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Research on the Application of Wearable Devices in Monitoring Adolescent Physical Fitness Training

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Abstract

This study focuses on the application of wearable devices in adolescent physical training monitoring, aiming to address the inherent limitations of traditional monitoring approaches in data collection continuity, feedback immediacy, and evaluation objectivity. Through a systematic analysis of three fundamental principles for applying wearable devices to adolescent physical training monitoring—health and safety assurance, precise data acquisition, and age-appropriate adaptation—this paper proposes a monitoring strategy framework encompassing four dimensions: physiological load tracking, movement technique diagnosis, training behavior recording, and home–school data sharing. The results indicate that wearable devices enable real-time collection and dynamic presentation of basic physiological indicators such as heart rate, step count, exercise distance, and calorie expenditure during training, providing a feasible reference for building a scientific monitoring system for adolescent physical training.

Keywords

Wearable devices; adolescents; physical training; training monitoring.

1. Introduction

Adolescence represents a critical period for the development of human motor capacity. In this stage, scientifically designed physical fitness training plays a foundational role in promoting physical health and preventing sports-related injuries [1]. As the key link between training implementation and outcome evaluation, training monitoring directly shapes the extent to which the training process can be conducted in a scientific and evidence-informed manner. In conventional practice, however, training monitoring has largely depended on coaches' visual observation and experience-based judgment, usually supplemented by basic tools such as stopwatches and tape measures. Such approaches are characterized by fragmented data collection, delayed feedback, and a high degree of subjectivity in evaluation.

In response to these limitations, the Chinese government has successively introduced policy documents, including the 《Healthy China 2030 Planning Outline》 and the 《Youth Sports Activity Promotion Plan》, both of which call for more scientific and precise approaches to monitoring adolescent physical health and explicitly encourage the use of intelligent technologies to improve training supervision systems. Against this policy and technological backdrop, wearable devices have created new opportunities for monitoring adolescent physical fitness training. Through capabilities such as real-time data collection and movement analysis, these devices make it possible to obtain a more comprehensive understanding of adolescents' physiological condition and movement performance during training, thereby providing stronger support for the development of more scientific training-monitoring practices.

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2. Foundational Principles Governing the Use of Wearable Devices in Adolescent Physical Fitness Training Monitoring

2.1. Prioritizing Health, Safety, and Data Protection

When wearable devices are used to monitor adolescent physical fitness training, health and safety must be treated as the primary concern. Because adolescents often have sensitive skin and incompletely developed musculoskeletal systems, higher safety standards are required for such devices. At the hardware level, the outer casing and all skin-contact components should be made of medical-grade or food-grade materials and should pass skin-irritation testing in order to prevent contact dermatitis and related adverse reactions. In terms of structural design, the device should fit securely and remain stable during large-amplitude movement, while sharp edges and other potential sources of abrasion should be avoided. With regard to electrical safety, the battery system should incorporate protection against overcharging, overheating, and short circuits so as to reduce the risk of malfunction during vigorous exercise or in high-temperature environments. Data security is equally important. A hierarchical encryption mechanism should be established from the device terminal to the cloud platform to ensure full-process protection of sensitive information, including identity-related and physiological data, and to prevent unauthorized access, theft, or misuse.

2.2. Ensuring Accuracy and Reliability in Data Collection

The core value of wearable devices depends on the accuracy and reliability of the data they generate. If collected data deviate substantially from actual training conditions, subsequent adjustments to training may themselves create sports-related risks. For this reason, wearable devices should be equipped with calibrated, high-precision sensors capable of stably collecting signals such as heart rate, blood oxygen saturation, and acceleration. Heart-rate monitoring, for example, should maintain acceptable levels of accuracy across different phases of training, with measurement error controlled within recognized industry standards. At the same time, devices should possess adaptive anti-interference capabilities that enable them to filter motion artifacts and environmental noise during complex activities such as variable-speed running and jumping, thereby ensuring continuity and stability in data acquisition. In addition, measurement consistency across different brands and production batches should be maintained so as to facilitate cross-sectional comparison and long-term follow-up, as shown in Table 1.

Table 1. Types of Wearable Devices, Main Monitoring Indicators, and Typical Application Scenarios

Device Type	Main Monitoring Indicators	Typical Application Scenarios
Smart band	Heart rate, step count, exercise distance, calorie expenditure, sleep	Daily activity monitoring; basic physical fitness training
Sports watch	Heart rate, cadence, pace, GPS trajectory, blood oxygen saturation	Endurance training, such as middle- and long-distance running, cycling, and swimming
Chest-strap heart-rate monitor	High-precision heart rate; heart rate variability (HRV)	High-intensity interval training; precise assessment of training intensity

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Inertial sensor (e.g., motion-capture patch)	Acceleration, angular velocity, movement rhythm, body posture angle	Running-form analysis; technical diagnosis of squat, jump, and related movements

2.3. Adapting Monitoring to Developmental Characteristics and Individual Differences

Adolescents constitute a highly heterogeneous population, and the differences between a 7-year-old and a 17-year-old in terms of body form, physiological function, cognition, and movement capacity are substantial. Monitoring schemes must therefore take full account of developmental characteristics and individual variation [2]. For younger adolescents, operational procedures should be simplified through visual interfaces and voice prompts, with monitoring focused primarily on basic physiological indicators and relatively lenient warning thresholds. For older adolescents, especially those involved in competitive or systematic training, wearable devices should support more differentiated dimensions of analysis, including movement-technique assessment, load quantification, fatigue monitoring, and recovery evaluation. In such cases, warning thresholds should be defined more precisely in accordance with the individual's level of physical fitness, as shown in Table 2. In addition, the mode of wearing, weight, and size of the device should be optimized according to body dimensions at different developmental stages so that it does not interfere with exercise performance or reduce willingness to wear it. Excessive imbalance in the development of physical qualities may undermine the stability of sport-specific fitness and, in turn, increase the risk of injury [3]. Accordingly, training monitoring should pay particular attention to the balanced development of multiple physical qualities and avoid an overemphasis on any single performance indicator.

Table 2. Key Monitoring Priorities Across Different School Stages

School Stage	Age Range	Major Physical and Psychological Characteristics	Key Monitoring Priorities
Primary school	6-12 years	Sensitive period for neural development; broad interests; easily distracted attention	Basic activity volume (step count/activity duration); gamified motivation; safety warning (upper heart-rate threshold)
Junior secondary school	12-15 years	Rapid increases in height and body mass; improved cardiopulmonary function; sensitive period for motor-skill development	Endurance capacity (sustained heart-rate response); movement quality in foundational strength training; trend analysis of training load

Table 2 (continued). Key Monitoring Priorities Across Different School Stages

Senior secondary school	15-18 years	Body morphology largely stabilized; improved competitive capacity; stronger demand for specialization	Quantification of high-intensity load; fatigue and recovery monitoring (HRV); diagnosis of sport-specific technical movements

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3. Practical Pathways for Integrating Wearable Devices into Adolescent Physical Fitness Training Monitoring

3.1. Real-Time Tracking and Dynamic Regulation of Physiological Load

The scientific quality of physical fitness training is first reflected in the precise regulation of training load. Wearable devices can continuously monitor adolescents' heart-rate responses during training, and coaches can simultaneously review the data of multiple participants through mobile terminals. On the basis of age-predicted maximal heart rate, for example 220 minus age, coaches may make an initial judgment as to whether training intensity falls within an appropriate range. If one adolescent's heart rate remains above a preset safety threshold for an extended period, the system may issue an automatic alert, allowing the coach to reduce training intensity or arrange rest in a timely manner so as to prevent excessive fatigue caused by overload. In practice, when the heart rates of several students are generally lower than expected, training difficulty may be moderately increased or rest intervals shortened; when an individual's heart rate remains excessively high, that student should be instructed to reduce intensity or extend recovery time. This form of real-time, data-informed regulation compensates for the limitations of conventional load control based primarily on experiential judgment.

Recovery after training is equally important in the monitoring process. Wearable devices can continue to record resting heart rate and thereby provide a basic indication of recovery status. If an adolescent's resting heart rate on the following morning is significantly higher than his or her usual baseline, this may suggest that the previous day's training load exceeded the individual's recovery capacity, and the intensity of training on that day should therefore be reduced accordingly. Coaches may combine such data with adolescents' subjective perceptions of fatigue in order to arrive at a more comprehensive assessment. Continuous monitoring from training to recovery helps maintain a balance between training stimulus and recovery capacity, thereby reducing the risk of excessive cumulative fatigue. Over time, the accumulation of heart-rate data also makes it possible to establish individualized resting-heart-rate baselines for each adolescent, which can further improve the precision of abnormal-state identification.

3.2. Quantitative Diagnosis of Movement Technique and Immediate Corrective Feedback

Correct movement technique is fundamental to both training effectiveness and injury prevention. Traditional evaluations of technique rely largely on coaches' visual observation, and technical deviations in high-speed movement are often difficult to detect with the naked eye. Overcoming this limitation requires not only in-depth analysis of movement data based on sport-specific expertise, but also the provision of targeted feedback [4]. Through embedded accelerometers, gyroscopes, and related sensors, wearable devices can collect a range of basic kinematic indicators, including step frequency, step length, and trunk inclination. On the basis of these data, the device can identify movement characteristics such as running cadence and landing pattern. When clear technical deviations are detected, the device may issue reminders through vibration, screen display, or other feedback modes. For example, in running training, an adolescent whose cadence is excessively low may receive a vibration prompt; in squat training, excessive forward trunk lean may trigger a corrective alert.

This form of immediate feedback can help adolescents adjust their movements during training and gradually develop correct motor patterns. Compared with traditional observation by coaches, wearable feedback offers greater immediacy and objectivity because corrective information can be delivered at the very moment when the movement error occurs. In situations requiring more refined technical analysis, coaches may combine device-generated data with direct field observation in order to produce a more comprehensive assessment of

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technique. Over the long term, the accumulation of movement data also makes it possible to trace changes in motor patterns, evaluate the effectiveness of technical training, and provide a data-based foundation for subsequent technical instruction.

3.3. Objective Recording and Longitudinal Tracking of Training Behavior

Physical fitness training is a cumulative and long-term process. Although data from a single training session are useful, longitudinal data collected across several months or even years are better able to reflect training effects and developmental patterns in physical fitness [5]. The continuous wearing characteristics of wearable devices make them especially suitable for long-term tracking. Such devices can automatically record indicators including session start time, duration, exercise distance, step count, and estimated energy expenditure, thereby generating a more complete training log and reducing the subjectivity inherent in manual record keeping. Coaches can periodically export these data to review each adolescent's training completion status and identify those whose training volume is either insufficient or excessive. For example, by comparing activity volume across the days of a given week, it becomes possible to assess whether the distribution of training load is reasonable.

Trend analysis based on accumulated longitudinal data can further reveal stage-specific features of adolescent physical development. By examining running data collected over a period of several months, for instance, coaches may observe changes in endurance development and thereby evaluate the effectiveness of the current training program. When abnormal fluctuations emerge, such as a sudden decline in activity volume or a sustained decrease in completion quality, they may indicate latent injury risk or a reduction in motivation and should therefore receive timely attention. Another important function of longitudinal tracking is the establishment of individualized baselines. Because adolescents differ in genetic background and developmental level, their physical fitness indicators naturally vary. Through the long-term accumulation of individual data, it becomes possible to construct personalized baseline profiles, including resting heart rate and exercise-related heart-rate response patterns. Subsequent monitoring data can then be interpreted against these individualized baselines, thereby improving the accuracy of abnormal-state identification.

3.4. Home-School Information Sharing and Collaborative Intervention

Adolescent physical fitness training often spans multiple contexts, especially school and family. Fragmentation of information across these contexts constitutes an important barrier to training continuity. The cloud-based synchronization function of wearable devices provides a technical means of overcoming such information barriers. Data collected during training can be uploaded automatically to a cloud platform and made accessible to authorized parents and coaches. Through mobile applications, parents may review information such as their child's school-based training content, activity volume, and heart-rate fluctuations, rather than relying solely on the child's own verbal account. This increased transparency helps parents better understand the child's training status and provide more targeted support in everyday life. When parents observe that training load remains persistently too low or abnormally high, they can communicate proactively with the coach and jointly discuss possible adjustments.

From the coach's perspective, home-school information sharing makes it possible to obtain a more comprehensive understanding of the adolescent's overall training status. In addition to school-based data, coaches may also review information relating to supplementary home training and weekend activity volume. For example, if one adolescent's school training data indicate a moderate load, but home-school information reveals participation in a high-intensity competition over the weekend, the coach may appropriately reduce Monday's training demands so as to avoid overload. Coaches may also use the platform to assign home-based training tasks. For adolescents with limited flexibility, daily stretching exercises may be prescribed, and the completion of these tasks can be recorded through the wearable device. In this way, the cycle of task assignment, execution, and feedback extends training monitoring beyond fixed training periods and enhances continuity in everyday practice. Throughout this process, however, it remains essential to protect adolescents' privacy and to clearly define both the scope of data use and access permissions.

4. Conclusion

In summary, the use of wearable devices in adolescent physical fitness training monitoring represents an important pathway through which youth training can move from experience-based judgment toward data-informed regulation. By adhering to the foundational principles of health and safety protection, accurate data acquisition, and age-appropriate adaptation, and by implementing strategies such as physiological load tracking, movement-technique diagnosis, objective recording of training behavior, and home-school information sharing, wearable devices can contribute to the construction of a more scientific monitoring system that spans the entire training process and connects multiple participants. Future research may further explore how to improve device accuracy, optimize individualized exercise-prescription algorithms, strengthen multimodal data integration and analysis, enhance long-term wearing comfort, and refine data-security mechanisms. Such efforts will help move wearable devices from the role of auxiliary tools toward deeper forms of scientific support and provide a stronger foundation for the development of a more scientific and precise monitoring system for adolescent physical fitness training.

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