2024, Retos, 61, 1534-1545

The role of digital smart wearable technology in measuring VO2MAX to support athlete performance and public health

El papel de la tecnología digital inteligente para llevar puesta en la medición del VO2MAX para apoyar el rendimiento de los atletas y la salud pública

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Abstract. This study employed the systematic literature review to investigate to what extent digital smart wearable technology was used in measuring VO2MAX to support athlete performance and public health. To achieve the goal, data were obtained from articles searched through Google Scholar. The search was conducted in September 2024 using the following keywords: (Smart Wearable OR Wearable Technology AND VO2MAX OR VO2 Max OR Cardiorespiratory Fitness AND Athlete Performance OR Sports Performance OR Athletic Performance AND Public Health OR General Population OR Health Monitoring). The articles were selected by considering predetermined inclusion and exclusion criteria. For example, to be included in this review, the articles should be published in Scopus-indexed journals. Additionally, the publication period should be from 2019 to 2024. Based on this timeframe, 1,110 articles were found. Furthermore, they were screened again in multiple stages, and 16 articles that fit the theme and met the inclusion requirements were selected. During the article selection, this study followed the PRISMA guidelines. The results confirmed that wearable technology played an important role in athlete performance optimization through real-time monitoring of VO2MAX. The device enables exercise adjustments based on metrics such as heart rate and diurnal variations, which can improve exercise effectiveness and reduce the risk of injury. Interestingly, it also contributes significantly to improving public health by promoting active lifestyles, monitoring health parameters, and supporting self-health management, especially for the elderly and individuals with chronic diseases. Nonetheless, technical challenges, such as measurement accuracy, data synchronization issues, and user education needs, must be addressed for wearables to be optimally utilized. With proper development, wearable technology has great potential to improve athlete performance and public health.
Keywords: Role, Digital Technology, Smart Wearable, VO2MAX, Athlete Performance, Public Health

Resumen. Este estudio utilizó la revisión sistemática de la literatura para investigar el papel de la tecnología digital inteligente portátil en la medición VO2MAX para apoyar el rendimiento de los atletas y la salud pública. Los datos se obtuvieron de artículos buscados a través de Google Scholar. La búsqueda se centró en los publicados en revistas indexadas en Scopus publicadas en 2019 - 2024. Las revistas se seleccionaron teniendo en cuenta criterios de inclusión y exclusión. La búsqueda se realizó en septiembre de 2024 utilizando las palabras clave: (Smart Wearable OR Wearable Technology AND VO2MAX OR VO2 Max OR Cardiorespiratory Fitness AND Athlete Performance OR Sports Performance OR Athletic Performance AND Public Health OR General Population OR Health Monitoring). A partir de la búsqueda en el marco temporal 2019-2014, se encontraron 1.110 artículos. Además, se revisaron de nuevo en varias etapas y se obtuvieron 16 artículos que se ajustaban al tema y cumplían los requisitos de inclusión. Durante la selección de artículos, este estudio siguió las directrices PRISMA. Se llegó a la conclusión de que la tecnología vestible desempeña un papel importante en la optimización del rendimiento de los atletas a través de la monitorización en tiempo real del VO2MAX, lo que permite realizar ajustes del ejercicio basados en métricas como la frecuencia cardíaca y las variaciones diurnas, que pueden mejorar la eficacia del ejercicio y reducir el riesgo de lesiones. Además, los wearables también contribuyen significativamente a mejorar la salud pública mediante la promoción de estilos de vida activos, el seguimiento de los parámetros de salud y el apoyo a la autogestión de la salud, especialmente para la población de edad avanzada y las personas con enfermedades crónicas. No obstante, para que los wearables se utilicen de forma óptima, es necesario resolver problemas técnicos como la precisión de las mediciones y la sincronización de los datos, así como las necesidades de formación de los usuarios. Con un desarrollo adecuado, la tecnología vestible tiene un gran potencial para mejorar el rendimiento de los deportistas y la salud pública en general.
Palabras clave: Función, tecnología digital, wearable inteligente, VO2MAX, rendimiento del deportista, salud pública.

Fecha recepción: 30-09-24. Fecha de aceptación: 26-10-24
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Introduction

Digital technology, particularly wearable devices, has undergone rapid development and has brought a significant impact on sports and public health. One innovation that stands out is its ability to monitor various physiological parameters in real time, including VO2MAX. VO2MAX is an indicator of a person's maximal aerobic capacity. With these technological advancements, VO2MAX measurement has become easier and more accurate, providing great benefits to athletes and individuals looking to improve their cardiovascular health (Hines et al., 2023; Sivaraman, 2019), especially when it is powered by the Internet of Things (IoT). With IoT integration, data collected from wearable devices can be analyzed in real-time, allowing users to gain better insight into their physical condition. This is especially important in sports, where constant monitoring can assist athletes in planning and adjusting their training programs to

achieve optimal performance. Further, Hines et al. (2023) emphasized that wearables are important in addressing health disparities and increasing public trust in health technology. By providing objective and accessible data, these devices can assist individuals in self-monitoring their health, increasing participation in physical activity and overall public health.

In sports, VO2MAX measurement plays a crucial role in optimizing athlete performance. With accurate and continuous data, coaches and athletes can design more effective and measurable training programs. Smart wearable devices make it easy to collect data without interrupting training activities. The devices allow real-time strategy adjustments to achieve peak performance (Firdaus et al., 2023; Silva et al., 2023). Silva et al. (2023) showed that wearable devices can assist in monitoring changes in physical fitness parameters, including VO2MAX, which is particularly important in exercise during the COVID-19 pandemic when the research took place. In addition, Firdaus et al. (2023) confirmed that an intervention using sports drinks combined with training can increase the VO2MAX of soccer athletes, suggesting that the combination of proper nutrition and the use of wearable technology can have a positive impact on athlete performance. Similarly, Michaelides et al. (2021) found that a structured pre-season training program can improve the aerobic fitness of professional football players, with a significant increase in VO2MAX during that training period. This suggests that by utilizing data from wearable devices, coaches can adjust the intensity and type of training to achieve optimal results. The data obtained from wearable devices allows coaches to make better decisions regarding training programs that suit the individual needs of athletes.

In addition to the benefits mentioned above, Lorenzoni et al. (2020) documented that wearable devices can be used to monitor physical activity in patients undergoing medical procedures, such as aortic valve replacement. Their study highlighted the validity of wearables in monitoring physical recovery, which may provide new insights into the clinical management of patients. With the ability to monitor VO2MAX and other physiological parameters, these devices can assist clinicians in tailoring therapies and interventions based on patients' individual needs. In addition, wearable technology has become an invaluable tool in improving public health by making it easier for individuals to monitor their cardiovascular fitness. With the increasing awareness of the importance of health, these devices encourage a more active and healthier lifestyle. Research by Aripradono (2021), for example, shows that wearable technology can assist individuals in receiving notifications and monitoring their physical activity in real-time. This instant notification contributes to improved fitness and disease prevention. In a broader context, Krisna (2020) emphasized that geospatial technologies, including wearables, can be used to map the spread of diseases and assist in public health interventions.

However, while there are many benefits, the use of wearables also faces challenges. For instance, a study by Wang et al. (2023) on consumer acceptance of wearable devices shows that product attributes, such as comfort and ease of use, strongly influence the adoption of this technology. If wearables are uncomfortable or difficult to use, users may not utilize them to their full potential, which may reduce the effectiveness of monitoring VO2MAX and other health parameters. In addition, technical challenges such as synchronization issues and measurement accuracy also need to be considered. Pires et al. (2021) found that wearable devices often have problems accurately detecting changes in heart rate, especially in high-stress situations. Besides, Gagnon et al. (2022) showed that the accuracy of wearable devices in detecting changes in heart rate can vary, especially under high-stress conditions, which can affect the reliability of the data obtained. Guk et al. (2019) also noted that although wearable devices are increasingly popular in health monitoring, the accuracy of the data collected can vary depending on the type of device and the user's condition. These inaccuracies can affect health decisions made based on such data, making it important to continuously improve measurement technologies and methodologies. In addition, disparities in access to technology are also a challenge that needs to be addressed. Lewis et al. (2020) noted that while wearable devices are increasingly common, access to these technologies is still limited for some populations, especially in resource-limited areas. Another major concern is related to privacy and security issues related to health data. Users need to be assured that their personal data is protected and not misused (Dunn et al., 2018; Mone & Shakhlo, 2023). Therefore, it is important for coaches and athletes to understand the limitations of this technology and combine data from wearables with traditional measurement methods to get a more accurate picture of the athlete's fitness.

As such, wearable technology brings significant benefits to public health by making it easier for individuals to monitor their cardiovascular fitness and encourage a more active lifestyle. With the increasing awareness of the importance of health, these devices are becoming effective tools in disease prevention and health promotion (Najikh & Sukihananto, 2023; Timur et al., 2020). Despite its challenges, the utilization of accurate and real-time data can assist individuals and communities in achieving their health goals.

Indeed, research on human movement has touched on many areas. For example, some popular studies investigated the achievement of physical education learning outcomes (Martono et al., 2024; Komari et al., 2024a; Komari et al., 2024b; Septiantoko et al., 2024; Suyato et al., 2024; Widiyanto et al., 2024; Putro et al., 2024; Harmanto et al., 2024; Zulbahri et al., 2024; Susanto et al., 2024a), motor development (Susanto et al., 2024; Susanto et al., 2024), physical education or sport health and fitness (Widiyanto et al., 2024a; Widiyanto et al., 2024b; Syaukani et al., 2024; Pranoto, et al., 2024; Astuti et al., 2024; Wayoi et al., 2024; Akhmad et al., 2024), law and sports (Ardiyanto et al., 2024; HB et al., 2024a; HB et al., 2024b), sports communication (Charlina et al., 2024), active lifestyle with exercise (Tafuri et al., 2024a), interval training and physiological (Latino et al., 2024a), circuit

training programme (Tafuri et al., 2024b; Tafuri et al., 2024c; Latino et al., 2024b; Latino et al., 2024c; Adirahma et al., 2024), injury risk on sports (Anam et al., 2024a; Fahrosi et al., 2024), endurance training and physiological (Latino et al., 2024c), therapeutic sports (Zanada et al., 2024), movement skills (Susanto et al., 2023; Anam et al., 2024b; Pranoto et al., 2024), and sports training and performance (Kurniawan et al., 2024; Susanto et al., 2024), curriculum and management of physical education learning (Mardiyah et al., 2024a; Yani et al., 2024; Mardiyah et al., 2024b), and the management of sports education and archery (Hamsyah et al., 2024; Mulyanti et al., 2024; Setyawan et al., 2023a; Setyawan et al., 2023b; Setyawan et al., 2024a; Setyawan et al., 2024b; Destriani et al., 2024), students' motor skills (Sayekti et al., 2024), and adaptive physical education (Susanto et al., 2024b)

Despite the wealth of existing research on the above topics, there is still a lack of scientific research on the role of digital smart wearable technology in VO2MAX measurement to support athlete performance and public health. The lack of research on this topic may hinder understanding, research findings and scientific development in the field. Thus, it is important to conduct studies related to this topic by thoroughly reviewing the existing literature. Therefore, the present study aims to explore the role of digital smart wearable technology in VO2MAX measurement to support athlete performance and public health. It focuses on reviewing (1) the role of wearables in optimizing athlete performance, (2) the use of wearables for public health, and (3) the challenges of the device in VO2MAX. The focus of the review on several aspects is carried out in order to obtain findings and solutions to some of the existing problems.

Materials & Methods

This study employed a systematic literature review method by identifying, evaluating, and interpreting the results of relevant research articles. It was conducted with a comprehensive strategy by searching articles in research journal databases. The search took place in September 2024 using the keywords: Smart Wearable OR Wearable Technology AND VO2MAX OR VO2 Max OR Cardiorespiratory Fitness AND Athlete Performance OR Sports Performance OR Athletic Performance AND Public Health OR General Population OR Health Monitoring. In this study, inclusion and exclusion criteria were applied. To be included in the review, the articles must be published in Scopus-indexed journals. In addition, the publication period was limited between 2019-2024. The complete list of inclusion and exclusion criteria are shown in Table 1 below:

Table 1.
Inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Period	Journals published in 2019 - 2024	Journals published outside 2019-2024
Indexed	Scopus-indexed international journal	Non-Scopus-indexed international journal
Access	Open access	Close access (Subscription)
Language	English language journal	Non-English language journal
Article Type	Original research article and review article	Conference proceedings, book, book chapter, book series, editorial, etc.
Full Text	Articles fulfill the scope/topic of research	Articles do not fit the scope/topic of the research
Topic of Discussion	The article's content is relevant to the theme of the role of digital smart wearable technology in VO2MAX measurement to support athlete performance and public health.	The article's content is not relevant to the theme of the role of digital smart wearable technology in VO2MAX measurement to support athlete performance and public health.

Based on the above criteria, this study generated 1,110 articles from an international journal indexing database, Scopus. Furthermore, these articles undertook several stages of the screening process, and 16 articles that fit the theme and met the inclusion requirements were selected. During the article selection, this study followed the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses" (PRISMA) guidelines. These guidelines are expected to produce systematic literature review reports that are more transparent, complete, and accurate, thus facilitating evidence-based decision-making (Page et al., 2021). The article selection with the PRISMA method is illustrated in As shown in Figure 1.

Results

This section presents the findings of a comprehensive literature review on the role of digital smart wearable technology in VO2MAX measurement to support athlete performance and public health. Detailed results are shown in Table 2.

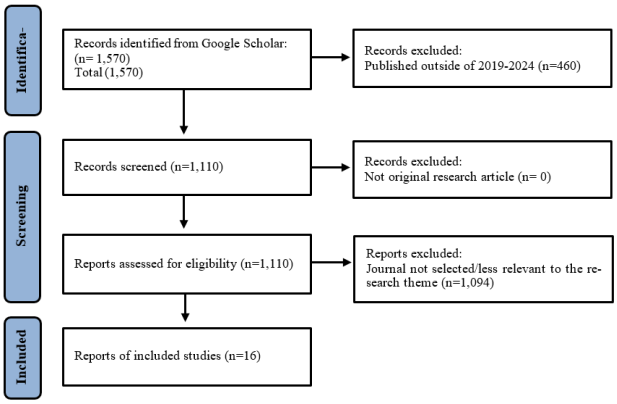

Figure 1. PRISMA flowchart of the article selection process

Table 2.
Literature Review Results

Author	Study objectives	Main Findings
(Helgerud et al., 2022)	Research Objective: The study aims to evaluate the accuracy of using a smartphone application, Myworkout GO, to predict maximal oxygen consumption (VO2max) from submaximal exercise.	Research Findings: The results demonstrated that the Myworkout GO application predicted VO2max with high accuracy, showing no significant difference compared to directly measured VO2max. The application's predictions were highly correlated with the direct measurements ($R^2 = 0.97$). The standard error of the estimate was low (2.2 mL/kg/min), making this method reliable for both men and women across different age groups.
(Browne et al., 2021)	Research Objective: The study evaluates the effectiveness of using a wearable biometric ring combined with guided feedback to improve sleep quality and physical fitness over a 12-month period.	Research Findings: The results showed that participants in the intervention group significantly improved their sleep onset latency, daily step count, time spent jogging, VO2max, and heart rate variability during the first three months of the study. The long-term feedback group continued to see these improvements throughout the 12-month period, while the short-term feedback group maintained most gains without further guidance. These findings suggest that the use of wearable biometric devices, coupled with personalized feedback, can lead to sustained improvements in sleep and physical fitness behaviors.
(Knaier et al., 2019)	Research Objective: The diurnal variations in maximal oxygen uptake (VO2max) are investigated among athletes. These variations are compared to observe the day-to-day fluctuations in VO2max.	Research Findings: The results indicated that the diurnal variations in VO2max were significantly larger than the day-to-day variations, with diurnal changes being more than twice as large. While the study did not find a consistent time of day when all athletes achieved their VO2max peak, individual differences in performance were notable, with VO2max peak occurring at different times for different athletes. Furthermore, chronotype had a significant influence on the time of VO2max peak, but habitual training time showed little effect. These findings underscore the importance of considering diurnal variations in athletic performance for both competitive events and research settings.
(Juarez et al., 2024)	Research Objective: The objective of this research is to explore the role of cardiopulmonary exercise testing (CPET) when assessing and managing patients with heart failure. CPET is analyzed as a diagnostic tool for measuring the dynamic interactions between the cardiovascular, respiratory, and metabolic systems during exercise.	Research Findings: The findings revealed that CPET was a highly valuable tool in heart failure management, providing detailed insights into a patient's exercise capacity and overall cardiovascular health. Key parameters, such as peak oxygen uptake (VO2) and the VE/VCO2 slope, were shown to have strong prognostic value, with lower VO2 and higher VE/VCO2 slopes correlating with poorer patient outcomes. The study also highlighted that advances in wearable technology can further assist in tracking cardiopulmonary health in everyday activities, offering real-time data that can improve individualized patient care and intervention strategies.
(Nayor et al., 2021)	Research Objective: This study aims to evaluate the relationship between different types of physical activity (PA), such as moderate-vigorous physical activity (MVPA), steps per day, and sedentary time with cardiorespiratory fitness in a community-dwelling population.	Research Findings: The results demonstrated a clear association between increased physical activity, especially MVPA, and improved cardiorespiratory fitness, as indicated by higher peak VO2 levels. Specifically, participants who increased their MVPA or steps per day over the observation period showed significant improvements in fitness, while reduced sedentary time was also beneficial. These findings suggest that even small increases in physical activity can lead to meaningful improvements in fitness and potentially lower cardiovascular risk, highlighting the importance of promoting active lifestyles in the community.
(Pakhomov et al., 2020)	Research Objective: This study assesses whether consumer-wearable devices, such as Fitbit, can be effectively used to monitor physiological responses to psychosocial stress in real-world settings.	Research Findings: The study found that wearable devices, specifically Fitbit, successfully detected elevated heart rates during stressful events, such as exams and other self-reported stressors. On average, heart rates increased by 8.9 beats per minute during exams, aligning with known physiological stress responses. These findings support the potential use of consumer-grade wearables for large-scale stress monitoring, offering a scalable, non-intrusive method for assessing stress exposure and physiological responses in everyday environments.
(Drent et al., 2020)	Research Objective: The objective of this study is to evaluate the impact of continuous activity monitoring using an electronic activity tracker (AT) on exercise performance and fatigue levels. The study examined sarcoidosis patients who had been given the aforementioned intervention and those who had not received any treatment in a control group.	Research Findings: The findings indicated that sarcoidosis patients wearing an AT showed significant improvements in exercise performance and reductions in fatigue compared to the control group. Patients with coaching exhibited greater enhancements in exercise capacity over time, as demonstrated by the Steep Ramp Test results and VO2max values. Specifically, patients with coaching showed an increase in exercise capacity ($\Delta 20.2 \pm 33.8$ watts) compared to those without coaching ($\Delta 5.7 \pm 26.4$ watts). These results suggest that the use of an AT, especially when combined with personal coaching, can be an effective strategy to encourage physical activity and reduce fatigue in sarcoidosis patients.
(Pope et al., 2019)	Research Objective: The objective of this 12-week pilot randomized trial is to investigate the feasibility and initial effectiveness of combining Polar M400 smartwatch use with a twice-weekly Social Cognitive Theory (SCT) and Self-Determination Theory (SDT) based Facebook-delivered health education intervention to improve college students' physical activity (PA) and dietary behaviors.	Research Findings: The study found that while both intervention methods were feasible and generated interest among college students, there was no significant advantage of combining the smartwatch with the health education intervention compared to the standalone health education intervention. Both groups showed small increases in moderate-to-vigorous physical activity (MVPA) and decreases in daily caloric consumption. However, the experimental group reported challenges with the Polar M400 smartwatch, such as syncing issues and device size, which may have limited its effectiveness. These results suggest that theoretically-based, social media-delivered health education alone may be sufficient for promoting health behavior changes in this population.
(Haglo et al., 2021)	Research Objective: The study aims to evaluate the effectiveness of self-administered high-intensity interval training (HIIT) sessions for patients with inflammatory rheumatic diseases (IRDs). Participants will complete 4x4 minute HIIT sessions guided by the smartphone app Myworkout GO. The objective is to determine whether a self-guided approach can yield similar improvements in maximal oxygen uptake (VO2max) and health-related	Research Findings: The study found that both the app-guided and supervised groups demonstrated significant improvements in VO2max, with no meaningful difference between the groups. Increases in VO2max were 3.6 mL/kg/min for the supervised group and 3.7 mL/kg/min for the app-guided group. Both groups also showed improvements in HRQoL in areas such as bodily pain, vitality, and social functioning.

	quality of life (HRQoL) compared to traditional, supervised HIIT sessions.	These results suggest that self-administered HIIT using a smartphone app can effectively improve cardiovascular health and quality of life in IRD patients, similar to supervised training.
(Brickwood et al., 2021)	Research Objective: The objective of this study is to determine if wearable activity trackers (ATs), supported by either professional feedback or telephone counseling (TC), can help older adults maintain physical activity levels and health outcomes over a 12-month period.	Research Findings: The results showed that both the AT and TC groups successfully maintained their daily step counts over the 12-month intervention, while the usual care (UC) group saw a significant decrease in activity levels. Specifically, the AT group maintained step counts with a mean reduction of 588 steps, and the TC group with a reduction of 79 steps, compared to a significant drop of 981 steps in the UC group. The findings suggest that ATs can be as effective as TC for maintaining physical activity, providing a potentially cost-effective method to support long-term exercise adherence in older adults.
(Succi et al., 2023)	Research Objective: The purpose of this study is to evaluate the test-retest reliability and examine both mean and individual responses for measuring maximal oxygen consumption (VO2max) in physically active women during a cardiopulmonary exercise test (CPET) and a subsequent verification phase on cycle ergometry.	Research Findings: The study found that the CPET and the verification phase demonstrated "excellent" test-retest reliability for measuring VO2max in healthy, physically active women. It was reported that both had intraclass correlation coefficients (ICCs) above 0.96. No significant difference was observed between the highest VO2max values obtained from the CPET and the verification phase, suggesting that the verification phase may not be necessary for confirming VO2max in this population. Individual analysis showed that only a few subjects exceeded the minimal difference threshold for VO2max between tests, indicating that the use of group mean data alone could misrepresent individual variability. These findings support the potential utility of MD as a criterion for assessing true changes in VO2max across training or interventions.
(Park & Yang, 2023)	Research Objective: The purpose of this study is to examine the different effects between high-intensity interval cardio yoga (HIICY) and traditional interval hatha yoga (TIHY) on cardiometabolic fitness, energetic contributions, and metabolic flexibility in physically active adults.	Research Findings: The study found that after a 4-week intervention, participants in the HIICY group demonstrated significantly improved cardiometabolic fitness. This finding was evidenced by higher increased maximal oxygen uptake (VO2max), better metabolic flexibility, and enhanced energetic contributions compared to the TIHY group. Specifically, HIICY significantly improved oxidative capacity and reduced reliance on glycolytic energy, making it a time-efficient method to improve fitness in relatively healthy individuals.
(Gagnon et al., 2022)	Research Objective: This study assesses the accuracy and reliability of a Fitbit Versa 2 in detecting heart rate (HR) variations caused by psychological stress. The study compared the HR measurements of the Fitbit device to a gold-standard electrocardiogram (ECG) during a controlled laboratory environment. The data were collected by having participants take psychological stress testing using the Trier Social Stress Test.	Research Findings: The results showed that while the Fitbit Versa 2 demonstrated acceptable accuracy in detecting short-term HR variations caused by psychological stress, there was poor agreement with the ECG measurements, particularly during high-stress phases. The Fitbit was more accurate during relaxed conditions but lost accuracy under stressful conditions. These findings indicate that although Fitbit devices can measure HR changes due to stress, they are not a substitute for ECGs in high-precision contexts.
(Khan et al., 2023)	Research Objective: The study aims to investigate how chronotype influences VO2 max performance in university students at different times of the day. Specifically, it examines the VO2 max of chronotypes during morning and evening hours to determine whether the time of day significantly affects cardiovascular endurance.	Research Findings: The findings revealed that morning-type students performed significantly better in the morning, while evening-type students showed better performance in the evening. There was no significant difference in VO2 max between the two chronotypes at the same time of day, but a trend showed that morning types had better VO2 max in the morning, while evening types performed better in the evening. This suggests that endurance training should consider individual chronotypes and optimal times for exercise sessions.
(Kinnunen et al., 2019)	Research Objective: The study examines the validity of wrist-worn accelerometers in estimating daily energy expenditure (TEE) and their ability to detect changes in TEE due to long-term training. It also evaluates whether combining accelerometers with heart rate monitors improves the estimation accuracy for energy expenditure during both aerobic and resistance training.	Research Findings: The results showed that wrist-worn accelerometers alone explained 62%-78% of the variation in TEE compared to the doubly labeled water (DLW) method. However, combining accelerometer data with heart rate monitoring improved the accuracy, explaining up to 85% of the variation. The wearable devices effectively tracked training-induced changes in energy expenditure, confirming their validity for long-term use in physical activity assessments.
(Souissi et al., 2022)	Research Objective: The objective of this study was to investigate the effects of the time of day (TOD) on physical performance and physiological responses during a 10-kilometer self-paced cycling time trial (TT10km).	Research Findings: The study found that participants performed significantly better in the evening, with faster completion times and higher intra-aural temperatures (IAT) compared to the morning. Additionally, physiological markers such as oxygen uptake (VO2), blood lactate concentration ([La]), and glucose levels ([Glu]) were higher in the evening trials. These findings suggest that core temperature and metabolic responses play a key role in the improved cycling performance observed in the evening, confirming the existence of diurnal variation in self-paced endurance exercise.

Discussion

The purpose of this systematic literature review is to investigate the role of digital smart wearable technology in VO2MAX measurement to support athlete performance and public health. As argued earlier, wearable technologies, such as smartwatches and biometric rings, have gained popularity these days and have become important tools in measuring VO2MAX, which is a key indicator of aerobic capacity and cardiovascular health. Helgerud et al. (2022) showed an example of such digital technology called the My Workout GO app. Their study revealed that the app could predict VO2MAX with high accuracy, with a coefficient of determination R^2 of 0.97 and a standard error of estimation of 2.2 mL/kg/min. These results suggest the method used in the app is reliable and applicable to men and women of different age groups (Helgerud et al., 2022). Another example of digital smart wearable technology was provided by Browne et al. (2021). Their study supported the use of biometric rings combined with targeted feedback, where participants using these devices experienced significant improvements in sleep quality, daily step count, jogging time, VO2MAX, and heart rate variability after 12 months (Browne et al., 2021). This confirms that wearable technol-

ogy not only provides accurate data but also serves as a motivating tool for users to improve their overall lifestyle and health.

Expanding on the role of wearable technology in VO2MAX assessment, recent studies highlight two major themes: the benefits of wearable technology in real-time health monitoring and the reliability of traditional VO2MAX measurement methods. First, Juarez et al. (2024) highlighted the importance of wearable technology in providing real-time data on cardiopulmonary health, especially for patients with heart failure conditions. This data allows healthcare professionals to conduct more effective monitoring and provide timely interventions (Juarez et al., 2024). According to Taufik (2023), wearable technology has opened up new opportunities in proactive health management through more comprehensive monitoring. However, while these technologies offer practicality and immediacy, traditional measurement methods remain important due to their reliability. Rasal et al. (2022), for example, found that the six-minute walk test and the Chester step test provided VO2MAX estimates closely aligned with direct measurements, suggesting these methods serve as practical alternatives (Rasal et al., 2022). Similarly, Chung and Lee (2022) confirmed that three traditional exercise tests they evaluated had significant correlations with direct VO2MAX measurements in Korean adults, further validating traditional methods across diverse populations. (Chung & Lee, 2022).

In addition, the ability of wearable devices to provide real-time data offers users an effective tool for monitoring and managing their physical progress. Browne et al. (2021) showed that participants who used biometric rings and received targeted feedback experienced significant improvements in VO2MAX and heart rate variability, suggesting that wearables also serve as powerful motivational tools. Similarly, Juarez et al. (2024) emphasized how real-time data from wearables can improve the effectiveness of health interventions, especially for cardiovascular conditions. However, as Nascimento et al. (2024) noted, cardiopulmonary testing remains the gold standard for assessing cardiovascular health and should be considered along with data from wearable technology for a more comprehensive picture.

Overall, wearable technology has transformed VO2MAX measurement by providing real-time, accurate data and personalized feedback. Existing studies consistently show that the combination of wearable technology and traditional measurement methods provides more comprehensive results in health and fitness monitoring. Therefore, integration between the two is necessary to improve health management and prevent cardiovascular diseases more effectively. As the significance of wearable technology continues to grow, it is essential to explore its multifaceted impact, particularly regarding athlete performance optimization, public health benefits, and the challenges that accompany its use. The following sections will delve into these three critical aspects.

The Role of Wearables in Athlete Performance Optimization

Wearable technology now plays a bigger role in athlete performance, particularly in monitoring VO2MAX and understanding the effects of diurnal variation and chronotype on athlete capabilities. Knaier et al. (2019) identified that diurnal variation in VO2MAX was more significant than daily variation, with diurnal changes being more than double that of fluctuations between days. This finding highlights the importance of timing in determining athletic performance, where individuals may reach peak performance at different times of the day. In addition, they also found that chronotype, i.e., a person's natural preference for morning or evening activities, had a significant impact on the timing of peak VO2MAX performance. Meanwhile, the usual training time did not have a significant effect. Other research (Purnomo et al., 2020) supports these findings, underscoring that understanding chronotype is critical to optimizing the most effective training time.

Furthermore, Khan et al. (2023) emphasized the importance of considering chronotype in exercise planning. They found that morning-type students had better VO2MAX performance in the morning, while evening-type students had better performance in the afternoon. This indicates that tailoring training schedules to an individual's chronotype can improve training effectiveness. Ghurri et al. (2020) also stated that this understanding can be key for coaches in developing more specific and effective training programs. By using wearable technology, coaches can monitor athletes' performance metrics in real time, providing the ability to set training schedules that are tailored to the physiological needs of each athlete.

Another evidence was shown by Souissi et al. (2022). They demonstrated that physical performance in endurance sports, such as the 10-kilometer bike test, was better at night than in the morning. They found that oxygen consumption, blood lactate levels, and body temperature increased during evening training sessions, suggesting that this time is more conducive to optimal performance in endurance sports. Wahyuni et al. (2023) support these findings by adding that training at night may be more beneficial for endurance athletes. The use of wearable technology allows coaches and athletes to monitor these changes and adjust training schedules to better suit the physiological readiness of the athlete at any given time.

Interestingly, wearable technology is not only limited to monitoring performance metrics but also provides personalized feedback, which can improve training results. For example, wearables that measure heart rate variability, sleep patterns, and recovery time can help athletes optimize training loads and recovery strategies. Scholars emphasize that this personalized approach is important because it allows athletes to tailor their training programs based on each individual's unique physiological responses, which can ultimately improve performance and reduce the risk of injury (Irfan & Kasman, 2021). Mubarok and Kharisma (2021)

also noted that data from wearables can aid better communication between athletes and coaches, where coaches can provide immediate feedback and make real-time exercise adjustments. Thus, wearable technology is useful not only in monitoring performance metrics but also in optimizing training time based on physiological variables such as diurnal variation and chronotype. The integration of wearable technology in training allows for a more personalized and adaptive approach, which will ultimately improve training effectiveness and athlete performance outcomes.

The Role of Wearables for Public Health

In addition to affect sports performance, scholars have recognized the significant role of wearable technology in improving public health. One example of the device's effect on health is promoting active lifestyles and monitoring various health parameters. Nayor et al. (2021) showed that increasing physical activity, such as moderate-vigorous physical activity (MVPA) and daily steps, is closely related to improving cardiorespiratory fitness as measured through VO2MAX. Their findings suggest that individuals who increase MVPA or reduce sedentary time experience significant improvements in fitness, which may lower cardiovascular risk. Hong (2023) then asserted that this relationship underscores the potential of wearables in motivating individuals to be more physically active, thus contributing to better health outcomes at the community level. Therefore, wearables can be an important tool in public health strategies to encourage physical activity. In conclusion, wearables can increase physical activity and cardiorespiratory fitness, reducing the risk of cardiovascular disease.

Besides promoting physical activity, wearables are essential in monitoring physiological responses to stress. Studies demonstrated that devices such as Fitbit can effectively detect physiological responses to stress, such as increased heart rate during stressful situations like exams. This capability positions wearables as a non-invasive tool for stress monitoring, which can be integrated into mental and physical health interventions at the community level. (Pakhomov et al., 2020). Furthermore, Robinson et al. (2023) added that by providing real-time data on stress levels, wearables can help individuals manage their stress more effectively, potentially improving mental well-being. Thus, wearables offer a practical solution for stress monitoring and management in everyday life.

Wearable devices were also reported to have a noticeable effect on the elderly. The device significantly helped them maintain stable physical activity levels over a 12-month period (Elkefi & Asan, 2022). Their research suggests that wearables can serve as an effective and cost-effective tool to support long-term physical activity, especially in populations that may be at risk of becoming sedentary (Elkefi & Asan, 2022). Similarly, Brickwood et al. (2021) added that these devices can be an effective tool in supporting long-term physical activity among older adults. This is particularly relevant in an aging population, where maintaining physical activity is crucial for overall health and quality of life. Therefore, wearables have great potential to support the health of older adults through increased physical activity.

In addition, integrating wearable technology into public health initiatives can increase the effectiveness of health promotion strategies. Liverani et al. (2022) stated that the use of wearables can facilitate personalized health interventions by providing customized feedback based on an individual's activity level and health metrics. Furthermore, Hodambia (2023) emphasized that the potential of wearables to collect and analyze large amounts of health data can inform public health policies and interventions. With this data-driven approach, health authorities can identify trends and patterns in physical activity and health outcomes, enabling more targeted and effective public health strategies (Hodambia, 2023). In conclusion, wearables can be an important tool in health data collection to support more effective public health policies and interventions.

Wearable devices are also evidenced to affect chronic disease management by monitoring health conditions and promoting self-management among patients. Studies mentioned that individuals with chronic diseases can use wearables to track vital signs and other health metrics, allowing them to manage their conditions more effectively and communicate relevant information to healthcare providers (Kang & Exworthy, 2022). This continuous monitoring could lead to timely interventions and better health outcomes, ultimately reducing the burden on the healthcare system (Ferguson et al., 2020). Nevertheless, it is important to address potential barriers when adopting wearable technology in public health. Ferguson et al. (2020) also highlighted that factors such as affordability, technological literacy, and privacy concerns may hinder the widespread use of wearables among certain populations. Therefore, public health initiatives should focus on educating communities about the benefits of wearable technology and providing resources to overcome these barriers. Wearables can improve chronic disease management and health equity if these barriers are handled well.

In short, wearable technology holds significant promise for improving public health by promoting active lifestyles, monitoring health parameters, and facilitating chronic disease management (Hodambia, 2023; Liverani et al., 2022).

The integration of wearables in public health strategies can lead to improved health outcomes, increased participation in health promotion behaviors, and better resource allocation. Nevertheless, it is important to ensure that it remains accessible and beneficial to all segments of the population. When this issue can be addressed, wearables have the potential to be a key component in future public health improvement efforts.

Challenges of Wearable Use in VO2MAX

As argued earlier, the use of wearable technology in VO2MAX measurement and health monitoring not only offers many benefits but also poses significant challenges. The

challenges are particularly related to healthcare and performance. For example, Drent et al. (2020) found that sarcoidosis patients using activity tracker (AT) devices experienced significant improvements in exercise capacity and reductions in fatigue, especially when combined with coaching and personalized feedback. However, these results also revealed that the effectiveness of wearables is highly dependent on the ongoing support and training received by users (Drent et al., 2020; Iyakrus et al., 2023). In addition, although the use of the Polar M400 smartwatch in a social theory-based health education intervention on Facebook showed potential, there were technical constraints, such as synchronization issues and the size of the device, that could reduce the effectiveness of the wearable (Pope et al., 2019; Rahadianti, 2019). Furthermore, Gagnon et al. (2022) found that the Fitbit Versa 2 had varying degrees of accuracy in detecting stress-induced heart rate changes, with accuracy decreasing under high-stress conditions (Gagnon et al., 202; Wantonoro et al., 2022). Therefore, although wearables offer various advantages, technical challenges and long-term use still need to be addressed to ensure better integration in users' daily lives. In conclusion, continuous development and support are essential to maximize the benefits of wearables in the context of health.

Given these challenges, the potential for wearable technology to impact public health and disease management remains substantial. Addressing these issues effectively requires both user-centered strategies and technical advancements.The challenges involved are significant in public health and disease management. First, there is a need to improve training and support for wearable users to enable them to make the most of the technology. Agustina and Rafiyah (2023) emphasized the importance of providing adequate education on how to use the devices as well as providing constructive feedback to improve users' skills and understanding. Second, wearable developers should focus on improving the functionality and reliability of the devices, including improvements to technical aspects such as data synchronization, device size, and measurement accuracy (Dewi et al., 2023). In addition, Melyana et al. (2021) suggested that data collected from wearable devices can be used to provide healthcare providers with better insights into patient conditions, assisting in clinical decision-making and the development of more targeted interventions. Finally, further research is needed to explore how wearables can be used in different contexts, including more diverse populations and varying health conditions, to provide new insights into the utilization of this technology in improving overall public health (Paramita et al., 2021). Thus, addressing these challenges through better training, technical device improvement, wider health system integration, and continued research will enable wearables to become more effective tools in improving individual and community health.

Thus, while wearables offer many benefits in VO2MAX measurement and health monitoring, existing challenges must be overcome to ensure that this technology can be used effectively and efficiently. With the right approach, including increased user support, technical improvements, integration with health systems, and continued research, wearables can be an invaluable tool in improving individual and community health.

Conclusion

In conclusion, wearable technology has proven to play an important role in optimizing athlete performance, especially in monitoring VO2MAX, a key indicator of aerobic capacity and cardiovascular health. Wearables provide real-time monitoring of various performance metrics–such as heart rate, heart rate variability, and recovery time, allowing coaches and athletes to customize training based on chronotype and diurnal variations. This personalized approach increases training effectiveness and reduces the risk of injury, making wearables a crucial tool for supporting optimal athlete performance. In addition, wearables also make a significant contribution to public health by promoting active lifestyles and monitoring various health parameters. Wearables facilitate physical activity monitoring, such as daily step count and moderate to vigorous physical activity (MVPA) levels, and provide feedback on physiological responses to stress. In elderly populations and individuals with chronic diseases, wearables have proven effective in supporting long-term health monitoring and self-management of health conditions. Thus, wearable technology has great potential to be used as a strategic tool in public health promotion and quality of life improvement. However, the use of wearables in VO2MAX measurement and health monitoring still faces a number of challenges, mainly related to technical aspects such as measurement accuracy and data synchronization issues. In addition, better education for users on how to effectively utilize wearables is needed. Continuous support and training, technical improvements, and better integration with the health system will be essential to ensure the effectiveness of this technology. The implication is that wearables have great potential to improve athlete performance and public health. However, further development and improved support for users are required for wearables to be optimally utilized in various contexts, including in VO2MAX monitoring and more comprehensive health management.

Conflicts of interest

The authors declare no conflicts of interest.

References

Adirahma, A. S., Widiyanto, W. E., Setyawan, H., Hamsyah, K., Darmawan, A., Nurkadri, N., Novita, N., Safrudin, S., HB, G., Harmanto, H., Pranoto, N. W., & Pavlovic, R. (2024). Badminton training management strategy with circuit training method to improve athlete performance among students. *Retos*, *61*, 108–120.

https://doi.org/10.47197/retos.v61.109067

Akhmad, I., Heri, Z., Hariadi, H., Nurkadri, N., Novita, N., Ali, S. K. S., Mohamed, M. F., Ismail, W. M., Balakrishnan, V. A., Gontara, S. Y., & Setyawan, H. (2024). Physical activity levels among Malaysian University and State University of Medan Students: gender difference and the influence of BMI. *Retos*, *60*(SE-Artículos de carácter científico: trabajos de investigaciones básicas y/o aplicadas), 429–438. https://doi.org/10.47197/retos.v60.109190

Anam, K., Setiowati, A., Nurrachmad, L., Indardi, N., Azmi, D. A. N., Aditia, E. A., Irawan, F. A., Susanto, N., Latino, F., Tafuri, F., Pavlović, R., Setyawan, H., & Kozina, Z. (2024). Injury Risk Analysis of Soccer Academy Students: A Review of Functional Movement Screen Scores and Demographic Data. *Retos*, *55*, 900–907. https://doi.org/10.47197/retos.v55.105955

Ardiyanto, S. Y., HB, G., Nurkadri, N., Novita, N., Bahriyanto, A., Setyawan, H., Putro, B. N., Harmanto, H., Darmawan, A., Latino, F., & Tafuri, F. (2024). Legal and social perspectives on the phenomena of supporter violence in sport. *Retos*, *60*(SE-Revisiones teóricas sistemáticas y/o metaanálisis), 232–241. https://doi.org/10.47197/retos.v60.108804

Astuti, Y., Orhan, B. E., Setyawan, H., Karacam, A., & Susanto, N. (2024). Exploring the Connection between Physical and Mental Health in Women and Dog Ownership. *Retos*, *58*, 190–204. https://doi.org/10.47197/retos.v58.106626

Charlina, C., Roziah, R., Ismail, S., Piliang, W. S. H., Siswanto, S., Setyawan, H., Zulbahri, Z., Darmawan, A., Shidiq, A. A. P., Eken, Ö., Pavlovic, R., Latino, F., & Tafuri, F. (2024). Effective Verbal Communication in Physical Education Learning and Sports Coaching to Improve Achievement and Health: A Systematic Review. *Retos*, *56*(SE-Revisiones teóricas, sistemáticas y/o metaanálisis), 1139–1147. https://doi.org/10.47197/retos.v56.107308

Destriani, D., Yusfi, H., Destriana, D., Setyawan, H., García-Jiménez, J. V., Latino, F., Tafuri, F., Wijanarko, T., Kurniawan, A. W., Anam, K., Shidiq, A. A. P., Rahmatullah, M. I., & Eken, Ö. (2024). Results of Beginner Archery Skills Among Adolescents Based on Gender Review and Shot Distance. *Retos*, *56*, 887–894. https://doi.org/10.47197/retos.v56.106629

Fahrosi, A. T., Anam, K., Setiowati, A., Sugiarto, S., Susanto, N., Wijanarko, T., Setyawan, H., Fitriady, G., Eken, Ö., Kozina, Z., Latino, F., Tafuri, F., & Vicente García-Jiménez, J. (2024). Analysis of injury risk levels in young footballers: A review of functional movement screens and static balance scores. *Retos*, *58*. https://doi.org/10.47197/retos.v58.107683

Hamsyah, K., Nopembri, S., Komari, A., Setyawan, H., Hermawan, H. A., Eken, Ö., Sugiyanto, S., Shidiq, A. A. P., Pavlovic, R., Latino, F., Tafuri, F., Pranoto, N. W., & Rahmatullah, M. I. (2024). Implementation of Archery Class Management at the Pre-Extracurricular Program Stage To Increase Elementary School Students' Interest. *Retos*, *55*, 849–856. https://doi.org/10.47197/retos.v55.105258

Harmanto, H., Setyawan, H., Umar, F., Safrudin, S., Bahriyanto, A., Yeni, M., Ginting, A., Novita, N., Nurkadri, N., Kurniawan, A. W., HB, G., Pranoto, N. W., & Pavlovic, R. (2024). Integrating citizenship education into secondary school physical education lessons in Indonesia: an approach to reducing character degradation. *Retos*, *60*, 865–876. https://doi.org/10.47197/retos.v60.108758

HB, G., Ardiyanto, S. Y., Nurkadri, N., Novita, N., Widiyanto, W. E., Setyawan, H., Putro, B. N., Harmanto, H., Darmawan, A., & Radulovic, N. (2024). Ensuring fairness and transparency in sports through compliance to legal principles and ethical standards. *Retos*, *60*, 204–216. https://doi.org/10.47197/retos.v60.108935

HB, G., Ardiyanto, S. Y., Setyawan, H., Putro, B. N., Kurniawan, A. W., Zulbahri, Z., Gerdijan, N., Eken, Ö., Latino, F., & Tafuri, F. (2024). Legal Review of Bullying Cases against Students with Disabilities in Physical Education Learning at Schools: A Systematic Review. *Retos*, *57*, 840–848. https://doi.org/10.47197/retos.v57.107448

Komari, A., Setyawan, H., Kriswanto, E. S., Sujarwo, S., García-Jiménez, J. V., Pavlovic, R., Nowak, A. M., Susanto, N., Kurniawan, A. W., Gusliana HB, G. H. B., Shidiq, A. A. P., Putra, A. M. I., & Roziah, R. (2024). The Effect of Physical Education (PE) Class Management Using Badminton Materials to Improve Elementary School (ES) Students' Concentration. *Retos*, *55*, 520–526. https://doi.org/10.47197/retos.v56.104609

Komari, A., Yuliarto, H., Solikhin, M. N., Sadewa, Y. R., & Setyawan, H. (2024). Differences in the Implementation of Physical Education (PE) planning Containing 21st-century Skills Based on Period of Work and Gender. *Retos*, *57*, 697–706. https://doi.org/10.47197/retos.v57.105895

Kurniawan, A. W., Wiguno, L. T. H., Mu'arifin, M., Setyawan, H., Shidiq, A. A. P., García-Jiménez, J. V., Eken, Ö., Latino, F., Tafuri, F., Pranoto, N. W., Rahmatullah, M. I., & Anam, K. (2024). I-Spring Assisted Development of a Basketball Shooting Technique Program. *Retos*, *55*, 874–881. https://doi.org/10.47197/retos.v55.105437

Latino, F., Martinez-Roig, R., Setyawan, H., Susanto, N., Anam, K., Saraiello, E., & Tafuri, F. (2024). Physiological Responses of Wheelchair Basketball Athletes to a Combined Aerobic and Anaerobic Training Program. *Retos*, *57*, 800–808. https://doi.org/10.47197/retos.v57.107483

Latino, F., Martinez-Roig, R., Susanto, N., Setyawan, H., Anam, K., Saraiello, E., Tafuri, D., & Tafuri, F. (2024). Endurance Training and Physiological

Variables: Effects on sub-elite Volleyball Players. *Retos*, *58*, 522–527. https://doi.org/10.47197/retos.v58.107636

Latino, F., Martinez-Roig, R., Susanto, N., Setyawan, H., Anam, K., Saraiello, E., & Tafuri, F. (2024). High-Intensity Interval Training and Physiological Demands in Wheelchair Tennis Players: A Pilot Study. *Retos*, *58*, 238–246. https://doi.org/10.47197/retos.v58.107485

Latino, F., Susanto, N., Anam, K., Setyawan, H., Saraiello, E., & Tafuri, F. (2024). The effects of circuit training versus high-intensity interval training on the endurance of volleyball athletes: a randomized controlled trial. *Retos*, *58*, 1050–1060. https://doi.org/10.47197/retos.v58.107877

Mardiyah, S. U. K., Setyawan, H., García-Jiménez, J. V., Eken, Ö., Latino, F., Pranoto, N. W., Darmawan, A., Shidiq, A. A. P., Rahmatullah, M. I., Tafuri, F., & Anam, K. (2024). Differences in the Implementation of Physical Education (PE) Learning Management Based on Years of Work: Analysis of Differences in the Quality of Quality Assurance Culture. *Retos*, *55*, 797–803. https://doi.org/10.47197/retos.v55.104865

Mardiyah, S. U. K., Setyawan, H., Pavlovic, R., Darmawan, A., Susanto, N., & Kozina, Z. (2024). Management for Strengthening Literacy Learning Culture Physical Education in Secondary Schools in Indonesia. *Sportske Nauke i Zdravlje*, *14*(5), 81–91. https://doi.org/10.7251/SSH24V081M

Martono, M., Suherman, W. S., Nugroho, S., Setyawan, H., Sulistiyono, S., Pambudi, D. K., Puri, L. W., Septiantoko, R., Hermawan, Y., García-Jiménez, J. V., Pavlovic, R., Eken, Ö., Pranoto, N. W., Darmawan, A., Shidiq, A. A. P., & Rahmatullah, M. I. (2024). Achievement of Physical Education Learning Results Based on Gender Review and Learning Motivation on High School Students in the Yogyakarta Region, Indonesia. *Retos*, *55*, 1045–1052. https://doi.org/10.47197/retos.v55.106831

Mulyanti, C., Prasetyo, Y., Sumarjo, S., Setyawan, H., Kurniawan, A. W., Shidiq, A. A. P., Eken, Ö., Pavlovic, R., Latino, F., Tafuri, F., Wijanarko, T., Rahmatullah, M. I., & Anam, K. (2024). Differences in Archery Skill Results for Vocational School Students and Beginners Based on Shooting Distance. *Retos*, *55*, 957–962. https://doi.org/10.47197/retos.v55.106081

Pranoto, N. W., Fauziah, V., Anugrah, S., Fitriady, G., Setyawan, H., Geantă, V. A., Sibomana, A., & Ndayisenga, J. (2024). The effectiveness of diet and exercise in the management of obesity. *Retos*, *58*, 951–959. https://doi.org/10.47197/retos.v58.105295

Pranoto, N. W., Fauziah, V., Muchlis, A. F., Komaini, A., Rayendra, R., Susanto, N., Fitriady, G., Setyawan, H., Pavlovic, R., Sibomana, A., & Nadyisenga, J. (2024). in motor skills of s Exploration of Children's Motor Skills with Stunting Vs. Non-Stunting. *Retos*, *54*, 224–234. https://doi.org/10.47197/retos.v54.103107

Putro, B. N., Nurkadri, N., Sahabuddin, S., Laksana, A. A. N. P., Setyawan, H., HB, G., Harmanto, H., Darmawan, A., Tafuri, F., & Latino, F. (2024). Examining physical education learning outcomes of senior high school students: the impact of gender and learning frequency. *Retos*, *60*(SE-Artículos de carácter científico: trabajos de investigaciones básicas y/o aplicadas), 393–404. https://doi.org/10.47197/retos.v60.109042

Sayekti, O. M., Efendi, A., Sujarwo, S., Setyawan, H., Sunaryo, H., Sahabuddin, S., Safrudin, S., Ardiyanto, S. Y., Harmanto, H., Putro, B. N., Susanto, S., Zulbahri, Z., & Pavlovic, R. (2024). Analyzing the role of motor skill training on critical reading ability in elementary school students: a systematic literature review. *Retos*, *61*, 1101–1115. https://doi.org/10.47197/retos.v61.109633

Septiantoko, R., Murdiono, M., Saliman, S., Setyawan, H., García-Jiménez, J. V., Latino, F., Tafuri, F., Pranoto, N. W., Kurniawan, A. W., Anam, K., Shidiq, A. A. P., Rahmatullah, M. I., & Eken, Ö. (2024). Differences in Achievement in Physical Education Learning Outcomes for High School Students Based on Parental Occupation: Analysis of Differences in Parental Social Status in Providing Learning Motivation. *Retos*, *55*, 882–888. https://doi.org/10.47197/retos.v55.105980

Setyawan, H., Alim, A. M., Listyarini, A. E., Suri, P. T., Mahsusi, J., Rahmatullah, M. I., Sugiarto, T., Shidiq, A. A. P., Kozina, Z., Eken, Ö., Latino, F., Tafuri, F., & Pranoto, N. W. (2024). Implementation of Archery Class Management at the Pre-Extracurricular Program Stage To Improve Archery Skills of Elementary School Students. *Retos*, *55*, 867–873. https://doi.org/10.47197/retos.v55.105275

Setyawan, H., Suyanto, S., Ngatman, N., Purwanto, S., Suyato, S., Darmawan, A., Shidiq, A. A. P., Eken, Ö., Pavlovic, R., Latino, F., Tafuri, F., Wijanarko, T., Ermawati. S, E. S., & Gusliana HB, G. H. (2024). The Effect Of Implementing Physical Education Class Management Archery Material To Improve Concentration Elementary School Students. *Retos*, *56*, 879–886. https://doi.org/10.47197/retos.v56.105216

Setyawan, H., Suyanto, S., Suharjana, S., Prasetyo, Y., Wayoi, D. S., Hardianto, H., Susanto, N., Gani, I., & Rithaudin, A. (2023). Archery sport class management using demonstration methods to improve results learn beginner archery skills. *Fizjoterapia Polska*, *23*(4), 208–218. https://doi.org/10.56984/8ZG20A80C

Setyawan, H., Suyanto, Suharjana, Sumaryanto, Prasetyo, Y., Wayoi, D. S., Hardianto, Susanto, N., Gani, I., Komari, A., & Mardiyah, S. U. K. (2023). The effect of archery class management implementation using the 3-step focus technique for beginners. *Journal of Physical Education and Sport*, *23*(9), 2503–2512. https://doi.org/10.7752/jpes.2023.09288

Susanto, N., Dinata, W. W., Ihsan, N., Bahtra, R., Andria, Y., Pranoto, N. W., Anam, K., Sofyan, D., Lourenço, C. C. V, Burhaein, E., García-Jiménez, J. V, & Setyawan, H. (2023). Instrument for Assessing Basketball Skills in Junior High School Students in Indonesia. *Journal of Physical Education and Sport*, *23*(12), 3220–3227. https://doi.org/10.7752/jpes.2023.12368

Susanto, N., García-Jiménez, J. V., Nowak, A. M., Setyawan, H., Pavlovic, R., Rusdiawan, A., & Syaukani, A. A. (2024). Development Assessment Model for Talent Identification of Young Indonesian Basketball Players: Anthropometrics, Biomotor, Technical, and Tactical Skills. *International Journal of Human Movement and Sports Sciences*, *12*(4), 625–635. https://doi.org/10.13189/saj.2024.120403

Susanto, N., Setyawan, H., Fitriady, G., Anam, K., Jiménez, J. V. G., Latino, F., Tafuri, F., Eken, Ö., Taufik, M. S., Bahtra, R., Rifki, M. S., Hafidz, A., Pratama, R. S., & Purwoto, S. P. (2024a). Adaptive physical education learning: evaluation by teachers of deaf students at special elementary schools. *Human Movement*, *25*(3), 121–128. https://doi.org/10.5114/hm/192889

Susanto, N., Setyawan, H., Fitriady, G., Anam, K., Jiménez, J. V. G., Latino, F., Tafuri, F., Eken, Ö., Taufik, M. S., Bahtra, R., Rifki, M. S., Hafidz, A., Pratama, R. S., & Purwoto, S. P. (2024b). Adaptive physical education learning: evaluation by teachers of deaf students at special elementary schools. *Human Movement*, *25*(3), 121–128. https://doi.org/10.5114/hm/192889

Susanto, S., Setyawan, H., Susanto, N., García-Jiménez, J. V., Latino, F., Tafuri, F., & Eken, Ö. (2024). The Influence Of Modified One-Hole Game Media In Improving Fine Motor Skills In Early Childhood. *Sports Science and Health*, *14*(5), 151. https://doi.org/http://dx.doi.org/10.7251/SSH24V151S

Susanto, Setyawan, H., García-Jiménez, J. V., Pavlovic, R., Nowak, A. M., & Susanto, N. (2024). Analysis of One-Hole Game Tools in Developing Fine Motor Skills in Early Childhood. *Sportske Nauke i Zdravlje*, *14*(5), 135–139. https://doi.org/10.7251/SSH24V135S

Suyato, S., Setyawan, H., Sukarti, S. E. E., Shidiq, A. A. P., Darmawan, A., HB, G., Zulbahri, Z., Eken, Ö., Pavlovic, R., Latino, F., & Tafuri, F. (2024). The Integration of Social values in Physical Education and Sport to Develop Teenage Students' Character: a Systematic Review. *Retos*, *58*, 960–968. https://doi.org/10.47197/retos.v58.107763

Syaukani, A. A., Jariono, G., Susanto, N., & Setyawan, H. (2024). Perception on health and exercise among indonesian older adults: a sequential exploratory study in javanese rural communities. *Retos*, *59*, 156–164. https://doi.org/10.47197/retos.v59.107148

Tafuri, F., Martinez-Roig, R., Anam, K., Susanto, N., Setyawan, H., Saraiello, E., & Latino, F. (2024). Effects of a circuit training program in improving cardiorespiratory fitness, upper extremity strength, and agility in paraplegic subjects. *Retos*, *58*, 552–559. https://doi.org/10.47197/retos.v58.107488

Tafuri, F., Martinez-Roig, R., Setyawan, H., Susanto, N., Anam, K., Saraiello, E., Avino, U., & Latino, F. (2024). Circuit training improves physiological conditions among wheelchair basket players. *Retos*, *58*, 138–146. https://doi.org/10.47197/retos.v58.107484

Tafuri, F., Martinez-Roig, R., Susanto, N., Setyawan, H., & Latino, F. (2024). Physically Active Lifestyles within the School context: Morpho-Physiological and Functional Aspects. *Retos*, *58*, 48–60. https://doi.org/10.47197/retos.v58.106154

Wayoi, D. S., Setyawan, H., Suyanto, S., Prasetyo, Y., Lastiono, S. T., Nurkadri, N., Putro, B. N., Harmanto, H., Darmawan, A., HB, G., & Eken, Ö. (2024). Implementing management of the physical fitness education program for the drug rehabilitation patients in drug addict therapy centre. *Retos*, *60*, 309–319. https://doi.org/10.47197/retos.v60.104433

Widiyanto, Setyawan, H., Suharjana, García-Jiménez, J. V., Pavlovic, R., Nowak, A. M., & Shahri, M. I. Bin. (2024). The differences of learning outcomes in students archery skill according to physiological ability. *Jurnal Cakrawala Pendidikan*, *43*(2). https://doi.org/10.21831/cp.v43i2.63268

Widiyanto, W., Setyawan, H., Suharjana, S., Purwanto, S., Indra, E. N., Prayudho, S., García-Jiménez, J. V., Pavlovic, R., Nowak, A. M., Susanto, N., Darmawan, A., Purnomo Shidiq, A. A., & Andriansyah, A. (2024). The Differences Result in Serve Skill of Junior Tennis Players Assessed Based on Gender and Age. *Retos*, *54*, 272–278. https://doi.org/10.47197/retos.v54.102757

Widiyanto, W., Setyawan, H., Suharjana, S., Purwanto, S., Indra, E. N., Sujarwo, S., Prayudho, S., García-Jiménez, J. V., Pavlovic, R., Eken, Ö., Purwanto, S., Darmawan, A., Shidiq, A. A. P., Rahmatullah, M. I., & Wali, C. N. (2024). Fitness Levels of Elementary School Students Based on Gender and Race in Indonesia: Are There Differences? *Retos*, *55*, 963–968. https://doi.org/10.47197/retos.v55.105679

Yani, A., Henjilito, R., Noviardila, I., Hasan, B., Setyawan, H., Shidiq, A. A. P., Gerdijan, N., Latino, F., Eken, Ö., Zulbahri, Z., Kurniawan, A. W., & HB, G. (2024). The Role of School Supervisors in the Quality Assurance of Physical Education Learning: A Systematic Review. *Retos*, *57*, 589–597. https://doi.org/10.47197/retos.v57.107189

Zanada, J. F., Setyawan, H., Susanto, N., Bahtra, R., Wijanarko, T., Anam, K., Fitriady, G., García-Jiménez, J. V., Pavlovic, R., & Nowak, A. M. (2024). Reducing Dysmenorrhea In School-Aged Teenagers By Practising Yoga: A Literature Review. *Retos*, *54*, 76–83.

https://doi.org/10.47197/retos.v54.103066

Zulbahri, Z., Putra, A. N., Syampurma, H., Wulandari, I., Lawanis, H., Sari, D. N., Sasmitha, W., Nurrochmah, S., Nurkadri, N., Putro, B. N., HB, G., Harmanto, H., Eken, Ö., Pavlovic, R., & Tafuri, F. (2024). Physical education learning outcomes of senior high school students based on gender and intellectual intelligence review. *Retos*, *60*, 362–369. https://doi.org/10.47197/retos.v60.108990

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