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Curve Characteristics of Biomechanical Variable Functions and Their Effect on Analyzing the Physical Dimensions of the Volleyball Blocking Skill

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Abstract
Background: Volleyball blocking combines rapid positioning, vertical projection, and segmental coordination. Video-derived kinematic measures may help explain how these movement characteristics relate to technical execution.
Purpose: To describe selected block-jump kinematics and examine their exploratory associations with expert-rated technical performance in university volleyball players.
Methods: Ten members of the University of Al-Qadisiyah volleyball team each completed five successful blocking trials from court position 4 (50 trials in total). Two Galaxy S25 Ultra cameras recorded at 240 frames/s from lateral and posterior views. Kinovea 2025. was used to derive ascent velocity, peak hip height, and total movement time. Three evaluators rated five technique phases on a 100-point scale. The source analysis reported descriptive statistics and Pearson correlation coefficients between each kinematic variable and the technique score.
Results: Mean +/- SD values were 5.68 +/- 0.93 m/s for ascent velocity, 1.536 +/- 0.036 m for peak hip height, 2.69 +/- 0.48 s for movement time, and 71.16 +/- 4.72 points for technique. Reported correlations with the technique score were r = -0.78 for ascent velocity, r = 0.69 for peak hip height, and r = 0.91 for movement time.
Conclusion: The expert-rated technique score was strongly related to the measured movement characteristics. The directions - especially the negative velocity association and positive time association - should be interpreted as task- and scoring-specific rather than causal.
Keywords:
Volleyball; block jump; sports biomechanics; two-dimensional video analysis; kinematics; technical performance

1. Introduction

Blocking is a decisive volleyball action that requires the athlete to identify the attacking context, move efficiently along the net, and generate a vertical jump that positions the hands above and across the net. Effective blocking therefore depends on anticipation, movement speed, jumping capacity, and coordinated control of the body segments (Ficklin et al., 2014; Lobietti, 2009).

Biomechanical assessments can translate visible technique into measurable kinematic features. Previous research has shown that block-jump approach strategy, movement direction, anticipation, blocking technique, and starting posture can influence take-off time, vertical velocity, jump height, joint kinematics, hand penetration, effective blocking coverage, force production, and landing mechanics (Amasay, 2008; Fatahi et al., 2019). Related volleyball research has also demonstrated that exercises targeting antagonistic muscle action according to joint angles can improve biomechanical variables and electromyographic activity during the spike, supporting the combined assessment of movement mechanics and neuromuscular function in explosive volleyball skills (Abdel Abbas & Shubbar, 2024). These findings support the use of task-specific measurements rather than relying only on a global technical impression.

Two-dimensional video analysis is attractive in applied sport settings because it is inexpensive and accessible. However, its accuracy depends on camera alignment, calibration, filtering, and the extent of out-of-plane motion. Validation studies have shown that Kinovea can provide valid and reliable measurements of angles, distances, jump height, and take-off velocity under controlled recording conditions (Pueo et al., 2020; Puig-Diví et al., 2019). Nevertheless, measurement error may increase when the camera is not perpendicular to the movement plane or when calibration is based on a one-dimensional reference (Shishov et al., 2021). Transparent reporting of the recording and digitization procedures is therefore essential.

The original study framed the analysis in terms of the curve characteristics and physical dimensions of the block. Because no mathematical curve model or functional-data procedure was documented, the present English version retains the published title while aligning the stated objectives with the data actually reported: three discrete kinematic variables and an expert-rated technique score. The purpose was to describe ascent velocity, peak hip height, movement time, and technique performance, and to explore the associations between the kinematic measures and the technical score. It was hypothesized that the kinematic variables would be associated with the technique score.

2. Materials and Methods

2.1 Study design and setting

These exploratory cross-sectional biomechanics study was conducted at the indoor sports hall and Biomechanics Laboratory of the College of Physical Education and Sport Sciences, University of Al-Qadisiyah, Iraq. The study period extended from December 28, 2024, to April 17, 2025. A pilot test involving two players was conducted on January 3, 2025, and the main experiment was conducted on February 17, 2025.

2.2 Participants

The study population comprised all 10 players on the University of Al-Qadisiyah volleyball team during the 2024-2025 academic year. Complete enumeration was used, yielding 100% coverage of the team. Each player completed five successful trials, for 50 recorded trials.

Table 1. Participant characteristics (n = 10)

Variable	Unit	Mean	SD	Median	CV (%)	Minimum	Maximum
Age	years	21.10	1.33	21.0	6.32	19	23
Training experience	years	5.15	0.88	5.0	16.99	4	7
Body mass	kg	80.50	3.98	80.0	4.94	73	88
Standing height	cm	186.50	4.76	188.5	2.55	179	192
Lower-limb length	cm	105.90	1.82	106.5	1.72	103	108
Trunk length	cm	83.90	2.20	85.0	2.62	79	86
Arm length	cm	70.80	3.62	70.5	5.12	66	77

CV, coefficient of variation; SD, standard deviation.

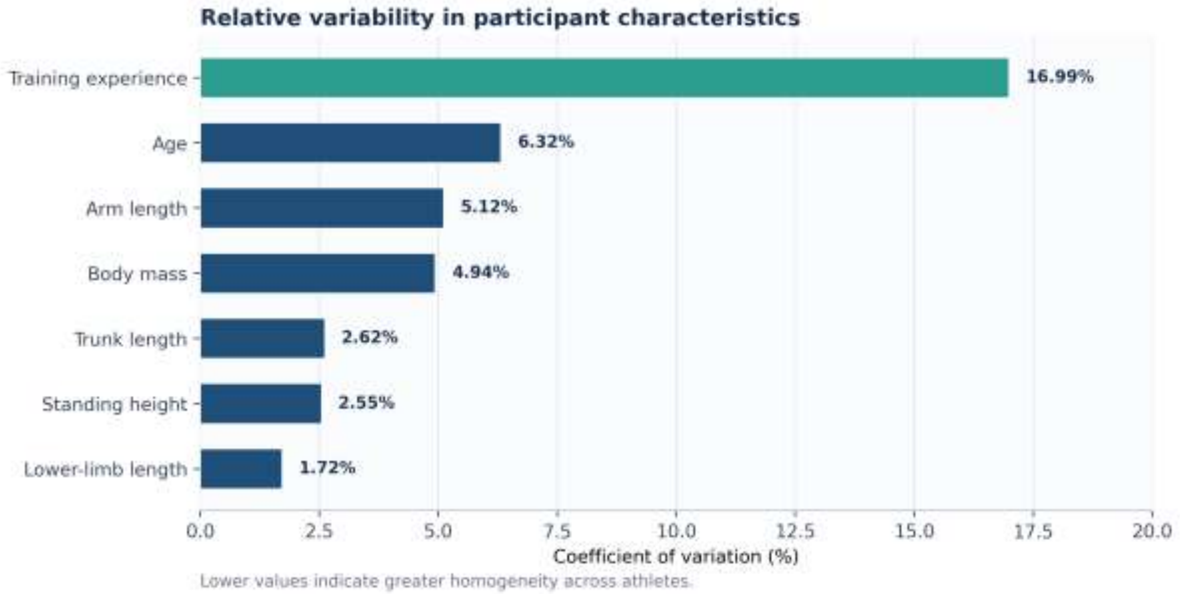

Figure 1. Relative variability in participant characteristics.

2.3 Test protocol and technical evaluation

Testing was performed on a volleyball court. Each player executed five successful blocking trials after moving to block from court position 4. The trials were recorded for subsequent biomechanical analysis.

Technical performance was divided into five observable phases: ready position (10 points), preparatory phase (30 points), main phase (40 points), follow-through (10 points), and recovery (10 points). Three evaluators reviewed the video recordings and assigned scores for each trial. The maximum total score was 100 points.

2.4 Video acquisition and kinematic analysis

Two Galaxy S25 Ultra smartphones recorded at 240 frames/s. One camera was positioned laterally and perpendicular to the primary plane of performance; the second was positioned posterior to the athlete. Both cameras were placed 4.80 m from the performance area with the

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lens center 1.63 m above the floor. The cameras were mounted on tripods. Anatomical landmarks were identified, and the recordings were analyzed in Kinovea version 2025.

Previously measured body-segment lengths were entered into the software and used as scale references. The lateral view was used for planar kinematic measurement, while the posterior view supported observation of the movement path and anatomical landmarks.

2.5 Outcome definitions

Ascent velocity (m/s): Defined in the source as hip-point displacement from immediately before loss of ground contact to peak hip height divided by the corresponding elapsed time. This is more accurately described as mean ascent velocity than as instantaneous take-off velocity.

Peak hip height (m): The vertical distance between the hip landmark and the floor at the highest recorded position, converted using the stated scale procedure.

Movement time (s): The elapsed time from the start of the blocking movement to its end. Operational start and end events were not further specified in the source report.

Technique score (points): The expert-rated score across the five technique phases, with a maximum of 100 points.

2.6 Statistical analysis

The original analysis was performed in SPSS; the software version was not reported. Descriptive statistics included the mean, standard deviation, median, skewness, coefficient of variation, minimum, and maximum. Pearson correlation coefficients were reported between the technique score and each kinematic variable.

Because the 50 trials were generated by 10 athletes, the correlation coefficients are presented as effect magnitudes. The nested trial structure should be considered when interpreting statistical significance.

3. Results

3.1 Descriptive outcomes

Across the observations reported in the source article, ascent velocity averaged 5.68 +/- 0.93 m/s, peak hip height averaged 1.536 +/- 0.036 m, total movement time averaged 2.69 +/- 0.48 s, and the technique score averaged 71.16 +/- 4.72 points (Table 2). The conversion of hip height from centimeters to meters and the interpretation of the performance outcome as points correct apparent unit-labeling errors in the source table.

Table 2. Descriptive statistics for the biomechanical and technique outcomes

Outcome	Unit	Mean	SD	Median	Skewness	CV (%)	Range
Ascent velocity	m/s	5.68	0.93	6.00	0.54	16.41	4.00-8.00
Peak hip height	m	1.536	0.036	1.540	-0.39	2.36	1.460-1.590
Movement time	s	2.69	0.48	3.00	-0.78	17.76	2.00-3.10
Technique score	points	71.16	4.72	69.00	0.97	6.64	65-83

CV, coefficient of variation; SD, standard deviation. Hip height values were converted from centimeters to meters. The source article did not state whether these summaries were based on trials or athlete-level averages.

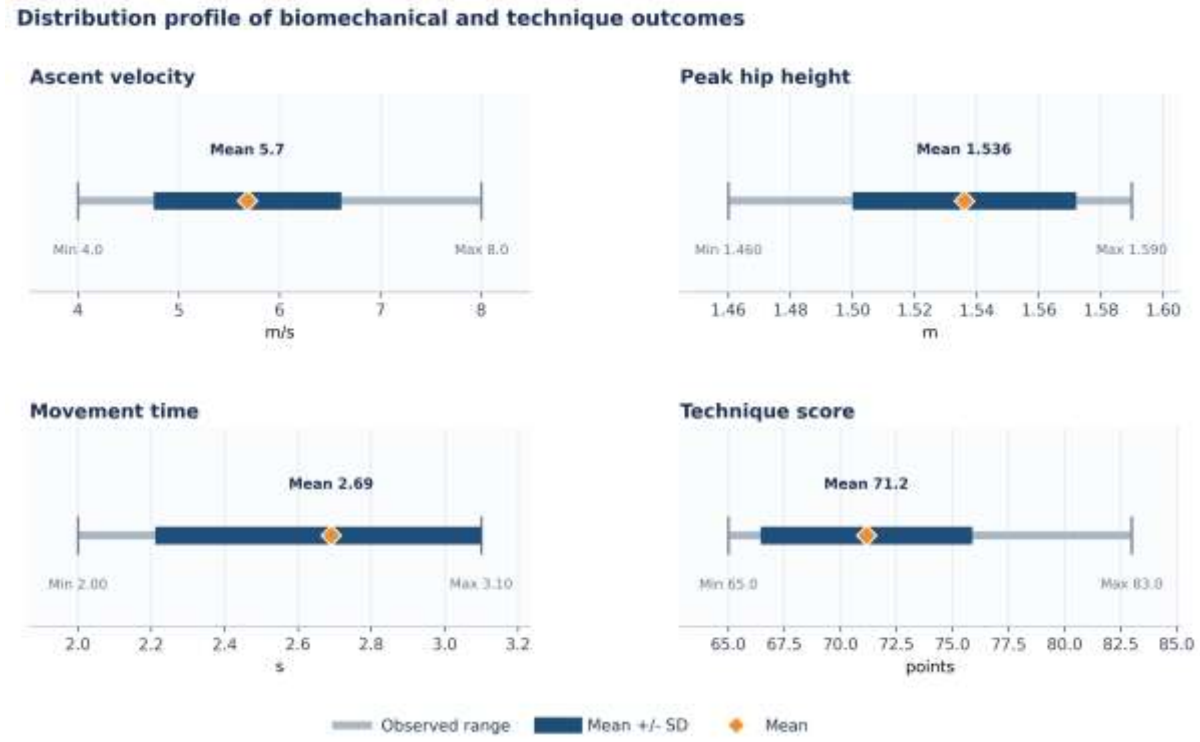

Figure 2. Distribution profile of biomechanical and technique outcomes.

3.2 Exploratory associations

A strong negative correlation was observed between ascent velocity and the technique-performance score. velocity and technique score (r = -0.78), a positive correlation between peak hip height and technique score (r = 0.69), and a strong positive correlation between movement time and technique score (r = 0.91) (Table 3). These coefficients describe the original results.

Table 3. Reported correlations with expert-rated technique performance

Kinematic variable	Reported r	Direction	Magnitude	Inferential status
Ascent velocity	-0.78	Negative	Strong	Requires clustered or athlete-level reanalysis
Peak hip height	0.69	Positive	Moderate-to-strong	Requires clustered or athlete-level reanalysis
Movement time	0.91	Positive	Very strong	Requires clustered or athlete-level reanalysis

r, Pearson correlation coefficient. The original report classified all three correlations as statistically significant, but it did not account for five trials nested within each of 10 athletes; p values are therefore intentionally not reproduced here.

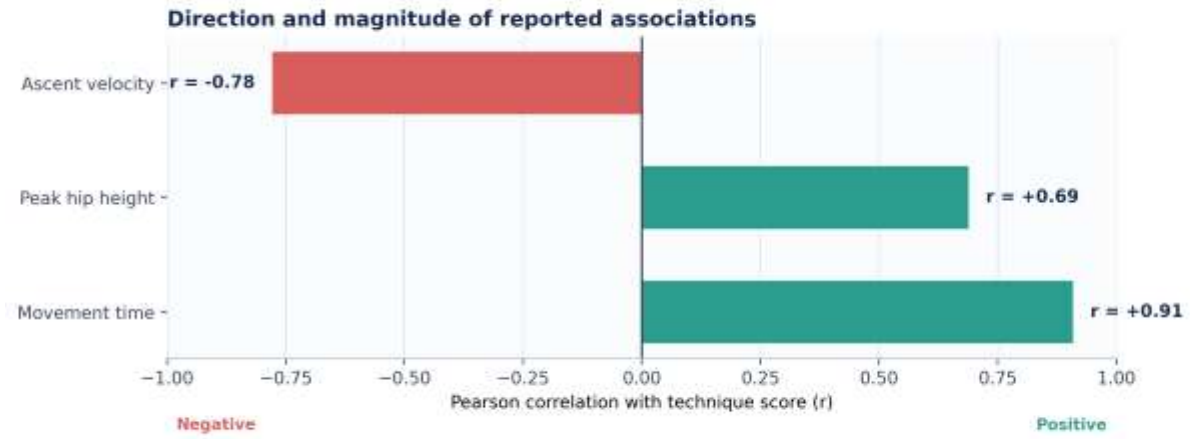

Figure 3. Direction and magnitude of reported correlations with technique score.

4. Discussion

This exploratory study described three video-derived movement characteristics and their relationships with an expert-rated block-jump technique score. The largest reported association was the positive relationship between movement time and technique score, followed by a negative relationship for ascent velocity and a positive relationship for peak hip height. Together, these coefficients indicate that the scoring system captured a coordinated movement pattern, but they do not establish that slower movement causes better blocking performance (Abbas & Shubar, 2024).

The positive association between peak hip height and technique score is mechanically plausible. A higher hip position at the apex generally reflects greater vertical displacement, which may improve the player's ability to project the hands above the net. Previous work has linked block-jump performance with lower-limb kinematics and approach strategy, although the specific determinants vary across testing protocols and populations (Fatahi et al., 2019; Garcia et al., 2022).

The negative velocity association warrants particular caution. The source variable was calculated as displacement divided by elapsed time from a pre-take-off instant to peak hip height, rather than an instantaneous take-off velocity. Its value therefore depends on event selection, displacement, and flight timing. In addition, a technically controlled trial may receive a high score even when this average velocity is lower. The result should not be interpreted as evidence that athletes should intentionally reduce take-off speed.

Likewise, the positive relationship between total movement time and technique score may reflect the construction of the rating scale. Seventy percent of the available points were assigned to the preparatory and main phases, and raters may have rewarded visible sequencing and control. In match play, however, excessive movement time can reduce the blocker's ability to respond to the setter and attacker. Contemporary block-jump research shows that approach style and anticipation alter time to take-off and mechanical output, emphasizing that time variables must be interpreted within the tactical task (Ibrahim & Shubbar, 2023; Schmorantz et al., 2024; Zhao et al., 2024).

The use of high-frame-rate video is a practical strength, but frame rate alone does not guarantee accurate kinematics. Camera orientation, calibration, filtering, marker identification, and out-of-plane movement all affect two-dimensional estimates (Shishov et al., 2021). The lateral camera was described as perpendicular to the main plane, which is appropriate for vertical measures, but lateral blocking inherently contains movement outside a single sagittal plane. Future work should use a two-dimensional calibration frame in the performance plane, report digitization reliability, and consider synchronized three-dimensional motion capture when available. Validated AI-assisted markerless motion-analysis systems may offer a more accessible option for future studies; however, their validity and reliability remain dependent on the motion-capture system, movement task, anatomical joint, plane of motion, and specific kinematic outcome being assessed (Yoma et al., 2025).

4.1 Limitations

Several limitations constrain interpretation. First, the sample comprised only 10 players from one university team, limiting precision and generalizability. Second, five trials per athlete were treated as independent in the source correlation analysis, which may underestimate uncertainty. Third, participant sex, eligibility criteria, injury history, warm-up, rest periods, and task stimulus were not reported. Fourth, the calibration and filtering procedures were insufficiently specified, and no intra-rater or inter-rater reliability statistics were provided for digitization or technical scoring. Fifth, total movement time was not defined by reproducible start and end events.

4.2 Practical applications

Coaches may use high-frame-rate video to supplement technical observation of the block jump, particularly for monitoring vertical displacement and movement sequencing. However, the present coefficients should not be used as normative targets. Applied feedback should combine kinematic measures with tactical timing, block reach, approach direction, and the quality of hand positioning over the net. A standardized protocol and reliability testing are necessary before repeated measurements are used to evaluate individual progress.

5. Conclusion

The source data showed substantial associations between expert-rated block-jump technique and three video-derived measures: ascent velocity, peak hip height, and total movement time. Peak hip height and movement time were positively associated with technique score, whereas ascent velocity was negatively associated. These findings are exploratory and task-specific. A valid athlete-level or mixed-effects reanalysis, clearer operational definitions, and documented measurement reliability are required before the findings can support strong performance recommendations.

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