Research Paper: Block Jump Height Assessment Based on Kinetic Approach in Volleyball Players: Is There any Difference Between Methods?

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ABSTRACT

Purpose: Various kinematics and kinetics methods have been proposed for the assessment of jumping ability as a critical skill in professional volleyball players, but little is known about the accuracy and differences between these methods. Therefore, the objective of the current study was to answer the question "Is there any difference between the results of various kinetic methods in the assessment of block jump height in volleyball players or not?"

Methods: Twenty-one healthy male junior volleyball players of the Iran national team performed the block jump task on a force platform. Three common formulas mostly used in literature based on kinetics output of force platform were selected for the comparison of resultant jump height. Descriptive analysis, Shapiro-Wilk test, and ANOVA were used for statistical calculations ($P<0.05$).

Results: The results showed no significant difference between the means of block jump heights measured based on different kinetic methods in volleyball players.

Conclusion: Formula calculation methods are very valid for measuring the jump height of the block jump and lead to very similar results for estimating jump height and are also replaceable with each other.

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Highlights

- Accuracy of jumping assessment.
- Presenting a new method to calculate jumping height regarding kinetics approach.
- A comparison of different biomechanical methods in calculation.

Plain Language Summary

Vertical jump ability is a critical physical component to success in volleyball, allowing a competitive advantage in attack as well as defense. It is important for volleyball players to reach the maximum height above the net, specifically in attacking and blocking techniques. The height of vertical jump during a block jump reports the potential of reduction in effectiveness of the attacking opponent. many anthropometrical, physiological and kinematical parameters can influence jump height, but kinetic variables have critical effect on this characteristic.

1. Introduction

Volleyball is a non-contact net sport that requires players to perform short bursts of running, positioning, jumping, and blocking [1, 2]. Vertical jump ability is a critical physical component to success in volleyball, allowing a competitive advantage in attack as well as defense [3-6]. Volleyball players need to reach the maximum height above the net [6], specifically in attacking and blocking techniques [7]. The height of vertical jump during a block jump reports the potential of reduction in the effectiveness of the attacking opponent [8]. Biomechanically effective blocking in volleyball partially depends on forceful jumping to elevate the body Center of Mass (COM) as high as possible that the hands can reach the greatest possible height [9]. Therefore, volleyball coaches permanently are searching for the most effective and efficient exercises or methods to improve their player's jumping ability [10].

In point of biomechanical view, block jump is stretch-shortening cycle movements, which involve a high-intensity eccentric contraction immediately before rapid concentric contraction [11]. Thus, in order to maximize performance in this jump, it is important to quickly switch from yielding work to overcoming work and to rapidly develop maximal forces during the concentric phase [11]. It means that during the vertical jump, potential energy and kinetic energy are transformed mutually and muscular work, which is converted into mechanical energy during the flight phase, is performed by the athlete [12].

Although many anthropometrical, physiological [13], and kinematical parameters [14] can influence jump height, kinetic variables play s critical role in this characteristic [15-17]. Thus, common methods to estimate vertical jump height are based on the measurements of Flight Time (FT) to Vertical Ground Reaction Force (VGRF) [18, 19]. The assessment of vertical jump by the VGRF method has been validated in previous studies and is considered the gold standard for the assessment of vertical jump height performance [20-23]. Through measuring the VGRF with a force plate, the vertical height of the jump can be estimated by various techniques and different formulas [14, 24-27], and based on our knowledge, there is no common opinion regarding which methods or formulas are more practical in measuring height in the vertical jump when using a force plate.

Bui et al. compared and analyzed three devices of different methods (contact mat, optical system, and Sargent jump) to evaluate vertical jump height [28]. They found that the contact mat and the optical system essentially provide similar results; however, the Sargent jump tends to overestimate the height, providing a measurement that is significantly different from the other two methods as the jumps are higher. Blosch et al. did a comparative analysis of postural control and vertical jump performance between three different measurement devices (HUMAC balance system, balance trainer BTG4, and force platform) [29]. Their findings suggested that the BTG is a reliable and valid measurement tool capable of assessing Vertical Jump Performance (VJP) compared to other devices.

Some other studies have compared and identified different methods of measuring jump height [30, 31], but to the best of our knowledge, no comparison and analysis were found among different kinetic methods based equations used by biomechanical scientists for jump height estimation, especially in block jump of volleyball players. The main challenge of this study was comparing three kinetic-based approaches in the assessment of block jumping height in volleyball players. Regarding our question, we hypothesized that there is no difference in volleyball block jumping height assessments based on kinetic approaches.

2. Materials and Methods

Subjects

Twenty-one healthy male junior volleyball players of the Iran national volleyball team (Mean±SD age: 17.71±0.90 years, body mass: 76.82±5.96 kg, height: 195.66±2.93 cm, BMI: 20.47±1.54 kg/m^2) participated in this study by convenience sampling method. Participants fulfilled the individual information questionnaire and signed a self-satisfactory form for participating in this study. They were excluded from the study if they had any musculoskeletal or neurological deficit or injury history that could influence jumping biomechanics. All the players used to engage in the normal volleyball training program, including six training sessions weekly, 2 hours per session equally. The procedure was described for each subject clearly. All participants signed individual consent forms according to the Helsinki Deceleration before data collection.

Study design

The athletic task tested in this study was block jump. This technique is a vertical jump performed with the contribution of a stretch-shortening cycle. The subject starts from a ready position with the hands in front of his chest and fingers extended. Block jump begins with a preliminary downward movement by flexing at the knees and hips (eccentric phase) and then, the knees and hips are immediately extended again to jump vertically (concentric phase), while the hands move upward and totally extended above the head. It is well accepted to have a minimum stop between the eccentric and the concentric phases to take advantage of the energy stored by the elastic elements of the muscles [32]. At the beginning of the test, a warm-up protocol was performed individually for 15 minutes according to the official condition of the volleyball training sessions or games. For each subject, three to five times practice was allowed to get more familiar with the appropriate procedure of the test. For minimizing the coach role, no verbal instructions were described for players. The testing procedure was performed in the Olympic Laboratory and under the supervision of the volleyball federation of the Islamic Republic of Iran.

Data collection

Data collection started with the calibration of the force platform system (Kistler® force platform with a sampling rate of 1000 Hz). Participants were asked to perform three maximal block jumps and between each trial, one minute of rest was considered. All the participants were observed carefully along the block jump performance to maintain the appropriate formation of hands and sequences of the mentioned skill.

The vertical GRF was obtained directly from force plate system output. The beginning of the block jump performance was considered according to the instantaneous velocity of the center of mass when it drops under zero and becomes negative. In order to calculate the instantaneous velocity of the center of mass, first, instantaneous acceleration of the center of mass was calculated by dividing vertical ground reaction force minus the weight of the participant to his mass and then, integrating to time by trapezoid method [33]. In the next step, three common formulas that are mostly used in the literature [24-26] were selected for comparison of the resultant jump height. As mentioned above, all data required were extracted directly from the force plate.

In the first method, jump height was calculated from Equation 1 (flight time formula) [26] (Figure 1):

1. $H=g\times ft^2/8$

where, the jump height is in cm; ft (ms) is the flight time, the interval time between taking off the player till landing where the vertical component of force (F_z) in force plate output is zero, and g is the gravity acceleration (9.81 m.s^{-2}).

In Equation 2, peak jump height (H) of the COM was defined as the vertical displacement of the COM from takeoff to its peak according to the projectile principle and was estimated using the vertical takeoff velocity, V_y, [24] was calculated by the acceleration of the center of mass by dividing vertical ground reaction force minus the weight of the participant to his mass and then, integrating to time by trapezoid method (Equation 2, projectile formula):

2. $H=V_y^2/2.g$

Third equation [25] estimated jump height (H) using the impulse method (Equation 3). The impulse method incorporates the impulse-momentum and projectile motion equations (Equation 3, Impulse-momentum formula).

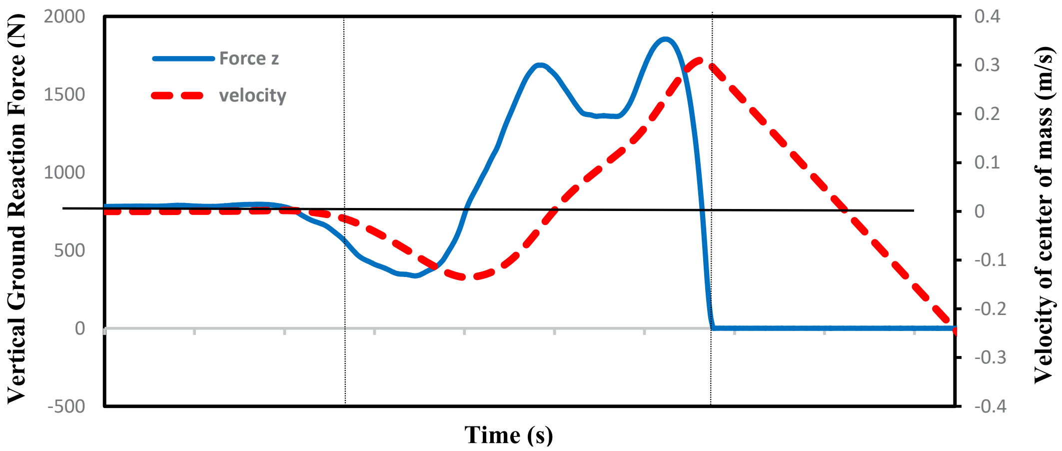

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Figure 1. Flight time was considered when the magnitude of the vertical component of force reaches was lesser than 10N till more than 10N again

3. $h=g/2(\sum_{Start}^{Takeoff}(F_Z-F_W)\Delta t)/F_W-F_0)^2$

Start=before first movement (s), Takeoff=the instant the foot leaves the ground (s), F_z=VGRF (N), F_w=BW (N), F_0=offset, when the force plate is unloaded (N), Δt=sample duration (s), h=upward vertical displacement of the body COM (m), g=9.806 m/s^2.

Data extraction and calculation of the process of jump height according to the three mentioned formulas were conducted and processed by MATLAB software (Math Works Inc., Cambridge, MA, USA). After jump height calculation via each equation, statistical analysis was used to identify differences between them.

Statistical analysis

Statistical analysis was undertaken using SPSS v. 21. The mean and standard deviation were used for descriptive analysis. The Shapiro-Wilk test was used to examine the normality of data, followed by a one-way Analysis of Variance (ANOVA) to examine differences in various outputs of jump height extracted by different formulas. All analyses were considered significant at $P<0.05$.

3. Results

The results of the Shapiro-Wilk test indicated the normal distribution of the data of the variables in both groups. Block jump height results (Mean±SD) of flight time formula (41.87±6.90 cm), projectile formula (41.52±6.45 cm), and impulse-momentum formula (41.74± 6.88 cm) are shown in Figure 2.

Table 1 shows the results of ANOVA to define significant differences between block jump height calculations based on three kinetic approaches in elite junior volleyball players. According to Table 1, no significant difference was observed between the means of block jump heights measured with different methods.

4. Discussion

The objective of the current study was to answer the question "Is there any difference between the results of various kinetic methods in the assessment of block jump height in volleyball players or not?" The results of statistical analysis (Table 1) showed that there was no significant difference between the means of block jump heights measured based on different kinetic methods in volleyball players. Block jump is considered a vital skill to be successful in volleyball. Of the main challenges for volleyball coaches and players, is designing and implementing training programs to promote this skill as much as possible. Moreover, it has been documented that besides improvement in jumping height skills, great concerns should be focused on landing techniques for injury prevention and assessment of kinetic parameters that are applicable mainly through force detection during landing [34].

Although best of our knowledge there is no survey on the analysis of different kinetic methods regarding jump height in volleyball players, limited a few studies have compared different tools or methods for the assessment of block jump height. Blosch et al. conducted a comparative analysis of vertical jump performance between three different measurement devices (HUMAC balance system, balance trainer BTG4, and force platform) [29]. Their results are different from our study indicating that different devices and methods should not be used interchangeably and these various tools will not obtain the

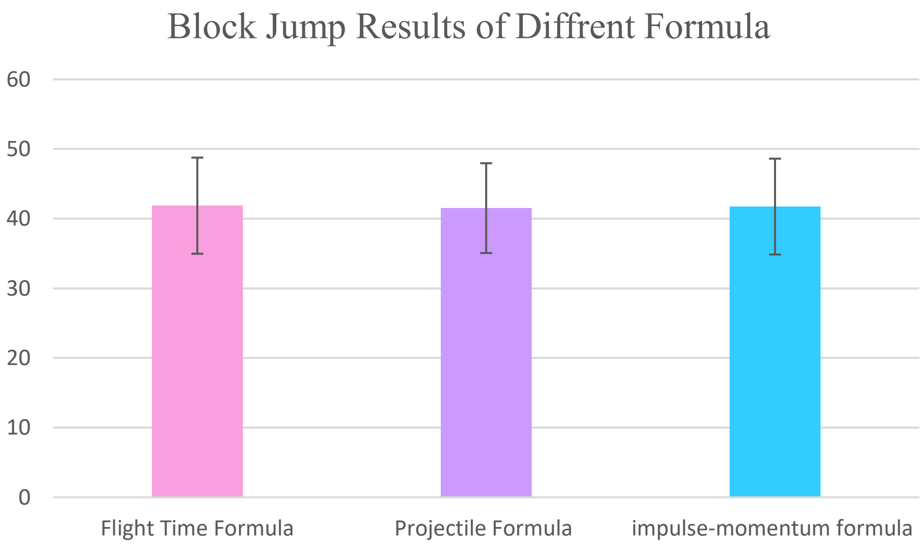

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Figure 2. Block jump height results (Mean±SD) of flight time equation (41.87±6.90 cm), projectile equation (41.52±6.45 cm), and impulse-momentum equation (41.74±6.88 cm)

same outputs. Specifically, this contradiction with our results can be referred to the fact that our method was based on various formulas but with a single kinetic device: force platform. Also, Tien Bui et al. compared and analyzed three different methods (contact mat, the optical system, and the Sargent jump) to evaluate vertical jump height [28]. They concluded that the optical system and the contact mat essentially provide the same information, but in contrast, the Sargent jump only showed a few coefficients with the optical system and the contact mat. Therefore, they stated that in general, the Sargent jump overestimates the height of a vertical jump and its accuracy is reduced as jump height increases. Since in their article they did not focus on different mathematical calculations and concentrated on device and practical assessment methods, analysis of the results of our study would not be comparable with them. But interestingly, despite the conclusion of the mentioned article that increasing height during jumping would influence its results, calculations in our study were performed by exact equations, and jump height will not be susceptible to significant errors and inaccuracy.

In this regard and in another study, Attia et al. investigated the differences in jump heights from Flight Time (FT) (with opt jump) and Double Integration of Force (DIF) (with Quattro-jump). Their results indicated that jump heights from the DIF method were significantly greater compared to the FT method [20]. In comparison with our study, although this survey used a flight time method similar to our research, their main comparison method was based on different tools applied for jump height assessment and they did not concentrate on different kinetic formulas extracted from the force plate device.

In our study, block jumpers were considered as isolated masses, located in the center of mass and all the calculations, especially in the two first formulas (Equations 1 and 2), were considered according to the projectile rules. Vertical velocity of COM in the peak height was considered zero and the time to reach the peak (Equations 1) and the peak height of COM was calculated. Equations 1

Table 1. Results of ANOVA test for comparison of three different methods of block jump height calculation

Variables	Sum of Squares	df	Mean Square	F	Sig.
Between formulas	1.360	2	0.680		
Within formulas	2734.534	60	45.576	0.015	0.985
Total	2735.894	62			

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was based on flight time and acceleration of gravity. Some authors have performed their investigations according to this equation [26, 35-39]. For instance, consistent with our study, Annino et al. investigated the acute effects of static and dynamic stretching on block jump performance using this equation [36]. Also, Peng et al. studied optimum drop jump height in athletes with this method [37].

In the second method, jump height was calculated based on takeoff velocity and projectile principle (Equation 2). Some of the investigations using these approaches for the calculation of jumping height were mentioned; however, some of them used this approach and are consistent with or study regarding the method, concentrating on volleyball performance, and jumping height assessment [14, 24, 40, 41]. Also, Loturco et al. used this method to analyze the validity and reliability of a new contact mat, alongside testing its sensitivity as a system to detect meaningful changes in the neuromuscular performance of elite team sport athletes [42]. Venier et al. conducted a study on the enhancement of caffeinated gel ingestion on jump performance in trained men using this formula [43]. Authors and researchers mainly used this formula for the assessment of jumping height, especially in performing jumping skills in volleyball as well as investigating the validity of the new devices.

The third formula, the impulse-momentum formula, is based on conservation of the momentum and projectile law during the takeoff stage and is calculated by the integration of the force-time curve to time. Amasay [25] used this impulse-moment equation for estimating the effect of upright versus squat staring standing position on block jump in volleyball players. This study was consistent with our study regarding the volleyball jumping height assessment method. Zhang et al. performed an investigation to examine the metatarsal strapping tightness effect on vertical jump performance. Few studies have used this method; however, our results can prove that the results of jumping height assessment even in a specific skill, such as volleyball block, are valid and referable [44].

In general, as height is a kinematic variable, most assessments of jumping height are executed according to kinematic approaches, such as marker setting and optic cameras [28]. Although it should be noted that in comparison to kinetic approaches, kinematic ones are more expensive and require a skilled operator for calibrating and initiation of cameras and marker setting. One of the main points of our study was mentioning the outstanding advantage of kinetic approaches, especially using a force platform, in which researchers can use it as a valid biomechanical instrument for various purposes, including jump height assessment in jumping skills.

5. Conclusion

Great concerns exist regarding advanced biomechanical assessment in the elite population of volleyball players for monitoring their performance as well as other related parameters. According to our investigation, as kinematic methods are more expensive and require a skilled operator for calibrating and initiation of cameras and marker setting than kinetic approaches, kinetic calculation measurements using various equations extracted from force platform for the calculation of block jump height in volleyball players are valid, accessible, and accurate in this regard. Researchers may use all mentioned equations in this study for the assessment of jumping height along with other kinetic parameters.

Ethical Considerations

Compliance with ethical guidelines

All athletes read and signed a written informed consent before testing and completed a detailed injury history form. The study participants were informed about the purpose of the research and its implementation stages. They were also assured of the confidentiality of their information. Moreover, they were allowed to discontinue participation in the study as desired. Finally, if desired, the results of the research would be available to them.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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