Research Paper

A Kinetic-temporal Phasic Comparison Between Middle and Side Blockers of Elite Volleyball Players During Block Jump

Ali Fatahi[1*], Razieh Yousefian Molla[2], Rozhin Molavian[1], Nazfar Nikjoo[1]

1. Department of Sports Biomechanics, Faculty of Physical Education and Sport Sciences, Central Tehran Branch, Islamic Azad University, Tehran, Iran.
2. Department of Physical Education and Sports Sciences, Faculty of Physical Education and Sport Sciences, Karaj Branch, Islamic Azad University, Karaj, Iran.

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ABSTRACT

Purpose: The successful performance of block skills is crucial for volleyball players, requiring efficient techniques that optimize time, movement, and vertical jump. The purpose of the present investigation was to compare the kinetic temporal phasic differences between middle and side blockers among elite volleyball players during block jump.

Methods: Seventeen junior male volleyball players, consisting of eight middle blockers and nine side blockers, participated in this research. The evaluated skill was the block jump ability. Data collection involved calibrating a force plate (Kistler® 1000 Hz). An independent t-test was used to compare mean values between the two groups during jumping ($P<0.05$).

Results: The results indicated no significant differences between middle and side blockers in terms of time and force during the amortization phase.

Conclusion: These findings provide valuable insights into monitoring time and force variables among middle and lateral blockers. Trainers can utilize these results to tailor task-specific training programs that optimize performance outcomes.

*** Corresponding Author:**
Ali Fatahi, Assistant Professor.
***Address:** Department of Sports Biomechanics, Faculty of Physical Education and Sport Sciences, Central Tehran Branch, Islamic Azad University, Tehran, Iran.*
***Phone:** +98 (912) 5607581*
***E-mail:** ali.fatahi@iauctb.ac.ir*

Highlights

- Kinetics analysis of a specific volleyball skill.
- Demonstrating the importance of Biomechanics in the professional volleyball game.
- Separating the various phases of performance regarding biomechanics of block jump.

Plain Language Summary

The main goals of biomechanics are human performance optimization as well as injury prevention. The important keynote is to find the glorious skills in each sport, and in volleyball, the block jump is known as a key factor of success. Combining and merging biomechanical principles in volleyball block jump will result in a better understanding of the nature of skills performance. Seventeen junior volleyball players attended the recent investigation and performed block jumps on the force platform. Kinetic data were collected and different phases of jumping were also derived according to the force-time data. No significant differences were found between the side blockers and middle blockers in volleyball when it comes to the kinetics of jumping and landing. This means that both positions exhibit similar patterns and mechanics in terms of their jumping and landing movements

1. Introduction

Performing a successful block skill is a critical aspect for achieving victory in modern volleyball, a sport that has emerged as the second most popular worldwide [1-3]. To execute appropriate block skills, subjects should employ a technique that minimizes the time required to reach the target (the point of attack), maximizes side-to-side motion beside the net, and facilitates the countermovement skill. Several key factors contribute to the effectiveness of the block skill, including anticipation, decision-making, movement speed, jumping ability, and various parameters, such as jump height, speed of performance, and timing of initiating the jump. Additionally, the positioning and position of the hands concerning the netplay a significant role in creating an appropriate surface on the net and controlling the ball passing to the court. In volleyball, a countermovement jump is typically employed during fast-static block jumps. Depending on the situation, volleyball athletes employ a pair of distinct techniques for executing block jumps: One involves commencing from an erect stance, while the other entails initiating the jump from a crouched position. In both instances, a countermovement is employed [4, 5]. Volleyball players are classified based on anthropometric characteristics and physical fitness indicators in different positions of the game, and among these positions, middle and side blockers who perform the action of blocking in the form of a central block and a side block on the net, are debatable. The difference between the mentioned positions in the type of performance of different skills, such as spike and defense on the net is obvious, but the remarkable point in all of them is the landing after the jump. The most obvious difference between these two volleyball positions is in the position, in which they perform their defense skills on the net.

A block jump is a type of countermovement jump executed from a stationary condition, characterized by an initial descending motion (eccentric phase) followed by an ascending motion (concentric phase). This biomechanical sample, involving the sequential activation of eccentric and concentric muscle contractions including a brief amortization phase, is investigated as the stretch-shortening cycle (SSC). The SSC is a fundamental mechanism utilized in various daily and athletic activities, such as running, jumping, and throwing [6-11]. During the eccentric stage of the SSC, the muscle undergoes preloading and stretching, which results in the storage of potential energy. This stretching stimulates the muscle spindles and specialized sensory receptors within the muscle. These muscle spindles transmit signals that ultimately lead to muscle contraction. The next stage of the SSC is the amortization phase, also referred to as the transition phase. It encompasses the time interval between the eccentric contraction and the subsequent concentric contraction. Essentially, it is the period that elapses between landing and initiating the next jump. It is crucial to keep the amortization phase as short as possible since a lengthier duration results in a more substantial depletion of accumulated potential energy. The final phase of the SSC is the concentric phase. In this stage, the accrued elastic energy is utilized together with voluntary, concentric muscular contractions to produce the required force for the subsequent motion or leap [12, 13]. Therefore, phases produced during jumping are very important components in performing block techniques on the net [14-16].

A few studies have been done on comparing a volleyball-specific game's position regarding kinetics or kinematics variables. In this regard, only Fatahi et al. [14] investigated the velocity of block jump skills in middle and side blockers and reached some differences between the two groups. Furthermore, investigations predominantly concentrate on analyzing the technical aspects utilized by middle blockers during their core maneuvers, particularly when executing the fundamental action of blocking [17] and the attack [15]; however, a comparison between side and middle blockers has not been done [18]. Also, Sarvestan et al. assessed the correlations between kinetic-temporal variables and jumping performance in professional volleyball players [19], but they did not focus on comparing and considering the amortization phase in different positions on the court. Hence, deficiency in terms of group comparison among the volleyball players, especially about their kinetic variables, is obvious. Thus, the goal of the present research was to compare the kinetic temporal phasic between middle and side blockers of elite volleyball players during block jump.

2. Materials and Methods

Participants

The present controlled quasi-experimental study was done on junior male volleyball players, including eight middle and nine side blockers. Subjects were included in the research in case of continuous participation in volleyball training sessions six days a week. The exclusion criteria s were a history of musculoskeletal or neurological deficits and any prior injuries that could potentially affect the jumping and landing task.

Study design

The present investigation examined the block jump skill, which incorporates the SSC. The participant begins in a standing situation while hands extended in front of their chest. The block jump involves an initial downward movement by flexing the knees and hips (eccentric phase), followed by immediate extension of the knees and hips to jump vertically (concentric phase), while simultaneously raising the hands above the head. This movement is executed as quickly as possible [14, 20]. Prior to the test, each participant underwent an individual warm-up protocol lasting 15 minutes, following official volleyball training or game conditions. Both groups of volleyball players were instructed to jump maximally. Every single player was given five execution trials to become familiar with the test. Verbal instructions were intentionally limited to minimize the coach's influence. Data collection began with calibrating the force plate (Kistler®-1000 Hz). Participants performed three maximal jumps, with a one-minute rest between each trial. The best jump out of the three attempts was selected for further analysis. The duration of the jump and the maximum force recorded from the force-time curve variables were evaluated for the best jump performance and entered for processing in MATLAB® (Math Works Inc., USA).

Data analysis

The division of jumping phases was determined based on the instantaneous velocity of the center of mass (COM) during the jumping task. To compute the instantaneous velocity of the COM, the instantaneous acceleration of the COM was derived. This was achieved by dividing the vertical ground reaction force minus the participant's weight by their mass. The acceleration was then integrated with respect to time using the trapezoid method [21].

The distinct stages of leaping were delineated in the subsequent manner (Figure 1):

• Eccentric phase (ECC) (ms): This phase commenced from the lowest negative point and continued until the instant velocity of the COM reached zero.

• Concentric phase (CON) (ms): The CON phase commenced when the instantaneous velocity of the COM turned positive and persisted until the participant exited the force plate.

• Amortization phase (AM) (ms): The AM phase represented the temporal interval between the negative work of the eccentric pre-stretch and engendering force generation. It involved the quickening of muscle contraction and the spring-like rebound in the direction of the SSC. Also, the time duration and maximum force of each phase from the force-time curve of the jump were calculated according to a similar investigation [19, 22] (Figure 1):

• Eccentric time (T ECC) (ms): The length of the eccentric phase.

• Amortization time (T AM) (ms): The length of the amortization phase.

• Concentric time (T CON) (ms): The length of the concentric phase.

• Maximum eccentric force (FECC MAX) (N/kg): The maximum force obtained during the eccentric phase, normalized to body weight.

• Maximum amortization force (FAM MAX) (N/kg): The maximum force achieved during the amortization phase, normalized to body weight.

• Maximum concentric force (FCON MAX) (N/kg): The maximum force generated during the concentric phase, normalized to body weight.

The normality of variable distributions was evaluated using the Shapiro-Wilk test. Descriptive statistics, such as Mean±SD, were calculated. An independent t-test was employed to compare the means of variables between the two groups during jumping ($P<0.05$).

3. Results

The Shapiro-Wilk test findings demonstrated that the data followed a normal distribution. Table 1 presents the demographic characteristics of the participants in the two groups.

In addition, there was no significant relationship between the variables of the study (Table 2).

4. Discussion

The objective of the present investigation was to compute the kinetic temporal phasic characteristics between middle and side blockers of elite volleyball players during block jumps. The results revealed that there was no significant difference in time and force during the amortization phase between the middle and side blockers.

Volleyball is recognized as a highly explosive and fast-paced sport in contemporary times [23-26], necessitating the development of muscular fitness qualities, such as strength, power, agility, and speed. Among elite male volleyball players, studies have reported approximately 250-300 high-power activities, with 50% of them involving various types of jumps that need lower joints' extension. During landing, the knee extensors exhibit maximal activity for deceleration and controlling knee flexion eccentrically, while the take-off phase of the jump demonstrates increased activity. Moderate activity is obvious along the duration of the amortization phase [27].

In this study, according to Table 2, the time and force variables in the eccentric, amortization and concentric phases were investigated, and there was no significant difference in the amortization phase of the time variable in the middle and lateral blockers and also no significant difference was found in the middle and lateral blockers' maximum force in the amortization phase.

One of the primary duties of middle blockers in volleyball is to perform blocking actions. Blocking serves as the initial action for teams to impede the opponent's attack [28] and middle blockers are tasked with executing blocks across the entire 9-meter span of the net. Middle blockers are responsible for a significant proportion of block jumps, accounting for 45.5% of a team's total, whilst position four and two blockers contribute only 27.0% and 27.5%, respectively [18, 29].

Middle blockers not only engage in block jumps from a central position near the net but also frequently need to move laterally to the left or right side to support outside hitters in blocking toward the sideline. On the other hand, outside hitters often have to swiftly shift to the middle-net position to assist middle blockers with their blocking duties. Therefore, the demands of a volleyball match extend beyond the stress of jumping and landing; the rapid lateral movements involved in blocking tasks must also be taken into account. This aspect is especially crucial for middle blockers and outside hitters [16].

Table 1. Demographic characteristics of the two groups

Blocker Groups	Mean±SD			
	Age (y)	Height (cm)	Weight (N)	Body Mass Index (kg/m²)
Middle	18.0±1.06	197.50±1.77	802.97±62.79	20.61±5.45
Side	17.67±0.86	193.22±0.86	748.19±50.53	19.56±4.44

PHYSICAL TREATMENTS

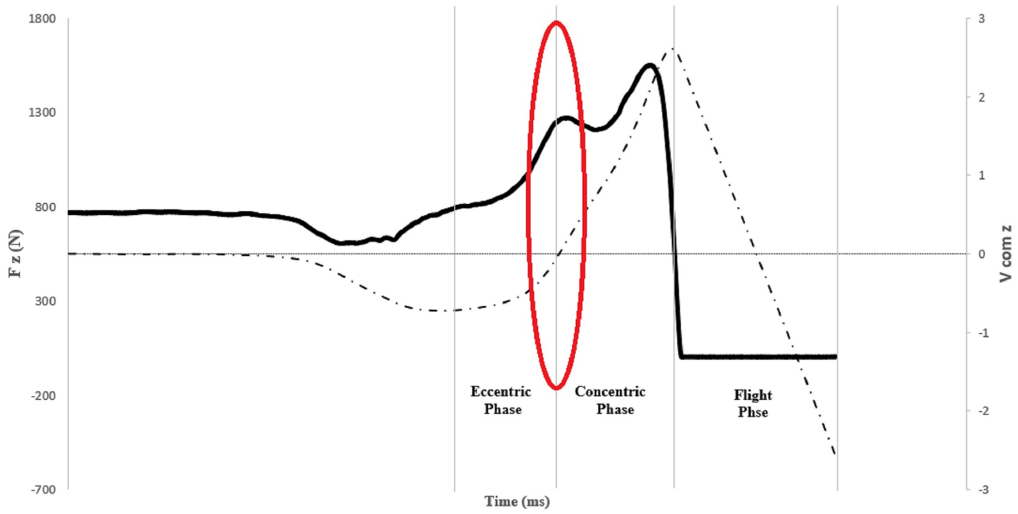

Figure 1. The graph displays the vertical force, instantaneous velocity, and time during the block jump and landing impact Also, the amortization phase is expressed by the red circle between eccentric and concentric phases, which are clarified based on the velocity curve: 1) Eccentric phase, 2) Concentric phase, and 3) Airborne phase.

Performing block jumps during a volleyball game requires several critical elements, including the height of the jump, the speed of the performance, and the sequences of the jumping performance. The optimal amalgamation of these factors enables the performer to accurately place themselves in the required position at the precise moment to obstruct the ball. While there is no specific investigation comparing the force and time characteristics of middle and lateral blockers during the amortization phase, there are related studies that have focused on the kinetics of blocking based on the player's role.

Table 2. Results of the independent t-test

Variables	Blockers	Mean±SD	t	P
T ECC (ms)	Middle	281.87±47.59	0.39	0.70
	Side	266.55±85.95		
T AM (ms)	Middle	100.125±3.72	0.59	0.56
	Side	97.66±11.11		
T CON (ms)	Middle	315.62±102.56	-1.07	0.29
	Side	354.55±34.79		
FECC MAX (N/kg)	Middle	1.90±0.20	-0.62	0.54
	Side	1.96±0.18		
FAM MAX (N/kg)	Middle	1.87±0.06	-1.14	0.27
	Side	1.95±0.17		
FCON MAX (N/kg)	Middle	2.23±0.12	1.58	0.13
	Side	2.11±0.18		

PHYSICAL TREATMENTS

Abbreviations: T ECC: Eccentric time; T AM: Amortization time; T CON: Concentric time; FECC MAX: Maximum eccentric force; FAM MAX: Maximum amortization force; FCON MAX: Maximum concentric force.

For example, Amasay [4] compared the effect of variant starting positions (upright and squat) in static block jumps on variables, such as maximum vertical height, force, and impulse and the findings were consistent with our study demonstrating no significant relationship between force, impulse, and time between peak values for the two types of jump [4].

In numerous daily and athletic endeavors, such as running, jumping, and throwing, the routine pattern involves an eccentric contraction followed by a concentric muscle contraction, with a short amortization phase. This pattern is known as the SSC and is commonly utilized in various movements [4].

Coaches should prioritize enhancing their players' jumping ability to decrease the ratio between submaximal and maximal jumps. By doing so, athletes can reduce their fatigue levels and enhance their overall game ability. Specific training modalities, such as resistance-power training, and counter and bounce drop jumps, which have been shown to improve players' ability to jump higher are recommended [30].

SSC is a crucial mechanism that utilizes the elastic properties of muscles and the stretch reflex to promote muscle power during activities [4, 15]. The SSC consists of two important phases: Eccentric (ECC) and concentric (CON). Fatahi et al. reported a relationship between these two phases, highlighting that the ECC phase has a stronger correlation with other parameters. The role of the ECC phase may be significant in achieving efficient and successful block jumps. They found a significant correlation between the ECC phase and various variables, such as CON, average rate of force development (ARFD) during ECC, peak rate of force development (PRFD) during ECC, and ARFD during CON. The aforementioned findings indicate that the execution of block jumps is primarily determined by the capacity to generate force swiftly and to a lesser degree, by the level of maximal strength [31].

Kumar and Alexander proposed the utilization of plyometrics training in order to optimize the muscle cycle involving elongation and contraction to augment maximal power. This involves a rapid and strong eccentric contraction, where a muscle is lengthened, followed by an explosive and forceful concentric contraction, where the same muscle is shortened. The SSC consists of three phases, with the first phase known as the eccentric phase or stretch phase, which is important in understanding muscle physiology.

In the initial stage of the SSC, also known as the eccentric phase, there is a preloading of the agonist muscle. This is achieved through a rapid eccentric contraction of the agonist muscles, which utilizes the series elastic component (SEC) to store elastic energy. Phase 2, often referred to as the amortization phase or transition phase, is considered the most crucial phase of the SSC. The process of amortization involves a gradual reduction or elimination of something. In this phase, there is a brief period that elapses between the end of phase 1 (eccentric action) and the initiation of the concentric contraction (phase 3). Phase 3, also known as the concentric phase of the SSC or the violent shortening of the agonist muscles, is characterized by an explosive and forceful concentric contraction. The force generated during this phase is greater than that of an isolated concentric muscle action due to the stimulation of alpha motor neurons, which activate the agonist muscle group through the stretch reflex. Additionally, this phase utilizes the stored elastic energy from phase 1, further augmenting the energy required for force production [32].

Block jumping is a complex movement involving multiple joints and muscles, requiring both intra- and intermuscular coordination. The ability of agonist, antagonist, and synergist muscles to work together is crucial for successful performance. In this technique, there is moderate activation of eccentric muscle contraction, succeeded by high activation of concentric muscle contraction.

Furthermore, block jumping necessitates quick and synchronized coordination of the body segments, including push-off, flight, and landing phases [33]. Our investigation highlights two main factors derived from this study: Knee and ankle flexion angles. The introduction of these angles may occur due to the activation of the bi-articular gastrocnemius muscle before the completion of the push-off. This activation allows the transfer of power generated by the knee extensors from the knee joint to the ankle joint. Rapid foot extension is facilitated through gastrocnemius muscle activation, which has a greater impact on block velocity compared to the extension of a nearly straightened knee.

The recoil-state attachment between the gastrocnemius muscle and the foot should be considered an outstanding parameter in enhancing human performance by optimizing the efficiency and effectiveness of movements. Proper sequencing and magnitude of knee and ankle dorsiflexion contribute to the optimal generation and transfer of energy from muscles to elastic tendons and across body segments [34].

Block jump performance in volleyball is influenced by various factors, including muscle force production, power output, kinematics of the lower joints, and appropriate technique and joint sequence. The capacity of the lower limbs to generate sufficient force is crucial for an effective block skill. Anthropometrical and physiological characteristics also play a vital role in determining the kinematics of the lower joints during a block jump [14].

Furthermore, the act of block jumping relies heavily on the power of the muscles in the legs and their ability to generate sufficient force [35]. Additionally, it is crucial to consider the appropriate technique and the correct sequence of joint movements in order to achieve optimal jumping performance. None of the aforementioned studies took into account the angle of the joints as a potential necessary element to the improved execution in block jumping.

The duration required to generate force during the descending phase is a noteworthy factor in determining the height achieved during a vertical jump [7]. A shorter eccentric phase results in a shorter amortization phase and lower vertical jump (VJ) height. Therefore, it is important to analyze sports movements and design specific strength and conditioning exercises that target the required force development [36]. Slowing down the amortization phase has been found to be less efficient for increasing VJ height [37]. Instead, increasing the speed of movement and allowing for longer acceleration through gravity, which leads to an increased height of the center of gravity, can be a more effective means of intensifying training and enhancing the plyometric effect [36].

The comparison between the two different starting positions for block jumps (indicated that the peak height was significantly higher in the maximal BJ from the upright position. There was no significant difference observed in net impulse duration in maximal BJs between the upright and squat positions [4].

Interestingly, Fatahi et al. demonstrated a significant correlation between peak and ARFD values, identified as the most effective predictors among all variables in the force-time variables. This correlation was observed specifically during eccentric (ECC) and concentric (CON) phases, as well as temporal variables [31].

Block jump performance plays a crucial role in volleyball. Further investigations are required to identify the determinants that affect blocker jumping performance in volleyball players. The primary constraint of the present investigation was the absence of data concerning the nutritional characteristics of the athletes, as they were juniors and outside the training camp. Additionally, the familiarity of the players with jumping precisely on the force plate might have influenced the results. It is suggested that future analyses focus on the kinematic aspects of block jumps, along with other important skills, such as spiking and serving.

Practical applications

Block jump performance is crucial in volleyball, and it requires not only the ability of muscles to generate force and produce power but also consideration of kinematic variables, like knee and ankle angles for optimizing block jumps.

5. Conclusions

There is no significant difference between middle and side blockers in terms of time and force during the amortization phase. This finding can be valuable for trainers who aim to design effective training programs by managing task constraints to enhance performance and achieve greater success.

Ethical Considerations

Compliance with ethical guidelines

Consent was acquired in written form from all participants before conducting the tests, and the study adhered to the recommendations outlined in the Declaration of Helsinki. All procedures carried out in the study were authorized by the Research Ethics Committee of the Sport Sciences Research Institute (Code: IR SSRI.REC.1151).

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interests.

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