

Research article

Landing Techniques in Beach Volleyball

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Abstract

The aims of the present study were to establish a detailed and representative record of landing techniques (two-, left-, and right-footed landings) in professional beach volleyball and compare the data with those of indoor volleyball. Beach volleyball data was retrieved from videos taken at FIVB World Tour tournaments. Landing techniques were compared in the different beach and indoor volleyball skills serve, set, attack, and block with regard to sex, playing technique, and court position. Significant differences were observed between men and women in landings following block actions ($\chi^2(2) = 18.19$, $p < 0.01$) but not following serve, set, and attack actions. Following blocking, men landed more often on one foot than women. Further differences in landings following serve and attack with regard to playing technique and position were mainly observed in men. The comparison with landing techniques in indoor volleyball revealed overall differences both in men ($\chi^2(2) = 161.4$, $p < 0.01$) and women ($\chi^2(2) = 84.91$, $p < 0.01$). Beach volleyball players land more often on both feet than indoor volleyball players. Besides the softer surface in beach volleyball, and therefore resulting lower loads, these results might be another reason for fewer injuries and overuse conditions compared to indoor volleyball.

Key words: Video analysis, gender differences, volleyball, injuries, overuse condition.

Introduction

In beach volleyball there is a significant amount of landings following jump movements which are related to high forces in the lower limb joints (Bisseling et al., 2007; Edwards et al., 2012; Lindner et al., 2012). Such high forces may cause acute and overuse injuries like anterior cruciate ligament ruptures or patellar tendinopathies, respectively (Bahr and Reeser, 2003). Bahr and Reeser (2003) reported 54 acute injuries (knee 30%, ankle 17%, and finger 17%) in 178 interviewed professional beach volleyball players during a 7.5-week interval of the summer season. More than one third of the players (67 out of 178) reported overuse injuries (back pain 19%, knee pain 12%, and shoulder 10%) for which they received medical attention. A great part of the reported injuries and overuse conditions can be related to high loads in the injured joints during jumping and specifically during landing actions (Eerkes, 2012).

Comparing male and female beach volleyball players, Reeser et al. (2006) reported no differences in injury pattern and frequency. However, they noted a prevalence of tendinopathy in men. A cross-sectional study on nine different sports Lian et al. (2005) showed that indoor

volleyball had the highest prevalence of jumper's knee (44% +/- 6%). Bahr and Reeser (2003) reported that in beach volleyball 12 % of all athletes suffered of knee pain of which 76 % were associated with patellar tendinopathy. Although injuries and overuse conditions are common in beach volleyball, Reeser et al (2006) stated that it appears more safe than indoor volleyball. The authors hypothesized that lower rates of tendinopathy in beach compared to indoor volleyball might be due to the softer landing surface which decreases peak forces during landings.

Since landing techniques affect the amount of load (Bisseling et al., 2007; McNitt-Gray 2000), they were in the focus of research in the past. Tillman et al. (2004a) reported that one-footed landings result in higher ground reaction forces and muscle activity than two-footed landings because the momentum of the body must be absorbed by one instead of two legs. Therefore, researchers (Tillman et al., 2004b, Lobiatti et al., 2010) categorized landings into two-footed when touch-down of feet was simultaneous or one-footed when there was a time delay (e.g. 0.2 s in Lobiatti et al., 2010) between touch-down of leading and trailing leg. Tillman et al. (2004b) analyzed women's college volleyball and reported high frequencies of landings on both feet following spiking (55%) and blocking (57%) and tendencies for landing on the left foot when spiking (35%) and landing on the right foot when blocking (27%). Lobiatti et al. (2010) analysed 48 men and 48 women during volleyball games of the professional Italian League. They reported prevalence of one-footed landing techniques following spiking in court positions 4 and 6 and after block movements of middle blockers. They also observed different use of landing techniques between the sexes, court positions, and types of set when players were blocking. Marquez et al. (2011) also reported one-footed landings in Brazilian elite male volleyball players following spiking from position 4.

Although certain kinematic differences between beach volleyball and indoor volleyball spike jumps have been reported (Tilp et al., 2008), athletes of these sports use similar techniques during service, dig, set, attack, block, and defence movements. However, tactical differences occur e.g. due to the different amount of players (beach volleyball team: two, indoor volleyball: six) which affect movements and landing strategies. These could lead to different amount of "land and go" and "land and stop" movements as classified by McNitt-Gray (2000) who reported different loads in the lower limbs according to this categorization. Further differences in movement conditions are due to differences in court size and playing surface. Biomechanical differences of playing surfaces

and their influence on loading and injury risk (Nigg and Yeadon, 1987) as well as on coordination (Moritz and Farley, 2006) have already been studied. Sand surface decreases maximum vertical ground reaction forces during take-off phase of squat jumps by 8% (Giatsis et al., 2004) compared to rigid surface. To our knowledge, no data about forces during landings on sand compared to indoor courts is available. However, Mills et al. (2010) calculated that decreased stiffness and increased damping, like sand surface compared to indoor surface, reduces ground reaction forces and subsequently bending moments in the shank and thigh during landing movements.

Summarizing, landings following aerial movements might be risk factors for beach volleyball players. Although injury risk in beach volleyball is lower than in other sports (Reeser et al., 2006), acute and overuse injuries are still common (Bahr and Reeser, 2003). Lower injury rates compared to indoor volleyball have so far been explained by the softer playing surface (Reeser et al., 2006). Another explanation might be a possible difference in landing techniques between beach and indoor volleyball.

Therefore, the aims of the present study were twofold. First, we intended to establish a detailed and representative record of the landing technique in professional beach volleyball for men and women and analyze possible differences. We hypothesized no differences between the sexes due to similar injury reports. However, we hypothesized differences between different court positions and between different playing techniques due to similar results already reported for indoor volleyball.

Second, we intended to compare landing patterns in beach volleyball with those previously reported in indoor volleyball. We hypothesized to find significant differences between the two sports due to different technical and tactical requirements for the players.

Methods

Video recordings from 10 women's and 10 men's professional beach volleyball games from the FIVB World Tour were recorded for this study. All videos (25 Hz) from men's games were recorded at the tournament in Klagenfurt 2011. All videos (25 Hz) from women's games were recorded at different venues of the FIVB world tour in 2011. Filming was approved by the local tournament organizers and in agreement with the athletes. The analysis included types of landing following jumping movements from 28 men and 18 women. The different number of subjects results from the fact that some of the female teams were recorded more than once which was due to the availability of video material. However, each athlete was only analyzed in one game to avoid any bias. In line with Lobietti et al. (2010) landings were classified as two-footed when both feet touched the sand within five frames (0.2 s). Otherwise the landing was classified as landing on the right or left foot. Additional to the landing technique, the performed skill (jump serve, attack, set, or block) was identified and recorded. Jump serves were classified into spike jump and float jump service. Attack movements were classified into spike and shot movements (for a

detailed description of these techniques see e.g. Koch and Tilp (2009). Furthermore, attack, set, and block movement were classified regarding position into right or left half of the court. All annotations were done with custom-made software for notational analysis (Tilp et al., 2006). In line with Lobietti et al. (2010) only right-handed players were included in the analysis.

Statistical analyses

Possible difference in mean number of jumps per game during men and women games were tested with a t-test for independent samples. Due to the categorical type of remaining data, non-parametric chi-square tests were used to assess the differences between the different frequency distributions. Chi-square tests were run with absolute data. The alpha level was set at 0.05.

Both for men and women differences in landing technique were analysed based on

- the type of jump serve, i.e. spike serve or jump-float,
- the type of attack, i.e. spike or shot,
- the court position of attacks (left or right),
- the court position of blocks (left or right),
- the court position of sets (left or right).

Both attacks and jump serves are asymmetric skills which are played with the preferred hand and with the aim to score a direct point. Therefore, landing techniques following these techniques were compared. Furthermore, differences between men and women in all techniques (serve, set, attack, and block) were analyzed and results in volleyball reported by Lobietti et al. (2010) were compared with results of this study.

To correct for the amount of chi-square tests, the specific alpha level was adapted with Bonferroni-Holm corrections (Holm, 1979). Nineteen chi-square tests in beach volleyball (landings of men, women and differences between sexes, technique, and position) and 14 chi-square tests for the comparison of beach volleyball to volleyball data were corrected separately.

The data were processed using Microsoft Excel and SPSS.

Results

Landing technique in beach volleyball

Mean values for landings during a match (irrespective of the number of sets) were 55 ± 13 and 60 ± 15 for men and women respectively. This difference was not significant. Table 1 shows a summary of the detailed results of both sexes. The frequency distributions for the asymmetric skills (attacks: $\chi^2(2) = 4.78$, $p = 0.09$, serves: $\chi^2(2) = 2.27$, $p = 0.32$) are not different between the sexes. It is noticeable that following asymmetric skills men and women rarely land on the right foot (0.8% and 1.5% for men and women). However, landings on the left foot are fairly frequent: 25.9% for men and 23.5% for women.

For blocks ($\chi^2(2) = 18.19$, $p < 0.01$) and the sum of all symmetric skills (blocks and sets), males and females show different behaviours ($\chi^2(2) = 12.93$, $p < 0.01$).

Table 1. Landing technique used in different skills by male and female beach volleyball players.

Skill	Men				Women			
	Both feet (%)	Left foot (%)	Right foot (%)	Total (n)	Both feet (%)	Left foot (%)	Right foot (%)	Total (n)
Attack	66.2	32.4	1.4	740	70.3	27.4	2.4	464
Serve	84.3	15.7	.0	478	81.7	18.0	.3	327
Asymmetric	73.3	25.9	.8	1218	75.0	23.5	1.5	791
Block ^a	72.0	20.5	7.5	711	81.0	9.6	9.3	311
Set	60.3	28.2	11.5	78	47.4	52.6	.0	19
Symmetric ^a	70.8	21.3	7.9	789	79.1	12.1	8.8	330
Total	72.3	24.1	3.6	2007	76.2	20.2	3.7	1121

^a Significant difference between sexes

Following blocks, females land more often on both feet than their male colleagues (81% vs. 72%), who tend to land on the left foot more often than on the right (20.5% vs. 7.5%, respectively). Following symmetric skills, landings on the right foot could be observed more often than following asymmetric skills. However, they are still observed in less than 10% of all symmetric landings.

Table 2 shows the landing technique used following different types of serve technique. Both men ($\chi^2(2) = 55.53$, $p < 0.01$) and women ($\chi^2(2) = 12.38$, $p < 0.01$) show differences between landings following spike serves and jump float serves. Both sexes land more often on both feet following jump float than following spike serves. Furthermore, men use spike serves more frequently than women (46% vs. 18% of all jump serves for men and women, respectively).

Landing techniques following spikes were analyzed with regard to court position (Table 2). While men land differently following attacks from the left compared to the right side of the court ($\chi^2(2) = 37.88$, $p < 0.01$), women do not. Following spikes from the right side of the court men land more often on both feet (76.0% vs. 56.0%) but less often on their left foot (22.2% vs. 43.2%) compared to spikes from the left position.

In both men ($\chi^2(2) = 26.45$, $p < 0.01$) and women

($\chi^2(2) = 14.46$, $p < 0.01$) the frequency distributions of landings following hard (spike) and precise (shot) attacks are different. Men (75.8% vs. 59%) and women (77.5% vs. 61.9%) land more often on both feet following shots than following spikes (Table 2). In contrary, following spikes more landings on the left foot in men (40% vs. 22.3%) and women (35.8% vs. 20.1%) than compared to landings following shots could be detected.

Only in the men's group there is a significant difference between landings following blocks from the right and left half of the court ($\chi^2(2) = 21.86$, $p < 0.01$). They land on both feet more often when blocking on the right compared to the left side of the court (78% vs. 67.3%, Table 2). Women do not show a different landing behaviour when blocking at the right or the left side of the court.

Neither men ($\chi^2(2) = 3.21$, $p = 0.2$) nor women ($\chi^2(2) = 3.32$, $p = 0.19$) show differences in landings following jump sets from the left and the right half of the court (Table 2).

Finally, the landing techniques following attacks and jump serves were compared (Table 2). Both men ($\chi^2(2) = 50.9$, $p < 0.01$) and women ($\chi^2(2) = 15.81$, $p < 0.01$) show differences between attacks and jump serves. Men (84.3% vs. 66.2%) and women (81.7% vs. 70.3%) land on

Table 2. Landing technique used following different skills and on different positions.

	MEN				WOMEN			
	Both feet (%)	Left foot (%)	Right foot (%)	Total (n)	Both feet (%)	Left foot (%)	Right foot (%)	Total (n)
Serve skill								
Jump float ^a	95.7	4.3	0	258	85.1	14.6	.3	268
Spike serve ^a	70.9	29.1	0	220	66.1	33.9	0	59
Total	84.3	15.7	0	478	81.7	18.0	.3	327
Attack position								
Left ^b	56.0	43.2	.8	361	66.4	31.8	1.7	292
Right ^b	76.0	22.2	1.8	379	76.7	19.8	3.5	172
Total	66.2	32.4	1.4	740	70.3	27.4	2.4	464
Attack skill								
Spike ^c	59.0	40.0	.9	422	61.9	35.8	2.3	215
Shot ^c	75.8	22.3	1.9	318	77.5	20.1	2.4	249
Total	66.2	32.4	1.4	740	70.3	27.4	2.4	464
Block position								
Left ^d	67.3	26.7	6.0	397	79.1	13.0	7.8	115
Right ^d	78.0	12.7	9.2	314	82.1	7.7	10.2	196
Total	72.0	20.5	7.5	711	81.0	9.6	9.3	311
Set position								
Left	61.8	20.6	17.6	34	61.5	38.5	0	13
Right	59.1	34.1	6.8	44	16.7	83.3	0	6
Total	60.3	28.2	11.5	78	47.4	52.6	0	19
Asymmetric offensive skills								
Attack ^e	66.2	32.4	1.4	740	70.3	27.4	2.4	464
Jump Serve ^e	84.3	15.7	0	478	81.7	18.0	.3	327

Significant difference between ^a type of jump, ^b position of attack, ^c type of attack, ^d position of block, and ^e different asymmetric skill.

Table 3. Landing techniques used following different skills in beach and indoor volleyball of men (indoor data from Lobietti et al., 2010).

Action	Men					
	Both Feet (%)		Left Foot (%)		Right Foot (%)	
	BV	HV	BV	HV	BV	HV
Attack ^a	66.2	60.0	32.4	31.0	1.4	8.5
Service ^b	84.3	74.5	15.7	25.5	-	-
Asymmetric ^a	73.3	65.1	25.9	29.4	.8	5.5
Block ^a	72.0	51.2	20.5	25.6	7.5	23.2
Set ^a	60.3	93.9	28.2	1.1	11.5	5.0
Symmetric ^a	70.8	62.9	21.3	18.9	7.9	18.2
Total ^a	72.3	58.6	24.1	27.6	3.6	13.8

^a Significant difference between beach volleyball and indoor volleyball (both feet, left foot, right foot). ^b Significant difference between beach volleyball and indoor volleyball (both feet, one foot)

both feet following jump serve more often than following attacks.

Differences in landing technique between beach and indoor volleyball

Table 3 shows that men have different landing patterns in beach volleyball compared to indoor volleyball in all four analyzed skills (attack, serve, block, and set). Following attacks ($\chi^2(2) = 40.4$, $p < 0.01$) and serves ($\chi^2(1) = 72.4$, $p < 0.01$) beach volleyball players land more frequently on both feet than indoor volleyball players. This is also observable in block situations ($\chi^2(2) = 95.1$, $p < 0.01$) where 72% of landings following a beach volleyball block but only 51.2% in indoor volleyball are executed on both feet. Contrary, male setters in indoor volleyball land more often on both feet than beach volleyball player (93.9% vs. 60.3%).

Based on these results, the total of all jumping skills also shows significantly different landing patterns ($\chi^2(2) = 161.4$, $p < 0.01$) between male beach and indoor volleyball players. The amount of two-footed landings is higher on sand compared to indoor court (72.3% vs. 58.6%).

In women, differences in landing technique are not as apparent as in men (Table 4). Only the symmetric techniques block ($\chi^2(2) = 54.13$, $p < 0.01$) and set ($\chi^2(2) = 45.21$, $p < 0.01$) reveal differences in landing patterns. While women land on both feet following a blocking action more frequently on the sand (81.0% vs. 58.7%), they behave contrary following setting actions where indoors more two-footed landings (82.8% vs. 47.4%) could be observed. No differences could be observed in the distribution of landings in attack and serve. In summary, a significant total difference ($\chi^2(2) = 84.9$, $p < 0.01$)

in landing patterns between women's beach and indoor volleyball could be observed. Female beach volleyball professionals land more often on both feet (76.2% vs. 65.5%) than their colleagues indoor.

Summarizing, one footed landings (in which the left foot contacted the ground at least 0.2 seconds prior to the right foot) occurred more frequently in right hand dominant males than females, and after performing volleyball-specific asymmetric overhead skills. In addition, the frequency of one-footed landings was increased following skills with a significant lateral component performed more quickly compared to those performed in a more premeditated fashion with a more linear component. Lastly, beach volleyball players tended to land on two feet more often than did indoor volleyball players.

Discussion

One-footed landings are common in beach volleyball and even more common in indoor volleyball. Speculating about the reasons for such behaviour, biomechanical explanations seem most probable: During aerial movements the angular momentum is preserved. In asymmetric (beach) volleyball techniques (serve, attack) the movement by one arm (which produces an angular momentum) must therefore be balanced by the movement of another body part, e.g. a leg. Thus, asymmetrical movements of the upper body might lead to asymmetrical movements of the legs. These can be reversed in the landing phase but might also lead to unilateral landings. Subjective video analyses and reports by Lobietti et al. (2010) in volleyball suggest that unilateral landings are more probable when an athlete is under time pressure and/or has to perform a subsequent movement following the jump (e.g. a sprint

Table 4. Landing technique used following different skills in beach and indoor volleyball of women (indoor data from Lobietti et al., 2010).

Action	Women					
	Both Feet (%)		Left Foot (%)		Right Foot (%)	
	BV	HV	BV	HV	BV	HV
Attack	70.3	74.7	27.4	23.7	2.4	1.6
Service	81.7	80.0	18.0	20.0	-	-
Asymmetric	75.0	75.3	23.5	23.3	1.5	1.4
Block ^a	81.0	58.7	9.6	19.4	9.4	21.9
Set ^a	47.4	82.8	52.6	6.1	0	11.1
Symmetric ^a	79.1	62.4	12.1	17.3	8.8	20.2
Total ^a	76.2	65.5	20.2	21.0	3.7	13.5

^a Significant difference between beach volleyball and indoor volleyball (both feet, left foot, right foot).

towards the net to block following the serve). During symmetric movements (set, block) lateral aerial movements could be responsible for unilateral landings. Following an aerial movement to the right a touch-down with the right foot against the movement direction will produce a ground reaction force which will decelerate the lateral movement and help the athlete to regain his balance. However, in our study we only related movement position to type of landing and did not analyze the movement direction during symmetric movements. Therefore, this hypothesis is not based on our findings and therefore speculation. Especially in symmetric movements, there could be further explanations (e.g. the asymmetric tonic neck reflex) for one-footed landings.

If athletes/coaches do not pay specific attention on landing techniques during the motor learning process, e.g. because they are not directly related to playing performance, it might be that motor patterns will be consolidated and difficult to relearn in a later stage.

Landing technique in beach volleyball

In the present study, landing technique (both feet, right/left foot) following different types of beach volleyball skills (serve, set, attack, and block) was analyzed.

Differences in landings between the sexes were only observable following block situations and the sum of all symmetric skills (block and set). The reason why women landed more often on both feet following block actions might be explained by the greater dynamics during block actions performed by men. This causes greater jumping heights but also less controlled landing movements. Another explanation could be that in men's beach volleyball the second ball played within a team, which is usually a set, is more frequently used for an attack (second ball hit) than by women. Thus, male opponent block players have less time to reach the eventual block position. Koch and Tilp (2009) already reported a tendency to more second ball hits of men than women. However, the rate of second ball hits is still below 10 % (Koch and Tilp, 2009). Summarizing, male beach volleyball players land more often on one foot than women following block and symmetric actions. Assuming that one-footed landings might lead to higher stress and strain for the athlete (Tillman et al., 2004a), male players appear to be at greater risk for injuries.

The analysis of service techniques in beach volleyball revealed that players land more often on both feet following jump float compared to spike serves. During a spike jump serve the player hits the ball as hard as possible to reach high ball velocities. Furthermore, the jump has a significant forward component and the ball receives a forward rotation with a linear trajectory. Contrary, following a jump float serve the ball has no or little rotation and the trajectory is random and therefore difficult to anticipate for the opponent. The high angular velocity of the right arm during spike jump serves produces high angular momentum which might be balanced by contralateral movement of the left leg. Together with the forward component this might cause the high amount of single-footed landings, predominantly on the left foot. This speculation is supported by the fact that in men, who

produce higher angular momenta with their arm movement than women, the proportion of single-footed landings is higher than in women.

The position of the attack affects the landing technique only in men. They land more often on one leg (preferable the left) when they hit the ball from the left side of the court. A similar result was reported by Lobietti et al. (2010) in indoor volleyball and could be interpreted as higher injury risks for players at the left side of the court. In women, no differences with regard to attack position could be observed.

The two typical attacking techniques played in beach volleyball are spike and shot. While in a spike attack the player hits ball as hard as possible to reach great ball velocities and therefore reduce the reaction time for the opponent, the shot attack is a rather precise technique where the attacker tries to place the ball in a part of the court which is not covered by the opponents. Similar to serve techniques the observed differences between the two landing techniques in both sexes might be due to the difference in movement dynamics, i.e. joint moments and angular velocities. Following shots, both sexes land more often on both feet compared to landings following spike attacks.

The comparison of landings following attacks and serves also revealed significantly different landing patterns. Landings following attacks are more often on one foot (predominantly the left) than following jump serves. This might be explained by the conditions under which these techniques are performed. Prior to a jump serve the athlete has sufficient time for preparation and the ball is at rest and then tossed by him or herself. Contrary, prior to an attack the ball is set by his or her team colleague and the attacking player has to approach to the attack following a preceded own action. Therefore, the attacking player is under greater temporal and coordinative pressure which might be the reason for less coordinated landings.

Block position affected the landing technique only in men's games significantly. When blocking at the left side of the court, athletes tend to land less often on both feet than compared to blocks from the right side. This was not hypothesized since most block actions in beach volleyball are performed from a rather stable position without greater approaching pathways, irrespective from position. Further research, e.g. differentiating into slide step and cross over technique or one and two-handed blocks, is necessary to explain this phenomenon.

Although jump sets are not as frequent in beach volleyball as compared to indoor volleyball, they are still noticeable. Different to indoor volleyball, beach volleyball players generally set in front and only very rarely (e.g. in cases of imprecise digs) behind of him or herself. In this study, landings pattern following sets are not related to the position of the set. However, it is notable that 4% of all sets of men are executed in the air but only 2% of all sets of women. This indicates that women's beach volleyball is still not as physical as men's beach volleyball which has already been hypothesized by Koch and Tilp (2009). They reported that female beach volleyball players set the ball less often with an overhand pass than their male colleagues. However, according to the small

amount of jump sets, the set does not appear to be a main injury factor.

Differences in landing technique between beach and indoor volleyball

Since landings following jumps produce high loads for athletes and injuries and overuse conditions are more frequent in indoor compared to beach volleyball (Reeser et al. 2006), landing pattern of these two sports were compared.

Differences in landing pattern following all technical skills between men's beach and indoor volleyball were detected. However, in women such differences are only observable in symmetric (block and set) but not in asymmetric skills (attack and serve). The differences in attacks from men can be explained by the fact that sets in indoor volleyball are played much faster and therefore controlled landings on both feet are difficult. Lobiatti *et al.* (2010) already reported that attacker tend to land more often with one foot when the set was a "super" (79% of landings), which is a fast ball, than when the set was "high" (54% of landings). In beach volleyball sets are generally played not as fast because it is obvious which player will attack the ball and therefore there is no use for fast balls. Lobiatti *et al.* (2010) also reported that landings following attacks from women are different from those of men. Females land more often on both feet and therefore more similar to the data presented here for beach volleyball. This might explain that no differences between landings following attacks between female beach and indoor volleyball were observed.

Differences in landings following serves could be detected only in men. Beach volleyball players tend to land on both feet more frequently than indoor volleyball players. The reason for this behaviour might be explained by the different distribution of spike and jump float serves in beach volleyball (jump float/spike serve: men: 258/220; women: 268/59) compared to indoor volleyball (jump float/spike serve: men: 122/255; women: 18/82).

Landings following block situations are different between beach and indoor volleyball in both sexes. The most obvious tactical difference is that indoors the setter has the option to set the ball to four attackers. The opponent's block intends to block the attack with at least one, preferable with two or three players. Therefore, indoor block players have to anticipate and decide within some hundreds of a second where to block and have to move laterally and as fast as possible to the block position. Thus, block jumps have a significant lateral component and landings following blocks are often difficult to control and therefore one-footed only. In beach volleyball contrariwise, it is rather easy to anticipate which player will attack from which position and therefore the blocker has enough time for the lateral movement prior to the block.

Only following sets athletes land more often on one foot in beach volleyball compared to indoor volleyball. Indoors there is a high specialisation and each team has a setter who always should play the second ball. Together with high rates of perfect receptions in professional

indoor volleyball, the setter has enough time to anticipate the position where to jump and set. In beach volleyball, the team roles (i.e. who sets and who attacks) are distributed only after the opponent's serve. Thus, the time to move to the setting position in beach compared to indoor volleyball is shorter which could explain the higher amount of landings on one foot. Furthermore, jump sets in beach volleyball are not very effective and therefore rarely played. Jump sets are often only used because the reception is too close to the net which causes an emergency tactics for the setter. However, especially for women the presented results have to be interpreted with care because only very few jump sets in beach volleyball were recorded.

Although the present study revealed interesting results, some general methodological difficulties have to be mentioned. Landings following blocking and attacking actions were analyzed with regard to position and playing technique. However, the direction of attacking was not considered although it likely affects the jumping and landing technique of attackers and blockers. Furthermore, it was assumed that the load of the landing is equally distributed on both legs when both feet touched the sand within 0.2 s. It might be suggested that athletes could also land on both feet within this time period but distribute the load only on one foot which would lead to loads comparable to one-footed landings. It is well known that different FIVB venues use different sand quality with different mechanical characteristics. Therefore, it would have been ideal to have videos from one venue (ideally from one court) only to compare data from men and women. Further research is required to address these points.

Conclusion

The results of this study might provide interesting data for practitioners with regard to beach volleyball landing techniques. However, the data has to be interpreted with caution. Individuals of lesser expertise, or athletes playing under different conditions, e.g. different mechanical sand properties, might demonstrate different behaviour. One-footed landings are common (28% and 24% in males and females, respectively) and related to sex, applied technique, and court position. Especially following hard attacks from the left side of the court, a significant amount of one-footed landings were observed. Assuming that one-footed landings yield to higher loads, and therefore higher injury risk, for the athlete than two-footed landings, it is suggested to focus on training regimens where athletes have to concentrate on two-footed landings specifically in playing situation with high dynamics and under coordinative/time pressure.

Furthermore, data showed that beach volleyball players land less often unilaterally than their indoor colleagues. This could be interpreted as a reduced injury or chronic knee-pain risk since it goes along with less such findings in beach compared to indoor volleyball. However, to proof a causal correlation of this conclusion further research should be performed. In order to connect landing strategy with injury risk, video analysis along with injury data should be collected. In order to connect

landing strategy with chronic knee pain, video analysis of athletes together with interviews regarding their knee pain status should be performed.

Acknowledgements

This project was funded by the Austrian Science Fund (P22299). We thank Franz Kaiser for providing videos from women's beach volleyball competitions.

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Key points

- About 1/3 of all jumping actions in beach volleyball result in a landing on one foot.
- Especially following block situations men land on one foot more often than women.
- Landing techniques are related to different techniques and positions.
- Landings on one foot are less common in beach volleyball than indoor volleyball. This could be a reason for fewer injuries and overuse conditions.

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