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Research article

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 (v_y and v_x), jump height (H), duration of the block (t_{BLOCK}), blocking coverage during the block (C) as well as hand penetration above and through the net's plane (Y_{PEN}, Z_{PEN}). The traditional technique had significantly greater approach time (t_{APP}). The results of this study suggest that the swing technique results in both greater jump height and effective blocking area. However, the shorter t_{APP} 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).

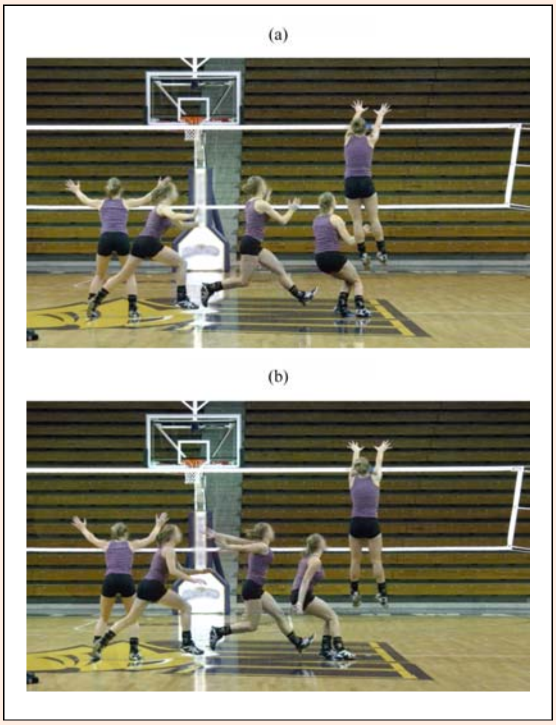

Figure 1. **Typical sequence of the TR (a) and SW (b) techniques.**

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 e. 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

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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 unknown 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 velocity 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 considered, along with any effects of horizontal jumping velocity on game play.

Therefore, the purpose of this study was to compare traditional technique to swing technique in terms of body COM airborne motion and effective blocking coverage. 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 coverage.

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 team medical staff at the time of the study. After signing an informed consent form, each individual completed a five-minute dynamic warm-up routine followed by practice blocks of each style until feeling comfortable in their ability to do both successfully. The majority of the participants had been trained in both blocking patterns but was much more familiar with the traditional technique and required less time to practice that method.

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 counterbalanced order. Each subject started in a "ready" position with both feet within in a rectangle marked on a volleyball 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 possible above the blue tape (see Figure 2). Therefore, each subject started from the middle of the court and moved rightward a distance of 3.0 m to execute each block as though the opponent's attack was coming from above the blue target. This was done in lieu of using a ball or lives attack in order to standardize the point of attack to allow for comparison between trials and conditions. One researcher with volleyball expertise, as both a Division I collegiate player and coach, verified on a per-trial basis that the technique used was the correct one called-for in the counterbalanced order and that the target was between the extended arms of the blocker while the hands were above the net. If the blocker did not keep the target between the arms, the trial was repeated. Blockers were highly successful in this regard, with only three total trials needing to be repeated over the course of the study.

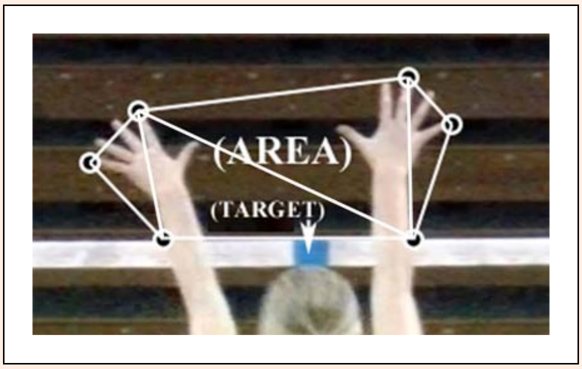

Figure 2. Blue target for blockers and total blocking area covered by hands.

Video data

Two high-definition (1080p) video cameras (JVC GC-PX1, Victor Corporation, Tokyo, Japan) recording at 60 Hz were used to record each block. One camera was placed with its optical axis perpendicular to the plane of the net and approximately 30 m behind the subject. Video from this camera was used to digitize body landmark data to obtain COM locations and blocking area in a plane parallel to the net.

The second camera was positioned with its optical axis horizontal and in the plane of the net, directed along the top of the net. Video from this camera was used to digitize hand position with respect to the top of the net to measure height and penetration of the hands during the block. All video data were transferred to digitizing software (MaxTraq 2D, Innovision Systems, Inc., Columbiaville, MI) and calibration points allowed converting from digitized measurements to standard units for both camera views. To establish the accuracy of the calibration, the scale factor used to convert from digitizing units to real meters derived from the calibration points was tested by re-digitizing the known calibration length ten times and converting its length to meters using the scale factor. The standard deviation of the measurement when repeated thusly was ± 0.004 m, representing ± 0.2% error.

For the data from the camera aligned with the top of the net, only the locations of the most distal fingertips of each hand were digitized. They were converted to standard units and expressed with respect to the top of the net.

For the video data from the camera recording perpendicularly to the net, the locations of 21 body landmarks (vertex, gonion, suprasternale, right and left shoulders, elbows, wrists, third knuckles, hips, knees, ankles, 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:

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

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:

$$t_{AIR} = (fr_{TD} - fr_{TO}) \cdot \left(\tfrac{1}{60}\right) s \qquad [2]$$

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:

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

and:

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

where g represents the acceleration due to gravity, which had a magnitude of 9.81 $m \cdot s^{-2}$ 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:

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

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:

$$t_{BLOCK} = n_{FR} \cdot \left(\tfrac{1}{60}\right) s \qquad [6]$$

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.

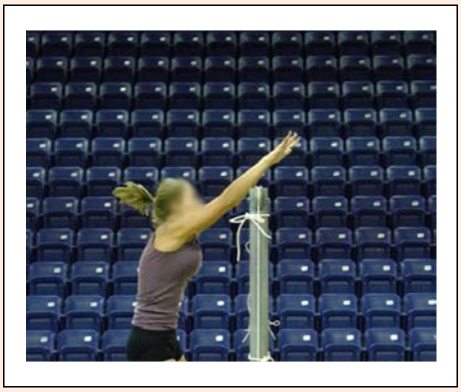

Figure 3. The view from the second camera directed along the top of the net.

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 finger-tip 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_{APP}, 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) compared to the traditional technique (618 ± 112 cm^2·s). 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.

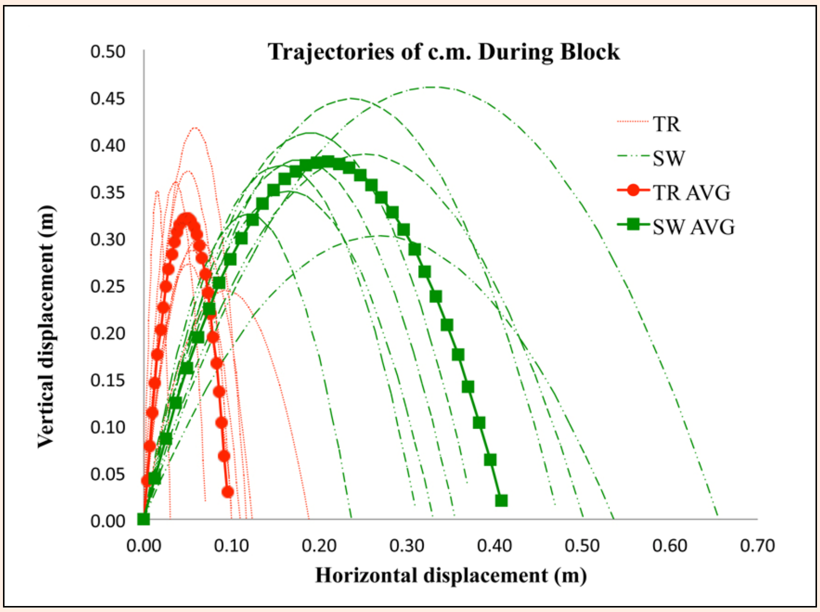

Figure 4. **Trajectories of c.m. for TR and SW airborne phases (with respect to location of c.m. at takeoff). Average TR trajectory is marked by red circles. Average SW trajectory is marked by green squares.**

Taken together with an increased t_{BLOCK}, Y_{PEN}, and Z_{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_x and shorter t_{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_{APP} and greater v_x 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.

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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