A Comparison of Jump Height, Takeoff Velocities, and Blocking Coverage in the Swing and Traditional Volleyball Blocking Techniques

Travis Ficklin, Robin Lund and Megan Schipper
Biomechanics Laboratory, University of Northern Iowa, Cedar Falls, IA, USA

Abstract
The purpose of this study was to compare traditional and swing blocking techniques on center of mass (COM) projectile motion and effective blocking area in nine healthy Division I female volleyball players. Two high-definition (1080 p) video cameras (60 Hz) were used to collect two-dimensional variables from two separate views. One was placed perpendicular to the plane of the net and the other was directed along the top of the net, and were used to estimate COM locations and blocking area in a plane parallel to the net and hand penetration through the plane of the net respectively. Video of both the traditional and swing techniques were digitized and kinematic variables were calculated. Paired samples t-tests indicated that the swing technique resulted in greater (p < 0.05) vertical and horizontal takeoff velocities (vy and vx), jump height (H), duration of the block (tBLOCK), blocking coverage during the block (C) as well as hand penetration above and through the plane of the net’s plane (YPEN, ZPEN). The traditional technique had significantly greater approach time (tAPP). The results of this study suggest that the swing technique results in both greater jump height and effective blocking area. However, the shorter tAPP that occurs with swing is associated with longer times in the air during the block which may reduce the ability of the athlete to make adjustments to attacks designed to misdirect the defense.

Key words: Volleyball, blocking, technique, penetration, jumping.

Introduction
In volleyball, the skill of blocking, in which a player or players jump and extend their hands above and over the net (without touching the net) to block an attack (spike) by the opponent, is crucial to team success (Eom and Schutz, 1992; Lenberg, 2004). Effective blocking in volleyball is partially dependent upon forceful jumping in order to elevate the body center of mass (COM) as high as possible in order that the hands can reach the greatest possible height (Farokmanesh and McGown, 1988). Further, hand penetration through the plane of the net has importance in taking away possibilities from the attacking player by reducing the set of directions in which the ball can be hit (Farokmanesh and McGown, 1988; Lenberg, 2004).

A recent study has shown that jump height, hand penetration, and time to get hand above the net vary with the choice of a traditional blocking technique versus a swing blocking technique (Neves et al., 2011). Both techniques feature similar footwork, called the approach. In the traditional technique, the player makes the approach with the hands held neutrally in front of the shoulders (see Figure 1a). In the swing technique, the approach is made while allowing the arms to swing lower, similarly to the approach used by an attacker (see Figure 1b).

This added arm swing causes the jumping motion of the blocker to be more like that of a countermovement jump. In general, arm swing, like that used in a countermovement jump, allows for greater elevation of the COM compared to using less arm swing (Harman et al., 1990, Lees et al., 2004; 2006; Shetty and Etnyre, 1989). Jump height achieved in countermovement jumping is also correlated to height achieved in spike jumping for the attacker (Wagner et al., 2009), and it seems reasonable that the swing blocking technique also benefits from the countermovement. It has been shown that in blocking the swing technique allows for better COM height and hand penetration (Neves et al., 2011), but the full effect of technique choice on lateral horizontal jumping velocity and the time required to execute the jumping approach remains unclear.

Because the body COM path is determined during takeoff and unchangeable in the air, differences in this
horizontal velocity between techniques could lead to
differences in the ability of the athlete to adjust to attacks
and misdirection once airborne. Additionally, it is un-
known what effect, if any, the swing technique has on the
effective blocking area a player can cover with their
hands and the time over which this area is presented.

The effect of technique choice on horizontal veloc-
ity and blocking coverage should be investigated in order
to provide further information to practitioners about the
potential advantages and disadvantages. The potential for
greater blocking coverage above the net should be consid-
ered, along with any effects of horizontal jumping veloc-
ity on game play.

Therefore, the purpose of this study was to com-
pare traditional technique to swing technique in terms of
body COM airborne motion and effective blocking cover-
age. It was hypothesized that the swing technique would
feature a greater lateral horizontal takeoff velocity of the
body COM and would allow for greater blocking cover-
age.

Methods

Participants
The study was first approved by the Institutional Review
Board and nine female NCAA Division I intercollegiate
volleyball players (age: 20.9 ± 1.9 years; height: 1.85 ±
0.05 m; mass: 76.3 ± 7.8 kg) volunteered to participate.
Subjects were free of injury and cleared for activity by
the coach and medical staff at the time of the study. After signing
an informed consent form, each individual completed a
counterbalanced order. Each subject started in a “ready” position
with both feet within in a rectangle marked on a volley-
ball court. This rectangle was 82.5 cm by 45 cm and was
marked 30 cm from the court’s centerline such that its
long axis was parallel to the plane of the net and exactly
centered at the midpoint of the centerline.

A blue square “target” was affixed to the top of the
net in order to provide the blocker with a location at
which they should make the block. This target was placed
on the net’s top at a distance of 150 cm from the antenna
denoting out of bounds. Subjects were asked to jump
maximally, as though in game conditions, and to block as
though an attack were coming from a point as high as
maximally, as though in game conditions, and to block as
denoting out of bounds. Subjects were asked to jump
on the net’s top at a distance of 150 cm from the antenna

Study procedures
Each participant was asked to execute six successful
blocking trials; three of the swing method and three of the
traditional method, which were executed in a counterbal-
anced order. Each subject started in a “ready” position
with both feet within in a rectangle marked on a volley-
ball court. This rectangle was 82.5 cm by 45 cm and was
marked 30 cm from the court’s centerline such that its
long axis was parallel to the plane of the net and exactly
centered at the midpoint of the centerline.

For the video data from the camera recording per-
pendicularly to the net, the locations of 21 body land-
marks (vertex, gonion, suprasternale, right and left shoul-
ders, elbows, wrists, third knuckles, hips, knees, ankles,
Volleyball blocking technique

Heels, and toes) were manually digitized, and their horizontal (X) and vertical (Y) locations were expressed in standard units with respect to a planar origin at the midpoint of the centerline and on the ground. One trial for each technique per player was chosen for analysis. In each case, this was the trial in which the player’s head reached the greatest height based upon visual inspection. If the subject failed to center the blue target between the hands during the block, the trial was not considered for analysis.

Center of mass motion

The body was modeled as a 14-segment system. Segmental COM locations were computed using methods similar to those used by Dapena (1986). The whole-body COM location was calculated using a segmentation method (Winter, 2005) in first the X and then the Y dimensions:

$$S_{CM} = \sum_{i=1}^{14} m_i S_i$$  \[1\]

where $S_{CM}$ is the location of the COM in either the X or Y dimension, $S_i$ is one of 14 segmental COM locations, and $m_i$ is the corresponding segmental relative mass (de Leva, 1996). Using these segmental parameters and photogrammetry with live subjects has been shown to estimate the COM location to ± 0.016 m compared to measuring its location with a precision reaction board in young adult females (de Leva, 1996).

Because the COM trajectory of an airborne player is predictable, player COM takeoff velocities were computed based upon projectile motion. First, the horizontal and vertical locations of the COM were calculated using Eq. 1 in each dimension in two video frames: at takeoff ($X_0, Y_0$) and at touchdown ($X, Y$). The long time period between these frames, as opposed to using consecutive frames, was chosen to minimize percentage error while allowing for usable data from minimal digitizing to reduce error stemming from COM location calculation. The time between the frames was calculated using:

$$t_{AIR} = (fr_{TD} - fr_{TO}) \cdot \frac{1}{60} \text{s}$$ \[2\]

where $t_{AIR}$ represents the total airborne time, and $fr_{TO}$ and $fr_{TD}$ represent the numbers of the takeoff and touchdown frames, respectively, estimated to the nearest half-frame. Takeoff was defined as the last frame in which the second takeoff foot to leave the ground was in contact with the ground before the block. Touchdown was defined as the first frame in which the first foot to touch the ground again after the block made contact with the ground.

The horizontal and vertical takeoff velocities ($v_x$ and $v_y$, respectively) of the COM were calculated using the formulas:

$$v_x = \frac{X - X_0}{t}$$ \[3\]

and:

$$v_y = \frac{Y - Y_0 + \frac{1}{2} \cdot g \cdot t^2}{t}$$ \[4\]

where $g$ represents the acceleration due to gravity, which had a magnitude of 9.81 m·s$^{-2}$ for the purposes of the present study.

Peak jump height (H) of the COM was defined as the vertical displacement of the COM from takeoff to its peak, and was estimated using the vertical takeoff velocity, $v_y$, and the following formula:

$$H = \frac{v_y^2}{2 \cdot g}$$ \[5\]

Blocking coverage and penetration

Blocking performance depends not only on a blocking area ($A_B$) presented by the blocker in the plane of the net, but also upon the duration of the block ($t_{BLOCK}$). Therefore, a method was conceived to express blocking coverage $C$ achieved by the subject.

First, $t_{BLOCK}$ was computed using:

$$t_{BLOCK} = n_{FR} \cdot \frac{1}{60} \text{s}$$ \[6\]

where $n_{FR}$ represents the total number of frames during which the subject’s wrist joints were both at or above the level of the top of the net.

To calculate blocking area in the plane of the net, six defining points were digitized on the extended arms and hands for every frame during the period spanned by $t_{BLOCK}$. These points were the lateral-most intersections of the forearms with the net top in the plane of the net, the lateral-most finger tips and the uppermost finger tips for each arm (see Figure 2). The blocking area, $A_B$, of the resulting polygon in the plane of the net was calculated by dividing the hexagonal shape into four triangles and summing their individual areas, which were found through vector geometry. To calculate $C$, a plot was made for each trial of $A_B$ versus $t_{BLOCK}$, and the area under this curve was found through definite integration using the mean value theorem with 0.0 s and $t_{BLOCK}$ as the defining endpoints.

Figure 3. The view from the second camera directed along the top of the net.

To measure hand penetration through the plane of the net, the average of the locations of the most distal fingertips of each hand as seen by the second camera, which was aligned with the top of the net, were digitized and calculated in the vertical ($Y_{PEN}$) direction. Additionally, anterior penetration was defined as being in the Z
direction (Z\_PEN) and was likewise calculated from the average position of the most distal fingertips (see Figure 3). This was done for each frame in which a distal fingertip from both hands was at or above the level of the top of the net from the view along the top of the net. The maxima of Y\_PEN and Z\_PEN were determined for each block.

The time of approach (t\_APP) taken by each subject to move from their starting position to the initiation of takeoff was also calculated. t\_APP was defined as the time period between the instant the right foot left the ground to start the lateral approach and the instant that a second foot touched the ground to begin the two-footed takeoff.

### Statistical analysis

Paired t-tests were made between traditional and swing techniques for: v\_x, v\_y, H, t\_BLOCK, C, Y\_PEN, and Z\_PEN. An alpha value of p < 0.05 was used to indicate statistical significance.

### Results

Both v\_x and v\_y were greater for the swing technique. v\_x for the traditional technique was 0.19 ± 0.13 m\(\)s\(^{-1}\) compared to 0.74 ± 0.24 m\(\)s\(^{-1}\) for swing (p < 0.01). In the swing technique, the blocker initiates takeoff sooner than in the traditional technique, which is seen in a smaller t\_APP (1.08 ± 0.08 s for swing compared to 1.21 ± 0.11 s for TR).

The greater v\_y for the swing technique (2.73 ± 0.19 m\(\)s\(^{-1}\)) compared to that of the traditional technique (2.51 ± 0.21 m\(\)s\(^{-1}\), p < 0.01) also led to a greater H (0.38 ± 0.05 m) for the swing technique when compared to traditional blocking (0.32 ± 0.05 m, p < 0.01). The differences in average trajectory of the COM in each condition can be seen in Figure 4.

At the hands, this increase in H allowed for greater t\_BLOCK, Y\_PEN, and Z\_PEN in swing blocking (0.46 ± 0.04 s, 17.0 ± 2.9 m, and 36.5 ± 4.2 m, respectively) than in traditional blocking (0.40 ± 0.04 s, 14.2 ± 5.7 m, and 33.2 ± 5.0 m; p < 0.01, p < 0.05, p < 0.01).

C was greater for the swing technique (729 ± 107 cm\(^2\)\(\)\(\)s\(^{-1}\)) compared to the traditional technique (618 ± 112 cm\(^2\)\(\)\(\)s\(^{-1}\)). C was affected by both t\_BLOCK and A\_B. These effects are not separated in the current analysis, but it is noted that while the increased H associated with swing blocking technique would be associated with a greater A\_B in a given frame (by allowing the hands to reach a higher level), the greater t\_BLOCK with swing also increases C by protracting the time domain of the integration.

### Discussion

As hypothesized, the swing blocking technique was marked by greater v\_x while achieving greater vertical takeoff velocity v\_y. The swing blocking technique also allowed for greater coverage C, which is partially related to planar blocking area by the hands, and partially related to the time period during which the hands are above the net.

The increased v\_y and H for swing blocking found in the present study are consistent with previous findings made using other analysis methods (Neves et al., 2011), but are presented here with analysis of C and v\_x as they relate to the success of a block. The time of approach t\_APP was shorter for the swing technique in the present study, while “time to takeoff,” as described in Neves et al. (2011) was the same for both techniques. This discrepancy arises because in the present study, t\_APP is defined to be the time between starting the approach and initiating the two-footed takeoff, while in the prior study, the time to takeoff was defined to be the time period between starting the approach and leaving the ground after the two-footed takeoff.

---

**Figure 4.** Trajectories of c.m. for TR and SW airborne phases (with respect to location of c.m. at takeoff). Average TR trajectory is marked by red circles. Average SW trajectory is marked by green squares.
Taken together with an increased $t_{\text{BLOCK}}$, $Y_{\text{PEN}}$, and $Z_{\text{PEN}}$, the greater coverage $C$ and COM height $H$ possible with swing blocking could allow for a very effective block compared by these criteria with the traditional technique. However, these techniques are employed as responses to the attacking team’s tactics, and other factors may be important to the effectiveness of the block. For example, if only vertical displacement were key to blocking success, probably all teams would want to deploy the swing technique, but given that adjusting to the attack could be vital to the success of the block, it is important for coaches and athletes to consider the implications of the greater $v_s$ and shorter $t_{\text{APP}}$ associated with swing blocking.

In the present study, subjects were required to make a block to a target a given distance away from their starting location laterally. The shorter $t_{\text{APP}}$ and greater $v_s$ of the swing technique imply that the blocker starts take-off earlier and covers that lateral distance more in the air and less on the ground when compared to traditional blocking. While this should not impact the ability of the blocker to reach that target on-time, it does mean that more of the distance is covered while airborne. The swing blocker commits to an airborne trajectory earlier than the traditional blocker, and once committed, the COM travels further laterally while airborne. Though the hands can be repositioned while airborne, no adjustment to the trajectory of the COM can be made, and so the options available to the player for using the hands are constrained. This is true for the airborne traditional blocker as well, but the commitment comes slightly later than for the swing blocker, and this may mean that the traditional blocker can make adjustments to an attack slightly later in order to avoid being fooled by misdirection.

Considering the advantages of the swing technique found here, it becomes important to examine the reasons a team would still employ the traditional blocking technique. It may be possible that beyond a certain point, increased $H$ for the blocker may not continue to increase blocking advantage when compared to the need for late adjustment. Additionally, traditional blocking is thought to be more effective against deceptive, fast-tempo attacks (Gonzalez, 2005). Given the overall goal of the block, increasing jump height in itself does not necessarily equate to increased blocking success.

For example, because of the importance of the timing of hand arrival, the swing technique has an inherently increased degree of difficulty due to the path of the hands from outside the body because of swinging, making it possible for their arrival to be late or mistimed. This could result in undesired deflection of the ball by the block. In contrast, in the traditional technique, the hands remain in front of the body, making them easier to control and therefore time their arrival properly and control deflections better. This latter approach, of course, means that attacking players see the hands sooner and for more time, and therefore have additional information to avoid the block.

Additionally, blockers need to achieve lateral movement to initiate the block and then must jump vertically to execute the block, but only need to reach a height that matches that of the oncoming attack. Players who can readily reach that height, but who have difficulty with timing the block while moving laterally through the air stand to benefit from the traditional technique by being able to make the lateral movement more efficiently, and retaining contact with the ground longer to make fine adjustments. These advantages potentially outweigh any further benefit that may or may not be realized through employing the swing technique. When a greater blocking height is required against an opponent that has hitters who can reach higher, the use of the swing technique may be considered in order to attain the required reach height.

Typically, teams implement one style or the other on a team-wide basis, but it is possible that some players are not likely to realize much advantage from swing blocking - at least, not advantages that warrant altering current strategies, skills, and roles within the team. Coaches may wish to consider the individual characteristics and strengths of individual players rather than adopt one strategy over the other on a whole-team basis. For example, tall players may be able to achieve sufficient jump height and blocking coverage while retaining any advantages to using the traditional technique. By contrast, shorter players, but who are capable of developing jumping force at greater rates could produce the same upward jumping impulse in less time, allowing for the use of the swing technique without having to leave the ground as early.

**Conclusion**

In the present study, several potential advantages to swing blocking are supported. These include increased jump height, which stems from increased vertical takeoff velocity, increased time of blocking with the hands above the net, effective coverage, which comes from increased planar blocking area associated with increased height of the hands as well as the time the block is presented above the net, and increased vertical and anterior penetration by the hands. Also associated with swing blocking technique, however, are increased horizontal takeoff velocity and a shorter time of approach before becoming airborne.

Considering the advantages and disadvantages of both techniques found here, it is not surprising that both techniques are employed at even the highest levels of play. It is reasonable to conclude that coaches should be open to both techniques based on the variation of certain anthropometric and athletic variables. That is, taller players should be able to achieve adequate $C$ and $H$ while employing the traditional technique when compared to smaller players. Furthermore, players who are able to achieve jumping impulses via high rates of force development (i.e., in less time) should theoretically be able to employ the swing technique while minimizing the negative aspects of decreased approach time and increased time in the air by initiating the swing technique later.

This study was limited by the fact that subjects were asked to execute blocks without the benefit of a real attack to defend. This choice was made in order to standardize the lateral distance that the subjects covered in making the blocks, but it is impossible to tell what, if any,
effect this had on the blocker’s motion if it were to be made in game-play conditions.

Acknowledgements
The authors wish to thank the players who volunteered to participate in this study, as well as their coaches for allowing the use of their practice facilities in which to collect data. We also thank coach Kalani Mahi from the University of Northern Iowa for his insight and wisdom in consulting about the practical uses of these techniques.

References

Key points
- Swing blocking technique has greater jump height, effective blocking area, hand penetration, horizontal and vertical takeoff velocity, and has a shorter time of approach.
- Despite these advantages, there may be more potential for mistiming blocks and having erratic deflections of the ball after contact when using the swing technique.
- Coaches should take more than simple jump height and hand penetration into account when deciding which technique to employ.

AUTHORS BIOGRAPHY
Travis FICKLIN
Employment
Assistant Professor of Movement and Exercise Science at the University of Northern Iowa.
Degree
PhD
Research interests
Biomechanics of sport.
E-mail: travis.ficklin@uni.edu

Robin LUND
Employment
Assistant Professor of Movement and Exercise Science at the University of Northern Iowa.
Degree
PhD
Research interests
Strength and conditioning.
E-mail: robin.lund@uni.edu

Megan SCHIPPER
Employment
Sport Performance Coach at Superior Athletic Advantage, Barrington, IL, USA.
Degree
BA
Research interests
Volleyball.
E-mail: megan.schipper15@gmail.com

Travis Ficklin, PhD
Assistant Professor, University of Northern Iowa School of HPELS, WRC 123 Cedar Falls, Iowa 50614-0241, USA