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Original Research

Three-Dimensional Analysis of Selected Kinetics and Impulse Variables between Middle and Wing Volleyball Attackers during Block Jump Based on Integration Method

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ABSTRACT

Within the volleyball game skills, Block and Attack are presenting the highest correlation with success, independent of the game phase. Monitoring block jump actions in middle and wing attackers are crucial to improve performance and avoid injuries during this skill, therefore the aim of this study was to investigate the 3-Dimensional analysis of selected kinetics and impulse variables between middle and wing volleyball attackers during block jump based on integration method. 21 healthy junior volleyball players of the national team (11 wing attackers and 10 middle attackers) were selected to participate in this study. The athletic task was Block Jump, performed by middle and wing volleyball attackers. The 3-Dimentional average, maximum and minimum of GRF (Average Force (X, Y, Z), Maximum Force (X, Y, Z), and Minimum Force (X, Y, Z)) were obtained from Force plate system output directly and 3-Dimentional impulse (X, Y, Z) were calculated by integrating force with respect to time. Also, time between two minimum and maximum GRF's peaks (Time between Two Peaks) were calculated for each jump. Average Mean and Standard Deviation were used for descriptive analysis. Shapiro-Wilk test was used for the normality of data. If so, an Independent t-test was performed to compare any differences of variables in three-dimension between two attackers' groups during block jump. The results highlight that middle attackers have greater average force in Anteroposterior (X) and vertical (Z) directions during block jumps, but wing attackers show larger impulse in vertical (Z) direction as well as greater time duration between minimum and maximum force peaks ($p<0.05$). These specific differences in variables of two groups may be useful for physical trainers coaches and specialists who will be able to manage task constrains to design proper training programs for optimal performance and minimizing related injuries.

Keywords: Kinetics, Impulse, Volleyball Attackers, Block Jump, Biomechanics

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Introduction

Volleyball is one of the most popular net sports in the world that is characterized by powerful skills performing intensively followed by low rest periods (1, 2). Within the volleyball game skills, Block and Attack are presenting the highest correlation with success, independent of the game phase (3). Attack and Block are skills achieving most of the points during competitions. Moreover attack effectiveness is consequently thought to be one of the most important predictors of the victory (4-6). It is noticeable that in high level volleyball game, at least one block action is presented against attack of the opponent team. Tillman et al. (2004) and Kugler et al. (1996) indicated that elite attackers use to participate about 16-20 hours a week, performing approximately 40,000 attacks as well as jumps in a year (2). The number of jumps varies in terms of attacker's role, because of different technical-tactical and match motor requirements (1, 7). Critical elements in block jump performance during an attack include height of jump, quickness of jump's execution and timing of jump's initiation (8). Modern volleyball is highlighted by specific game's position according to the ability of skills execution as well as anthropometric measurements (9). For example taller players mostly are recruited to play in the middle of the net according to their ability in higher jumping ability but players with better reception are mainly playing as the wing attackers. Monitoring jump actions in middle and wing attackers are crucial to improve performance and avoid injuries during mentioned skill (10), because it can be performed in a number of ways, most commonly in the form of spike, middle attack and wing attack as described former (11).

Sports biomechanics directing efforts in order to reduce injuries and improve the technique components of athletic performance (12, 13). According to this point of view, factors contributing to high-level performance in the jumps with the least injuries (1, 4) are correlated positively with biomechanical variables and its subsets, i.e. kinetics and kinematics parameters (14). Between different characteristics of biomechanics, Ground Reaction Force (GRF) and Impulse (integral of force over its period of application) are two important kinetics variables that have impressive effects on block jump skills (15-17).

In this way only some sporadic investigations have studied about limited biomechanical variables in volleyball block jumps and to best of our knowledge none of them focused on comparison of different attacker's role. For instance, Singh et al. (2017) have investigated about kinematics analysis of spiking skill in volleyball and they found significant relationships in some kinematic variables like ankle joint, velocity and acceleration of wrist joint (4). Coarcia et al. (2016) investigated analysis of jump load during a volleyball season in terms of different volleyball player role. They found that an assignment and moderate higher amount of jumps performed by middle blockers, and contrarily the setter performing the least jump load in all variables analyzed (18). Also, Amasay investigated the differences in maximal jump height between static block jumps starting from a squat position in women about maximal upright of two jumps in height jump, but they announced no significant differences about the time between two jumpers (8). In another study a comprehensive kinematic analysis of the attack hit, utilizing observations of inverse dynamic variables, was described by Wanger et al. (2009). In that study they tried to find differences between the countermovement jump and spike jump (1).

So, despite the huge requirement to monitor kinetics study of block jump in terms of attack player's role, no comprehensive information related to jumping skills of Volleyball attackers with respect to their position has been found. Also, there is a Paucity of research on monitoring Block jumps on attacker's role. Therefore the aim of this study was to investigate the 3-Dimensional analysis of selected kinetics and impulse variables between middle and wing volleyball attackers during block jump based on integration method.

Material and Methods

Subjects

The study was conducted at the Biomechanics Laboratory of National Olympic Committee of Iran. In the first step, 21 healthy junior volleyball players of national team were selected to participate in this study by available sampling method. In all players, right leg and right hand were dominant limbs. They were excluded from study if they had any musculoskeletal or neurological deficit or injury history that could influence Jumping biomechanics. Subjects were then divided into two groups, 10 middle attackers and 11 wing attackers based on their position on the volleyball court.

All the players participated in normal Volleyball training program including 6 training session weekly, 2 hours per session equally. The procedure was described for each subjects clearly. All participants signed

individual consent form according to Helsinki Deceleration before data collection. Testing procedure was approved by Ethical Committee of Kharazmi University.

Instruments and examination

The athletic task tested in this study was Block Jump that was performed by middle and wing volleyball attackers Block technique is a vertical jump performed with contribution of Stretch-Shortening cycle. The subject starts from ready position with the hands in front of his chest and fingers extended. It 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 moving upward and totally extended above the head. It is well accepted to have minimum stop between the eccentric and the concentric phases to take advantage of the energy stored by the elastic elements of the muscles (6, 19).

At the beginning of the test, warm up protocol equally was performed for two groups for 15 minutes according to official condition of the game. For each subjects, three to five times practice were allowed to be more familiar with the appropriate procedure of the test. For minimizing coach role no verbal instructions was described for players.

Data collection started with the calibration of the force platform system (Kistler® force platform with sampling rate of 1000 Hz). Participants were asked to perform three maximal Block jump and between each trial one minutes rest was considered. In order to perform analysis, Block jump technique was considered form the minimum of the force plate output till the maximum force in vertical direction. The 3-Dimentional average, maximum and minimum of GRF (Average Force (X, Y, Z), Maximum Force (X, Y, Z), and Minimum Force (X, Y, Z)) obtained from Force plate system output directly, and 3-Dimentional impulse (X, Y, Z) were obtained by integrating force with respect to time. For applying integration method, trapezoid rules were conducted. According to this rule, the area under the curves of force- time evaluated by dividing the total area into smaller trapezoids rather than using rectangles. This integration works by approximating the region under the graph of a function as a trapezoid, and it calculates the area. This rule takes the average of the left and the right sum. Also, time between two minimum and maximum GRF's peaks (Time between Two Peaks) were calculated for each jumps. All calculating process and integrations was performed by Microsoft Excel® 2010 by Trapezoid rule.

Statistical analysis

Statistical analysis was performed with SPSS Version 21.0 statistic software package. Mean and Standard Deviation were used for descriptive analysis. Shapiro-Wilk test was used for normality of data. If so, Independent t-test was performed to compare any differences of variables in three dimension between two attacker's groups during block jump. All analysis were considered significant at $p<0.05$.

Results

Table 1 shows demographic characteristics of two attacker groups. The results of the Shapiro-Wilk test indicated normal distribution of the data of the variables in both groups.

Table 1. Demographic characteristics of two attacker groups

Groups	Average ± SD			
	Age (Year)	Height (cm)	Weight (N)	Volleyball Background (Year)
Wing Attackers	19.00±0.77	192.18±4.26	772.43±2.44	5.12±1.07
Middle Attackers	19.00±0.81	198.60±1.77	741.86±3.12	4.99±0.91

Independent T-Test analysis results showed statistically significant differences in Average force X ($p=0.01$), Average force Z ($p=0.005$), Impulse Z ($p=0.00$), and Time Between peaks ($p=0.00$) variables between two attacker groups ($p<0.05$) (Table 2).

Table 2. Independent T-Test analysis of variables between two groups

Variables	Attackers	Mean ± SD	T	df	Sig
Average Force X (N)	Wing	0.014 ± 0.007	-2.857	19	**0.01***
	Middle	0.030 ± 0.017			
Maximum Force X (N)	Wing	0.128 ± 0.031	-1.709	19	0.10
	Middle	0.157 ± 0.046			
Minimum Force X (N)	Wing	-0.228 ± 0.658	-0.652	19	0.52
	Middle	-0.207 ± 0.084			
Impulse X (N.S)	Wing	12.821 ± 3.483	-1.249	19	0.22
	Middle	15.241 ± 5.295			
Average Force Y (N)	Wing	0.007 ± 0.009	0.635	19	0.53
	Middle	0.003 ± 0.018			
Maximum Force Y (N)	Wing	0.048 ± 0.023	-0.031	19	0.97
	Middle	0.048 ± 0.026			
Minimum Force Y (N)	Wing	-0.031 ± 0.016	1.050	19	0.30
	Middle	-0.041 ± 0.026			
Impulse Y (N.S)	Wing	5.068 ± 6.248	1.310	19	0.20
	Middle	0.831 ± 8.500			
Average Force Z (N)	Wing	1.316 ± 0.071	-3.168	19	**0.005***
	Middle	1.448 ± 0.115			
Maximum Force Z (N)	Wing	2.119 ± 0.153	-1.708	19	0.10
	Middle	2.227 ± 0.133			
Minimum Force Z (N)	Wing	0.618 ± 0.209	1.463	19	0.16
	Middle	0.470 ± 0.253			
Impulse Z (N.S)	Wing	978.023 ± 162.278	5.345	19	**0.00***
	Middle	668.379 ± 88.593			
Time Between Peaks (S)	Wing	0.956 ± 0.204	4.893	19	**0.00***
	Middle	0.617 ± 0.081			

* Significant differences p<0.05

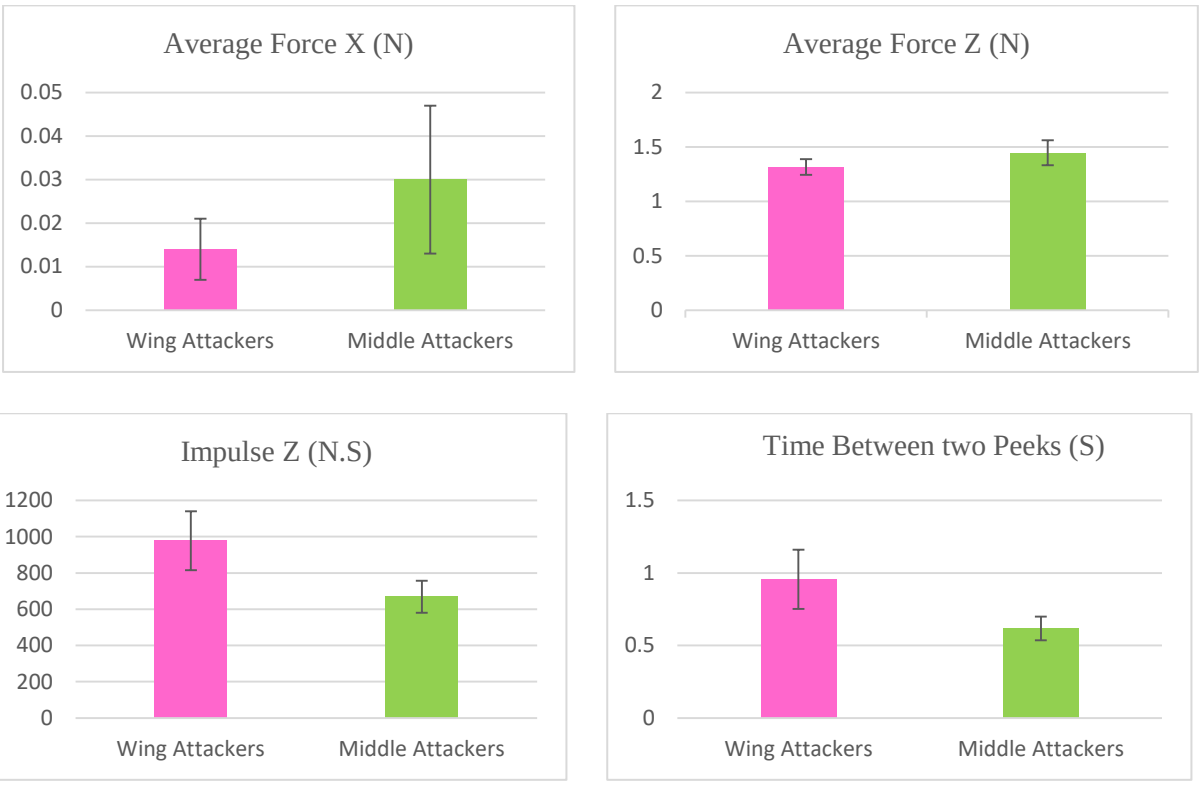

Figure 1. Greater average force in anteroposterior (X) and vertical (Z) directions during block jumps in middle attackers, and larger impulse in vertical (Z) direction and time duration between minimum and maximum force peaks in wing attackers.

Discussion

The aim of this study was to investigate the 3-Dimensional analysis of selected kinetics and impulse variables between middle and wing volleyball attackers during block jump based on integration method. The results highlight that, middle attackers have greater average force in anteroposterior (X) and vertical (Z) directions during block jumps, but wing attackers show larger impulse in vertical (Z) direction as well as time duration between minimum and maximum force peaks (Figure 1).

According to our information, there is no investigation about comparison of force and impulse of middle and wing attackers in three dimensions during block jump. But there are some researches close to our study that focus on kinetics of jumping according to the volleyball player's role. For instance, Kapasinski et al. (2016) compared the take-off dynamics in countermovement jump, volleyball block and spikes (20). Their results were in consistence with our study and showed that the highest values were recorded during take-off in the back row attack: peak vGRF, integral mean vGRF, and impulse of vGRF. As our results show differences in anteroposterior force load in two attacker groups and as we know kinematics of knee flexion and how this two group's jumps and landings are different, this similarity in results may be acceptable. In the other way, Amasay (2008) performed an investigation with contrary results with our study about the influence of two starting (upright and squat) in static block jump on the peak vertical height, force and impulse variables (8). He founded that there is no significant relation between force, impulse and time between peaks of this two kinds of jumping. As the main focus in his study was about starting position for jumping and there was no consideration about player's role, this contrary result is justified. Also, since middle attackers try to reach the second defense in a very short time, they might be faster in block jumps comparing to wing attackers. So their hard landings and greater vertical impulse loading are considerable: it could be verified by the greater time duration between two minimum and maximum peaks.

According to the nature of game's position of these two groups, functional differences may come throughout their performance in Block jump, where middle Blockers generally have more tendencies to jump with less knee flexion. Their main role is first blocking the opponent middle attackers and then covering the net against opponent' wing attackers, so their priority is saving time through lesser knee flexion and faster displacement to both sides of the net. On the other side, wing attackers during their block performance have enough time to reach to their best performance as they would jump against the opponent wing attackers.

Conclusion

This study provides new information about monitoring differences between kinetics and impulse of block jumps of volleyball player attackers. The middle attackers showed greater average force in anteroposterior (X) and vertical (Z) directions during block jumps, but wing attackers show larger impulse in vertical (Z) direction and also, time duration between minimum and maximum force peaks. This specific differences in variables of two groups may be useful and physical trainers who will be able to learn that different player roles require specific jump training loads, and coaches, who will be able to manage task constrains in order to design proper training programs for optimal performance and minimizing related injuries.

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چکیده فارسی

تحلیل سه بعدی متغیرهای منتخب کینتیکی و ایمپالس بین اسپکرهای قدرتی و سرعتی والیبال هنگام اجرای پرش در دفاع روی تور بر پایه روش انتگرال گیری

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چکیده

در میان مهارت های بازی والیبال، دفاع روی تور و اسپک بالاترین سهم را در موفقیت های تیمی برعهده دارند. بدین منظور بررسی پرش دفاع روی تور در اسپکرهای قدرتی و سرعتی با هدف بهبود عملکرد و پیشگیری از بروز آسیب در طی این مهارت حائز اهمیت است. هدف از مطالعه حاضر تحلیل سه بعدی متغیرهای منتخب کینتیکی و ایمپالس بین اسپکرهای قدرتی و سرعتی والیبال هنگام اجرای پرش در دفاع روی تور بر پایه روش انتگرال گیری بود. ۲۱ اسپکر جوان تیم ملی والیبال (۱۱ اسپکر سرعتی و ۱۰ اسپکر قدرتی) به عنوان آزمودنی در این پژوهش انتخاب و مهارت دفاع روی تور را اجرا نمودند. داده های مورد بررسی پرش از طریق صفحه نیرو از فواصل زمانی بین حداکثر تا حداقل نیروی عکس العمل عمودی ثبت شده توسط دستگاه در نظر گرفته شد. میانگین، بیشینه و کمینه میزان نیروی عکس العمل زمین به صورت سه بعدی (X ،Y ،Z) از خروجی سیستم صفحه نیرو و میزان ایمپالس سه بعدی (X ،Y ،Z) نیزاز طریق محاسبه مساحت سطح زیر منحنی نیرو - زمان بدست آمدند. از آمار توصیفی برای محاسبه میانگین و انحراف معیار، از آزمون شاپیرو-ویلک برای بررسی نرمال بودن توزیع داده ها و از آزمون t مستقل برای مقایسه تفاوت میانگین متغیرهای بین دو گروه اسپکرها در حین پرش روی تور استفاده شد. نتایج نشان دهنده این بود که اسپکرهای قدرتی در جهات قدامی-خلفی (X) و عمودی (Z)، میانگین نیروی بیشتری را جذب می کنند، اما اسپکرهای سرعتی، ایمپالس بیشتری در جهت عمودی (Z) بر اندم تحتانی انها وارد شده و همچنین مدت زمان بیشتری را جهت پرش در بین دامنه کمینه و بیشینه نیروی وارده، نشان می دهند ($p < 0.05$). تفاوت های ذکر شده در میان دو گروه از اسپکرهای قدرتی و سرعتی، می تواند برای ورزشکاران و مربیان با رویکرد مدیریت و طراحی برنامه های تمرینی و آموزشی به منظور بهنیه سازی عملکرد والیبال و کاهش میزان بروز آسیب ها سودمند باشد.

واژه‌های کلیدی: کینتیک، ایمپالس، اسپکر، پرش دفاع روی تور، والیبال، بیومکانیک