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تطوير جهاز ذكي لمراقبة أداء الرياضيين

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يوضح هذا العمل تصميم وتطوير ونمذجة نظام مراقبة شامل للاعبي كرة القدم في الوقت الفعلي. باستخدام متحكم ESP8266 ووحدة GPS ومستشعر النبض، أنشأنا حلاً قويًا وموثوقًا به لتتبع وتحليل مقاييس اللاعب مثل معدل ضربات القلب ومستوى الأكسجين والسرعة وبيانات الموقع.
يعمل دمج تطبيق سهل الاستخدام على تعزيز وظائف النظام بشكل أكبر، مما يسمح للمدربين بمراقبة أداء اللاعب وتلقي ملاحظات فورية واتخاذ قرارات مستنيرة لتحسين اللعب بشكل عام.
على الرغم من مواجهة التحديات المتعلقة بدقة المستشعر واستقرار الطاقة، فقد أدى الاختبار التكراري والتحسين إلى اختيار المكونات الأكثر موثوقية، مثل وحدة Neo-8M GPS. لا يلبي النموذج الأولي النهائي أهداف المشروع الأولية فحسب، بل يوفر أيضًا منصة قابلة للتطوير للتحسينات المستقبلية، بما في ذلك التحليلات الأكثر تقدمًا وتكامل المستشعر الإضافي.
بالنظر إلى المستقبل، هناك عدة طرق لتعزيز وتوسيع قدرات النظام. قد يكون أحد التحسينات الرئيسية هو زيادة وتيرة نقل البيانات من وحدة نظام تحديد المواقع العالمي (GPS) إلى التطبيق المحمول، مما يوفر رؤى أداء أكثر دقة وفي الوقت المناسب. بالإضافة إلى ذلك، يمكن أن يشمل التطوير الإضافي للتطبيق المحمول ميزات مثل القدرة على تنزيل تقارير مفصلة لكل مباراة، مما يسمح بالتحليل الشامل وحفظ السجلات.
بشكل عام، يوضح هذا العمل التطبيق الناجح لمبادئ هندسة الميكاترونيات لحل المشكلات الواقعية، وتوفير أدوات قيمة لمراقبة الأداء الرياضي والمساهمة في تقدم التكنولوجيا الرياضية. مع التحسينات المقترحة، يمكن أن يصبح النظام أصلًا أكثر قوة للمدربين والرياضيين على حد سواء، مما يعزز التحسين المستمر والتميز في الأداء الرياضي.

الكلمات المفتاحية: أداء وحركات اللاعب، المراقبة، إدارة الرياضيين، الميكاترونيات الحيوية.

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Development of an intelligent device for monitoring the performance of athletes

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This work demonstrates the design, development and prototyping of a comprehensive monitoring system for football players in real time. Utilizing the ESP8266 microcontroller, GPS module, and pulse sensor, we have created a robust and reliable solution for tracking and analyzing player metrics such as heart rate, oxygen level, speed, and positional data.

The integration of a user-friendly app further enhances the system's functionality, allowing trainers to monitor player performance, receive instant feedback, and make informed decisions to improve overall game play.
Despite encountering challenges with sensor accuracy and power stability, iterative testing and optimization led to the selection of the most reliable components, such as the Neo-8M GPS module. The final prototype not only meets the initial project objectives but also provides a scalable platform for future enhancements, including more advanced analytics and additional sensor integration.
Looking ahead, there are several ways to enhance and expand the capabilities of the system. One key improvement could be increasing the frequency of data transmission from the GPS module to the mobile app, providing even more precise and timely performance insights. Additionally, further development of the mobile app could include features such as the ability to download detailed reports of each match, allowing for comprehensive analysis and record-keeping.
In general, this project exemplifies the successful application of mechatronics engineering principles to solve real-world problems, providing valuable tools for athletic performance monitoring and contributing to the advancement of sports technology. With the proposed improvements, the system can become an even more powerful asset for trainers and athletes alike, promoting continuous improvement and excellence in sports performance.

Keywords: Performances and movements of player, monitoring, athlete management, bio-mechatronics.

1. Introduction

The physical performance of football players is a critical factor influencing match outcomes. Metrics such as total distance covered are affected by various elements, including playing style and match dynamics, highlighting the importance of thorough analysis of players' physical output.

In the realm of sports technology, advancements have revolutionized the monitoring of elite football players (Dellaserra et al., 2014; Chambers et al., 2015). Global Positioning System (GPS) technology (Aughey, 2011; Latino and Tafuri, 2024), integrated into professional sports, enables teams to track players' movements during training and competitions. Utilizing Electronic Performance and Tracking System (EPTS) (Robertson et al., 2023) devices such as GPEXE (GEPEXE, 2020), StatSports (Statsports, 2024) and Catapult (Catapult, 2024), coaches can gather extensive data on running speed, distance, heart rate, and overall workload. This information is pivotal for injury prevention, as monitoring metrics like sprints and distance allows coaching staff to assess a player's readiness for upcoming matches and identify the need for rest.

Research indicates that training at intensities exceeding the season average increases injury risk (Jones et al., 2017). By analyzing GPS metrics, coaches can predict and mitigate injuries, distinguishing between players who are overtraining and those in peak conditions. Beyond health monitoring, the data from EPTS devices also provides insights into player movements on the field, allowing for tailored training and the development of strategies based on individual physical and tactical needs.

2. Materials and Methods

2.1.Mechanical Design and 3D printing

The mechanical design of the intelligent portable device involved creating a compact and ergonomic structure to ensure ease of use for football players during training and competitions. The design was executed using SolidWorks, focusing on minimizing weight while maintaining durability. The enclosure was designed to house all necessary sensors and components securely, ensuring they remain functional in various environmental conditions. Prototyping techniques such as 3D printing were employed to refine the design and verify fit and functionality.

Figure 1 presents the 3D design of the case, including the internal layout for the components. It features dedicated compartments for the battery and the GPS module, as well as four mounting bosses to secure the PCB with small screws. The shell of the case has a thickness of 2 mm, with internal ribs to strengthen the sections housing the battery and GPS module. This design ensures the durability and stability of the components within the case.

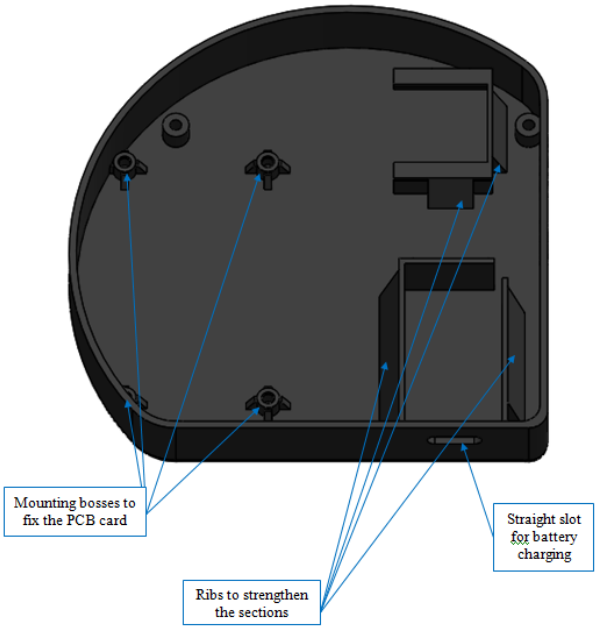


Figure 1: 3D design of the portable device.

The conical format of the cover adds a sleek and modern look, contributing to functionality and visual design (Figure 2).

The sides of the case are designed with extruded cuts that form a straight slot for the battery charging port. Additionally, there are four circular openings: three are designated for battery level indicators, allowing users to easily check the battery status, and one is for the button, providing convenient access for user interaction.

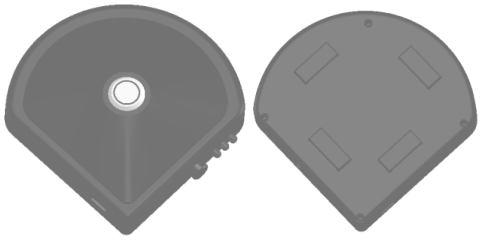


Figure 2: Device's top and back views.

The two 3D models are meticulously arranged on the printing platform, surrounded by necessary support structures to ensure successful printing of overhanging parts. The total estimated printing time is approximately 5 hours and 17 minutes, with a material usage of 164.124 grams, corresponding to a material length of 55.03 meters and a cost estimation of 3.28248 units. The breakdown of the print process is displayed in the structure type section, revealing that the skin and support structures consume the largest portion of the print time, at 32.5% and 19.7% respectively.

2.2.Electrical Design and Components

The electrical design of the device incorporated advanced sensors to capture physiological metrics, including heart rate, acceleration, and distance (Table 1). Components were selected for their low power consumption and processing capabilities, ensuring efficient data acquisition and transmission. Additionally, wireless communication was integrated to facilitate real-time data transfer to a mobile app. The circuit was designed using Proteus ISIS to optimize battery life while ensuring reliable performance under continuous operation.

Table 1: List of electrical and electronic components for an athlete performance tracking device

Component	Description
ESP32	Central processor enabling Wi-Fi and connectivity.
Neo-8M GPS with Compass	Provides accurate location tracking and orientation data.
Grove - Heart Rate Monitor	Monitors heart rate during training and matches.
Battery Level Indicator	Displays battery status to prevent unexpected shutdowns.
Blue Illuminated Metal Push Switch	Allows easy device activation with visibility in low light.
Battery 9V	Powers the entire device for extended use.

Figure 3 illustrates the complete circuit implemented in this project, integrating all the sensors and electronic components. This comprehensive diagram highlights the interconnections and layout of each component, providing a clear visualization of the electrical framework. It serves as a practical reference for understanding how the various elements work together to achieve the project's objectives.

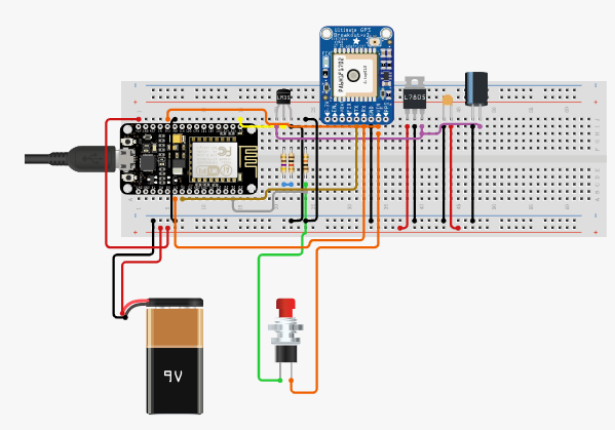
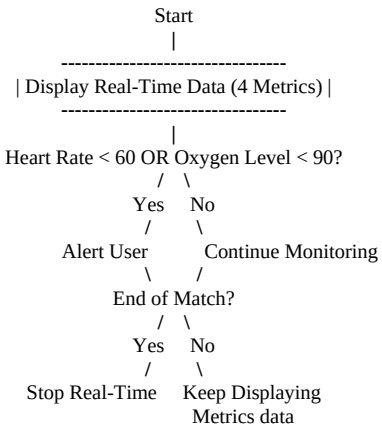


Figure 3: Electrical design and electronic components for an athlete performance tracking device

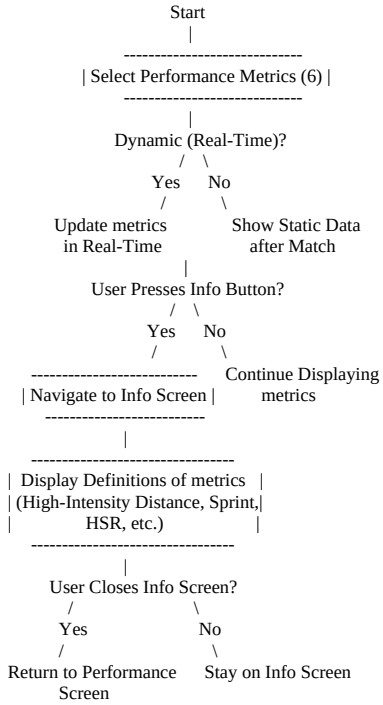
2.3.Mobile App Development

Utilizing FLUTTER, the app designed features five key screens that provide comprehensive insights into athlete performance. The Real-Time screen displays four metrics in real time: heart rate, oxygen level, speed, and state (acceleration, deceleration, or stable). The heart rate of a normal person should not be below 60, and the oxygen level (SpO2) should not be below 90. If either of these values falls below their respective thresholds, it indicates that the player is in a dangerous situation and requires immediate attention. To ensure safety, the app displays these values in red when they drop below the thresholds, alerting the user (trainer) that something is wrong with the player.

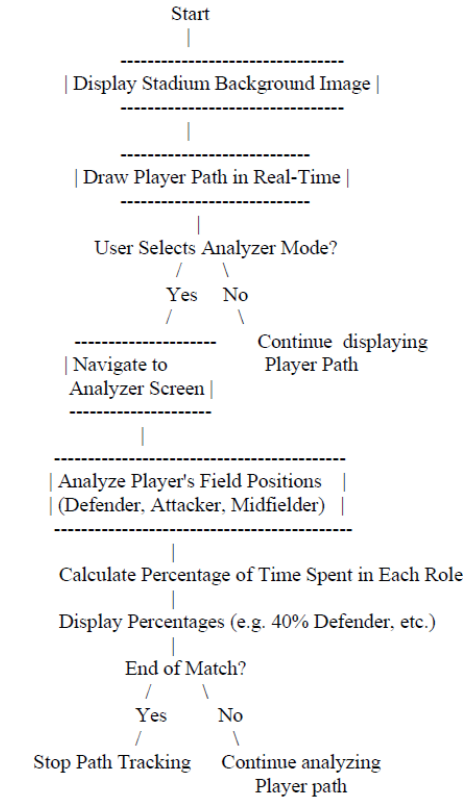


The Personal Performance screen displays six key metrics essential for evaluating a football player's performance. These metrics include high-intensity distance, high-speed running, sprint, distance per minute, total distance, and maximum speed.

This screen is both dynamic (real-time) and static, allowing the user to view performance metrics during and after the match

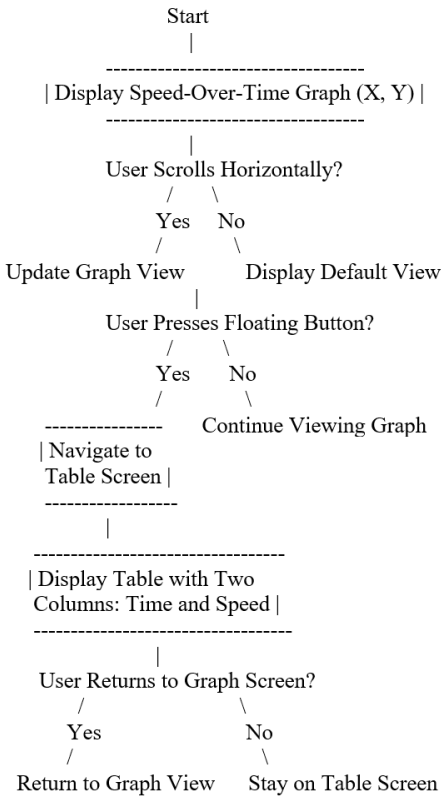


The Path Map screen is one of the app's crucial features. It displays the player's path over a stadium background image, giving the user a clear visual representation of their movements during the match.



The Analyzer screen is integrated into the Path Map screen and provides detailed insights into the player's field positions. It displays the percentage of time the player spends in each role: defender, attacker, and midfielder.

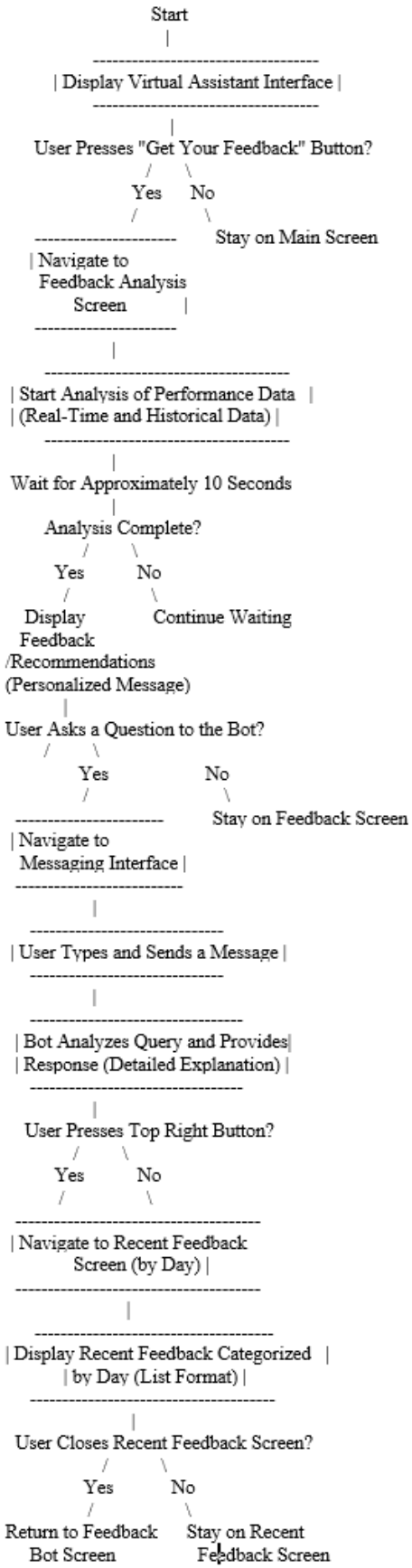
The Graph screen displays a speed-over-time graph for the duration of the match. It features horizontal scrolling, allowing users to navigate through the data based on its length.



When the user presses the floating button on the Graph screen, the app navigates to the Table screen. This screen displays a table with two columns: one for Time and the other for Speed, providing a clear and simplified view of the data for the user.

The final screen, Feedback_Bot, is one of the app's most valuable features.

Having a robot that offers such precise feedback based on real-time and historical data is an exceptional tool for any athlete looking to enhance their performance.



The Feedback Bot screen includes a robust messaging feature. This allows users to interact with the bot by sending messages if they have any questions or need additional explanations about their performance metrics.

When the user presses the top right button, another screen appears, presenting recent feedbacks categorized by day.

3. Results and discussion

The device's capabilities will be critical for performance monitoring. Data collected will enable continuous tracking and facilitate timely interventions to enhance performance and prevent injuries.

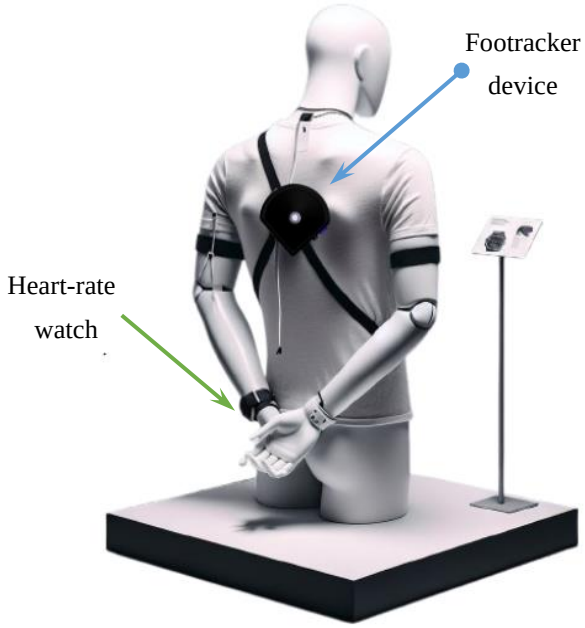


Figure 4: The prototype of a device for tracking and monitoring athletes' performance.

The integration of a user-friendly application and cloud-based connectivity further enhances the device's utility. Athletes and coaches will benefit from remote monitoring capabilities by making informed decisions regarding training adjustments.

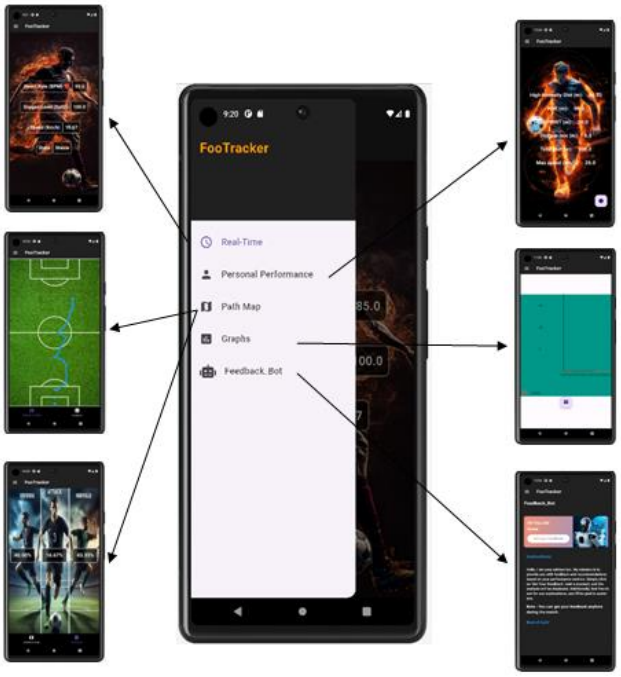


Figure 5: The mobile app " FooTracker "

The potential for this device to empower athletes is immense. By providing detailed performance metrics, the technology will enable athletes to refine their skills and address specific areas for improvement. The project is positioned to contribute significantly to the sports science field, with implications for injury prevention and performance enhancement.

4. Conclusions

The development of this intelligent, portable device marks a significant advancement in sports technology. By merging advanced monitoring capabilities with user-friendly design, this study paves the way for a new approach to athlete performance evaluation. Teams can leverage this technology to optimize training methods, enhance athlete performance, and mitigate injury risks. The future of professional sports will benefit greatly from innovations that bridge the gap between technology and athletic performance. The development of this intelligent, portable device marks a significant advancement in sports technology. Teams can leverage this technology to optimize training methods, enhance athlete performance, and mitigate injury risks. The future of professional sports will benefit greatly from innovations that bridge the gap between technology and athletic performance.

Conflict of interest The authors declare that they have no conflicts of interest to report regarding the present study.

5. References

1. Chambers R, Gabbett TJ, Cole MH, Beard A. (2015). **The Use of Wearable Microsensors to Quantify Sport-Specific Movements – A Systematic Review**. *Sports Med (2015) 45:1065–1081.*
2. Dellaserra, C. L., Y. Gao, and L. Ransdell. (2014). **Use of Integrated Technology in Team Sports: A Review of Opportunities, Challenges, and Future Directions for Athletes**. *Journal of Strength and Conditioning Research, 28(2), 556-573.* doi:10.1519/JSC.0b013e3182a952fb.
3. Aughey RJ. (2011). **Applications of GPS technologies to field sports**. *Int J Sports Physiol Perform. 2011 Sep;6(3):295-310.* doi: 10.1123/ijspp.6.3.295.
4. Latino F, Tafuri F. (2024), **Wearable Sensors and the Evaluation of Physiological Performance in Elite Field Hockey Players**. *Sports (Basel). 2024 Apr 29;12(5):124.* doi: 10.3390/sports12050124.
5. Robertson S, Duthie GM, Ball K, Spencer B, Serpiello FR, Haycraft J, Evans N, Billingham J, Aughey RJ. (2023). **Challenges and considerations in determining the quality of electronic performance & tracking systems for team sports.** *Front Sports Act Living. 2023 Dec 20;5:1266522.* doi: 10.3389/fspor.2023.1266522.
6. GEPEXE. (2020). **Technology - devices: gpexe pro2, LPS, lt, gk – gpexe.** https://www.gpexe.com/
7. Statsports. (2024). APEX Athlete Series | Features. https://statsports.com/apex-athlete-series
8. Catapult. (2024). Catapult | Sports Technology | Unleash Potential. https://www.catapult.com/
9. Jones, C.M., Griffiths, P.C. & Mellalieu, S.D. (2017). **Training Load and Fatigue Marker Associations with Injury and Illness: A Systematic Review of Longitudinal Studies**. *Sports Med 47, 943–974 (2017).*