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The effects of circuit training versus high-intensity interval training on the endurance of volleyball athletes: a randomized controlled trial

Los efectos del entrenamiento en circuito frente al entrenamiento en intervalos de alta intensidad en la resistencia de los atletas de voleibol: un ensayo controlado aleatorio

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Abstract. Despite its intermittent nature, volleyball places significance on a high aerobic capacity, particularly evident in multiset games that demand sustained high-performance levels. Various training approaches exist to enhance the endurance of volleyball athletes. Thus, the fundamental aim of this research is to examine the contrasting effects of utilizing high-intensity interval training (HIIT) and circuit training methods to enhance volleyball athletes' endurance. The study used an Experimental group that partook in a HIIT training regime, and a Contrast group that undertook a Circuit training program. Thirty male volleyball players aged between 17 and 22 years (M=19.14; SD±1.61) were purposefully selected for the study and split into Contrast and Experimental groups of 15 each. At the beginning and end of the intervention programs both groups underwent physiological assessments for Maximum Oxygen Consumption (VO_2max), Heart Rate Recovery (HRR), Peak Inspiratory Flow (PIF), Peak Expiratory Flow (PEF), and Force Vital Capacity (FVC). As result a meaningful Time x Group interaction for the VO_2max, HRR, PIF, PEF and FVC was observed. This represents a significant improvement in the treatment group ($p < 0.001$). No material change was observed in the comparison group. Findings revealed that the HIIT training approach outperformed the circuit training method in enhancing volleyball athletes' endurance. Consequently, it is should be beneficial for volleyball players to incorporate HIIT into their standard training regimens.
Keywords: VO_2max; physiology; sport; exercise; aerobic capacity.

Resumen. A pesar de su naturaleza intermitente, el voleibol otorga importancia a una alta capacidad aeróbica, particularmente evidente en juegos de múltiples sets que exigen niveles sostenidos de alto rendimiento. Existen varios enfoques de entrenamiento para mejorar la resistencia de los atletas de voleibol. Por lo tanto, el objetivo fundamental de esta investigación es examinar los efectos contrastantes de la utilización de métodos de entrenamiento en intervalos de alta intensidad (HIIT) y entrenamiento en circuito para mejorar la resistencia de los atletas de voleibol. El estudio utilizó un grupo experimental que participó en un régimen de entrenamiento HIIT y un grupo de contraste que realizó un programa de entrenamiento en circuito. Treinta jugadores de voleibol masculino con edades comprendidas entre los 17 y los 22 años (M=19,14; DS±1,61) para el estudio y se dividieron en grupos de contraste y experimentales de 15 cada uno. Al inicio y al final de los programas de intervención, ambos grupos se sometieron a evaluaciones fisiológicas para el Consumo Máximo de Oxígeno (VO_2max), la Recuperación de la Frecuencia Cardíaca (HRR), el Flujo Inspiratorio Máximo (PIF), el Flujo Espiratorio Máximo (PEF) y la Capacidad Vital de Fuerza (FVC). Como resultado, se observó una interacción significativa de Tiempo x Grupo para el VO2max, HRR, PIF, PEF y FVC. Esto representa una mejoría significativa en el grupo de tratamiento ($p < 0,001$). No se observaron cambios sustanciales en el grupo de comparación. Los hallazgos revelaron que el enfoque de entrenamiento HIIT superó al método de entrenamiento en circuito para mejorar la resistencia de los atletas de voleibol. En consecuencia, debería ser beneficioso para los jugadores de voleibol incorporar HIIT en sus regímenes de entrenamiento estándar.
Palabras clave: VO_2max; fisiología; deporte; ejercicio, capacidad aeróbica.

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Introduction

Volleyball has been characterized as a sport that involves intervals, encompassing both anaerobic and aerobic aspects (Amat, Ortega, Olmedo, & Gasch, 2020; Latino et al., 2021). Aerobic endurance denotes the utilization of oxygen as the principal energy source. Aerobic endurance, also known as aerobic fitness, relates to physical activities requiring the use of oxygen for prolonged periods (Vidarte Claros et al., 2019). Activities like long-distance running, cycling, and a number of other sports fall under this category (Biçer, 2021; Tafuri, & Latino, 2024). Conversely, anaerobic endurance pertains to the capacity to engage in physical activities without oxygen. The body can sustain a certain level of intensity for a brief period without oxygen. Nevertheless, anaerobic endurance can be enhanced through training to fulfill the metabolic needs of different high-intensity sports (Kızılet, 2021). Therefore, maintaining a high aerobic capacity holds significant importance, particularly in multiset games where sustained high performance is necessary (Halouani et al., 2023). Volleyball athletes are tasked with generating maximal or near-maximal efforts repeatedly, such as in blocking and spiking, interspersed with short recovery periods consisting of low to moderate-intensity activities, throughout an extended duration of approximately 90 minutes (Shalaby & Fadl, 2020). While anaerobic capacity remains a crucial element in volleyball, a heightened aerobic capacity can enhance recovery rates during gameplay, as well as the ability to endure the intensity and duration of a match. Hence, enhancing the fitness levels of volleyball players through training represents a multifaceted process that involves augmenting both aerobic and anaerobic capacities (Gielen, Mehuys, Berckmans, Meeusen, & Aerts, 2022). Indeed, volleyball participants typically operate at 85-90%

of their maximum heart rate (HRmax) (Karçeşme et al., 2022) and 75% of their maximum oxygen consumption (VO_2max) (Issa, 2022). Consequently, possessing a high level of endurance is imperative for all volleyball athletes.

In order to achieve high athletic performance that allows volleyball player to generate maximal or submaximal efforts during competitions, there are several training techniques that can be utilized. Among them, the most widely used ones include interval training, high-intensity interval training (HIIT), fartlek, tabata, and circuit training. The present research will specifically concentrate on analyzing the HIIT methodology and the circuit training approach. High-Intensity Interval Training aims to enhance both aerobic and anaerobic systems (Mcweeny, Boule, Neto, & Kennedy, 2020). HIIT is widely accepted as a powerful exercise approach, renowned for its ability to greatly boost cardiovascular endurance and promote overall strength (Saravanan, & Pushpa, 2021). Fundamentally, HIIT relies on the alternating pattern of short, intense exercise intervals with brief periods of rest or low-intensity activity (Yue, & Hong, 2023). This harmonious blend of rigorous training and strategic recovery phases positions HIIT as an exceptional option for individuals seeking a highly effective and impactful workout (Wu, 2023).

On the contrary, circuit training is a training modality that integrates a sequence of individual exercises executed consecutively and without interruption within a single round or circuit (Irfan, Yasriuddin, Hudain, & Martono, 2023). Circuit training represents a form of physical activity designed to optimize time effectiveness while simultaneously eliciting greater and swifter physiological responses (Parasuraman, 2020). This methodology serves as the concluding segment of the complete set of exercises outlined in the programme. Upon completion of one circuit, the athlete will either recommence the initial exercise or progress to the subsequent circuit. Historically, the rest intervals between exercises are brief, typically involving swift transitions to the subsequent station. Circuit training stands out as the most efficient approach for enhancing flexibility, muscular strength, and endurance. The circuit training protocol mirrors the concept of stations, with each station featuring a specific exercise that every athlete must execute. Studies conducted by Mayorga-Vega, Viciana, & Cocca (2013) demonstrate the efficacy of circuit training programs in enhancing and sustaining muscular and cardiovascular endurance in school-aged children. In recent years, circuit training has gained widespread popularity as a prevalent form of physical exercise (Hakim, Ishak, & Bismar, 2023).

Despite the substantial growth and extensive adoption of both HIIT and circuit training methodologies across different nations previous research, focusing on their effects on enhancing cardiovascular endurance in athletes (Liu, & Li, 2024), has not produced statistically significant findings (Andrade et al., 2020). Furthermore, there is a paucity of research that has undertaken a comparative evaluation of these two training modalities concerning their effectiveness in augmenting the endurance capacities of volleyball players (Vaccari et al., 2020). Prior literature suggests that HIIT training holds promise in enhancing endurance (Stankovic, Djordjevic, Trajkovic, & Milanovic, 2023; Trisaptono, & Sumintarsih, 2020). Similarly, various studies have indicated that the utilization of circuit training can result in endurance improvements (Beqa Ahmeti, Idrizovic, Elezi, Zenic, & Ostojic, 2020; Corvino et al., 2020; Vadivel, & Maniazhagu, 2022). Therefore, drawing upon the background and analysis of the issue, the present study sought to investigate which of the two methodologies is more effective in improving the endurance levels of volleyball players, examining their divergent effects on performance reinforcement.

Materials and Methods

This research employed a randomized controlled design to examine the effects of incorporating the HIIT training approach and the circuit training technique on improving the endurance capacity of volleyball players. The study lasted for 16 weeks, during which the participants were assigned randomly to either the experimental group or the contrast group. After the random assignment, the researchers evaluated the initial similarity between the groups, utilizing double blinding to guarantee that both the participants and the evaluators were unaware of the group assignment. The experimental group followed a HIIT training regimen, while the contrast group participated in circuit training. Throughout the 16-week period, both groups engaged in their specific workout routines three times weekly, with assessments carried out before and after the training sessions.

As for the randomization protocol, the simple randomization method through the random number table was used. An electronic tool for generating numerical sequences was used for this purpose. Subsequently, it was established as an allocation rule that subjects corresponding to "even" digits would fall into the experimental group (EG), while all those corresponding to "odd" digits would fall into the control group (CG).

Participants

By utilizing G*Power (version 3.1.9.6), a priori power analysis was conducted, revealing that a sample size of 15 would yield sufficient statistical power (α=0.05, 1-β= 0.80) for detecting a moderate effect size (f= 0.25 or 0.4) with a correlation coefficient of p=0.80, a 95% power level, and α=0.05, employing a within-between mixed design. To mitigate experimental attrition resulting from participant dropout, 32 individuals were recruited. Out of the 34 individuals recruited, 1 was eliminated due to incomplete tests, 1 due to missing all assessments, and 2 for not meeting inclusion criteria. Consequently, the final sample comprised 30 male volleyball athletes with their ages falling between 17 to 22 years (M=19.14; SD±1.61). To qualify for inclusion, candidates needed to possess: (i) a minimum of three years of involvement in competitive play at the National level; (ii) being between 17 and 22 years old at enrollment; (iii) absence of cardiovascular, neuromuscular, orthopedic, or neurologic conditions; (iv) capability to adhere to measurement instructions. Exclusion criteria included: (i) presence of artificial prostheses; (ii) manifestation of symptoms warranting exclusion as determined by a medical professional; (iii) interference of any (medical) event with testing outcomes leading to participant exclusion. Conversely individuals with a medical history of cardiorespiratory ailments or lower extremity musculoskeletal traumas within the preceding three months were deemed ineligible for participation in the investigation. The flowchart of the study can be observed in Figure 1.

A detailed overview of the study's objectives was provided to all participants and contrasts, elucidating the specific research procedures. Following this, written consent was procured from all participants. The researchers ensured the protection of confidentiality for all individuals involved in the study. The investigation was carried out from February 2024 to May 2024, in accordance with the guidelines set forth in the Helsinki Declaration and its subsequent amendments. The study protocol was reviewed and approved by the Department of Medical Science, Exercise and Wellbeing – University of Naples "Parthenope" (DiSMMeB Prot. N. 88592/2024).

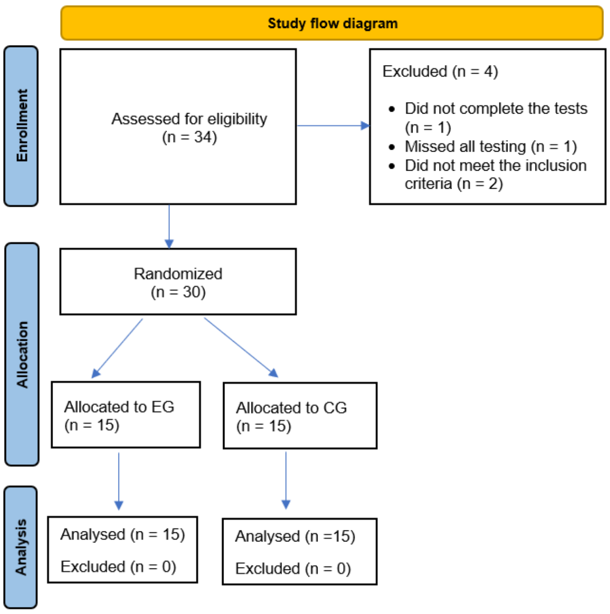

Figure 1. Study flow diagram.

Procedures

Participants were instructed to maintain their usual sleep patterns and avoid engaging in vigorous physical activities 48 hours before the beginning of data collection (COCIS, 2023; Monteiro et al., 2019). All assessments were conducted during two separate sessions. Initially, individuals were required to fill out a questionnaire detailing demographic information such as age, gender, medical background, smoking behavior, and other relevant traits. Subsequently, athletes underwent the Multistage Fitness Test and spirometry to assess their aerobic capacity pre- and post-intervention. The next day, participants completed the Queen's College step test, with Heart Rate Recovery measurements taken. Subjects involved in the research received customized evaluations, with each assessment following a consistent sequence, occurring at the same daily time, and in similar experimental conditions. The entire evaluation procedure and physical exercise regimens were monitored, specified, and supervised by two proficient fitness experts.

Data collection

Physiological Performance

The Multistage Fitness Test (MSFT) was created by Léger, Mercier, Gadoury, and Lambert in 1988 for the assessment of maximal oxygen uptake (VO_2max). It is a valid and high reliable test (ICC=0.96) for predicting VO_2 max in children, adolescents, and adults (Cuenca-Garcia et al., 2022). This test was developed with the aim of examining peak oxygen consumption in various age categories, ranging from children to adults. Its primary objective was to offer a feasible and cost-effective estimation of maximal oxygen consumption within a real-life environment. Research studies have shown that the MSFT serves as a reliable measure of maximal oxygen uptake (Cooper et al., 2005; Goosey-Tolfrey, & Tolfrey, 2008). Throughout the MSFT, participants were instructed to shuttle run to and between 20-meter intervals upon hearing an auditory signal (beep). The starting velocity was established at 8.5 km/hr, with increments of 0.5 km/hr every minute. Each participant was required to complete a stage before the subsequent beep, endeavoring to maximize the number of shuttles completed. Inability to sustain the specified pace for two consecutive shuttles or premature termination of the test due to fatigue resulted in discontinuation. The equation developed by Flouris et al. (2005) was utilized for the computation of maximal oxygen uptake.

Heart Rate Recovery (HRR) denotes an assessment of the cardiac system's capacity to revert to its baseline resting rhythm subsequent to the cessation of physical exertion. This metric represents the disparity between the maximum heart rate reached during exercise and the heart rate registered shortly after cessation. The quantification of HRR is typically expressed in beats per minute (bpm). Following the completion of the Queen's College step test, HRR was computed as delineated in the study by Castro-Piñero (2021). The experimental procedure involved the utilization of bench stepping as a sub-maximal exercise modality specifically tailored for male participants in accordance with the established protocol. Prior to the start of the test, individuals were instructed to engage in a preparatory phase consisting of 5 to 7 minutes dedicated to warming up, comprising exercises targeting lower limb flexibility and brisk walking (COCIS, 2023). A standard wooden bench with a height of 16.25 inches was designated for the execution of the test protocol. The temporal aspects of the test were meticulously monitored using a stopwatch. Furthermore, a Metronome was employed to ensure a consistent stepping cadence set at 96 beats per minute, corresponding to 24 complete steps for male subjects. Following a concise demonstration, all participants performed the step test continuously for a duration of three minutes. Upon the conclusion of the test protocol, subjects remained in a standing position, and their carotid pulse rate was assessed precisely 60 seconds post-exercise, using the Pulse-pen device (Diatecne, Milan, Italy). It is a reliable and easy to use device for evaluate, among the other, the heart rate (ICC=0.98) (Rinderknecht, De Balasy, & Pahlevan, 2020). It correlates well with other noninvasive methods and the measurements have good reproducibility and low variability (Solomon, Cipăian, Beca, & Mihăilă, 2022). The calculation of HRR was subsequently standardized in beats per minute for comprehensive analysis.

Peak Inspiratory Flow (PIF), Peak Expiratory Flow (PEF), and Force Vital Capacity (FVC) were evaluated using a portable electronic spirometer (Vyntus Spiro, Vyaire Medical GmbH, Hoechberg, Germany) specifically designed for physiological assessments. Intraclass correlation indicated excellent reliability (>0.75) for all pulmonary function indicators. The evaluations were conducted in controlled laboratory settings. Participants followed the experimental protocol and alleviated any concerns. In accordance with the guidelines of the American Thoracic Society REF, participants engaged in forced inhalation and exhalation maneuvers while seated, with their nostrils blocked. Using the spirometer's mouthpiece tube, each participant performed a maximal inhalation followed by a strong exhalation until all air was expelled. Each participant completed a minimum of three attempts, with the best three efforts chosen for further analysis. Verbal encouragement and motivation were utilized to prompt the most efficient inhalation and exhalation endeavors from the participants. The process ended with the individual performing a maximal inhalation.

Intervention training

Throughout the 16-week observation period, both groups engaged in their specific workout routines three times weekly 45 minutes per session. The method implemented by the Experimental Group in the intervention program involved engaging in high-intensity interval training for a duration of four minutes. This regimen consisted of eight sets, each comprising 20-second intervals of intense physical activity followed by 10 seconds of rest. The HIIT training program administered to the experimental group included warm-up, primary exercise, and cool-down components.

The warm-up routine encompassed activities such as stationary marching, wide toe touches, leg and arm swings, rotations of the shoulders and hips, push-ups, lunges, walking jacks, jumping jacks, hip rotations, and bodyweight squats. Primary exercises performed were: (1) Forward lunges; (2) Jump Squat; (3) Push-up; (4) Burpees; (5) Spider crawl; (6) Plank; (7) Mountain Climber; (8) Abdominal crunches. Similarly, the intervention program conducted by the Contrast Group also encompassed warm-up, primary exercise, and cool-down. Primary exercises executed were: (1) Jump Rope; (2) Butterfly Sit-Ups; (3) Hundle Hop; (4) Straight Push-Ups; (5) Jack-Knife; (6) Squat; (7) Inverse Sit-Ups; (8) Comando dance. Cool-down consisted of a variety of static stretching exercises which included glute stretch, standing quad stretch, side bench stretch, arm-cross shoulder stretch, overhead triceps stretch, lower back stretch, abdominal stretch, and child's pose. It was important for muscle relaxation and for the improvement of joint range of motion.

Each individual session lasted 30 seconds, with a 15-second rest period designated for transitioning between exercises. Furthermore, a rest period of 45 seconds was provided for each set during the training, which was organized into three sets.

The exercise intensity of each training session was monitored using an OMNI scale to respect exertion in the MVPA range of a $5 < RPE < 8$ and to avoid possible differences between training sessions.

Statistical Analysis

Data were depicted in terms of group mean (M) values and standard deviations (SD). Before initiating any analysis, the dataset was thoroughly examined for missing data, outliers, normality using the Shapiro-Wilk test, and homoscedasticity employing the Bartlett criterion (Cordeiro, & Cribari-Neto, 2014). Furthermore, we checked for assumption of statistical tests used by using the one-sample T test, where $H = 0$ (null hypothesis). The results showed that all measures demonstrated homoscedasticity and adhered to a normal distribution. Subsequently, parametric tests were employed for conducting inferential statistical analyses. A two-way ANOVA design, incorporating group (experimental/contrast) and time (pre/post-intervention) with repeated measures on the time dimension, was implemented to evaluate the impact of the exercise program on physiological measures. In cases where 'Group x Time' interactions showed significance, paired t-tests were performed to identify significant differences. The partial eta squared (η^2p) value was computed to measure the effect size, with delineations of small ($\eta2p < 0.06$), medium ($0.06 \leq \eta2p < 0.14$), and large ($\eta2p \geq 0.14$) (Norouzian, & Plonsky, 2018). Additionally, Cohen's d was calculated to determine the effect sizes between groups, classified as small ($0.20 \leq d < 0.50$), moderate ($0.50 \leq d < 0.79$), and large ($d \geq 0.80$) (Peng, & Chen, 2014). Statistical significance was established at a threshold of $p < 0.05$. The reliability of the dependent measures was calculated using the Intraclass Correlation Coefficient (ICC) where values below 0.5 indicate poor reliability, between 0.5 and 0.75 moderate reliability, between 0.75 and 0.9 good reliability, and any value above 0.9 indicates excellent reliability (Koo & Li, 2016). The entire analysis was carried out using IBM

SPSS version 25.0 (IBM, Armonk, NY, USA).

Results

All subjects received the specified treatment conditions according to the assignment, and there were no reported injuries throughout the course of the study. The participants exhibited consistency in terms of age, gender, and anthropometric features (p > 0.05). The results for all variables investigated are detailed in Table 1.

Table 1.
Changes in VO_2max, HR, and Spirometric values after a 16-week HIIT and Circuit Training program.

	Experimental Group (n = 15)			Contrast Group (n = 15)		
	Baseline	Post-test	Δ	Baseline	Post-test	Δ
$V0_2$max	48.45 (1.88)	57.38 (3.20)†*	9.08 (1.52)	47.78 (2.42)	48.78 (2.42)	0.32 (0.73)
HR	25.86 (1.35)	20.80 (1.37)†*	-5.06 (2.08)	26.26 (2.01)	24.93 (2.28)	-1.33 (0.72)
PIF	128.86 (1.66)	136.63 (2.39)†*	7.96 (2.27)	127.78 (2.30)	128.00 (2.35)	0.23 (0.40)
PEF	2.60 (0.23)	2.90 (0.23)†*	0.30 (0.30)	2.47 (0.29)	2.52 (0.36)	0.04 (0.10)
FVC	4.02 (0.70)	5.20 (0.17)†*	1.28 (0.73)	4.06 (0.62)	4.07 (0.52)	0.02 (0.31)

Note: values are presented as mean (± SD); Δ: pre- to post-training changes; †Significant 'Group x Time' interaction: significant effect of the intervention (p< 0.001). *Significantly different from pre-test (p< 0.001).

VO_2max

A two-factor repeated measures ANOVA found a large significant difference in VO_2max ($F_{1,28}$ = 400.94, p < 0.001, η^2_p = 0.93, large effect size). The post-hoc analysis revealed a significant improvement in the score for this variable (t = 5.58, p < 0.001, d = 1.02, large effect size; df = 14) in the intervention group. The The test-retest reliability reported high reliability for VO_2max (ICC (r)= 0.76). No significant changes were found for the contrast group (p > 0.05).

HR

A two-factor repeated measures ANOVA found a large significant difference in HR ($F_{1,28}$ = 42.87, p < 0.001, η^2_p = 0.93, large effect size). The post-hoc analysis revealed a significant improvement in the score for this variable (t = -7,18, p < 0.001, d = -1,31, large effect size; df = 14) in the intervention group. The test-retest reliability reported high reliability for HR (ICC (r)= 0.81). No significant changes were found for the contrast group (p > 0.05).

PIF, PEF and FVC

A two-factor repeated measures ANOVA found a large significant difference in *PIF* ($F_{1,28}$ = 167.05, p < 0.001, η^2_p = 0.85, large effect size), *PEF* ($F_{1,28}$ = 9.50, p < 0.001, η^2_p = 0.91, large effect size), *and FVC* ($F_{1,28}$ = 36.66, p < 0.001, η^2_p = 0.76, large effect size). The post-hoc analysis revealed a significant improvement in the score for *PIF* (t = 5,29, p < 0.001, d = 0.96, large effect size; df = 14), *PEF* (t = 3.68, p < 0.001, d = 0.67, large effect size; df = 14) and *FVC* (t = 4.20, p < 0.001, d = 0.76, large effect size; df = 14) in the intervention group. The test-retest reliability reported high reliability for PIF (ICC (r)= 0.89), PEF (ICC (r)= 0.76) and FVC (ICC (r)=0.85). No significant changes were found for the contrast group (p > 0.05).

Discussion

The aim of this research was to investigate the contrasting effects of a 16-week implementation of the HIIT training approach and the circuit training approach on enhancing the endurance performance of volleyball athletes. The results derived from this study indicated that the HIIT training and circuit training regimen could significantly enhance the physiological performance and physical endurance of volleyball athletes. These results were consistent with the objectives of the two training methodologies since they showed a significant improvement in different cardiorespiratory factors. Nevertheless, the HIIT training approach demonstrated superior outcomes compared to the circuit training approach in augmenting the endurance of volleyball athletes.

This phenomenon could be attributed to the impact of HIIT on the endurance of volleyball athletes, which can be dissected into two facets: aerobic and anaerobic endurance (Junior, 2020). Volleyball entails activities of moderate intensity that incorporate both static and dynamic components, utilizing anaerobic and aerobic energy systems (Rocca et al., 2016; Trajković et al., 2021). Consequently, endurance stands as a crucial trait for volleyball players, with elite athletes typically showcasing elevated levels of this attribute (Ghafourian, Haghshenas, & Avandi, 2021; Silva et al., 2022). HIIT activates both aerobic and anaerobic energy systems, enabling athletes to enhance their velocity and strength in volleyball by targeting high-power muscle fibers (Ghasemi, & Amini, 2023).

HIIT has the ability to enhance an athlete's VO_2max significantly, which represents the maximal utilization of oxygen during physical activity. Increased levels of VO_2max indicate superior aerobic capacity and endurance, facilitating prolonged submaximal-intensity training sessions over extended durations (Akarçeşme et al., 2022; Mazzeo et al., 2016). HIIT workouts, in comparison to traditional steady-state cardiovascular exercises or prolonged strength training sessions, are notably briefer. These short-duration, high-intensity exercises result in metabolic adaptations such as heightened mitochondrial density and improved glucose utilization, both of which are vital for strength enhancement (Morsanuto et al., 2023; Muscogiuri et al., 2016).

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Numerous studies have illustrated that HIIT significantly enhances the VO_2max and lactic acid absorption in the blood of volleyball players (Doma et al., 2020; Krzysztofik, Kalinowski, Filip-Stachnik, Wilk, & Zajac, 2021; Latino, Tafuri, Saraiello, & Tafuri, 2023). While HIIT is categorized as anaerobic exercise, the post-exercise oxygen consumption induced by intervals enables athletes to partake in continuous, moderate-intensity physical activity. Maximum oxygen consumption, commonly known as VO_2max, functions as a crucial quantitative measure for evaluating both anaerobic and aerobic endurance. The escalation in oxygen utilization during rigorous physical exercises indicates a rise in energy generation via aerobic metabolism (Latino et al., 2021; Latino & Tafuri, 2023; Ma et al., 2023). The effectiveness of HIIT in augmenting maximal oxygen uptake originates from the intense intervals that enable athletes to achieve or momentarily surpass their anaerobic thresholds, succeeded by periods of decreased aerobic intensity (Festiawan, Suharjana, Priyambada, & Febrianta, 2020). Furthermore, HIIT not only enhances aerobic capacity but also anaerobic endurance in volleyball practitioners. Research conducted by Ko et al. (2021) revealed that HIIT raised the levels of lactate and anaerobic thresholds as proportions of VO_2max by four percent compared to athletes engaged in Moderate Continuous Training (MCT). This discovery aligns with the notion that HIIT can induce heightened levels of exertion in the cardiovascular system, respiratory system, and musculature, thereby improving anaerobic metabolism (La Torre et al., 2023; Latino, Saraiello, Tafuri, 2023; 2024 a-b).

Within the current investigation, a comparison of ventilatory parameters' pre- and post-training values revealed a significant enhancement in PIF, PEF, and FVC within the experimental group ($p<0.05$). Conversely, the contrast group showed no improvements in any lung parameters following the training program ($p>=0.05$) (Table 1). Moreover, subsequent to the 16-week intervention program, PIF demonstrated a notably higher value ($p= 0.04$) in the experimental group in contrast to the contrast group (Table 1). Presumably, this disparity can be attributed to the notion that HIIT training elicits more pronounced ventilatory responses when juxtaposed with circuit training, thus facilitating enhanced and sustained ventilation to accommodate gas exchange requirements during physical exertion and subsequent training adaptations (Görner, & Reineke, 2020). Previous studies have indicated that HIIT has the capacity to elevate maximal respiratory function in both sedentary individuals and master athletes (Grace, Herbert, Elliott, & Sculthorpe, 2016) while also enhancing inspiratory muscle strength in physically active, healthy individuals (Dunham, & Harms, 2012; Hackett, 2020). Concurrently, strength training has been recognized for instigating distinctive adaptations in the respiratory system, exemplified by heightened diaphragm mass and respiratory muscle strength in powerlifters when compared to untrained healthy adults (Brown et al., 2013). This phenomenon is doubtless a result of strength exercises, such as jump squats and burpees, which induce a stimulatory effect on the respiratory muscles through their engagement in supporting spinal stability (Hackett, 2020). Numerous prior studies have echoed similar outcomes, showcasing enhancements in PIF subsequent to HIIT training (Gantela, & Choppara, 2015; Hebisz, Hebisz, & Zatoń, 2015; Prasertsri, & Padkao, 2021). Peak inspiratory flow (PIF) denotes the swiftest flow rate achieved during maximal inspiration and serves as an indicator of the utmost contraction capacity of the inspiratory muscles (Tiaprapong, & Tiaprapong, 2022). The HIIT regimen implemented in this study encompassed deep inspirations and inspiratory hiccups, exercises designed to fortify the inspiratory muscles, while activities like planks and push-ups aimed at enhancing expiratory muscle strength.

Finally, High-Intensity Interval Training (HIIT) activates fast-twitch muscle fibers, responsible for the generation of high levels of strength and power. This activation facilitates muscle adaptation and an increase in strength (Eken, & Kafkas, 2022; Farì et al., 2023; Guerra et al., 2014; Kayhan et al., 2024). Furthermore, HIIT initiates the secretion of anabolic hormones such as testosterone and growth hormone, pivotal in muscle protein synthesis and, consequently, muscle growth and hypertrophy (Safarimosavi, Mohebbi, & Rohani, 2021). HIIT also induces metabolic stress and creates micro-tears in muscle fibers, initiating physiological responses that stimulate anabolic signaling and growth factors, ultimately resulting in enhanced muscle strength and hypertrophy (De Revere, Clausen, & Astorino, 2021; Farì et al., 2021). Recent studies suggest that even short sessions of HIIT can notably enhance an individual's maximal oxygen uptake and muscle oxidase activity, thus improving performance in endurance activities over the long term (Talsnes, van den Tillaar, & Sandbakk, 2021).

Limitation of the Study and Future Directions

Although this research offers support regarding the beneficial impacts of HIIT training and Circuit training on the performance of volleyball athletes, certain constraints of this investigation necessitate attention. To begin with, the current study is delimited by the recruitment of athletes from a specific geographical region, thus limiting the generalizability of the results to athletes in different locations or with diverse backgrounds. Additionally, the small sample size (N=30), contributed to challenges in participant recruitment, serving as another constraint. Lastly, another limitation pertained to the absence of an assessment of the enduring effects of physical exercise on stamina performance. Furthermore, it does not encompass a broad age range, and data was gathered within a specific timeframe. Consequently, it is advised that future studies examine similar variables on a more extensive and diverse sample. Scholars propose the utilization of a more comprehensive research tool to explore the impacts of this training regimens on athletes' psychological well-being, as well as gathering input from coaches regarding the application of HIIT and Circuit training. Future investigations could involve incorporating gender and age as selection criteria for participants to enrich the breadth of data supporting the advancement of training protocols for physical endurance in volleyball athletes.

Nevertheless, the findings obtained could offer valuable insights for upcoming research endeavors. Indeed, the study's effectiveness was bolstered by a systematic approach that yielded immediately applicable positive results for day-to-day training regimens.

Practical implications

In the realm of volleyball, athletes necessitate a varied skill repertoire encompassing speed, strength, endurance, and swift recovery. Such athletic disciplines require rapid motions, quick reflexes, and consistent performance, underscoring the pivotal role of physical conditioning in achieving success. High-Intensity Interval Training (HIIT) has emerged as a prominent training methodology renowned for its capacity to enhance athletic performance across diverse spheres, particularly in volleyball (Cataldi et al., 2019). HIIT's efficacy in efficiently expending substantial energy in brief intervals renders it especially pertinent for volleyball, where it can enhance physiological aspects such as speed and power. The short yet intense bursts of activity characteristic of HIIT are well-suited to the explosive movements required by this sport, enabling athletes to significantly enhance their capacity to execute swift, impactful maneuvers on the court. Furthermore, HIIT uniquely stimulates sensory nerves, enhancing proprioception and agility, crucial attributes for rapid decision-making in volleyball (Herlan, & Komarudin, 2020; Messina et al., 2015).

Metabolically, HIIT harmonizes with the energy requirements of volleyball by predominantly activating the glycolytic energy system crucial for short, high-intensity efforts. This training modality mirrors the intermittent nature of volleyball, enabling athletes to optimize their speed, strength, and endurance while efficiently managing energy expenditure (Aidar et al., 2022; Marterer, Menz, Amin, & Faulhaber, 2020). In essence, HIIT serves as a performance amplifier for volleyball players, refining their physiological and sensory capacities and resulting in significant enhancements in speed, strength, and endurance. Thus, it is highly advisable for volleyball athletes to integrate HIIT into their regular training routines, ideally engaging in a minimum of two sessions per week over a four-week period. This systematic approach could assist athletes in unleashing their full potential and excelling in competitive settings.

Conclusions

This investigation sheds light on the expanding body of literature that backs the efficacy of High-Intensity Interval Training (HIIT) in augmenting speed, and power in athletes engaged in a sporadic sport, like volleyball. The principal objective is to induce an increase in metabolic rate and improve anaerobic endurance, consequently promoting a more substantial enhancement in endurance capacities among volleyball athletes. The outcomes underscore the capability of HIIT to enhance overall athletic performance in contrast to alternative training approaches. Therefore, when formulating the training program, it is crucial to take into account the physiological functional aspects that correspond to the particular requirements of the exercises.

Nevertheless, it is important to mention the scarcity of studies examining the precise impact of HIIT on skill aspects in volleyball, such as techniques for strokes and strategies for matches. Subsequent research endeavors should concentrate on these domains to provide thorough insights that could enhance the skill performance of athletes in competitive environments.

References

Akarçeşme, C., Cengizel, E., Şenel, Ö.,Yıldıran, İ., Akyildiz, Z., & Nobari, H. (2022). Heart rate and blood lactate responses during the volleyball match. *Scientific reports*, *12*(1), 15344.

Aidar, F.J., Cataldi, S., Badicu, G., Silva, A.F., Clemente, F.M., Latino, F., Greco, G., & Fischetti, F. (2022) Paralympic Powerlifting as a Sustainable Way to Improve Strength in Athletes with Spinal Cord Injury and Other Disabilities. *Sustainability*; 14(4):2017. https://doi.org/10.3390/su14042017

Amat, S. S., Ortega, B. P., Olmedo, J. M. J., & Gasch, L. V. (2020). Anthropometric profile and conditional factors of U21 Spanish elite beach volleyball players according to playing position. *Retos: nuevas tendencias en educación física, deporte y recreación*, (38), 620-625.

Andrade, D. C., Arce‐Alvarez, A., Parada, F., Uribe, S., Gordillo, P., Dupre, A., ... & Izquierdo, M. (2020). Acute effects of high‐intensity interval training session and endurance exercise on pulmonary function and cardiorespiratory coupling. *Physiological reports*, *8*(15), e14455.

Beqa Ahmeti, G., Idrizovic, K., Elezi, A., Zenic, N., & Ostojic, L. (2020). Endurance training vs. circuit resistance training: effects on lipid profile and anthropometric/body composition status in healthy young adult women. *International journal of environmental research and public health*, *17*(4), 1222.

Biçer, M. (2021). The effect of an eight-week strength training program supported with functional sports equipment on male volleyball players' anaerobic and aerobic power. *Science & Sports*, *36*(2), 137-e1.

Brown, P.I., Venables, H.K., Liu, H., de-Witt, J.T., Brown, M.R., Faghy, & M.A. (2013). Ventilatory muscle strength, diaphragm thickness and pulmonary function in world-class powerlifters. *Eur J Appl Physiol*;113(11):2849-2855.

Castro-Piñero, J., Marin-Jimenez, N., Fernandez-Santos, J. R., Martin-Acosta, F., Segura-Jimenez, V., Izquierdo-Gomez, R., ... & Cuenca-Garcia, M. (2021). Criterion-related validity of field-based fitness tests in adults: a systematic review. *Journal of clinical medicine*, *10*(16), 3743.

Cataldi S, Latino F., Greco, G., Fischetti F. (2019). Multilateral training improves physical fitness and fatigue perception in cancer patients. *Journal of Human Sport and Exercise*, vol. 14, p. 910-920, ISSN: 1988-5202, doi: https://doi.org/10.14198/jhse.2019.14.Proc4.54

COCIS (2023). *Cardiological protocols for the judgment of fitness for competitive sport 2023*. Casa Editrice Scientifica Internazionale

Cooper, S. M., Baker, J. S., Tong, R. J., Roberts, E., & Hanford, M. (2005). The repeatability and criterion related validity of the 20 m multistage fitness test as a predictor of maximal oxygen uptake in active young men. *British journal of sports medicine*, *39*(4), e19-e19.

Corvino, A., Pignata, S., Campanino, M. R., Corvino, F., Giurazza, F., Tafuri, D., ... & Catalano, O. (2020). Thyroglossal duct cysts and site-specific differential diagnoses: imaging findings with emphasis on ultrasound assessment. *Journal of Ultrasound*, *23*, 139-149.

Cuenca-Garcia, M., Marin-Jimenez, N., Perez-Bey, A., Sánchez-Oliva, D., Camiletti-Moiron, D., Alvarez-Gallardo, I. C., ... & Castro-Pinero, J. (2022). Reliability of field-based fitness tests in adults: a systematic review. *Sports Medicine*, 52(8), 1961-1979.

De Revere, J. L., Clausen, R. D., & Astorino, T. A. (2021). Changes in VO2max and cardiac output in response to short-term high-intensity interval training in Caucasian and Hispanic young women: A pilot study. *PLoS One*, *16*(1), e0244850.

Doma, K., Connor, J., Gahreman, D., Boullosa, D., Ahtiainen, J. P., & Nagata, A. (2020). Resistance training acutely impairs agility and spike-specific performance measures in collegiate female volleyball players returning from the off-season. *International Journal of Environmental Research and Public Health*, *17*(18), 6448.

Dunham, C., & Harms, C.A. (2012). Effects of high-intensity interval training on pulmonary function. *Eur J Appl Physiol*;112(8):3061-3068.

Eken, Ö., & Kafkas, M. E. (2022). Effects of low and high intensity interval training exercises on VO2max and components of neuromuscular and vascular system in male volunteers. *Journal of Musculoskeletal & Neuronal Interactions*, *22*(3), 352.

Farì, G., Di Paolo, S., Ungaro, D., Luperto, G., Farì, E., & Latino F. (2021). The Impact of COVID-19 on Sport and Daily Activities in an Italian Cohort of Football School Children. *International Journal of Athletic Therapy and Training*, *26(5):274-278*. https://doi.org/10.1123/ijatt.2020-0066

Farì, G., Latino, F., Tafuri, F., Dell'Anna, L., Raele, M.V., Fai, A., De Serio, C., Intonti, G., De Salvo, A.L., Ricci, V., et al. (2023). Shoulder Pain Biomechanics, Rehabilitation and Prevention in Wheelchair Basketball Players: A Narrative Review. *Biomechanics,* 3, 362–376. https://doi.org/10.3390/biomechanics3030030

Festiawan, R., Suharjana, S., Priyambada, G., & Febrianta, Y. (2020). High-intensity interval training dan fartlek training: Pengaruhnya terhadap tingkat VO2 Max. *Jurnal keolahragaan*, *8*(1), 9-20.

Gantela, S., & Choppara, S. (2015). Effect of physical training on lung function in healthy young adults. *J. Evol. Med. Dent. Sci*, *4*, 14973-14979.

Ghafourian, A., Haghshenas, R., & Avandi, M. (2021). The effect of dynamic warm-up and dynamic warm-up with PAP on muscle power and agility of girls volleyball players. *Journal of Sport and Exercise Physiology*, *14*(2/77), 86.

Ghasemi, A., & Amini, H. (2023). The effect of four weeks of intense plyometric and intermittent exercises with zinc supplementation on the serum levels of growth hormone and like growth factor in male volleyball players. *Journal of Sport Biosciences*, *15*(2).

Gielen, J., Mehuys, E., Berckmans, D., Meeusen, R., & Aerts, J. M. (2022). Monitoring Internal and External Load During Volleyball Competition. *International Journal of Sports Physiology and Performance*, *17*(4), 640-645.

Goosey-Tolfrey, V. L., & Tolfrey, K. (2008). The multistage fitness test as a predictor of endurance fitness in wheelchair athletes. *Journal of sports sciences*, *26*(5), 511-517.

Görner, K., & Reineke, A. (2020). The influence of endurance and strength training on body composition and physical fitness in female students. *Journal of Physical Education and Sport*, *20*, 2013-2020.

Grace, F., Herbert, P., Elliott, A., & Sculthorpe, N. (2016). High intensity interval training (HIIT) is an effective method to improve maximal respiratory function, blood pressure and resting cardiac work in lifelong sedentary ageing men. *Heart Lung Circ*. 2016;25(2):S326.

Guerra, G., Testa, D., Montagnani, S., Tafuri, D., Salzano, F. A., Rocca, A., ... & Motta, G. (2014). Surgical management of pleomorphic adenoma of parotid gland in elderly patients: role of morphological features. *International Journal of surgery*, *12*, S12-S16.

Hackett, D.A., (2020). Lung function and respiratory muscle adaptations of endurance- and strength-trained males. *Sports*, 8(12):160.

Hakim, H., Ishak, M., & Bismar, A. R. (2023). The Effectiveness of Training Circuits in Volleyball Games. *Global Journal of Sport Education, Coaching, and Health (GOJOCCA)*, *3*(2), 87-95.

Halouani, J., H'mida, C., Trabelsi, K., Clark, C. C., Glenn, J., & Chtourou, H. (2023). Physiological responses of small-sided vs. regular games in youth volleyball players. *Biology of sport*, *40*(1), 303-309.

Hebisz, R.G., Hebisz, P., & Zatoń, M.K., (2015). Impact of Trainin g with Additional Res piratory De ad Space on Spirome try and Exercise Res piratory Pattern in Cyclists. *Central European Journal of Sport Sciences and*

Medicine, 9, 1: 75–83

Herlan, H., & Komarudin, K. (2020). Pengaruh metode latihan high-intensity interval training (Tabata) terhadap peningkatan VO2Max pelari jarak jauh. *Jurnal Kepelatihan Olahraga*, *12*(1), 11-17.

Irfan, I., Yasriuddin, Y., Hudain, M. A., & Martono, M. (2023). The Effect of Circuit Training and Interval Training on Leg Muscle Endurance on Women's Volleyball Athletes at Velocita. *Jurnal Pendidikan Glasser*, 7(2), 279-286.

Issa, S. N. (2022). Effect of interval training and drinking vital water on anaerobic capacity, functional indicators and some skills in volleyball. *SPORT TK-Revista EuroAmericana de Ciencias del Deporte*, 55-55.

Junior, N. (2020). Specificity principle applied in the volleyball. *MOJ Sports Med*, *4*(1), 13-15.

Kayhan, R. F., Bayrakdaroğlu, S., Ceylan, H. İ., Eken, Ö., Bayrakdaroğlu, Y., Badicu, G., ... & Ardigò1, L. P. (2024). Effects of different rest intervals in high intensity interval training programs on VO2max, body composition, and isokinetic strength and power. *Journal of Men's Health*, *20*(5), 1-11.

Kızılet, T. U. B. A. (2021). The Effects of High-Intensity Functional Training on Aerobic Capacity, Metabolic Adaptation and Neuromuscular Responses in Young Female Volleyball Players. *European Journal of Molecular & Clinical Medicine*, *9*(08).

Ko, D. H., Choi, Y. C., & Lee, D. S. (2021). The effect of short-term wingate-based high intensity interval training on anaerobic power and isokinetic muscle function in adolescent badminton players. *Children*, *8*(6), 458.

Koo, TK e Li, MY (2016). Una linea guida per la selezione e la segnalazione dei coefficienti di correlazione intraclasse per la ricerca sull'affidabilità. *Giornale di medicina chiropratica* , *15* (2), 155-163.

Krzysztofik, M., Kalinowski, R., Filip-Stachnik, A., Wilk, M., & Zajac, A. (2021). The effects of plyometric conditioning exercises on volleyball performance with self-selected rest intervals. *Applied Sciences*, *11*(18), 8329.

La Torre, M.E., Monda, A., Messina, A., De Stefano, M.I., Monda, V., Moscatelli, F., Tafuri, F., Saraiello, E., Latino, F., Monda, M., Messina, G., Polito, R., Tafuri, D. (2023). The potential role of nutrition in Overtraining syndrome. *Nutrients*, 15, 4916. https://doi.org/10.3390/ nu15234916.

Latino F., Saraiello, E., Tafuri, F. (2023). Outdoor Physical Activity: A Training Method for Learning in an Experiential and Innovative Way. *Journal of Physical Education and Sport (JPES)*, 23 (7): 1852 – 1860. DOI:10.7752/jpes.2023.07225

Latino F., Tafuri F. (2024a). Physical Activity and Cognitive Functioning. *Medicina*, 60(2):216. https://doi.org/10.3390/medicina60020216.

Latino, F., & Tafuri, F. (2024b). Wearable Sensors and the Evaluation of Physiological Performance in Elite Field Hockey Players. *Sports*, 12(5), 124.

Latino, F., Cataldi, S., & Fischetti, F. (2021). Effects of an 8-week yoga-based physical exercise intervention on teachers' burnout. *Sustainability*, 13(4), 2104.

Latino, F., Cataldi, S., Carvutto, R., De Candia, M., D'Elia, F., Patti, A., ... & Fischetti, F. (2021). The importance of lipidomic approach for mapping and exploring the molecular networks underlying physical exercise: A systematic review. *International Journal of Molecular Sciences*, *22*(16), 8734.

Latino, F., Tafuri, F. (2023). Physical Activity and Academic Performance in School-Age Children: A Systematic Review. *Sustainability,* 15(8):6616. https://doi.org/10.3390/su15086616

Latino, F., Tafuri, F., Saraiello, E., & Tafuri, D. (2023). Classroom-based Physical Activity as a Means to Improve Self-efficacy and Academic Achievement among Normal-weight and Overweight Youth. *Nutrients,* 15, 2061. https://doi.org/10.3390/nu15092061.

Léger LA, Mercier D, Gadoury C, Lambert J. (1988). The multistage 20 metre shuttle run test for aerobic fitness. *J Sports Sci*. 1988;6(2): 93–101. https://doi.org/10.1080/02640418808729800

Liu, G., & Li, H. (2024). High-Intensity Interval Training (HIIT): Impacts on Cardiovascular Fitness and Muscle Development. *Revista de Psicología del Deporte (Journal of Sport Psychology)*, *33*(2), 210-219.

Ma, X., Cao, Z., Zhu, Z., Chen, X., Wen, D., & Cao, Z. (2023). VO2max (VO2peak) in elite athletes under high-intensity interval training: A meta-analysis. *Heliyon* Editors.

Marterer, N., Menz, V., Amin, S., & Faulhaber, M. (2020). 6-week high-intensity interval training (HIIT) of the lower extremities improves VO2max of the upper extremities. *International journal of sports medicine*, *41*(06), 380-390.

Mayorga-Vega, D., Viciana, J., & Cocca, A. (2013). Effects of a circuit training program on muscular and cardiovascular endurance and their maintenance in schoolchildren. *Journal of Human Kinetics*, *37*(1), 153-160.

Mazzeo, F., Monda, M., Messina, G., Santamaria, S., Messina, A., Montesano, M., ... & Tafuri, D. (2016). Doping in Italy: An analysis of its spread in ten years. *Biology and Medicine*, *8*(1), 1.

Mcweeny, D. K., Boule, N. G., Neto, J. H. F., & Kennedy, M. D. (2020). Effect of high intensity functional training and traditional resistance training on aerobic, anaerobic, and musculoskeletal fitness improvement. *Journal of Physical Education and Sport*, *20*(4), 1791-1802.

Messina, G., Valenzano, A., Moscatelli, F., Triggiani, A.I., Capranica, L., Messina, A., Piombino, L., Tafuri, D., Cibelli, G., & Monda, M. (2015). Effects of Emotional Stress on Neuroendocrine and Autonomic Functions in Skydiving. *Journal of psychiatry*, 18, 1-7.

Monteiro, E. R., Vingren, J. L., Corrêa Neto, V. G., Neves, E. B., Steele, J., & Novaes, J. S. (2019). Effects of Different Between Test Rest Intervals in Reproducibility of the 10-Repetition Maximum Load Test: A Pilot Study with Recreationally Resistance Trained Men. *International journal of exercise science*, *12*(4), 932–940.

Morsanuto, S., Peluso Cassese, F., Tafuri, F., & Tafuri, D. (2023). Outdoor Education, Integrated Soccer Activities, and Learning in Children with Autism Spectrum Disorder: A Project Aimed at Achieving the Sustainable Development Goals of the 2030 Agenda. *Sustainability*, 15(18), 13456.

Muscogiuri, G., Palomba, S., Caggiano, M., Tafuri, D., Colao, A., & Orio, F. (2016). Low 25 (OH) vitamin D levels are associated with autoimmune thyroid disease in polycystic ovary syndrome. *Endocrine*, *53*, 538-542.

Norouzian, R., & Plonsky, L. (2018). Eta-and partial eta-squared in L2 research: A cautionary review and guide to more appropriate usage. *Second Language Research*, *34*(2), 257-271.

Parasuraman, T. (2020). Effect of circuit training with Kettlebell on performance related variables among volleyball players. *International Journal of Physiology, Nutrition and Physical Education*, *5*(1), 24-26.

Peng, C. Y. J., & Chen, L. T. (2014). Beyond Cohen's d: Alternative effect size measures for between-subject designs. *The Journal of Experimental Education*, *82*(1), 22-50.

Pocek, S., Vukovic, J., Jaksic, D., Lakicevic, N., Messina, G., Bianco, A., & Drid, P. (2020). Fitness profile of young female volleyball players. *Medicina Dello Sport*, *73*(2), 197-209.

Prasertsri, P., & Padkao, T. (2021). Efficacy of High-Intensity Interval Resistance Training on Pulmonary Function and Respiratory Muscle Strength in University Athletes. *Journal of Exercise Physiology Online*, *24*(1).

Ramirez-Campillo, R., Garcia-de-Alcaraz, A., Chaabene, H., Moran, J., Negra, Y., & Granacher, U. (2021). Effects of plyometric jump training on physical fitness in amateur and professional volleyball: a meta-analysis. *Frontiers in Physiology*, *12*, 636140.

Rinderknecht, D., De Balasy, J. M., & Pahlevan, N. M. (2020). A wireless optical handheld device for carotid waveform measurement and its validation in a clinical study. *Physiological measurement*, *41*(5), 055008.

Rocca, A., Aprea, G., Surfaro, G., Amato, M., Giuliani, A., Paccone, M., ... & Amato, B. (2016). Prevention and treatment of peritoneal adhesions in patients affected by vascular diseases following surgery: a review of the literature. *Open Medicine*, 11(1), 106-114.

Safarimosavi, S., Mohebbi, H., & Rohani, H. (2021). High-intensity interval vs. continuous endurance training: Preventive effects on hormonal changes and physiological adaptations in prediabetes patients. *The Journal of Strength & Conditioning Research*, *35*(3), 731-738.

Sakthivel, S., & Vaithiyanathan, K. (2022). Impact Of Circuit Training On Muscular Strength And Leg Explosive Power Among Volleyball Players. *Journal of Positive School Psychology*, *6*(10), 3937-3939.

Saravanan, R. V. P., & Pushpa, M. (2021). A high intensity interval training profile for performance variables of collegiate volleyball players. *International Journal of Physical Education, Sports and Health*, *8*(3), 464-467.

Shalaby, M. N., & Fadl, M. A. (2020). A proposed training program and its effect on muscle strength responses and some physiological variables for volleyball beginners. *training*, *1*(15si0), 1-32.

Silva, A.F., Oliveira, R., Cataldi, S., Clemente, F.M., Latino, F., Badicu, G., Greco, G., Leão, C., Bonavolontà, V., & Fischetti, F., (2022). Weekly Variations of Well-Being and Interactions with Training and Match Intensities: A Descriptive Case Study in Youth Male Soccer Players. *International Journal of Environmental Research and Public Health*; 19(5):2935. https://doi.org/10.3390/ijerph19052935

Solomon, A. S., Cipăian, C. R., Beca, M. C., & Mihăilă, R. G. (2022). Non-invasive measurement of the arterial stiffness-is the arteriograph a reliable method?. Acta Medica Transilvanica, 27(4).

Stankovic, M., Djordjevic, D., Trajkovic, N., & Milanovic, Z. (2023). Effects of High-Intensity Interval Training (HIIT) on Physical Performance in Female Team Sports: A Systematic Review. *Sports Medicine-Open*, *9*(1), 78.

Tafuri F., Latino F. (2024). School Medical Service: Strategies to Promote Psycho-Physiological Well-Being. *Pediatric Reports*, 16, 214–231. https://doi.org/10.3390/pediatric16010019

Talsnes, R. K., van den Tillaar, R., & Sandbakk, Ø. (2021). Effects of increased load of low-versus high-intensity endurance training on performance and physiological adaptations in endurance athletes. *International Journal of Sports Physiology and Performance*, *17*(2), 216-225.

Tiaprapong, K., & Tiaprapong, K. (2022). The relationship between respiratory muscle strength and physical performance in college volleyball players. *Sport Mont*, 20(2), 41-45.

Trajković, N., Lazić, A., Trkulja-Petković, D., Barišić, V., Milić, V., Nikolić, S., & Sporiš, G. (2021). Effects of after-school volleyball program on body composition in overweight adolescent girls. *Children*, *9*(1), 21.

Trisaptono, T., & Sumintarsih, S. (2020). Effect of Circuit Training, Interval Training and Body Mass Index for Increase the VO2 Max. In *Proceeding of Lppm Upn "Veteran" Yogyakarta Conference Series 2020–Political and Social Science Series* (Vol. 1, No. 1, pp. 23-31).

Vaccari, F., Passaro, A., D'Amuri, A., Sanz, J. M., Di Vece, F., Capatti, E., ... & Lazzer, S. (2020). Effects of 3-month high-intensity interval training vs. moderate endurance training and 4-month follow-up on fat metabolism, cardiorespiratory function and mitochondrial respiration in obese adults. *European Journal of Applied Physiology*, *120*, 1787-1803.

Vadivel, G. R., & Maniazhagu, D. (2022). Effects of Circuit Training and Circuit Weight Training on Muscular Strength Endurance. *J Adv Sport Phys Edu*, *5*(3), 38-42.

Vidarte Claros, J. A., Castiblanco Arroyave, H. D., Villa

Barco, J. W., & Ortega Parra, A. J. (2019). Values of the resistance of the university football player in special conditions, of the city of Manizales (Colombia). *Retos: Nuevas Perspectivas de Educación Física, Deporte y Recreación*, *36*.

Wu, X. (2023). High-intensity interval training impacts on endurance of volleyball players. *Revista Brasileira de Medicina do Esporte*, *29*, e2023_0047.

Yue, L., & Hong, C. (2023). Influences of high-intensity interval training on physical ability in volleyball. *Revista Brasileira de Medicina do Esporte*, *29*, e2022_0701.

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