had sustained an acute MSK injury during a game or training session. The team's medical staff and the chief physiotherapist from the physical therapy clinics reported the injuries to an independent study worker, who then forwarded the information to the sports physician (AK) for evaluation and randomisation. Once randomisation was completed, the participants began rehabilitation at the physical therapy clinic and continued OFR on the football field.

Patient and public involvement

All participants provided written informed consent and were neither involved in the study conduct nor in disseminating study outcomes.

Equity, diversity, and inclusion statement

This is a randomised controlled trial on male professional football players participating in Greek Football categories. The research team comprised five men and one woman, including principal, senior and less experienced researchers. All authors are based and practising in Greece. The authors' disciplines include medicine, sports medicine, physiotherapy and sports science. The study population consisted of athletes from different ages, races/ethnicities, demographics and socioeconomic backgrounds. Due to the research design, there are no participating athletes with disabilities or complex illnesses. All the participants were addressed with equity in the analysis and interpretation of results.

Randomising and blinding

In this single-blinded prospective, randomised, controlled parallel study, the participants were randomly allocated to either the experimental or comparison group with a 1:1 distribution using a sealed envelope (https://www.sealedenvelope.com/simple-randomiser/v1/lists). A stratified block randomisation method was conducted, dividing players into the intervention (n=42) and comparison (n=42) groups. Computer-generated random numbers were implemented, and allocation with intervention details was sealed in an opaque envelope. The allocation remained concealed as the randomisation list was kept in the care of the sports physician (AK), who was not involved in the intervention application or outcome assessment. The allocation sequence was concealed until participants were enrolled and assigned to interventions. The communication between the sports physician and physiotherapists, who applied rehabilitation protocols and the participants, was continuous. However, as part of the study protocol, participants were requested to refrain from discussing the details of their protocols with the sports physician who made the assessment. Throughout the study, the participants were kept blinded regarding the intervention protocols.

Intervention

Before the intervention started, a sports physician (AK) evaluated each participant the day after the injury was sustained using clinical evaluation tests and the proper diagnostic imaging prescribed for the type of injury. All the participants filled out the FIFA Medical Assessment and Research Centre medical history form, sharing their basic characteristics and medical history. After evaluation and computer randomisation, each participant was assigned to either the experimental group, which followed the On FI.RE. (On-Field Rehabilitation) framework, or the comparison group, which followed the traditional OFR framework. The On FI.RE. framework is an accelerated approach that involves the early initiation of OFR. This means the player should begin OFR as soon as possible during rehabilitation.[15] The traditional OFR framework focuses on the late phase of injury recovery, corresponding to the overlap period between rehabilitation and RTS.[8] RTS is when the player has returned to their defined sport but is not performing at their desired level.[3] Each group was divided into subgroups according to the type of injury,[16] such as the muscle and tendon injury subgroup and the joint (non-bone) and ligament injury subgroup. The groups were also divided into subgroups according to the severity of the injuries, classified as either moderate (8–28 days) or severe (>28 days) injuries.[1] The injury characteristics are shown in online supplemental table 1. All participants completed all stages of rehabilitation under the guidance of the author's team. One physiotherapist, IS, was assigned to the experimental group, while another, AfK, was assigned to the comparison (control) group. Both IS and AfK had studied and knew all the protocols involved. They applied the off-filed rehabilitation protocols, including physiotherapy and gym exercises, and the OFR framework rehabilitation protocols for their respective groups. After the players had completed the full rehabilitation programme, the sports physician (AK) conducted evaluations to determine whether they were ready to participate in team training (return to team training; RTT), that is, the player be participating in team training (modified or unrestricted) but at a level lower than their RTS goal.[3] IS and AfK were responsible for monitoring criteria and collecting the data. Criteria were the same for both groups. Players who did not complete or quit the procedure (may be unwilling to continue participating in the research due to a subsequent injury during rehabilitation or transferring to another team) were removed from the data collection. All the participants were asked to report any subsequent injury during a 12-month follow-up period (starting the day that the player RTT and ending after 12 months) to an independent study worker.

Illinois agility test

On the last day of their OFR programme, all the participants performed an on-field Illinois agility test (IAGT), a valid test with excellent test reliability of 0.96 (95% CI) and moderate retest reliability of 0.68 (95% CI).[17] IAGT set as the on-field common denominator of the criteria for all the participants to return RTT. Each player's best performance out of three trials was recorded to mark the successful completion of the test.[17] Score for male athletes categorised as excellent <15.2 s, good 15.2–16.1 s, average 16.2–18.1 s, fair 18.2–18.3 s and poor >18.3 s.[18]

General rehabilitation protocol

During the rehabilitation period, which started from the day after the injury was sustained and ended the day that the player RTT, all the participants followed the same physiotherapy treatment, manual therapy, based on Maitland's philosophy.[19] During injury recovery, the StARRT framework of Ardern *et al*[8] for the RTS progress considering all the injuries for both groups. All players in both groups underwent the same exercise rehabilitation programme, which included gym exercises customised to their injuries, until the first day of OFR. On starting OFR, the experimental group adhered to the On FI.RE. framework, while the control group followed the Traditional OFR framework. Each group was subjected to specific criteria based on their respective injuries. Online supplemental tables 2–4 outline the off-field rehabilitation protocols and criteria for each injury. Players were deemed to have fully recovered when they returned to performance (RTP), that is, the player has gradually returned to their defined sport and is performing at or above their preinjury level.[3] On RTT, players followed a secondary injury prevention protocol for 2 months according to their injuries (online supplemental table 2). Medical and performance staff teams monitor the secondary prevention protocols and have been trained in implementing the protocols by the research team.

Table 1 An overview of the five stages of the On Fi.RE. Framework*

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Goals	Introduction	Adaptation	Football-specific skills restoration	Cognition	Football situations
	► Introduction to fieldwork ► Overall loads ► Endurance: approach to tissue elasticity ► Develop fundamental skills ► Encourage player confidence	► Player adaptation to on-field work ► Overall-targeted loads ► Endurance: – Moderate injuries: Approach to fatigue – Severe injuries: Muscular hypertrophy ► Evolve fundamental skills	► Targeted-specific loads ► Endurance: maximise muscle power ► Develop football-specific skills (technical/coordination) ► Develop perceptual-motor skills ability	► Specific loads ► Endurance: explosive strength to maximum effectiveness ► Maximise cognitive development ability	► Competition-oriented loads ► Endurance: explosive strength to fatigue ► Realistic football simulation situations

*The sessions of each stage are adapted based on the injury specific; At least 1–2 sessions are completed in stage, depending on the injury.
†For moderate (7–28 days) and severe (≥ 28 days) injuries; modified according to the injury; periodisation; abilities build up on a continuum; player and football-specific factors taken into account.
On FI.RE., On-Field Rehabilitation.

During the 2 months of secondary prevention, communication with the team's staff continues via telephone, email or visits.

After 2 months, players continued injury prevention programmes in primary prevention strategies with the team. The prevention programmes were designed by the staff of the teams, following the guidelines provided by the authors' teams. An independent study worker documented subsequent injuries among the players in both groups over a 12-month follow-up period (that starts the day that the player returns to participate in team training and ends after 12 months) via telephone and email.

Specific rehabilitation protocol

For both groups, the OFR framework was initiated from the first day of OFR (online supplemental figure 1). The application of the frameworks took place on football fields. The timeline of the OFR programmes is described in online supplemental figure 2. For both groups, OFR was implemented daily, once per day, except for 1 day off during the week. On FI.RE. framework, a five-stage football functional rehabilitation framework,[20–43] engages in therapeutic exercises that interact with football skills. This framework addresses aspects including function and power restoration, cardiorespiratory endurance, cognitive ability and neuromuscular skills specifically related to football scenarios (tables 1 and 2). Furthermore, table 3 outlines the daily On FI.RE. framework[44] with five components and provides descriptions for each, including warm-up,[45] main topic[46] and recovery.[47] Conversely, players following the traditional OFR framework initiated OFR after restoring function and power off-field. The traditional OFR framework, a five-stage framework,[8–13] focuses on the use of global positioning systems (GPS) as a valid instrument for measuring external loads.[48] This framework incorporates aspects such as movement quality, physical conditioning, football-specific skills and the gradual development of chronic load (table 4).

Both groups adhered to the same specific entry criteria for initiating OFR and progressing through different stages. These criteria were based on three factors: (a) pain, which was assessed using the Numerical Pain Rating Scale with excellent test–retest reliability (0.95, 95% CI 0.93 to 0.96) and validity (r=0.94, 95% CI 0.93 to 0.95),[49] (b) range of motion (ROM), evaluated using a standard goniometer, a valid instrument with good to excellent reliability[50] and (c) Oedema, assessed using diagnostic ultrasound imaging, known for its accuracy in MSK pathologies.[51] In the On FI.RE. framework group, OFR commenced when the pain was equal to or less than 5/10, ROM was equal to or higher than 80%, and there was either no oedema or a decrease in oedema compared with the initial time of injury. In stage 2, the pain had to be less than 5/10, players had to have full ROM, and there should be no or decreased oedema compared with the initial injury time. Finally, in stages 3–5, the pain had to be equal to or less than 2/10, players needed to have full ROM, and there should be no oedema. In the traditional OFR framework, players initiated OFR when the pain was less than or equal to 2/10, full ROM was achieved, and no oedema was present. The same criteria were followed in stages 2–5. Specific entry criteria for both groups are found in figure 1.

Furthermore, satisfactory progression between stages was considered for each stage, ensuring that the player completed each stage without any adverse events (tables 2 and 4). Both groups had to meet specific criteria for participants to be cleared for RTT. These criteria included: (a) clinical evaluation conducted by the sports physician (AK) following established protocols,[52–56] (b) injury-specific criteria outlined in online supplemental

Table 2 (A and B) On FI.RE. framework—description of the type of activities*

Content		Description
(A)		
Stage 1		
Cardiorespiratory endurance		► Increase in the oxidative capacity of type I muscle fibres Low-intensity aerobic exercises 50–60% of HRmax—eg, linear running 2 sets of 10 min, progressive increase duration
Overall loads		► Introduce kinematics football skills ► Development of low-intensity actions, 50–60% of HRmax ► Low volume exercises: 3 sets of 12–14 reps
Endurance: Approach to tissue elasticity		► Therapeutic exercises with mechanical stimuli ► Tissue recovery morphology ► Actions strictly elastic eg, lengthening adductors and hamstrings exercise 3 sets of 12–14 reps, work: rest ratio 1:2 or 1:3 (online supplemental video 1)
Linear movements		Forward and lateral movements eg, linear running and sidestepping running in square of 10×10 m x 10 reps
Neuromuscular control exercises		Control–prevention exercises eg, balance on Bosu, with passing and headers 4 sets of 20 s
Fundamental skills exercises		Range of movement—motor skills exercises eg, mobility drills such as hurdles, squatting with headers, lunging, 3 sets of 12 reps (online supplemental video 2)
Stage 2		
Cardiorespiratory endurance		► Maintain and improve cardiorespiratory capacity ► Special coordinated circuits Increased intensity/interval aerobic exercises, 60–70% of HRmax eg$_{,1}$ linear running 1 min joking –1 min running x 10 rep (progressive 1 min joking:2 min running and so on) eg$_{,2}$ Circuit of 30 m linear running/20 m sidestepping/20 m backward /30 m linear running x 8 min (online supplemental video 3)
Overall-targeted loads		► kinematic and dynamic requirements of football skills ► Moderate intensity exercises 60–70% of HRmax ► Moderate to high-volume exercises
Endurance	Moderate injuries: Approach to fatigue	► Gain strength ► Resistance to muscular fatigue, 4–5 sets x 10 reps work: rest ratio 1:1 (online supplemental video 4)
	Severe injuries: Muscular hypertrophy	Gaining muscle mass and strength 4–5 sets x 10–12 reps rest<1 min
Multidirectional movement		Introduce change-of-direction exercises Curved, figure–eight, turn, spin and cutting drills, e.g. butterfly COD exercise rectangle box 10 x 5 m, with or without ball x 10 reps (online supplemental video 5)
Fundamental skills exercises		Jump actions, e.g. W exercise (online supplemental video 6)
Physical variables		► Develop a total distance running about 10 000 m per session ► Acceleration/deceleration and sprint patterns at low speed < 19 km/h e.g. linear: running 10 m/acceleration pattern 5 m/sprint pattern 10 m/deceleration pattern 5 m/running 10 m x 10 reps
Stage 3		
Guided cardiorespiratory endurance		► Metabolism exercises/specific repetitions ► High-intensity aerobic (70–85% of HRmax), for example, linear running 4 min x 3–4 sets with rest 1–2 min ► Anaerobic exercises (85–95% of HRmax) with no or low competition conditions (rest depends on HR recovery. Player starts next set or exercise when HR is 70% of HRmax) eg$_1$, box-box running work: rest ratio 15 s:15 s for 4 min eg$_2$, (online supplemental video 7) work: rest ratio 1:2×4 min
Targeted-specific loads		► Maximum kinematic approach to a sporting gesture ► High-intensity actions>85% HRmax ► Moderate volume 4–5 sets x 6–8 reps

Continued

Table 2 Continued

Content	Description
Maximise muscle power	► Increase the ability to produce strength in interaction with football skills eg, strengthening with band and football skills (online supplemental video 8) 4–5 sets x 4–6 reps work: rest ratio 1:1,5
Neuromuscular coordination exercises	► Maximise the efficiency of neuromuscular control and coordination eg, ladder exercises with/without a ball using strobe glasses (online supplemental video 9)
Football-specific skills exercises	► Maintaining ball possession, short and long passes, crossing and shooting (online supplemental video 10)
Perceptual-motor skills exercises	► Reactive movements exercises, speed agility quickness ► Agility exercises, for example, agility T exercise (online supplemental video 11)
Physical variables	► High-speed running exposure (70–75% of maximum speed, (>19 km/h and < 25 km/h) ► linear control acceleration/deacceleration>2.5 m/s^2 ► Introduce sprint running at 80% of maximum speed online supplemental video 12
(B)	
Stage 4	
Competition cardiorespiratory endurance	► High-intensity aerobic (70–85% of HRmax) and anaerobic (85–95% of HRmax) exercises specific to football skills and situations ► Approach team training intensity
Specific loads	► Highest kinematic and dynamic football skills ► Maximum-intensity actions that affect reactivity approach 100% ► Low volume exercises 1 set x 5–6 reps
Explosive strength to maximum effectiveness	Enhance football skills by simulating real competition exercises, 5–6 reps work: rest ratio 1:4
Perceptual soccer-specific skills exercises	Reactive football skills exercises
Maximise cognitive development ability	Decision-making exercises/information analysis/problem-solving
Physical variables	► Targeted high-speed running/sprint running (>80% maximum speed) ► Multidirectional acceleration and deceleration>3 m/s^2 online supplemental video 13
eg, stage 4 online supplemental video 14	
Stage 5	
Competition cardiorespiratory endurance	► High variability of cardiorespiratory effort exercises simulated in realistic football situations ► Approach maximum intensity (95–100% HRmax) ► Mimic training intensity
Competition loads	► Highest kinematic and dynamic football skills ► Maximum intensity actions, approach 100% ► Moderate volume exercises 1 set x 8–10 reps, work: rest ratio 1:3
Explosive strength to fatigue	► Increase the volume of explosive exercises ► Resistance to fatigue in repeated maximum-intensity exercises
Competition scenario exercises	► Position agility exercises /football simulation exercises /contact exercises
Physical variables	► Develop chronic loading ► Load ≥80% of the game load
Eg, Stage 5 online supplemental video 15	

Game load, physical demands of the game and specific GPS metrics (total distance, high speed running, explosive distance, sprint distance).
*Implementation of strengthening occurred with load that used body weight, and bands.
COD, change of direction.; HR, heart rate; HRmax, maximum heart rate; m, metres; On FI.RE., On-Field Rehabilitation; rep, repetition.

tables 3 and 4, (c) IAGT as on-field agility test and (d) game load, which refers to the physical demands of the game and specific GPS metrics. For the experimental group, physical variables and GPS metrics had to reach or exceed 80% of the game load, while the control group had to reach or exceed 70% of the game load. These criteria were used to determine whether a player was ready for RTT after completing the full rehabilitation programme.

Table 3 On Fi.RE. framework daily session programming*†

Content	Description	Duration†
Introduction to the session	► General warm-up, eg, jogging 50%–60% of HRmax, dynamic-ballistic stretching ► Specific warm-up (preparation for the main topic), eg, skipping in hurdles, easy alternate bounding ► Carrying to the main topic, eg, active rest	20–30′
Main topic	► Transmission and implementation of basic rehabilitation elements, eg, maximise muscle power, competitive cardiorespiratory endurance	20–30′
Revaluation	► Rerun on the latest element (Repetition of elements that were implemented in previous sessions)	15′
Edutainment	► Improve general deficits, eg, ROM, muscle weakness, coordination deficit, technical deficits ► General and specific to injury prevention ► Funny football games, eg, cognitive football games	15–30′
Cool down	► Active recovery, eg, low-intensity Jogging<50% of the player's HRmax, playing with the ball	10′–20′

*Modify to injury-specific, individualisation.
†The recommended total duration of a session is 80 min–100 min.
On FI.RE., On-Field Rehabilitation; ROM, range of motion.

In addition, all the participants were requested to complete a psychology questionnaire to assess their psychological readiness to begin OFR. While there is a lack of a validated questionnaire, a modified version of the Psychological Readiness to Return to Sport scale was used, demonstrating sufficient validity and reliability.[57]

Moreover, all participants from both groups had to complete a psychometric questionnaire called Self-perception of Health[58] each morning on awakening. This questionnaire assessed their general wellness based on their reflections from the previous day's session. It was recommended that participants complete the questionnaire privately and simultaneously each morning. Furthermore, after every session, participants from both groups responded to the Rating of Perceived Exertion scale questionnaire, a reliable and valid tool for measuring session intensity.[59]

Outcomes

The primary outcomes were the effect of the rehabilitation programme, the type of injury, the severity of the injury as well as the interactions between them regarding the time a player needed to return to participation in team training (RTT), that is, the player be participating in team training (modified or unrestricted) but at a level lower than their RTS goal.[3] Time to return, namely lost days, is defined as the period of absence for a player following an injury.[1] The first secondary outcome was the correlation between the return to on-field activity, that is, the first day that the player starts OFR during the rehabilitation period, and the RTT (in other words, starting OFR as soon as possible, affects the number of days that elapse before a player can RTT). This outcome was added after the trial commenced to emphasise the evaluation of an accelerated return to on-field activity. The second secondary outcome is a subsequent injury (of the same or a different type), categorised into multiple, recurrent, exacerbation or new injuries.[60] The period in which a subsequent injury occurred was divided into months, and the second secondary outcome documented 'early occurrence' and 'late occurrence' within 12 months after a player's return to performance.[16]

Statistical analysis

Statistical analysis was performed using the statistical software SPSS V.25. The 'normal Q-Q plot' graphs confirmed that all the data were normally distributed; therefore, parametric tests were used. The Pearson coefficient was used to correlate two continuous variables. Three-way analysis of variance (ANOVA) was performed to find the effect of independent variables on dependent variables. The dependent variable was the RTT/return to on-field activity, while the independent variables were group, type of injury and severity of injury. In addition to investigating the main factor effects, the analysis also focused on the interaction effects between factors. ESs (η^2)[61] were calculated from the ANOVA results, as the ratio between the effect's sum of squares and the total sum of squares (<0.01: small ES, 0.01–0.14: medium ES, ≥0.14: large ES). The significance level was set at 97.5% ($p<0.025$).

A statistical power calculation was conducted using G-Power software. Regarding the three-way ANOVA test and based on the data: (a) power=80%, (b) α-error=0.01, (c) ES=0.4, (d) numerator df=1 and (e) number of groups=8, it was calculated that the sample had to consist of at least 76 players (38 in each group).

RESULTS

Between July 2021 and January 2022, 92 players with an acute low-limb MSK injury who were potentially eligible for the study were recruited. All participants completed rehabilitation and returned to the team training fully

Table 4 An overview of the five stages of the traditional OFR framework*

	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Goals	Return to running	Multidirectional movements	Football technical training	Football specific training	Training reconditioning
Sessions	2–5	2–5	3–5	3–6	3–6
Description	► Linear running (forward/lateral) ► Mobility drills (predictable volleys/passes) ► Simple technical drills ► Aerobic endurance eg, 3–4 x 3 min, 3–4 x 4 min, PR 1–2 min	► Multidirectional pre-planned movements (eg, change of direction, cutting) ► Easy football technical drills (volleys/passes, maintain balance) ► Linear acceleration/ deceleration ► Interval aerobic endurance ► High-speed running ► Running speeds eg, 3–5 x 3–4 min, PR 1–2 min	► Football technical programme (pre-planned closed tasks, for example, short, long passes/shooting) ► Reactive movements (eg, agility exercises) ► Aerobic/anaerobic endurance ► HSR ► Exposure to sprint running eg, Intensive 4–6 x 1–2 min, PR 1–2 min Extensive 4–6×5 min PR 2–3 min	► Football skills programme ► Reactive movements with perturbations ► Aerobic and anaerobic endurance during agility and sports-specific situations eg, Intensive 20–45 s /1–3 min, PR 1–2 min Extensive 4–8 min, PR 2–3 min	► Football-specific movement training with and without fatigue (eg, football training in realistic situations) ► Aerobic and anaerobic endurance during football-specific activities eg, Intensive 20–45 s /1–3 min, PR 1–2 min Extensive 4–8 min, PR 2–3 min
Loads	► 0.35 of game load†‡ ► Running speed: <60% maximum speed ► HR 70–85% of HRmax for≤10 min	► 0.35–0.45 of game load†‡ ► Running speed:60–70% of maximum speed ► VO_2>85% of VO_{2max} ► HR 70–85% of HRmax for 10–20 min ► HR >85% of HRmax for 0–5 min	► 0.40–0.60 of game load†‡ ► Running speed:65–80% of maximum speed ► VO_2 >85% of VO2max ► HR 70–85% of HRmax for 30 min ► HR >85% of HRmax,15 min	► 0.55–0.70 of game load†‡ ► Running speed: >75% of maximum speed ► VO_2 >85% of VO2 max ► HR 70–85% of HRmax for 20–30 min ► HR >85% of HRmax, 15–20 min	► >0.70 of game load†‡ ► Running speed: >90% of maximum speed ► VO_2 >85% of VO_{2max} ► HR 70–85% of HRmax for 20–30 min ► HR >85% of HRmax for 20+min

*For moderate t(≥7 days) and severe (≥ 28 days) injuries; modified according to the injury; periodisation; implemented intensity, volume, velocity and difficulty progressively increased; abilities build up on a continuum; player and football-specific factors taken into account.
†Game load, physical demands of game and specific GPS metrics (total distance, high speed running, explosive distance, sprint distance).
‡Game load adjustable dependent on injury type/severity.
HR, heart rate; HRmax, maximum heart rate; HSR, high speed running; OFR, on-field rehabilitation; Pe, passive recovery; VO_2, oxygen consumption; VO_{2max}, maximum oxygen consumption.

recovered. After their RTT, the players participated in an 8-week secondary injury prevention programme. They were also monitored for a 12-month follow-up period to ensure that subsequent injuries were recorded.

A total of 84 players (professional level of the players was respectively 41 players from Super League, 32 players from Super League 1 and 11 players from Super League 2) who met the eligibility criteria were randomly assigned to the experimental (n=42) and comparison (n=42) groups. Five players (three in the experimental group and two in the comparison group) withdrew from participating in the study either before it began or while it was underway because of a lack of time. Furthermore, one player from the experimental group and two from the comparison group missed the 8-week follow-up period because they were transferred to a foreign club. In contrast, another player from the comparison group missed it because he refused to participate in a secondary injury prevention programme. Thus, 76 players, equally distributed in the two groups, completed the study, and their data were statistically analysed for primary and secondary outcomes (figure 2).

There were no significant differences between players in the experimental and the comparison groups for age (p=0.765), height (p=0.645), body mass index (p=0.295) and football experience (p=0.661). Also, there was no significant association between group and league level (p=0.344) (table 5).

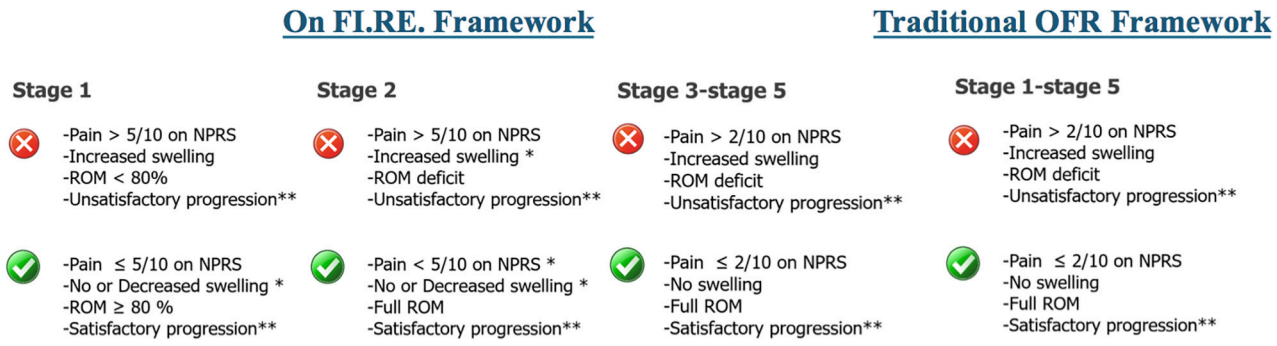

Figure 1 Specific entry and progression criteria for both groups about OFR. On FI.RE. On-Field Rehabilitation; OFR, on-field rehabilitation; NPRS, Numeric Pain Rating Scale; ROM, range of motion. *Specific to injury and individualisation. **Satisfactory progression between stages.

Illinois agility test

All the participants performed the IAGT before RTT. The experimental group's, excellent, good and average scores were 42.5%, 39% and 18.5%, respectively. For the comparison group, they were 29%, 32% and 39%, respectively. A fair score in the IAGT came in at 2.1% for the experimental group and 4.5% for the comparison group. The participants who achieved a fair score extended the number of days before their RTT and repeated the test until they scored at least an average score.

Outcomes

Primary outcomes

Regarding RTT, there was no significant three-way interaction ($F(1)=3.940$, $p=0.051$, $\eta^2=0.55$). There was also not a significant two-way interaction of «Group» and «Type of Injury» ($F(1) = 0.028$, $p=0.867$, $\eta 2<0.001$), «Group» and «Injury Severity» ($F(1)=0.480$, $p=0.491$, $\eta^2=0.007$) as well as «Type of Injury» and «Injury Severity» ($F(1)=2.015$, $p=0.160$, $\eta^2=0.029$). There was a main effect for «Group» ($F(1)=49.626$, $p<0.001$, $\eta^2=0.422$). Players in the experimental group needed fewer days (mean=23.8 days) than players in the comparison group (mean=30.3 days) to RTT. There was also a main effect for «Severity of Injury» ($F(1)=49.626$, $p<0.001$, $\eta^2=0.422$). Players with moderate injuries recorded fewer days to RTT (mean=19 days) than players with severe injuries (mean=36 days). There was no main effect for «Type of Injury» ($F(1)=0.777$, $p=0.381$, $\eta^2=0.011$) (table 6).

Secondary outcomes

Correlation between return to on-field activity and RTT (figure 3). The study of the «Normal Q-Q plot» charts showed that the normality condition was satisfied for both variables (RTT and Return to on-filed activity). Pearson's coefficient (r) was used for the analysis. Linear bivariate correlation analysis revealed that the variables «Return to Participation in team training» and «Return to On-filed Activity» had a statistically significant positive correlation ($r(76)=0.901$, $p<0.001$). On this basis, the sooner the player started on-filed rehabilitation during the rehabilitation period, the sooner the player returned to team training participation. The ESs of the above result were large ($r>0.5$) (table 6).

After the intervention period, during a follow-up period of 12 months, there was one documented reinjury in the experimental group (adductors-related groin pain). In the comparison group, there were three reinjuries (ankle sprain-lateral ligament, adductors-related groin pain and hamstring muscle tear), two exacerbation injuries (quadriceps muscle tear and lateral meniscus repair) and one new injury related to the index injury (patella tendinopathy after a partial tear of the anterior cruciate ligament).

Additional outcomes

Regarding return to on-filed activity, there was no significant three-way interaction ($F(1)=1.467$, $p=0.230$, $\eta^2=0.021$). There was also not a significant two-way interaction between «Group» and «Type of Injury» ($F(1)=0.115$, $p=0.736$, $\eta^2=0.002$), «Group» and «Injury Severity» ($F(1)=4.340$, $p=0.041$, $\eta^2=0.06$) as well as «Type_of_Injury» and «Injury Severity» ($F(1)=0.528$, $p=0.470$, $\eta^2=0.008$). There was a main effect for «Group» ($F(1)=182.725$, $p<0.001$, $\eta^2=0.729$). Players from the experimental group needed fewer days (mean=8.4 days) than players from the comparison group (mean=15.3 days) to initiate OFR.

Adverse events

No serious adverse events occurred while performing the general and specific protocols for both groups during the trial. Throughout the study period, no patients indicated the use of any cointerventions.

DISCUSSION

This study aimed to evaluate the effectiveness of the evidence-based On FI.RE. framework, an accelerated OFR framework, for RTS in male professional football players. This is the first randomised controlled trial conducted on an OFR framework. The results obtained from daily practice demonstrate that the implementation of the On FI.RE. framework enhances treatment outcomes. Specifically, it reduces the time required for a player to RTT participation by 6.5 days compared with a

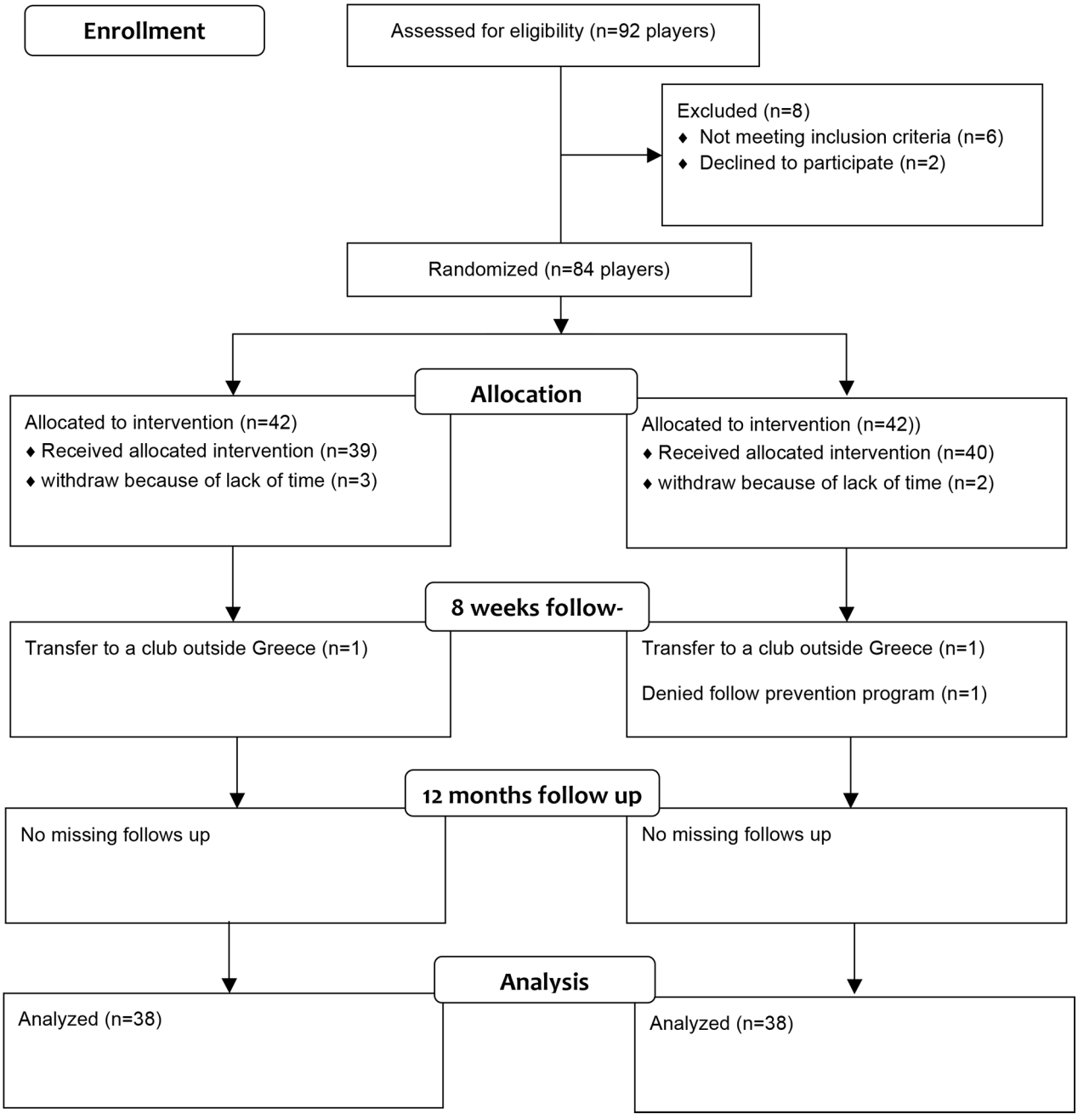

Figure 2 The CONSORT flowchart of the study population. CONSORT, Consolidated Standards of Reporting Trials.

traditional OFR framework, thus implying an earlier RTS and a decreased risk of subsequent injuries. This achievement is attributed to the On FI.RE. framework's ability to facilitate injury healing through on-field therapeutic exercises and expedite the restoration of physiological and mental capabilities.

A faster return to performance increases player availability for matches, which strongly correlates with team success ranking.[62] As mentioned in the 2020 UEFA Injury Elite Club study by Ekstrand *et al*,[63] a team with 25 players is expected to have about 50 injuries per season. The financial loss for an average team per season is approximately £45 million due to injury-related reductions in players' performance.[64] Improving injury prevention strategies and treatment outcomes enhances player availability for professional football teams.[65] This study provides strong statistical support for the ability of the On FI.RE. framework improves treatment outcomes and reduces time lost days caused by player injury, thereby improving players' career prospects and reducing financial losses for clubs.

Following the context of accelerated rehabilitation[15] and ecological theory in sports,[3–7 14] a beneficial finding of the study was that the accelerated start of OFR during injury recovery is critical to reducing time lost days for a professional football player and ensuring their faster incorporation into team play. The accelerated start of OFR during rehabilitation is strong with the time needed before RTT under On FI.RE. framework.

Table 5 Baseline characteristics of players in intervention and control groups

Characteristics	On FI.RE. framework (n=38)*	Traditional OFR framework (n=38)*	Pvalue	Total (n=76)†	
				Count	Column N %
Age, years	26.3±3.6	26.6±4.7	0.765		
Height, cm	182.3±6.7	181.9±5.7	0.645		
Body mass index (kg/m^2)	23.3±0.6	23.1±1.5	0.295		
Football experience, years	9.5±4.1	9.7±4.6	0.661		
Professional level			0.344		
Super League	22	17			
Super League 1	12	18			
Super League 2	4	3			
Leg dominance					
Right				68	89.5%
Left				8	10.5%

Significant difference set at 0.01 (p<0.01).
*Values are presented in mean±SD (number).
†Values are presented in number.
OFR, on-field rehabilitation; On FI.RE., On-Field Rehabilitation.

The type of injury (muscle/tendon and joint(no-bone)/ligament) did not affect the impact of different intervention protocols regarding the time needed before the return to the on-field activity or RTT. However, injury severity affected the previous variables with significant discrimination between moderate and severe injuries in both groups.

The results of the common on-field agility test, IAGT, for all participants indicated that the football players in the On Fi.RE. framework achieved higher scores. These findings suggest that players undergoing the On Fi.RE. framework RTT exhibited better performance to those following the traditional OFR framework approach.

Table 6 Main outcome measures in the intervention and the control groups

	On FI.RE. framework (n=38)	Traditional OFR framework (n=38)	P value	Pearson's correlation coefficient (r)
Primary outcome measures				
Days to return to participation in team training (RTT)*				
Groups	23.8±9.1	30.3±9.8	0.001	
Muscle/tendon	24.5±10.4	31.2±9.8		
Joint(no-bone)/ligament	23.1±7.6	29.2±10		
Moderate injuries	16±3.4	21.9±3		
Severe injuries	32.5±4.1	39.5±5.5		
Secondary outcome measures				
Effects of subgroups on intervention protocol				
Type of injury			0.38	
Injury severity			0.001	
Days return to on-field activity*				
Groups	8.3±3.3	15.2±4.7		
Correlation returns to on-field activity*return to participation in team training				
Groups			0.001	0.901

Significant difference set at 0.01(p<0.01).
*Values are presented as mean±SD (number).
OFR, on-field rehabilitation; On FI.RE., On-Field Rehabilitation.

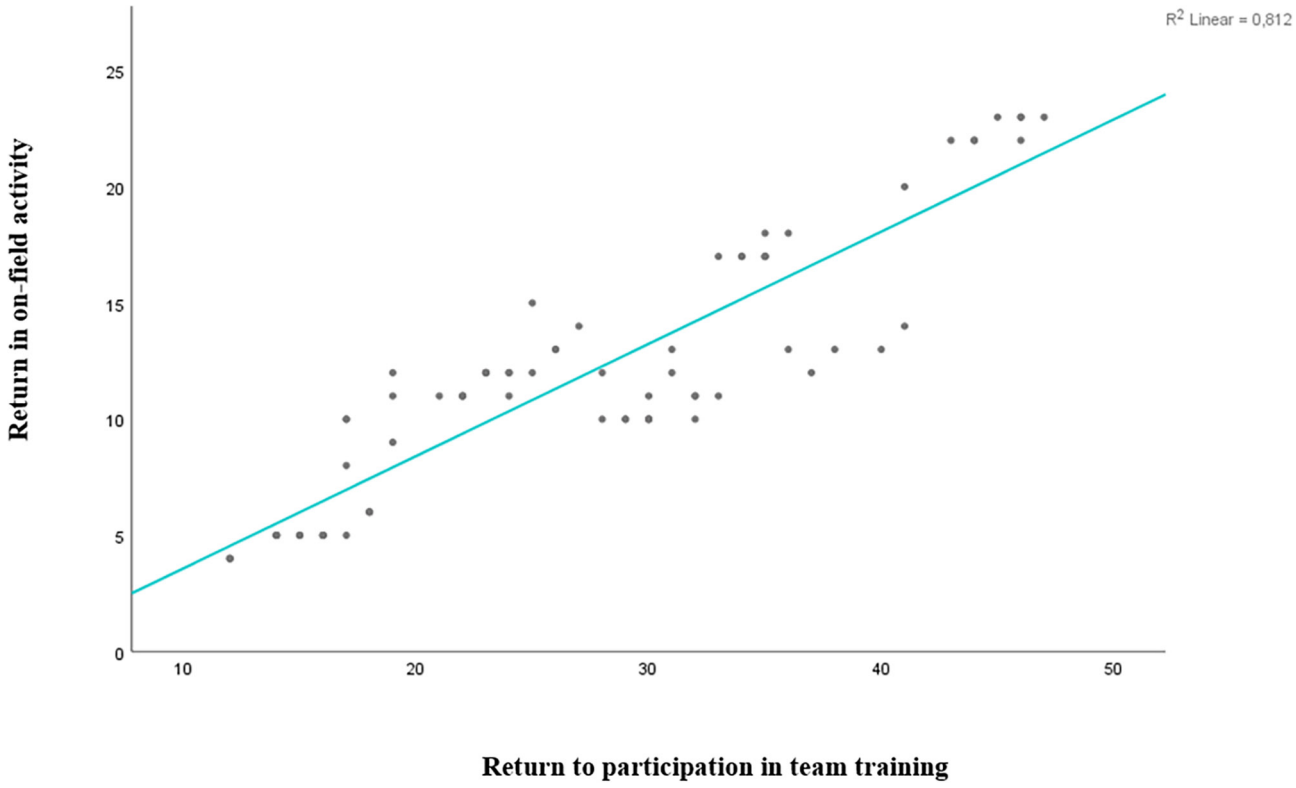

Figure 3 Scatter plot for the correlation between «return to on-field activity» and «return to participation in team training».

Using the On FI.RE. framework ensures that a proper exercise-based rehabilitation protocol improves therapeutic outcomes for avoiding subsequent injuries.[66] At this point, it has been mentioned the importance of a secondary prevention programme in avoiding subsequent injuries.[67] To reduce bias, both groups followed the same prevention protocols for each type of injury (online supplemental table 2) for 8 weeks after returning to participation in team training.

Study strengths

This is the first randomised controlled trial to be conducted for OFR. Another strength is that injury diagnosis and RTT were controlled by a single physician (AK) based on evidence-based clinical examination and additional diagnostic imaging. Clinical examination of the players relied on literature references.[52–56] The physician was not involved in the intervention application and outcome assessment. Moreover, one senior physiotherapist per group applied the off-field and OFR rehabilitation from the first day of rehabilitation until the day that the players returned to participation in team training. Additionally, during the rehabilitation procedure, the same senior physiotherapist supervised the execution of all therapeutic exercises.[68] Moreover, it is important to note that all participants in the study were blinded regarding which of the two intervention protocols they were assigned to follow.

Limitations

The study had methodological limitations that needed to be considered. Due to the extensive workload required for conducting the research, having one physical therapist implement the protocols for both groups were challenging. IS and AfK., long-time collaborators sharing the same philosophy, collaborated intensively to implement the protocols. Moreover, to optimise the study's objectivity without a similar randomised controlled trial for OFR, we supported both OFR frameworks with online supplemental videos 2, 4, 8, 14–18. Also, off-field rehabilitation protocols that were identical for both groups until players returned to on-field activity were designated as reference counterparts for each injury in online supplemental table 2. Analysing the extensive dataset in-depth was difficult due to the study's primary emphasis on offering a comprehensive overview of the OFR frameworks, which exhibited variations between the two intervention groups. The off-filed rehabilitation protocols for both groups were designed to be as similar as possible. For detailed information about the off-filed rehabilitation protocols, please refer to the corresponding citation for each injury in online supplemental table 2.

Furthermore, the research participants were drawn from various categories within the professional Greek league and different-level teams. However, it is important to note that the logistical equipment, facilities and rehabilitation services were uniform and consistent for all participants. There were also no statistically significant

differences regarding the somatometric characteristics of the participants.

Another weakness is that the joint (non-bone) and ligament subgroup was not as large as the muscle tendon subgroup. However, there were no marginal differences in the statistics to trigger an argument in this respect. Additionally, only the major injuries reported by teams and physical therapy clinics were analysed during the recruitment procedure. More types of injuries (fractures and bone stress) and specific injuries to joints and ligaments (dislocation/subluxation, osteochondral cartilage lesions of knee and ankle, etc) must be investigated in the future.

Finally, the two groups of physiotherapists who applied the interventions were not blinded. Regrettably, it is very difficult to achieve blinding for care providers in studies with therapeutic exercise-based protocols. To limit bias, the care providers were blinded for the randomisation procedure.

Clinical implications

The On FI.RE. framework benefits athletes by safely accelerating their functional progress and reintegration into their teams. Clinical practice could be empowered by implementing an accelerated therapeutic exercise-based OFR protocol for most lower limb MSK injuries, regardless of the type and severity of the injury. Treatment outcomes appear to be optimised, days before the RTT are reduced and the risk of subsequent injuries is minimised.

CONCLUSION

Based on the results of this study, three definite conclusions can be stated regarding the rehabilitation of male professional football players with an acute lower limb MSK injury (moderate or severe). The application of the On FI.RE. framework showed better treatment outcomes, namely, a faster RTT and a reduced risk of subsequent injury for 12 months. This is crucial for players' careers and team finances. Future research should focus on randomised controlled trials on specific rehabilitation protocols, criteria for RTS and injury prevention strategies in sports, specifically football, for enhanced treatment outcomes.

Author affiliations
[1]Physiotherapy Department, School of Health Rehabilitation Sciences, University of Patras, Patra, Greece
[2]Head of Physiotherapy and rehabilitation department, OFI Crete FC, Herakleion, Crete, Greece
[3]Deputy Director of B' Orthopedic Department, Henry Dunant Hospital Center, Athens, Greece
[4]Laboratory of Neuromechanics, School of Physical Education and Sport Science at Serres, Aristotle University of Thessaloniki, Thessaloniki, Greece
[5]Diagnostic Radiologist, Iatropolis, Athens, Greece
[6]Physiotherapy Dept School of Health Rehabilitation Sciences, University of Patras, Patra, Greece
[7]Physiotherapy Department Therapeutic exercise and Sports Rehabilitation exercise laboratory, University of Patras, Patra, Greece

Twitter Ioannis Stathas @Stathasloannis, Alkiviadis Kalliakmanis @AlkisKalliakma1 and Afxentios Kekelekis @afxentios

Acknowledgements The authors thank the Department of Physiotherapy, School of Health Rehabilitation Sciences of the University of Patras, as the sponsoring institute of the study and the teams and physical therapy clinics for assisting with the subjects' recruitment. We also thank Fotis Mitrakas for contributing to office work during the study.

Contributors KF and ET are the study guarantors. IS, AK, AfK and DDA participated in the design and conception of the study. IS and AfK were responsible for data collection. IS was the main investigator and responsible for analyses and writing of the manuscript, while the remaining co-authors revised the manuscript for important intellectual content. AK was responsible for the clinical eligibility assessment in this trial and final randomisation with treatment allocation. DDA was the responsible diagnostic radiologist. IS and AfK were responsible for the therapeutic exercise therapy performed in the trial.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Consent obtained directly from patient(s)

Ethics approval The University of Patras ethics committee approved the trial (file number 12193). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; externally peer-reviewed.

Data availability statement No data are available. The subjects are professional football players and their data aren't permitted to be shared.

ORCID iD
Ioannis Stathas http://orcid.org/0000-0002-9222-0910

REFERENCES

1 Ekstrand J, Krutsch W, Spreco A, *et al*. Time before return to play for the most common injuries in professional football: a 16-year follow-up of the UEFA elite club injury study. *Br J Sports Med* 2020;54:421–6.
2 Pruna R, Valle X, Iqbal Z, *et al*. Sport specific rehabilitation: the Barcelona football club vision. *Muscle Ligaments and Tendons J* 2018;08:308.
3 Ardern CL, Glasgow P, Schneiders A, *et al*. Consensus statement on return to sport from the first World Congress in sports physical therapy, Bern. *Br J Sports Med* 2016;50:853–64.
4 Bergmann F, Gray R, Wachsmuth S, *et al*. Perceptual-motor and perceptual-cognitive skill acquisition in soccer: a systematic review on the influence of practice design and coaching behavior. *Front Psychol* 2021;12:772201.
5 Araujo D, Davis K. Ecological approaches to cognition and action in sports and exercise: ask not only what to do, but where to do it. *Int J Sport Psychol* 2009;40:1–4.
6 Ashford M, Abraham A, Poolton J. Understanding a player's decision-making process in team sports: a systematic review of empirical evidence. *Sports (Basel)* 2021;9:65.
7 Woods CT, McKeown I, O'Sullivan M, *et al*. Theory to practice: performance preparation models in contemporary high-level sport

guided by an ecological dynamics framework. *Sports Med Open* 2020;6:36.
8 Buckthorpe M, Frizziero A, Roi GS. Update on functional recovery process for the injured athlete: return to sport continuum redefined. *Br J Sports Med* 2019;53:265–7.
9 Taberner M, Allen T, Cohen DD. Progressing rehabilitation after injury: consider the 'control-chaos continuum'. *Br J Sports Med* 2019;53:1132–6.
10 Buckthorpe M, Della Villa F, Della Villa S, *et al*. On-field rehabilitation Part 1: 4 pillars of high-quality on-field rehabilitation are restoring movement quality, physical conditioning, restoring sport-specific skills, and progressively developing chronic training load. *J Orthop Sports Phys Ther* 2019;49:565–9.
11 Buckthorpe M, Della Villa F, Della Villa S, *et al*. On-field rehabilitation Part 2: a 5-stage program for the soccer player focused on linear movements, multidirectional movements, soccer-specific skills, soccer-specific movements, and modified practice. *J Orthop Sports Phys Ther* 2019;49:570–5.
12 Bizzini M, Hancock D, Impellizzeri F. Suggestions from the field for return to sports participation following anterior cruciate ligament reconstruction: soccer. *J Orthop Sports Phys Ther* 2012;42:304–12.
13 Della Villa S, Boldrini L, Ricci M, *et al*. Clinical outcomes and return-to-sports participation of 50 soccer players after anterior cruciate ligament reconstruction through a sport-specific rehabilitation protocol. *Sports Health* 2012;4:17–24.
14 Renshaw I, Davids K, Araújo D, *et al*. Evaluating weaknesses of "perceptual-cognitive training" and "brain training" methods in sport: an ecological dynamics critique. *Front Psychol* 2018;9:2468.
15 Bleakley CM, O'Connor SR, Tully MA, *et al*. Effect of accelerated rehabilitation on function after ankle sprain: randomised controlled trial. *BMJ* 2010;340.
16 Fuller CW, Ekstrand J, Junge A, *et al*. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Clin J Sport Med* 2006;16:97–106.
17 Hachana Y, Chaabène H, Nabli MA, *et al*. Test-retest reliability, criterion-related validity, and minimal detectable change of the Illinois agility test in male team sport athletes. *J Strength Cond Res* 2013;27:2752–9.
18 Roozen M. Illinois agility test. *NSCA's Performance Training Journal* 2004;3:5–6.
19 MPT., PhD, Professor, College of Physiotherapy, Vinayaka Mission's Research Foundation (VMRF), Salem-636 308, Tamilnadu, India, Prabhakaradoss D, Sreejesh MS, *et al*. Effect of manual therapy and conventional physiotherapy on pain, movement, and function following acute and sub-acute lateral ankle sprain: a randomized clinical trial. *Int J Sport Exerc Health Res* 2021;5:76–82.
20 Cobble N, Burks JS. Introduction to principles of rehabilitation. *Neurorehabilitation Neural Repair* 1990;4:181–5.
21 Barnitt R, Pomeroy V. A holistic approach to rehabilitation. *Br J Ther Rehabil* 1995;2:87–92.
22 Baar K. Training for endurance and strength: lessons from cell signaling. *Med Sci Sports Exerc* 2006;38:1939–44.
23 Hostrup M, Bangsbo J. Performance adaptations to intensified training in top-level football. *Sports Med* 2023;53:577–94.
24 Eler N, Eler S. The effect of agility exercise on the COD speed and speed in terms of the frequency of the training. *Ujer* 2018;6:1909–15.
25 Konin JG, Bernier MR. Perturbation and agility training in the rehabilitation of soccer athletes. *Athl Ther Today* 2013;8:20–2.
26 Los Arcos A, Mendez-Villanueva A, Martínez-Santos R. In-season training periodization of professional soccer players. *Biol Sport* 2017;34:149–55.
27 Charron J, Garcia JEV, Roy P, *et al*. Physiological responses to repeated running sprint ability tests: a systematic review. *Int J Exerc Sci* 2020;13:1190–205.
28 Marimuthu K, Murton AJ, Greenhaff PL. Mechanisms regulating muscle mass during disuse atrophy and rehabilitation in humans. *J Appl Physiol (1985)* 2011;110:555–60.
29 Pérez-Gómez J, Adsuar JC, Alcaraz PE, *et al*. Physical exercises for preventing injuries among adult male football players: a systematic review. *J Sport Health Sci* 2022;11:115–22.
30 Griffiths B, Grant J, Langdown L, *et al*. The effect of in-season traditional and explosive resistance training programs on strength, jump height, and speed in recreational soccer players. *Res Q Exerc Sport* 2019;90:95–102.
31 Manolopoulos E, Katis A, Manolopoulos K, *et al*. Effects of a 10-week resistance exercise program on soccer kick biomechanics and muscle strength. *J Strength Cond Res* 2013;27:3391–401.
32 Sañudo B, Sánchez-Hernández J, Bernardo-Filho M, *et al*. Integrative neuromuscular training in young athletes, injury prevention, and performance optimization: a systematic review. *Applied Sciences* 2019;9:3839.
33 Bulow A, Anderson JE, Leiter JRS, *et al*. Safety and effectiveness of a perturbation-based neuromuscular training program on dynamic balance in adolescent females: a randomized controlled trial. *Int J Sports Phys Ther* 2021;16:1001–15.
34 Sabarit A, Reigal RE, Morillo-Baro JP, *et al*. Cognitive functioning, physical fitness, and game performance in a sample of adolescent soccer players. *Sustainability* 2020;12:5245.
35 Czyż SH. Variability of practice, information processing, and decision making—how much do we know. *Front Psychol* 2021;12:639131.
36 Scharfen H-E, Memmert D. The relationship between cognitive functions and sport-specific motor skills in elite youth soccer players. *Front Psychol* 2019;10:817.
37 Pruna R, Bahdur K, MHO FCBarcelona. FIFA Excellence Center. Barcelona Spain. Cognitive skills of elite football players are essential for developing high efficiency and reduce recovery time after an injury. *Int J Orthop* 2016;3:503–4.
38 Malone S, Owen A, Newton M, *et al*. The acute: chonic workload ratio in relation to injury risk in professional soccer. *J Sci Med Sport* 2017;20:561–5.
39 Helgerud J, Engen LC, Wisloff U, *et al*. Aerobic endurance training improves soccer performance. *Med Sci Sports Exerc* 2001;33:1925–31.
40 Manuel Clemente F, Ramirez-Campillo R, Nakamura FY, *et al*. Effects of high-intensity interval training in men soccer player's physical fitness: a systematic review with meta-analysis of randomized-controlled and non-controlled trials. *J Sports Sci* 2021;39:1202–22.
41 Sporis G, Ruzic L, Leko G. The anaerobic endurance of elite soccer players improved after a high-intensity training intervention in the 8-week conditioning program. *J Strength Cond Res* 2008;22:559–66.
42 Buchheit M. Managing high-speed running load in professional soccer players: the benefit of high-intensity interval training supplementation. *SPSR* 2019;53.
43 Harper DJ, Carling C, Kiely J. High-intensity acceleration and deceleration demands in elite team sports competitive match play: a systematic review and meta-analysis of observational studies. *Sports Med* 2019;49:1923–47.
44 Coffey VG, Hawley JA. The molecular bases of training adaptation. *Sports Med* 2007;37:737–63.
45 Gray SC, Devito G, Nimmo MA. Effect of active warm-up on metabolism prior to and during intense dynamic exercise. *Med Sci Sports Exerc* 2002;34:2091–6.
46 O'Connor D, Larkin P, Williams AM. Observations of youth football training: how do coaches structure training sessions for player development. *J Sports Sci* 2018;36:39–47.
47 Marqués-Jiménez D, Calleja-González J, Arratibel I, *et al*. Fatigue and recovery in soccer: evidence and challenges. *TOSSJ* 2017;10:52–70.
48 Cummins C, Orr R, O'Connor H, *et al*. Global positioning systems (GPS) and microtechnology sensors in team sports: a systematic review. *Sports Med* 2013;43:1025–42.
49 Ferreira-Valente MA, Pais-Ribeiro JL, Jensen MP. Validity of four pain intensity rating scales. *Pain* 2011;152:2399–404.
50 Gogia PP, Braatz JH, Rose SJ, *et al*. Reliability and validity of goniometric measurements at the knee. *Phys Ther* 1987;67:192–5.
51 Henderson REA, Walker BF, Young KJ. The accuracy of diagnostic ultrasound imaging for musculoskeletal soft tissue pathology of the extremities: a comprehensive review of the literature. *Chiropr Man Therap* 2015;23:31.
52 Mueller-Wohlfahrt H-W, Haensel L, Mithoefer K, *et al*. Terminology and classification of muscle injuries in sport: the Munich consensus statement. *Br J Sports Med* 2013;47:342–50.
53 Delahunt E, Bleakley CM, Bossard DS, *et al*. Clinical assessment of acute lateral ankle sprain injuries (ROAST): 2019 consensus statement and recommendations of the International ankle consortium. *Br J Sports Med* 2018;52:1304–10.
54 Arner JW, Li R, Disantis A, *et al*. Evaluation and treatment of groin pain syndromes in athletes. *Ann Joint* 2020;5:17.
55 Sternbach GL. Evaluation of the knee. *J Emerg Med* 1986;4:133–43.
56 Spanish Group for Tendon Consensus, Fernandez-Jaén T, Rey GÁ, *et al*. Spanish consensus statement: clinical management and treatment of tendinopathies in sport. *Orthop J Sports Med* 2017;5:2325967117734127.
57 Slagers AJ, Reininga IHF, Geertzen JHB, *et al*. Translation, cross-cultural adaptation, validity, reliability and stability of the Dutch injury - psychological readiness to return to sport (I-PRRS-NL) scale. *J Sports Sci* 2019;37:1038–45.
58 McGahan J, Lacey S, Burns C, *et al*. Variation in training load and markers of wellness across a season in an elite. *Gaelic Football Team Journal of Australian Strength & Conditioning* 2019;27:6–15.

59 Herman L, Foster C, Maher M, *et al*. Validity and reliability of the session RPE method for monitoring exercise training intensity. *S Afr j Sports Med* 2006;18:14.
60 Finch CF, Cook J. Categorizing sports injuries in epidemiological studies: the subsequent injury categorization (SIC) model to address multiple, recurrent and exacerbation of injuries. *Br J Sports Med* 2014;48:1276–80.
61 Lakens D. Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for T-tests and Anovas. *Front Psychol* 2013;4:863.
62 Hägglund M, Waldén M, Magnusson H, *et al*. Injuries affect team performance negatively in professional football: an 11-year follow-up of the UEFA champions league injury study. *Br J Sports Med* 2013;47:738–42.
63 Ekstrand J, Hägglund M, Waldén M. Injury incidence and injury patterns in professional football: the UEFA injury study. *Br J Sports Med* 2011;45:553–8.
64 Eliakim E, Morgulev E, Lidor R, *et al*. Estimation of injury costs: financial damage of English Premier League teams' underachievement due to injuries. *BMJ Open Sport Exerc Med* 2020;6:e000675.
65 Mosler AB, Weir A, Eirale C, *et al*. Epidemiology of time loss groin injuries in a men's professional football league: a 2-year prospective study of 17 clubs and 606 players. *Br J Sports Med* 2018;52:292–7.
66 Bleakley CM, Taylor JB, Dischiavi SL, *et al*. Rehabilitation exercises reduce reinjury post ankle sprain, but the content and parameters of an optimal exercise program have yet to be established: a systematic review and meta-analysis. *Arch Phys Med Rehabil* 2019;100:1367–75.
67 Ekstrand J, Spreco A, Bengtsson H, *et al*. Injury rates decreased in men's professional football: an 18-year prospective cohort study of almost 12 000 injuries sustained during 1.8 million hours of play. *Br J Sports Med* 2021;55:1084–92.
68 Hägglund M, Waldén M, Ekstrand J. Lower reinjury rate with a coach-controlled rehabilitation program in amateur male soccer: a randomized controlled trial. *Am J Sports Med* 2007;35:1433–42.