

Injury Epidemiology and Time Lost From Participation in Women's NCAA Division I Indoor Versus Beach Volleyball Players

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Background: Beach volleyball officially became a National Collegiate Athletic Association (NCAA) Division I sport in 2015-2016. Few studies have examined the epidemiology of injuries in indoor versus beach volleyball in NCAA Division I athletes.

Purpose: To compare the epidemiology of injuries and time lost from participation between female NCAA Division I athletes who participate in indoor versus beach volleyball.

Study Design: Cohort study; Level of evidence, 3.

Methods: Injury surveillance data (2003-2020) were obtained using an institutional database for all NCAA Division I women's beach or indoor volleyball athletes. The total injury rate was expressed per 1000 hours played. The injury rate per body site was calculated by dividing the number of injuries in each body region by the total number of injuries. The frequency of injury per body site was also expressed as number of injuries per 1000 hours of practice or number of injuries per 1000 hours of game. The injury rate (total and per body site) and time lost from participation were compared between indoor and beach volleyball athletes.

Results: Participants were 161 female NCAA Division I volleyball athletes (53 beach volleyball and 108 indoor volleyball athletes). In total, 974 injuries were recorded: 170 in beach volleyball and 804 in indoor volleyball. The injury rates for beach versus indoor volleyball were 1.8 versus 5.3 injuries per 1000 hours played ($P < .0001$). Indoor volleyball athletes had significantly higher injury rates compared with beach volleyball players for concussion (7.5% vs 6.5%; $P < .0001$) and knee injury (16.7% vs 7.6%; $P = .0004$); however, the rate of abdominal muscle injury was significantly higher in beach versus indoor volleyball (11.8% vs 4.7%; $P = .0008$). Time lost from sport participation was significantly longer in beach versus indoor volleyball for knee (24 vs 11 days; $P = .047$), low back (25 vs 17 days; $P = .0009$), and shoulder (52 vs 28 days; $P = .001$) injuries.

Conclusion: Based on this study, injury was more likely to occur in indoor compared with beach volleyball. Sport-related concussion and knee injuries were more common in indoor volleyball, but the rate of abdominal muscle injury was higher in beach volleyball. Beach volleyball players needed longer time to recover after injuries to the knee, low back, and shoulder.

Keywords: volleyball; indoor; beach; injury; collegiate; NCAA; Division I

Volleyball is one of the most widely played sports, with millions of participants worldwide.¹⁹ It is unique among team sports in that it has evolved into 2 distinct disciplines: indoor or court volleyball, featuring 6 players on each team, and beach or sand volleyball, featuring 2 players per team. Women's collegiate court volleyball is the second most-sponsored team sport in the National Collegiate Athletic Association (NCAA), with 96% of schools sponsoring a team, second only to women's basketball at 99%.² In addition, NCAA women's beach volleyball has become the

fastest-growing sport in the Division I sports, going from no varsity teams in 2011-2012 to 60 in 2015-2016.² The expansion of volleyball among women athletes might be the reason why the majority of the literature on volleyball injuries is on female players.^{5,8,9,13,15,19}

Volleyball injuries can occur during jumping, landing, hitting, and blocking movements, but also when a player is passing or setting the ball.¹⁵ The reported injury rate in NCAA volleyball athletes ranges between 4.2 and 4.4 per 1000 athlete-exposures.^{5,8} According to a 2012 study, of 16 NCAA sports, women's volleyball had one of the highest rates of overuse injuries, along with hockey, softball, and soccer.²¹ Another study of NCAA Division I female volleyball players found that most injuries occurred during

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volleyball practices rather than games, the majority of them were noncontact, and the knee was the most commonly involved body site.¹⁹

Although the basic skills required to participate in indoor and beach volleyball are similar, important differences exist between these 2 sport disciplines. Some examples include the court dimensions, the environmental conditions in which the players must compete, and the rules applied.¹¹ Differences in kinematics between the 2 sports have been reported.^{11,17} Using 3-dimensional (3D) kinematic models, Tilp et al²⁰ showed that elite volleyball athletes had to adjust their movements based on the surface played (sand vs court). A lack of studies exists comparing the epidemiology of injuries for indoor versus beach volleyball athletes. In 1997, Aagaard et al¹ reported a higher rate of self-reported injury in beach volleyball players compared with indoor volleyball players (4.9 vs 4.2 injuries per 1000 hours played, respectively), but the difference was not statistically significant. Their study included recreational and elite athletes reported the time lost after volleyball injury, but no comparisons were made between indoor and beach players.

The purpose of this study was to compare the epidemiology of injuries in women's collegiate indoor and beach volleyball per body site and per time lost from sport participation, based on our institutional experience. Our data will provide more information to trainers, coaches, and medical staff, so they can better understand potential differences in injury patterns between indoor and beach volleyball and develop appropriate prevention and treatment strategies.

METHODS

Data Collection

This institutional review board–approved study was a retrospective review of prospectively collected data from a single institution database during the period 2003-2020. Athletes included were NCAA Division I women's volleyball players, who were divided into 2 groups based on their participation in indoor versus beach volleyball.

Injury was defined as “an injury that occurred as a result of participation in an organized intercollegiate practice or competition, which required attention from an athletic trainer or physician.” This definition was used in previously published epidemiologic studies in NCAA athletes.⁴ Injury documentation was performed by the medical staff (athletic trainers and/or team physician) in a standardized

fashion. Time missed from volleyball participation was defined as the time period between the injury and the return of the athlete to practice without any restrictions related to his or her injury. The team physicians were responsible for clearing the athletes to return to full volleyball participation. The time lost from volleyball participation was autogenerated in the database by subtracting the date of injury from the date that the athlete returned to sport, which was documented in the database by the athletic trainers.

Data collected included the number of injured athletes; total number of injuries; site of injury (head, neck, spine, low back, abdominal muscle, shoulder, arm, elbow, forearm, wrist, hand, hip, thigh, knee, leg, ankle, and foot); injury setting (indoor vs beach); volleyball hours played in practice; volleyball hours played in game; and days lost from participation because of injury. Head injuries were divided into concussion injuries and nonconcussion injuries.

Statistical Analysis

The injury rate was expressed per 1000 hours played. The injury rate per body site was calculated by dividing the number of injuries in each body region by the total number of injuries in indoor or beach volleyball. The frequency of injury per body site was also expressed as the number of injuries per 1000 hours of practice or number of injuries per 1000 hours of game for the 5 most commonly observed injuries in each sport. The rates of injury per body site between indoor and beach volleyball athletes were compared using the chi-square test for comparison of proportions. The mean time lost (reported in days using the mean and standard deviation) because of injury between indoor and beach volleyball was compared using the Mann-Whitney test or *t* test. The level of statistical significance was set at $P < .05$. Data were analyzed using SPSS Version 25 software (IBM Corp).

RESULTS

Study Population and Total Rate of Injury

Participants were 161 NCAA Division I women's volleyball athletes who participated in either beach volleyball (53 athletes) or indoor volleyball (108 athletes). In total, 974 injuries (170 in beach volleyball, 804 in indoor volleyball) were recorded. The total injury rate was 5.3 injuries per 1000

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Ethical approval for this study was obtained from the University of Southern California Institutional Review Board.

TABLE 1
Injury Rate per Body Site in NCAA Division I Women's Indoor Versus Beach Volleyball^a

Injury Site	Total Injury Rate	Beach Volleyball	Indoor Volleyball	P Value (Indoor vs Beach)
Concussion	6.1 (59)	6.5 (11)	7.5 (60)	<.0001
Neck	2.2 (21)	3.5 (6)	1.9 (15)	.29
Chest	0.8 (8)	1.8 (3)	0.6 (5)	.3
Abdominal muscle	6 (58)	11.8 (20)	4.7 (38)	.0008
Upper back	1.6 (16)	0.6 (1)	1.9 (15)	.39
Low back	11 (107)	13.5 (23)	10.4 (84)	.3
Shoulder	11.6 (113)	15.3 (26)	10.8 (87)	.13
Arm	0.2 (2)	0 (0)	0.2 (2)	.55
Elbow	2.3 (22)	2.4 (4)	2.2 (18)	.85
Forearm	0.4 (4)	1.2 (2)	0.2 (2)	.05
Wrist	2.8 (27)	6.5 (11)	2 (16)	.003
Hand	4 (39)	5.3 (9)	3.7 (30)	.47
Thumb	0.8 (8)	0.6 (1)	0.9 (7)	.69
Hip	5.1 (50)	4.7 (8)	5.2 (42)	.93
Thigh	4.7 (46)	2.9 (5)	5.1 (41)	.31
Knee	15.1 (147)	7.6 (13)	16.7 (134)	.0004
Leg	6.3 (61)	0.6 (1)	7.5 (60)	.001
Ankle	10.2 (99)	7.1 (12)	10.8 (87)	.18
Foot	7 (68)	8.2 (14)	6.7 (54)	.59
Unspecified body injury	0.8 (8)	0 (0)	1.0 (8)	.24
Total	100 (974)	100 (170)	100 (804)	

^aData are reported as percentage (number of injuries). Bolded P values indicate a statistically significant difference between groups ($P < .05$). NCAA, National Collegiate Athletic Association.

hours played in indoor volleyball and 1.8 injuries per 1000 hours played in beach volleyball.

Rate of Injury per Body Site in Beach Versus Indoor Volleyball

Table 1 shows the comparison of injury rates per body site between the indoor and beach volleyball players. A total of 170 injuries were recorded in 53 beach volleyball athletes over the study period. The shoulder joint (15.3%) was the most common site of injury in these athletes, followed by the low back (13.5%), abdominal muscle (11.8%), foot (8.2%), and knee (7.6%). Regarding the 804 injuries recorded in the 67 indoor volleyball athletes, the knee (16.7%) was the most commonly injured site, followed by the shoulder (10.8%), ankle (10.8%), low back (10.4%), and leg (7.5%). All 5 of the most commonly observed injuries in each sport occurred at a higher rate during practice compared with games (Table 2).

Significantly lower injury rates were seen in indoor volleyball compared with beach volleyball athletes regarding abdominal muscle (4.7% vs 11.8%, respectively; $P = .0008$) and wrist (2% vs 6.5%; $P = .003$) injuries (Table 1). In contrast, significantly higher rates were seen in indoor volleyball versus beach volleyball regarding injuries to the knee joint (16.7% vs 7.6%, respectively; $P = .0004$) and leg

TABLE 2
Subgroup Analysis of the 5 Most Commonly Observed Injuries in NCAA Division I Women's Beach and Indoor Volleyball According to Practice Versus Games^a

Sport	Practice	Games
Beach volleyball		
Shoulder	4.9	0.4
Low back	3.9	0.4
Abdominal muscle	4.1	0.4
Foot	2.8	0.3
Knee	1.7	0.2
Indoor volleyball		
Knee	4.8	0.5
Shoulder	3.8	0.4
Ankle	4.4	0.4
Low back	1.5	0.1
Leg	2.3	0.2

^aData are presented as injury rate per 1000 hours. Both beach volleyball and indoor volleyball players were more likely to sustain these injuries during practice compared with games. NCAA, National Collegiate Athletic Association.

(7.5% vs 0.6%; $P = .001$). Indoor players had a significantly higher rate of concussion compared with beach volleyball players (7.5% vs 6.5%, respectively; $P < .0001$). Although beach volleyball players had a higher rate of shoulder injury (15.3% vs 10.8% in indoor; $P = .13$) and low back injury (13.5% vs 10.4% in indoor; $P = .3$), the difference in these 2 rates did not reach statistical significance.

Days Lost From Shoulder, Knee, and Low Back Injury in Beach Versus Indoor Volleyball

Time lost from participation for both indoor and beach volleyball was available for injuries to the shoulder, knee, and low back. The mean time lost because of knee injury was significantly longer in beach volleyball compared with indoor (3.4 ± 12 and 1.4 ± 8 weeks, respectively; $P = .04$). Low back injuries also resulted in longer time off from participation for beach volleyball athletes compared with indoor volleyball athletes (3.5 ± 4.5 and 2.4 ± 7.7 weeks, respectively; $P = .0009$). The mean time lost because of shoulder injury was longer in beach volleyball compared with indoor (7.4 ± 12.4 and 4 ± 12.4 weeks, respectively; $P = .091$), but the difference did not reach statistical significance.

DISCUSSION

Female collegiate athletes who participate in indoor volleyball are more likely to sustain an injury compared with beach volleyball athletes. Differences in the rates of injury per body site and time lost from participation because of injury were noted in female NCAA Division I athletes participating in beach versus indoor volleyball. The knee was the most commonly observed site of injury in indoor volleyball, and the shoulder was the most common site of injury in beach volleyball. Although the rate of knee injury in indoor

volleyball players was significantly higher compared with beach volleyball athletes, time lost from participation because of knee injury was significantly longer in beach volleyball. In addition, beach volleyball athletes had a significantly higher rate of abdominal muscle injury compared with indoor players. Shoulder injuries and low back injuries occurred at similar rates in beach and indoor volleyball, but time lost from participation because of these injuries was significantly shorter in indoor athletes.

Previous studies have reported the prevalence of injuries in collegiate volleyball players, but the majority of them examined multiple sports.^{6,7,16,21} As mentioned above, recent literature primarily focuses on female volleyball players, likely because of the significant increase in the popularity of the sport in women.^{5,8,9,19} There has been little investigation of the differences between indoor and beach volleyball in female collegiate athletes, and previous epidemiologic studies did not separate the 2 disciplines.^{6,7} About 2 decades ago, a research group from Denmark evaluated the injuries in indoor versus beach volleyball athletes.¹ The authors found that the overall rate of injury in beach volleyball players was 4.9 injuries per 1000 volleyball hours, which was higher than 4.2 injuries per 1000 hours played in indoor athletes.¹ This difference in rate, however, was not statistically significant.

In contrast, we found a significantly higher rate of injury in indoor athletes compared with beach volleyball players (5.3 and 1.8 injuries per 1000 hours played, respectively).¹ Fundamental differences in study methodology are likely responsible for the discrepancy in the overall rates of injury between our study and the study of Aagaard et al,¹ where injuries were self-reported by the distribution of surveys to the participants, while in our study we retrospectively collected data recorded in an institutional injury surveillance system by the members of the medical team. According to the NCAA, the overall injury rate in women's volleyball was 4.3 per 1000 athlete-exposures over the 2008-2009 season, which is similar to the corresponding rate reported by Aagaard et al (4.2 per 1000 hours played) but slightly lower than our rate (5.3 per 1000 hours played).⁴ This current analysis included injuries that occurred during multiple athletic seasons (2003-2020 in indoor, 2015-2020 in beach volleyball) in indoor and beach volleyball players. Aagaard et al evaluated the injuries over 2 athletic seasons (1993-1994, 1994-1995), while the abovementioned rate of injury in indoor volleyball reported by the NCAA was calculated over 4 athletic seasons, from 2004 to 2009. Overall, there is a severe lack of studies comparing the overall injury rate between beach and indoor volleyball athletes, and more evidence is needed to estimate these rates with accuracy.

Regarding the comparison of injuries in indoor versus beach volleyball, indoor volleyball players had a significantly higher rate of knee (16.7% and 7.6%, respectively; $P = .0004$) and leg injury (7.5% and 0.6%, respectively; $P < .0001$) compared with beach volleyball players. While Aagaard et al¹ reported a slightly increased rate of knee injury in indoor athletes compared with beach volleyball players, the difference was not statistically significant. The rate of knee injury in the study by Aagaard et al. fell between 15% and 20% in both indoor and beach volleyball

athletes, which agrees with our results in indoor volleyball (16.7%), but our rate of knee injury (7.6%) in beach volleyball was lower. Bahr and Reeser³ had found that knee injury was among the most commonly reported acute and overuse injuries in a cohort of beach volleyball athletes. The significantly greater rate of knee injury in indoor volleyball compared with beach volleyball could possibly be explained by differences in the biomechanical load applied to the knee joint when competing on court (indoor volleyball) versus the sand (beach volleyball). Repetitive jumping on a harder surface may preclude the power absorption that has been reported to occur with the performance of athletic activities on the sand.¹⁸ Tilp et al²⁰ showed decreased biomechanical forces and lower jump heights when elite male volleyball players performed the spiking motion on sand compared with an indoor surface. Nevertheless, future studies must focus on comparison of the biomechanical forces applied to the knee joint based on the surface type and the characteristics of the athletes, including sex and level of competition. The rate of lower leg injury was not reported by the study of Aagaard et al, which precluded any comparison with our findings.

Interestingly, the rate of concussion injury was high. Although volleyball is a noncontact sport, concussion may be the result of player-to-player contact, player-to-floor contact, or player-to-ball contact. Our detected concussion rate of 7.5% in indoor athletes confirmed the results of a previous survey in 663 registered Volleyball Canada members in which the incidence of concussion was estimated as 7.1 per 100 male volleyball players and 7.5 per 100 female volleyball players.¹⁰ In the study by Meeuwisse et al, ball-to-head contact was the most common mechanism of injury, followed by player-to-player contact (20.2%) and player-to-floor contact (15.5%). In addition, Meeuwisse et al¹⁰ reported that almost half of the concussion injuries occurred during practice (46.5%), while the rest occurred during the game (38.4%) or in warm-up (15.1%). We did not record the mechanism or setting (game vs practice) of concussion injury in our study. Contrary to the above, volleyball was among the 3 sports with the lowest incidence of concussion injury (0.03 per 1000 athlete-exposures) in a systematic review of concussion injuries among different sports.¹⁴ None of the above studies reported the rate of concussion injury in beach volleyball athletes. Further research is needed to provide more accurate estimates of the concussion rates in both indoor and beach volleyball. Although there has been increased awareness of the concussion risk in volleyball athletes, no study has examined whether the use of head protective equipment would be effective to reduce the frequency and/or severity of concussions in volleyball. The last represents an area of future research.

In this current analysis, the rates of abdominal muscle injury (11.8% in beach volleyball and 4.7% in indoor volleyball; $P = .0008$) and wrist injury (6.5% in beach volleyball and 2% in indoor volleyball; $P = .003$) were significantly higher in beach volleyball athletes compared with indoor players. According to the 2004 report of volleyball injuries by the NCAA,¹² the rate of abdominal wall injuries was 5.7%. Abdominal muscle injuries in elite volleyball athletes have only been described in case reports; trunk

hyperextension with eccentric contraction of the abdominal musculature during overhead swing in volleyball athletes usually results in strain of the nondominant rectus abdominis muscle. No studies have explored potential differences in abdominal wall musculature force applied when participating in indoor versus beach volleyball. In theory, performing the overhead swing motion in an outdoor environment might require increased contraction of the abdominal muscles during the swing motion. This could be explained by the wind causing the ball to move in unpredictable directions and/or a possible increase in overall resistance when an athlete attempts to hit the ball. The effect of environmental conditions and/or surface type on the biomechanical forces applied to the abdominal wall muscles in volleyball athletes constitutes a subject of further investigation.

Time lost from volleyball participation was examined for injuries to the shoulder, knee, and low back, which were among the most common injuries observed in both indoor and beach volleyball (Table 1). No difference in the rate of low back injury was noted between beach and indoor volleyball players (13.5% vs 10.4%; $P = .3$). However, time lost because of low back injury was significantly longer in beach volleyball athletes compared with indoor volleyball athletes (mean time lost, 3.5 weeks and 2.4 weeks, respectively; $P = .0009$). Further, beach volleyball athletes required significantly longer time off from participation because of injury to the knee (mean time lost, 3.4 weeks for beach volleyball and 1.4 weeks for indoor volleyball; $P = .04$), although indoor volleyball players more frequently sustained this type of injury (Table 1). Finally, the rate and time lost because of shoulder injury was similar between indoor and beach volleyball players; however, athletes participating in beach volleyball missed longer periods from sport participation compared with indoor players (mean time lost, 7.4 weeks in beach volleyball and 4 weeks in indoor volleyball; $P = .091$). Although this comparison was performed for injuries to the knee, shoulder, and low back and did not include other body sites, our results indicated that beach volleyball athletes may require longer periods for injury recovery compared with indoor players. We failed to record the severity of these analyzed injuries, which could have been helpful to explain the observed differences in time lost because of certain types of injury between the 2 volleyball disciplines.

Overall, this analysis provides an update on the rate of injuries in indoor versus beach volleyball athletes who compete at a high level, as well the time lost associated with some of the most common injuries. We conducted this study by retrospectively reviewing these injuries using our institutional database, and the documentation was done by the medical care team, including athletic trainers and physicians. Aagaard et al,¹ in contrast, reported the injuries in both indoor and beach volleyball athletes via the distribution of questionnaires. Therefore, the injuries in this last article were self-reported. In addition, the study population of Aagaard et al consisted of male and female elite and recreational volleyball players, while we focused on NCAA Division I athletes of female sex only. Nevertheless, our results remained comparable with the

findings by Aagaard et al because of similarities in the type of data reported.

Our study population consisted of NCAA Division I volleyball players of female sex, and therefore these results may not be representative of the injuries occurring in male players. This retrospective study carried the risk of utilizing inadequately reported, inaccurate, and/or missing data that may have negatively affected the accuracy of the results. Further, we were unable to analyze factors that could have made this study more applicable in clinical practice. These factors include the analysis of injuries based on mechanism or acuity, documentation of the actual diagnosis for each of the reported injuries, and stratification of injuries based on the severity or management. Time lost because of injury was not recorded for all types of injury in both sports, which limited our comparisons for this variable to 3 injury sites (shoulder, knee, and low back). Although our results shed light on the comparison of injuries in indoor versus beach volleyball, additional research is necessary to confirm or reject our findings. Prospective studies will result in improved documentation of the injuries and the analysis of factors that play a role in injury recovery. Future studies should analyze differences in biomechanical forces applied to different areas of the human body based on the surface type used in volleyball and reinforce the development of injury prevention protocols and therapeutic strategies, specific to each volleyball discipline.

CONCLUSION

Based on this study in the women's volleyball NCAA Division I category, injury was more likely to occur in indoor compared with beach volleyball. Sport-related concussion and knee injuries were more common in indoor volleyball, but the rate of abdominal muscle injury was higher in beach volleyball. Beach volleyball players needed longer time to recover after injuries to the knee, shoulder, and low back compared with indoor athletes.

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