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LANDING FORCES IN VOLLEYBALL SPIKING AND BLOCKING

Simon G.S. Coleman[1], Roberto Lobietti[2]

[1]Institute of Sport, Physical Education and Health Sciences, University of Edinburgh

[2]Department of Histology, Embryology and Applied Biology, Faculty of Exercise and Sport Science, University of Bologna

The present study sought to investigate Vertical Ground Reaction Forces during landings from volleyball spiking and blocking actions. 16 players from Scottish Division 1 and 2 teams performed 10 spikes, 10 blocks from the right and 10 from the left, landing on two Kistler force plates. Kinematic data were also obtained using a 6-camera Qualisys motion capture system. The spike resulted in significantly larger VGRF than either of the blocks, probably due to the greater maximum height attained in the jump. Analysis of the significant interaction between action and feet showed that in the block to the right, the right foot experienced a significantly larger VRGF than the left. There were large inter-individual differences and coaches need to examine techniques closely before making recommendations about landings.

KEY WORDS: Ground Reaction Force, Injury

INTRODUCTION: Spiking and blocking are two of the most important skills in volleyball for scoring points (Lobietti et al, 2006). Both of these skills require players to jump to their maximum height to play the ball before landing. Up to 100 jumps maybe performed in a volleyball match (Fontani et al, 2000), and many more are also completed in training. A high number of acute injuries happen during jumping and landing (63% according to Gerberich et al), with up to 60% occur in landing alone. As well as acute injuries, chronic conditions such as patellar tendinopathy ('jumper's knee') are caused by repeating landings from airborne activities in volleyball. Bisseling et al. (2007) compared the landings of players with and without a history of patellar tendinopathy and found that factors such as ankle and knee range of motion during the first phase of landing, knee extensor monent loading rate and knee angular velocity were risk factors associated with tendinopathy. However, these authors only studied the landings from spikes and their group sizes were small (8 and 7 respectively)
Lobietti et al (2010) qualitatively examined the landings during the spike and block to assess the probability of landing one or both legs when playing in particular court positions, with the hypothesis that one-footed landings might be associated with greater injury risks. They made recommendations for changing match warm-up procedures to try and ensure that players' jumping actions would result in two-footed landings before practising those which required landing on one foot.
It is important to assess the landings for spikes and blocks for the same group of players, as injuries might occur in either (or both) of these skills during match and practice situations. Lobietti et al (2009) did compare the spike and block landings of the same player but it was only a case study.
Therefore, it was the aim of the present study to examine the impacts experienced during landings from spikes, blocks from the right and from the left in the same group of high-level volleyball players.

METHODS: The participants were 16 players (9 male, 7 female) from Scottish National Divisions 1 and 2, including 8 full internationals. 15 players were right-handed and one was left-handed. Male were 24.9 ± 4.3 years of age (mean ± sd), mass 81.4 ± 4.8 kg and height 1.92 ± 0.07 m. Females were 25.3 ± 4.9 years of age, mass 66.3 ± 5.5 kg and height 1.75 ± 0.06 m. All players gave informed consent and methods were approved by the University of Edinburgh Ethics Committee.

Participants performed their own volleyball warm-ups and then 19mm reflective markers were attached in clusters of 4 on the foot, shank, thigh and pelvis of each leg. Calibration trials were then performed using a 388 mm wand with 2 reflective markers 230 mm apart pointed at specific bony landmarks as per the CAST system (Capozzo et al. 1995).
10 spikes with full approaches were performed with the players' jump height measured by a Vertec device (JUMP USA Ltd), positioned so that players landed with each foot on a 600 x 400 mm Kistler force plate (models 9281 and 9261) which were covered with a 7 mm specialized volleyball floor (Gerflor Taraflex). Kinetic data were captured at 500 Hz. A six-camera system (Qualisys ProReflex) with calibration residuals of less than 2mm was used to capture synchronized kinematic data at 500Hz.
After the spikes, 10 blocks to the right and 10 blocks to the left were performed. A ball was suspended at the player's blocking height (established with a practice trial) above a volleyball net strung across the laboratory at 2.43 m (men) or 2.24 (women). The ball's position was adjusted for each participant's maximum reach height and horizontal motion so that participants again landed with one foot on each force plate. The signal to start was given by the experimenter moving the Qualisys wand in the intended direction of travel.
Trials where players did not land correctly on the plates were discarded, leading to individual players' results being calculated from 3-10 trials for the different activities. One player could not land at all on the force plates during the spike and so his results were omitted for this action. Maximum Vertical Ground Reaction forces (VGRFs) in Newtons (N) and Bodyweights (BW) for each foot were calculated, and jump height was assessed by the vertical displacement of the pelvic markers. Touch height in the spike was also measured using the Vertec.
Comparison between VRGFs for spike and blocks and between feet were performed using a 3 x 2 (action x foot) Repeated measures ANOVA (alpha level of 0.05) with simple main effects and Bonferroni tests as post-hocs. Effect sizes were assessed using partial eta squared. The data from the feet for the spike for the Left-handed player was swapped (Left foot <-> Right foot) to allow comparison with the rest of the sample.
Maximum heights of the pelvic markers for the three actions were compared using a One-Way Repeated Measures ANOVA, with Bonferroni comparisons as post-hoc tests. Partial eta squared was again used for effect size.

RESULTS: Table 1 shows the Vertical Ground Forces (N) of the three actions

	Spike L. Foot (N)	Spike R. Foot (N)	Block to the Right L. Foot (N)	Block to the Right R. Foot (N)	Block to the Left L. Foot (N)	Block to the Left R. Foot (N)
Mean	2352.5	2112.6	1362.2	1978.3	1876.2	1611.5
SD	1024.2	1037.1	310.8	525.7	524.1	488.5

The spike showed the highest forces with the left foot being higher than the right. Statistical analysis showed a significant difference between actions (with degrees of freedom adjusted using the Greenhouse-Geisser Epsilon for non-sphericity) $F_{1.3,17.8}$ =11.805; P=0.002, no significant difference between feet $F_{1,14}$=0.051;P=0.825 and a significant interaction $F_{2,28}$=4.624; P=0.018. Effect sizes were very large for the action, trivial for the feet and large for the interaction.
Pairwise comparisons between actions showed that the spike was significantly higher than the block to the right (P=0.005) and the block to the left (P=0.018), but that the two blocks were not significantly different from each other. Simple main effects showed that the right and left foott VRGF were not different between the feet for the spike and the block to left, but in the block to the right, the right foot had a significantly greater VRGF than the left foot (P<0.001)
In the VRGF related to bodyweight, the left foot of the spike showed the largest forces. There was a significant difference between actions ($F_{1.3,18.0}$ =12.418; P=0.001) and in the

interaction between action and feet ($F_{2,28}$=3.308; P=0.016) but not between feet overall ($F_{1,14}$=0.141; P=0.723). Similar to the VGRF data, the effect sizes were very large for the action, trivial for the feet and large for the interaction.
Table 2 displays the Vertical Ground Reaction Forces/BW (BW) for the three actions.

	Spike L. Foot (BW)	Spike R. Foot (BW)	Block to the Right L. Foot (BW)	Block to the Right R. Foot (BW)	Block to the Left L. Foot (BW)	Block to the Left R. Foot (BW)
Mean	3.140	2.884	1.855	2.699	2.543	2.192
SD	1.115	1.325	0.363	0.672	0.571	0.581

Post-hoc analysis showed the same results as for the absolute VGRF (spike larger than the two blocks, but the blocks not different from each other) and the same for the interaction (right and left feet not different for the spike or block to the left, but significantly different for the movement to the right with the right foot being greater).
The spike had the highest maximum height of the pelvic markers (1676 $\pm$175mm) followed by the block to left (1568 $\pm$ 153mm) and then the block to the right (1554 $\pm$ 151mm). This was a significant difference ($F_{1.4,19.5}$=61.376; P<0.001) and a very large effect size. Post-hoc analysis showed that the spike was significantly higher than the two blocks(P<0.001, P<0.001), but that the blocks were not different from each other (P=0.223)

DISCUSSION: The results of the experiment showed that the landing forces were significantly larger in the spike than the two blocking techniques, This was perhaps not unsurprising as the spike action also achieved the highest vertical displacement. The two blocks were not different from each other in either measure of VRGF (absolute and bodyweight-related), but nor were they different in the height obtained.
There was not a difference in VGRF between the two feet overall, but there was a difference between feet in the block to the right when examined separately. The right foot VGRF force was significantly larger than that for the left for this action, and this was probably due to the right foot being the first to strike the ground when moving this direction. A similar effect was noted when moving left (the left foot had higher VGRF) but this was not significant. The reason for this may be that players are more used to moving to the right to block, as most attacks come from that side (the opposition's left front attacker known as position 4). Therefore, maybe blockers can move quicker this way. Horizontal COM velocity was not measured in this experiment and this is an area for future research.
Although the spike also did not show differences between VRGF for each the left was higher overall. This is usually the first foot landed for right handed spikers (the left hander's results were reversed as noted in the methods), due to the right shoulder and right hip being raised with the hitting arm. However, there was great inter-player variation and one player did not land his right foot at all, landing only on his left leg with a very large force (4755N, 5.93BW).

CONCLUSION: This paper showed that forces during landing from spikes and blocks are high (up to 6BW for some players) and that the spike showed the highest VGRF. There were no significant differences between feet in the spike and the block to the left, but the right foot experienced a significantly greater VRGF than the left in making the block to the left. Coaches should examine player's individual techniques closely before making recommending on landings as players vary in which leg experiences the greater stresses.

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