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Physical impact of volleyball matches on adolescent athletes: Insights into fatigue and recovery

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ABSTRACT

Background: Research on adolescent volleyball athletes is limited, especially regarding the acute effects of competition on physiological responses such as Blood Lactate Concentration (BLC), sprint performance, and Countermovement Jump (CMJ). This knowledge is important to improve recovery strategies and maintain performance. **Research Objectives:** The aim of this study is to investigate the effects of pre- and post-volleyball matches on Blood Lactate Concentration (BLC), sprint performance, and Countermovement Jump (CMJ) in adolescent athletes. **Methods:** The research applied quasi-experimental research with a pretest-posttest without a control group design approach. Furthermore, the research series was carried out in two sessions. In the first session, all research subjects underwent initial tests and measurements in the form of anthropometry, HR, and VO_2 max. Meanwhile, in the second session, before they did three sets of match simulations, the subjects did lactate, sprint, and Countermovement Jump (CMJ) tests as pretest values. In addition, lactate, sprint, and CMJ data were taken at 0 hours and three hours after completing the match simulation to determine the posttest value. **Finding and Results:** During the match simulation, sprint ability, countermovement jump, and lactate concentration in volleyball athletes experienced significant changes. There was a significant change with an increasing trend in lactate concentration (p -value < 0.05) and a decrease in sprint and countermovement jump abilities (p -value < 0.05), as well as the opposite condition that occurred three hours after the match. **Conclusion:** Volleyball matches impose significant physiological and physical demands, with BLC normalising within three hours but sprint and CMJ requiring extended recovery. Tailored recovery strategies and high-moderate intensity training modifications are vital for optimising performance and managing fatigue. Future studies should explore individualised training and recovery protocols.

Keywords: volleyball; fatigue; recovery; performance.



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INTRODUCTION

Volleyball has long been known as a very dynamic sport because it involves several sprinting movements, jumping (blocking and spiking), and high-intensity movements on the field that are repeated throughout the

game (Balasas et al., 2018). Heretofore, volleyball has become one of the five most played sports in the world, while a spike is one of the determining factors of an attack, which significantly affects the outcome of the game (Challoumas & Artemiou, 2018). Volleyball is one of the sports that is highly influenced by the anthropometric variables of the players. In addition to height, high aerobic capacity ensures the availability of oxygen and energy to maintain performance during long games (Challoumas & Artemiou, 2018). In volleyball, the spiking technique requires special skills along with excellent body coordination, such as running, jumping with countermovements, and a series of explosive overhead movements in the air and landing (Sattler et al., 2015). A previous study discovered that successful spikes were highly dependent on anthropometric and physical performance variables (Reeser, 2017). Elite volleyball athletes required pre-match training to improve their physical condition as well as the techniques and strategies that would be used during the match. Muscle strength and endurance, especially in the upper and lower extremities, determined the results of serving, passing, spiking, and blocking (Bobula et al., 2024). A theoretical review defines volleyball as a predominantly anaerobic and aerobic sport (Herrick et al., 2017), where movements are repeated and performed in several sets, with efforts evenly distributed from the beginning to tens or hundreds of repetitions. However, playing volleyball is not easy.

Several studies focusing on strength training have reported that the application of circuit training methods could increase the strength of the muscles on the left and right sides of the body that support flexion-extension movements at the hip. In addition to stronger back muscle strength and flexibility, muscle endurance increased, and side steps for agility increased. In contrast, jump speed, service speed, and spike speed also increased significantly during intensive circuit training (Noh et al., 2019). In a study examining endurance and strength, eight weeks of strength and endurance training were found to have certain effects on endurance and VO₂ max (Akarcemesme et al., 2022). Previous studies have concluded that elite and non-elite volleyball players showed differences in muscle strength, arm muscle strength, and aerobic endurance (Bobula et al., 2024). Elite volleyball athletes need pre-match training, supported by volleyball techniques and strategies, to improve their physical condition.

For instance, adequate energy range has become the most critical issue for athletes (Zapolska et al., 2014). For maximum results, athletes should be trained according to their genetic predisposition (Akarcemesme et al., 2022). For example, an athlete with a larger proportion of slow-contraction muscle fibers will adapt better to weekly training and muscular endurance programs with more repetitions but less load. Meanwhile, an athlete with a greater proportion of fast-contraction muscle fibers benefits greatly from sprint training and strength training programmes, with fewer repetitions but more load (Kenney et al., 2015; Plowman & Smith, 2017; van Schaardenburgh et al., 2017). Volleyball, from a literature perspective, shows the characteristics supported by type IIA muscle fibers that require fast, intermediate, and non-maximal contractions. This type of muscle fiber uses aerobic and anaerobic metabolism almost equally to produce energy. Therefore, type IIA muscle fibers are a mixture of type I and type II muscle fibers (Herrick et al., 2017). Dominant muscle fiber indicators will assist players and coaches in implementing training programs, considering how the balance between aerobic and anaerobic muscle fibres helps future elite players adapt to all types of training (Mujika et al., 2018).

Despite prior research on adolescent volleyball athletes, existing studies often fail to comprehensively address the acute physiological effects of competition, particularly on parameters such as Blood Lactate Concentration (BLC), sprint performance, and Countermovement Jump (CMJ). Studies like (Challoumas & Artemiou, 2018), have highlighted the dynamic and intense nature of volleyball, but there remains a lack of clarity on how these demands specifically influence adolescent athletes during and after matches. Additionally, while the importance of individualised training programmes is well-documented (Kenney et al., 2015; Mujika et al., 2018), there is limited understanding of how adolescent athletes recover from high-intensity activities inherent to volleyball. This gap hinders the development of effective recovery strategies tailored to this demographic.

This study is particularly urgent in the context of youth volleyball, as managing fatigue effectively is critical for athlete health, performance, and long-term development. Adolescents experience peak aerobic and anaerobic capability, making them highly susceptible to performance fluctuations and fatigue-induced injuries

during high-intensity sports (Herrick et al., 2017). Effective management strategies can not only optimise performance during competitions but also prevent long-term overtraining risks. By focusing on BLC, sprint performance, and CMJ, this research provides valuable insights into the physiological toll of volleyball and guides coaches in player rotation and workload management. Such advancements are essential for nurturing young athletes and ensuring sustainable engagement with the sport.

METHOD

This research applied quasi-experimental research with a pretest-posttest without a control group design approach. Furthermore, the research series was carried out in two sessions. In the first session, all research subjects would undergo initial tests and measurements in the form of anthropometry, HR, and VO₂ max. Meanwhile, in the second session, before they did three sets of match simulations, the subjects did lactate, sprint, and Countermovement Jump (CMJ) tests as pretest values. Furthermore, to find out the posttest value, lactate, sprint, and CMJ data would be taken at 0 hours and 3 hours after completing the match simulation. Heart rate during the match simulation was monitored using a Polar H-7 wireless heart rate monitor. In a study by Giles et al. (2016), this device demonstrated a high level of accuracy, especially during moderate to intense activity, with an average measurement error of less than 5 bpm. An explanation related to the research flow can be seen in Figure 1.

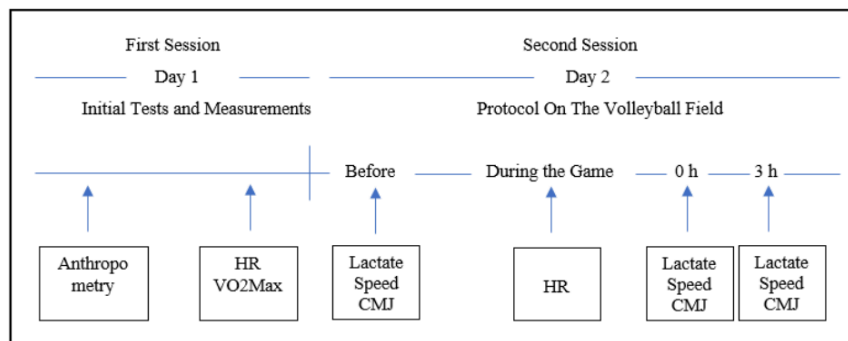


Figure 1. Research Flow

Subjects

The total subjects in this research were 12 players taken from two amateur volleyball teams in the Jambi area. The research subjects were selected by purposive sampling, where subjects were recruited based on the inclusion criteria including (1) male; (2) aged 17-20 years; (3) actively involved in a volleyball club; (4) had experience competing in championships for at least the last two years; and (5) had no injuries. The selection of amateur male volleyball players aged 17-20 years is based on the physiological characteristics and physical development of this age group, which is at the peak of its aerobic and anaerobic capabilities.

The study's sample consisted of 12 athletes, a limitation often associated with challenges in recruitment within a specific demographic. The selection of a small sample size was intentional to ensure homogeneity and control over confounding variables, as all participants shared similar characteristics (age, skill level, and training history). This method matches the goals of quasi-experimental research, enabling better observation of how volleyball matches affect Blood Lactate Concentration (BLC), sprint performance, and Countermovement Jump (CMJ). While a larger sample size could enhance the generalisability, the focus here was on obtaining precise and consistent data from a controlled group. However, future studies should aim to replicate findings with larger cohorts to confirm these results across broader populations.

Research Measurements and Procedures

Initial assessments included anthropometry, heart rate, and VO₂ max measurements.

Age data collection was obtained using a questionnaire distributed at the end of the lecture meeting, which was conducted offline. Then, height was measured using a manual stature meter, the GEA brand, which the researcher directly carried out. Furthermore, weight and BMI measurements were obtained using the OMRON Karada Scan HBF-375 digital scale (Dassanayake, 2016).

VO₂ max measurement in this study used the field method with the bleep test method. The bleep test was carried out in a closed field using a flat field surface, then marked between distances A and B using cones with a distance of 20 meters. The subject ran a line back and forth for 20 meters, adjusting to the rhythm of the active speaker stored in the testing area. Every minute, the sound of the marker from the active speaker media got faster. Testing stopped when the research subject was unable to keep up with the sound of the marker from the active speaker and did not reach the target line in two consecutive opportunities. In the bleep test, 21 levels with 16 reversals were used to predict the VO₂ max value (Apriantono et al., 2020).

Sprint Test

The sprint test was carried out on a straight track with a length of 20 meters. Before sprinting, participants were instructed to run as fast as possible. Then, measurements were taken using a stopwatch supervised by two officers (Carling et al., 2016; Lakhdar & Zerf, 2019).

Blood Lactate Concentration (BLC)

The blood lactate concentration examination employed the Accutrend Plus Portable Analyser. Lactate level measurement was done by taking blood samples from the subject's fingertips with a test strip and directly analysed using the Accutrend Plus Portable Analyser. Meanwhile, for heart rate data collection, all participants used the Polar H-7 wireless heart rate monitor. Studies such as those conducted by (Tanner et al., 2010), showed that the Accutrend Plus Analyser had a high correlation with laboratory reference devices for blood lactate measurement, with a correlation coefficient of ≥ 0.90 .

Countermovement Jump (CMJ)

Countermovement Jumping was applied by calculating the difference between the starting position standing with the right or left arm attaching the marker, then continued by jumping and marking with the hand as high as possible, and calculated the difference between the two. The countermovement jump, with the extension of the upper body movement, could stimulate a similar effect to the jumping movements carried out during a volleyball match (Sattler et al., 2015; Stanton et al., 2015). CMJ measurements are performed manually.

Data Analysis

The normal distribution of the data was tested using the Shapiro-Wilk test. This test was chosen because of its reliability in detecting deviations from the normal distribution, especially for small to medium samples. Means and standard deviations were calculated for all anthropometric and physiological variables. Next, the Bonferroni post-hoc test was used to compare variables before vs immediately (0h) vs 3 hours after the match simulation. Bonferroni helps adjust the level of significance by dividing the initial α by the number of comparisons performed. This makes it a conservative but effective method to ensure that significant results are truly statistically relevant. All statistical analyses were performed using SPSS version 22 with a significance level of $p < 0.05$.

RESULTS AND DISCUSSION

The results of the anthropometric data showed the mean (\pm SD) values of age, height, weight, BMI, HRmax, and VO₂ max. All players did not indicate any significant difference in their standard deviation (see Table 1).

Table 1. Anthropometric and Physiological Characteristics of the Volleyball Players

Variables	Mean (SD)	Experiment (N=12)	
		Min	Max
Age (years)	18,66 ± 1,02	17,00	20,00
Height (cm)	172,91 ± 2,56	169,00	177,00
Weight (kg)	67,08 ± 4,68	59,00	76,00
BMI (kg/m ²)	22,42 ± 1,37	19,71	25,10
HR (beats.min ⁻¹)	183 ± 5,61	174,00	192,00
VO ₂ max (ml.kg ⁻¹ .min ⁻¹)	52,58 ± 1,93	49,00	55,00

Figure 1 displays the results of the data pre- and post-match simulation for three sets. These findings emphasised that there were significant differences in several physical performance parameters, namely CMJ, BLC, and 20-meter sprint after the match simulation was carried out. After 0 hours of match simulation, all three variables showed a significant decrease $p < 0.05$. It indicated that the match had a direct impact on the explosive performance and metabolism of athletes. However, when measurements were taken again three hours after the match simulation, BLC returned to normal conditions, which were below 2.2 mmol/L. On the other side, performance on the CMJ and 20-meter sprint variables still decreased three hours after the match.

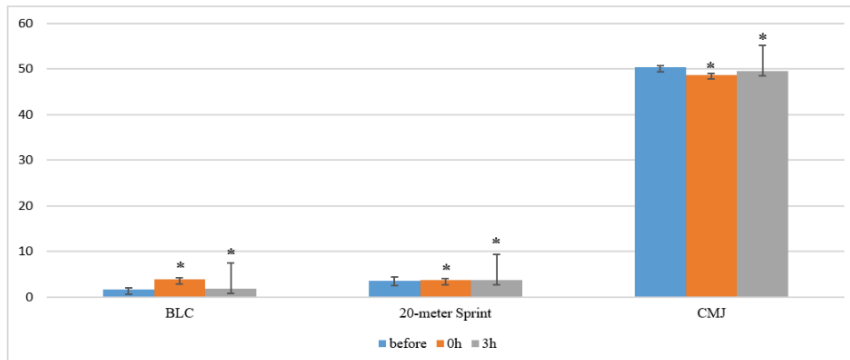


Figure 2. Effect of Volleyball Matches on BLC, 20-meter Sprint and CMJ

Furthermore, during the match simulation in three sets, the player's heart rate (HR) was monitored using the Polar H-7 wireless to obtain the average HR for each set. The research results indicated that the average HR of players before the match was 113.33 ± 10.88 . Then, it was at 156.50 ± 7.07 bpm (set 1) and 165.75 ± 31.96 bpm (set 2). In set 3, HR was at 170.08 ± 5.70 bpm. Then, 0 hours after the match, it was at 168.16 ± 31.22 bpm. After three hours of match simulation, it was at 116.58 ± 11.21 bpm.

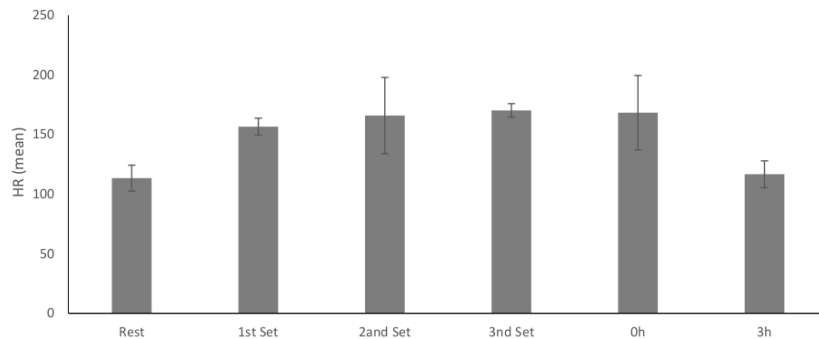


Figure 3. HR Monitor Graph during Match Simulation

The results of this study indicate that simulated ball matches will have a significant effect on several physical parameters of adolescent athletes. The data showed a significant increase in blood lactate levels (BLC) after the match, indicating increased anaerobic metabolic activity. After the match, BLC increased from 1.60 ± 0.39 mmol/L to 3.84 ± 0.91 mmol/L at 0 hours after the match, but returned to normal three hours later (1.81 ± 0.32 mmol/L). Decreased performance in the 20-meter sprint and Countermovement Jump (CMJ) were also observed after the match, although partial recovery occurred three hours later. These results are in line with studies conducted by (Ahmadi et al., 2021; Degens et al., 2019; Makaraci et al., 2021; Noh et al., 2019) which showed that high-intensity matches can cause a significant increase in physical fatigue.

Research conducted by Akarcesme et al. (2022) stated that monitoring blood lactate levels is very important in evaluating the physical condition and recovery of athletes. An increase in BLC after a match indicates that the body is experiencing significant metabolic stress, which requires sufficient recovery time before it can return to optimal performance. This study found that lactate levels returned to normal within three hours after the match, in line with previous research findings that the body needs about two to four hours to significantly eliminate blood lactate (Lucertini et al., 2017). These findings also emphasize the importance of post-match recovery strategies that include active cooling methods to accelerate lactate reduction and improve muscle recovery processes.

Sprint ability, countermovement jump during the match and lactate in this study experienced significant changes, both before, after and three hours after the match. This is in line with previous studies related to the need to perform explosive movements in volleyball athletes as some of the determining components as a need during a volleyball match. In volleyball, sprint and Countermovement Jump (CMJ) are integral parts of the dynamic movements needed for attack and defense (Ruffieux et al., 2020). Sprint allows athletes to move quickly around the field to respond to the opponent's play or prepare for an attack, while countermovement jump is very important for spiking, blocking, and serving (Challoumas & Artemiou, 2018). These explosive movements rely heavily on the anaerobic energy system, which produces rapid bursts of power (Heydenreich et al., 2017). Both of these movements require strong leg muscles, agility, and precise timing, which is why these movements are key performance indicators for volleyball players. However, the intensity of these movements also results in the production of lactate as a by-product of anaerobic metabolism (Makaraci et al., 2021), and this has been known for a long time. Lactate accumulation occurs during high-intensity, short-duration activities such as sprints and CMJs. When athletes perform multiple jumps and sprints in quick succession, as is often the case during rallying, the demand on their muscles exceeds their oxygen supply, forcing the body to rely on anaerobic pathways for energy production, as a long-standing literature review found (Berriel et al., 2020). This results in the production of lactate in the muscles and bloodstream. The faster

and more frequently these high-intensity actions occur, the higher the lactate buildup, which can lead to fatigue, decreased muscle function, and slower recovery times (Lehnert et al., 2017). If lactate accumulates faster than the athlete can excrete it, performance can suffer, especially in long events.

After the match, the players' HR decreased gradually but was still at a higher level than the initial condition, which was 168.16 ± 31.22 bpm immediately after the match, and only returned to near-normal values (116.58 ± 11.21 bpm) three hours later. This shows that although HR tends to recover quickly after the match, the full recovery process still takes time. The gradual decrease in HR after the match reflects the cardiovascular recovery process, which can be influenced by the intensity of the match and the individual's physical condition. A study by Carling et al. (2016) also emphasized the importance of monitoring HR during and after the match to assess the level of physiological stress and the recovery needs of athletes. This HR monitoring can be an important indicator for coaches in developing effective recovery strategies, both through active and passive recovery methods. Monitoring heart rate (HR) and lactate levels in volleyball athletes provides important findings related to cardiovascular fitness, energy expenditure, and recovery ability (Lehnert et al., 2017; Soslu et al., 2022). Heart rate monitoring helps track an athlete's cardiovascular response to these activities. During a rally, heart rate can quickly rise to 85-90% of maximum, indicating anaerobic effort. Consistent HR monitoring during training and competition can help coaches ensure that athletes are working at the appropriate intensity while preventing overtraining by monitoring recovery between sets or matches (Albaladejo-Saura et al., 2022).

Blood Lactate concentration in volleyball athletes also serve as a key marker of anaerobic exertion and fatigue (Kafkas et al., 2019). High-intensity movements such as jumping, spiking, and landing heavily engage the anaerobic energy system, leading to an accumulation of lactate in the bloodstream (Ruffieux et al., 2020). When an athlete exceeds their lactate concentration the point at which lactate is formed faster than it can be cleared fatigue sets in quickly, and performance begins to decline. By measuring lactate levels during and after exercise, coaches can determine how well an athlete is prepared for sustained high-intensity effort and make adjustments to increase the lactate concentration through targeted training (Kappenstein et al., 2015). Incorporating HR and lactate monitoring into a volleyball training program provides a comprehensive overview of an athlete's physiological response. A fast recovery heart rate and rapid lactate clearance after exercise indicate a well-conditioned athlete who can sustain performance over multiple sets or an entire volleyball match (Zagatto et al., 2016). Monitoring the fatigue marker and lactate is useful in balancing training intensity, optimising recovery, and ultimately improving endurance and peak power output, key to success in the fast-paced, dynamic game of volleyball. By understanding how the process of sprinting during a match and countermovement jumping contributes to lactate production, coaches can tailor training programmes to increase power output and endurance, optimising the volleyball athlete's performance during a match.

The absence of a control group in this study limits the ability to attribute observed changes in physiological parameters solely to the volleyball match simulations. A control group would allow comparison with athletes who did not undergo match simulations, providing a clearer distinction between normal physiological variations and exercise-induced effects. Without this, it is challenging to isolate the specific impacts of the intervention from other potential influences such as participant expectations or external environmental factors. Despite this limitation, the within-subject design used here offers valuable insight into individual responses to match-play scenarios. Future research should incorporate control groups to strengthen causal inferences and better contextualise the findings.

CONCLUSION

This study demonstrates that volleyball matches significantly impact the physiological and physical performance of adolescent athletes. Blood Lactate Concentration (BLC) levels increased immediately after matches but normalised within three hours, while sprint and Countermovement Jump (CMJ) performance required more extended recovery periods. These findings underscore the need for tailored recovery strategies to optimise athlete performance and manage fatigue effectively. The study faced several limitations. First, the small sample size of 12 athletes, although beneficial for maintaining homogeneity, limits the generalisability

of the findings to broader populations. Future studies should involve larger sample sizes to confirm these results and improve external validity. Second, the absence of a control group made it challenging to isolate the effects of volleyball match simulations from other factors. Incorporating a control group in future research would provide a more robust framework for causal inference. In addition, this study contributes to the development of the theory of exercise metabolism and anaerobic training by highlighting the acute impacts of high-intensity sports on physiological parameters. The findings support the dual reliance on aerobic and anaerobic systems in volleyball and emphasise the importance of type IIA muscle fibres in maintaining performance during repetitive high-intensity movements. By linking these insights to fatigue management strategies, this research advances understanding of how to optimise recovery and training protocols, particularly for adolescent athletes in anaerobic-dominant sports.

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CONFLICT OF INTEREST

Clearly explain whether there are any conflicts of interest related to the reported research.

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