

Influence of Exercise on the Rehabilitation of Vitamin D Deficiency among Athletes: A Study Protocol

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Abstract: Background: Vitamin D deficiency is a common nutritional concern among athletes and has been associated with impaired musculoskeletal health, reduced physical performance, delayed recovery, and an increased risk of sports-related injuries. Although vitamin D supplementation is widely recommended for correcting deficiency, the role of structured exercise-based rehabilitation in improving vitamin D status remains inadequately explored. A comprehensive rehabilitation approach integrating exercise with vitamin D supplementation may enhance recovery and optimize athletic performance. Objective: To describe the protocol for evaluating the influence of exercise-based rehabilitation on vitamin D deficiency among athletes and to investigate the effectiveness of a structured High Intensity Vigorous Exercise (HIVE) protocol in comparison with conventional sports-specific exercise training. Methods: This study protocol comprises three sequential phases. Phase I involves a cross-sectional assessment to determine the prevalence of vitamin D deficiency and identify eligible athletes. Phase II employs a single-blinded quasi-experimental design in which athletes diagnosed with vitamin D deficiency will receive either the HIVE protocol or conventional sports-specific exercise training, in addition to vitamin D supplementation. Phase III consists of a six-month follow-up to assess the sustainability of intervention outcomes. Primary outcome measures include changes in serum vitamin D levels, while secondary outcomes include physical performance, quality of life, and adherence to the prescribed exercise programme. Expected Outcomes: The proposed study is expected to generate evidence regarding the effectiveness of exercise-based rehabilitation in improving vitamin D status and functional outcomes among athletes. The findings may contribute to the development of evidence-based rehabilitation strategies for the management of vitamin D deficiency in athletic populations. Conclusion: This protocol provides a structured framework for investigating the role of exercise-based rehabilitation in the management of vitamin D deficiency among athletes. The study is anticipated to enhance current knowledge and support the development of comprehensive rehabilitation programmes that integrate exercise with nutritional management.

Keywords: Athletes; Vitamin D deficiency; Exercise-based rehabilitation; High Intensity Vigorous Exercise protocol; Sports physiotherapy; Study protocol.

1. Introduction

Vitamin D is an essential fat-soluble vitamin that plays a fundamental role in maintaining musculoskeletal health, immune function, and overall physiological function. It regulates calcium and phosphorus homeostasis, thereby promoting bone mineralization, skeletal integrity, and normal muscle function. In addition to its well-established role in bone health, vitamin D contributes to neuromuscular coordination, immune regulation, and muscle recovery, making it particularly important for individuals engaged in regular physical activity and competitive sports.

Athletes are exposed to repetitive mechanical loading, intensive training schedules, and increased physiological demands, all of which require optimal musculoskeletal function for peak performance. Despite maintaining an active lifestyle, vitamin D deficiency remains a common nutritional concern among athletes. Factors such as inadequate sunlight exposure, indoor training environments, seasonal variation, geographical location, skin pigmentation, dietary insufficiency, and increased metabolic requirements contribute to reduced vitamin D status in this population. Consequently, vitamin D deficiency has been associated with decreased muscle strength, impaired physical performance, delayed recovery, reduced bone mineral density, an

increased risk of stress fractures, and a greater susceptibility to illness.

Maintaining adequate vitamin D levels is therefore essential for optimizing athletic performance and preventing sports-related injuries. Beyond its effects on bone metabolism, vitamin D plays a significant role in skeletal muscle function by influencing muscle protein synthesis, neuromuscular efficiency, and post-exercise recovery. Furthermore, its immunomodulatory properties help maintain immune competence, thereby reducing the likelihood of infections that may interrupt training and competition. These physiological functions collectively emphasize the importance of maintaining adequate vitamin D status throughout an athlete's training and rehabilitation process.

Exercise is widely recognized as a cornerstone of sports rehabilitation and physical conditioning. Regular physical activity improves muscle strength, endurance, bone health, and functional capacity while facilitating recovery following injury or illness. Emerging evidence suggests that appropriately prescribed exercise may also influence vitamin D metabolism by enhancing musculoskeletal adaptation and improving the body's physiological response to rehabilitation. Moreover, outdoor physical activity may contribute to improved vitamin D status through greater

exposure to sunlight, whereas athletes who predominantly train indoors may remain at increased risk of deficiency.

Recent research has increasingly focused on understanding the relationship between exercise and vitamin D status among athletes. Several studies have highlighted the high prevalence of vitamin D deficiency in athletic populations and emphasized the importance of maintaining adequate vitamin D levels to support musculoskeletal health and athletic performance. Although vitamin D supplementation remains a common therapeutic approach, exercise-based rehabilitation has gained attention as a complementary strategy that may enhance functional recovery and overall health outcomes. Factors such as exercise intensity, duration, frequency, nutritional status, geographical location, and lifestyle characteristics may collectively influence rehabilitation outcomes and should therefore be considered while developing individualized rehabilitation programmes.

Despite growing awareness regarding the importance of vitamin D in sports medicine, evidence describing the influence of structured exercise programmes on the rehabilitation of vitamin D deficiency among athletes remains limited. A better understanding of this relationship may assist sports physicians, physiotherapists, rehabilitation specialists, and strength and conditioning professionals in developing comprehensive rehabilitation strategies that optimize vitamin D status, enhance recovery, reduce injury risk, and improve athletic performance. Therefore, the aim of this study is to evaluate the influence of exercise-based rehabilitation on vitamin D deficiency among athletes through a three-phase study protocol comprising cross-sectional screening, quasi-experimental intervention, and follow-up assessment

2. Materials and Methods

Study Design

This study protocol comprises three sequential phases designed to investigate the influence of exercise-based rehabilitation on vitamin D deficiency among athletes. Phase I involves a cross-sectional assessment to determine the prevalence of vitamin D deficiency and identify eligible participants. Phase II is designed as a single-blinded quasi-experimental study to evaluate the effectiveness of a structured exercise programme in conjunction with vitamin D supplementation. Phase III consists of a six-month follow-up to assess the long-term sustainability of the intervention outcomes.

Study Setting

The study will be conducted among athletes from the Kozhikode and Malappuram districts of Kerala, India. Registered sports academies from both districts will serve as the study sites. Fourteen official sports academies will be identified, from which four academies from each district will be selected using a random sampling method. Prior to participation, athletes will be informed about the purpose and procedures of the study, and written informed consent will be obtained.

Participant Recruitment

Athletes recruited from the selected sports academies will undergo screening for vitamin D status. Those diagnosed with vitamin D insufficiency or deficiency will be considered for inclusion in the intervention phase of the study. Recruitment will be carried out according to the predefined eligibility criteria.

Study Procedure

Phase I: Cross-Sectional Assessment

The first phase of the study will involve screening athletes to determine the prevalence of vitamin D deficiency. Blood samples will be collected for the assessment of serum vitamin D levels. Demographic information and relevant participant characteristics will also be recorded to evaluate factors potentially associated with vitamin D deficiency. The findings from this phase will be used to identify eligible participants for the intervention phase.

Phase II: Quasi-Experimental Intervention

Athletes identified with vitamin D insufficiency or deficiency during the screening phase will be enrolled in the intervention phase. As participants are selected from the initial screening, random allocation will not be feasible; therefore, the study will follow a single-blinded quasi-experimental design.

Eligible participants will be allocated into two intervention groups. Group A will receive a specifically designed High Intensity Vigorous Exercise (HIVE) Protocol along with vitamin D supplementation, whereas Group B will receive conventional sports-specific exercise training in combination with vitamin D supplementation. The intervention is intended to evaluate the effectiveness of structured exercise programmes in improving vitamin D status, physical performance, and overall quality of life among athletes.

Phase III: Six-Month Follow-up

Following completion of the intervention programme, participants will be followed for six months to evaluate the sustainability of treatment outcomes. Follow-up assessments will include reassessment of vitamin D status and other study outcomes. Participants who are unable to attend the scheduled assessment due to relocation or other logistical reasons will be contacted through alternative means whenever feasible. Information regarding participant compliance, continuation of exercise, and reasons for non-participation during follow-up will also be documented.

Outcome Measures

The primary outcome of the study will be the improvement in serum vitamin D levels following the intervention. Secondary outcomes will include changes in physical performance, quality of life, and adherence to the prescribed exercise programme.

Data Collection

Data collected during the study will include demographic characteristics, serum vitamin D levels, intervention compliance, and follow-up outcomes. All data will be recorded using standardized data collection procedures to ensure consistency throughout the study.

Expected outcome: The present study is expected to provide evidence regarding the effectiveness of exercise-based rehabilitation in improving vitamin D status among athletes diagnosed with vitamin D deficiency. It is anticipated that the structured High Intensity Vigorous Exercise (HIVE) protocol, when combined with vitamin D supplementation, will result in greater improvements in serum vitamin D levels, physical performance, and quality of life compared with conventional sports-specific exercise training.

The findings are also expected to enhance the understanding of the relationship between exercise and vitamin D metabolism in athletes and provide clinically relevant information for physiotherapists, sports physicians, exercise professionals, and rehabilitation specialists involved in the management of vitamin D deficiency. Furthermore, the study is expected to contribute to the development of evidence-based rehabilitation strategies aimed at reducing injury risk, promoting functional recovery, and optimizing athletic performance.

3. Discussion

Vitamin D deficiency is increasingly recognized as a significant concern among athletes because of its potential impact on musculoskeletal health, physical performance, and recovery. Although vitamin D supplementation is widely recommended for correcting deficiency, limited evidence is available regarding the effectiveness of structured exercise programmes as an adjunct to rehabilitation. This highlights the need for well-designed clinical studies that evaluate the role of exercise in improving vitamin D status and related functional outcomes among athletes.

The proposed study is designed to address this knowledge gap through a three-phase protocol consisting of cross-sectional screening, a quasi-experimental intervention, and a six-month follow-up assessment. This comprehensive approach is expected to facilitate the identification of athletes with vitamin D deficiency, evaluate the effectiveness of exercise-based rehabilitation, and examine the sustainability of intervention outcomes over time.

A key strength of this protocol is the inclusion of the High Intensity Vigorous Exercise (HIVE) protocol in combination with vitamin D supplementation. Comparing this intervention with conventional sports-specific exercise training may provide valuable insights into the role of structured exercise in enhancing vitamin D status, physical performance, and quality of life among athletes. The findings of the proposed study may contribute to the development of evidence-based rehabilitation strategies and support clinical decision-making in sports physiotherapy and sports medicine.

Furthermore, the study is expected to improve understanding of the relationship between exercise and vitamin D metabolism in athletic populations. The knowledge generated may assist healthcare professionals in designing individualized rehabilitation programmes that integrate exercise prescription with nutritional management, thereby promoting functional recovery, reducing injury risk, and optimizing athletic performance. The findings may also

provide a foundation for future multicentre studies investigating exercise-based rehabilitation in athletes with vitamin D deficiency.

4. Strengths and Limitations

Strengths

This study is designed using a three-phase approach comprising cross-sectional screening, a quasi-experimental intervention, and a six-month follow-up, enabling both short-term and long-term evaluation of exercise-based rehabilitation in athletes with vitamin D deficiency. The study incorporates a structured High Intensity Vigorous Exercise (HIVE) protocol alongside vitamin D supplementation, which may provide valuable evidence regarding the effectiveness of exercise in improving vitamin D status and overall athletic performance. Furthermore, the inclusion of athletes from multiple sports academies may enhance the applicability of the findings to similar athletic populations.

Limitations

The study is limited by its quasi-experimental design, as participants are recruited from the initial screening phase without random allocation. Additionally, the study is conducted in selected districts of Kerala, which may limit the generalizability of the findings to athletes from other geographical regions. Variations in dietary habits, sunlight exposure, training intensity, and participant adherence to the intervention may also influence the study outcomes.

5. Conclusion

Vitamin D deficiency remains a significant concern among athletes and may adversely affect musculoskeletal health, physical performance, and recovery. The present study protocol proposes a structured approach to evaluate the effectiveness of exercise-based rehabilitation combined with vitamin D supplementation in athletes diagnosed with vitamin D deficiency. The findings of the proposed study are expected to provide evidence regarding the role of exercise in improving vitamin D status, enhancing functional recovery, and supporting overall athletic performance. The results may also contribute to the development of evidence-based rehabilitation strategies for the management of vitamin D deficiency in athletic populations.

6. Future Directions

Future research should focus on multicentre studies involving larger and more diverse athletic populations to improve the generalizability of the findings. Long-term investigations evaluating the sustained effects of exercise-based rehabilitation on vitamin D status, musculoskeletal health, and sports performance are also warranted. Additionally, future studies should explore the influence of different exercise modalities, nutritional interventions, sunlight exposure, and genetic factors on vitamin D metabolism. Advances in wearable technologies and digital health platforms may further facilitate continuous monitoring of physical activity and vitamin D status, thereby support individualized rehabilitation programmes and improve long-term athlete health.

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