SAND VS. INDOOR AGILITY AND VERTICAL JUMP PERFORMANCE IN BOTH SAND AND INDOOR VOLLEYBALL PLAYERS

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By: Heather C. Boyan

Committee Members:
Ronald K. Hetzler, Chair
Nathan M. Murata
Christopher D. Stickley
Table of Contents

Index of Tables and Figures ........................................................................................................................................ iii

PART I ........................................................................................................................................................................ 1

  Introduction ......................................................................................................................................................... 1
  Methods .......................................................................................................................................................... 3
    Study Design ............................................................................................................................................... 3
    Participants ................................................................................................................................................ 4
    Procedures .................................................................................................................................................. 4
    Testing ......................................................................................................................................................... 5
    Statistics ...................................................................................................................................................... 7
  Results ........................................................................................................................................................... 8
  Discussion ..................................................................................................................................................... 9
    Limitations ................................................................................................................................................. 14
    Conclusion ............................................................................................................................................... 15

PART II ............................................................................................................................................................... 16

  Appendix A: Review of Literature ................................................................................................................ 16
    Introduction ............................................................................................................................................... 16
    Volleyball ................................................................................................................................................ 18
    Agility ....................................................................................................................................................... 21
    Vertical Jump ........................................................................................................................................... 23
    Conclusion ............................................................................................................................................... 26

References .......................................................................................................................................................... 28

Appendix B: Informed Consent Form .............................................................................................................. 31

Appendix C: General Health Questionnaire .................................................................................................. 33

Appendix D: PAR-Q ......................................................................................................................................... 34
Index of Tables and Figures
Figure 1. 4 Cone Star Agility Test.................................................................7
Table 1. Participant Characteristics..............................................................9
Table 2. Means and Standard Deviations....................................................9
Table 3. Correlations.......................................................................................9
PART I

Introduction

Sand volleyball is a relatively new competitive sport that is quickly expanding. There are numerous differences between sand and indoor volleyball, distinctly the variability of the training surface in sand volleyball. Beach sand, on which sand volleyball is played, is classified as highly absorptive on the surface stiffness scale (4). The differences between beach sand and a traditional volleyball court can affect an athlete’s performance, especially if he or she has not trained on that surface. Optimal performance of the indoor or sand athlete is dependent on the specific movements associated with the sport of interest. Jumping and agility are two of the main components in both indoor and sand volleyball. To best enhance jumping and agility performance, the incorporation of power training is essential for sand and indoor volleyball (13). The ability to tolerate high eccentric loads in elite volleyball players is critical for efficient jump performance (16). Maximal jumps have been reported to be lower when performed on sand compared to rigid surfaces similar to a wood-flooring court. However, a significant positive correlation between jump height on sand and land ($r=0.62$ for approach jump) suggests that land-based tests may be utilized for sand players (4).

When training for both sand and indoor volleyball, it is important to implement power, plyometric and agility exercises during training (13). Agile athletes have the capability to change direction and start and stop quickly (3). Strength gains relative to body mass improve performance in explosive lower body movements (13). Because it is
a power-dominated sport, volleyball requires quick and repeated movements to jump and react to the ball (19). When comparing the exertion levels of sand volleyball players versus indoor volleyball players, sand players had higher ratings of perceived exertion and increased heart rate but similar levels of blood lactate while playing (3). Another study found a significant difference in lower-body power between player positions in indoor volleyball, exhibiting the importance of specificity with training (16). Existing research shows that plyometric and agility training on sand have multiple benefits, including an increase in muscular endurance, explosive power, and improved neuromuscular control due to the constant shifting of sand (1, 7, 10).

Previous research has shown the complexities of training in sand and how it differs from training on indoor surfaces. Sand training requires an energy output 1.2 to 1.6 times greater than training on land, resulting in increased oxygen consumption (8, 11, 20). The small particles that compose sand create decreased firmness and friction, acting as a “damper” by absorbing energy and not returning as much back to the limb due to the displacement of the surface with each movement (3, 19). The differences between sand and indoor surfaces exist because of the overall increased external work required for movement in sand due to the athletes’ lack of ability to generate ground reaction forces (GRF), therefore decreasing the efficiency of positive work performed by soft tissue structures of the body and thus vertical jump height (4, 8, 19). Sand training can result in decreased stress on the lower extremity musculoskeletal system (8, 15). This could be one of the factors leading to the decreased rate of lower limb injuries (up to five times) in athletes competing on more forgiving surfaces (8). Numerous studies have shown that
sand-based agility and sport-specific training elicit improved results when compared to training on grass (3) and indoor surfaces (7).

While it is commonly noted that performing exercise on the sand is more difficult than on a rigid land surface (8, 11), no studies have yet explored the relationship between agility and vertical jump test scores on both sand and indoor surfaces in female elite volleyball players (10). Power and speed are more closely related to agility performance in female athletes than in male athletes ($r=0.77$ for men vs. $r=0.81$ for women) (17). More data is needed for sport-specific agility tests (3) and to better understand female elite sand and indoor volleyball performance. Therefore, the purpose of this study was to evaluate elite female sand collegiate volleyball players’ performances compared to elite indoor volleyball players’ heart rates and ratings of perceived exertion after completing agility and vertical jump testing in sand and on an indoor surface.

**Methods**

**Study Design**

A repeated measures design was conducted, consisting of two 30 minute data collection sessions (one for sand tests and one for indoor tests). Testing on both days consisted of the 4 Cone Star Drill test and the vertical jump test on both sand and indoor surfaces. A five-minute rest period was given between the two tests. The independent variables were type of athlete (sand or indoor volleyball) and testing surface (sand or indoor wooden floor). The dependent variables included recorded agility time (in
seconds), the vertical jump assessment (in cm), heart rate (in bpm), and Rating of Perceived Exertion (RPE).

Participants
Members of NCAA Division I women's indoor and sand volleyball teams were recruited for participation in this study. Participants were between the ages of 18-25 years old and were active in the conditioning regimen provided by the university strength and conditioning coaches. The players were divided into three groups: the sand group, which consisted of athletes who played exclusively on sand; the indoor group, which consisted of athletes who played exclusively indoors; and the “hybrid” group, which consisted of athletes who played for both the sand and indoor teams. The hybrid group, after finishing their indoor season in the fall, had approximately nine weeks of sand training prior to data collection. During the school year, both teams were actively training and playing both in and out of season. Exclusionary criteria included: 1) any lower extremity injury that would cause a reduction in training load; 2) any previous medical condition that deemed the subject unfit for exercise (14); and 3) self-reported pregnancy.

Procedures
Participants reported to the Human Performance Lab for anthropometric measurements on the first day of testing. Participants were given standardized written and verbal instructions prior to initiation of all testing procedures. Informed consent was obtained from all participants utilizing a written informed consent form approved by the university’s Human Studies Program prior to initiation of study procedures (Appendix B). All subjects also completed a health history questionnaire and the physical activity
readiness questionnaire (PAR-Q) (Appendices C and D, respectively) (5). All forms were
reviewed, and participation was approved by a Board of Certification certified athletic
trainer prior to beginning the study. Height was measured using a wall-mounted
stadiometer (Model 67032, Seca Telescopic Stadiometer, Country Technology, Inc., Gay
Mills, WI, USA). Body mass was recorded using a double beam scale (Model 442,
Detecto Scale Company, Webb City, MO, USA). On the first day of testing after
anthropometric measurements were taken, subjects were fitted with heart rate monitors
on their bare skin over the xiphoid process. Testing days were randomized by
convenience based on the availability of the facilities; 13 participants completed the sand
testing first, and 8 completed the indoor testing first. Participants then proceeded to either
the sand volleyball courts or an indoor volleyball court for surface specific testing. The
two testing sessions were separated by at least 48 hours (9 ± 6 days). On the second
testing day, participants had their body mass recorded prior to surface specific testing.
Aside from the different surface, procedures were the exact same as those performed on
Day 1 of testing.

Testing

Participants completed a standardized ten minute dynamic warm-up in the sand or
on the wooden indoor surface prior to testing.
Vertical Jump

Participants performed the vertical jump test first, using a volleyball approach jump and the Vertec (Sports Imports, Hilliard, Ohio). Jump testing using a Vertec is a reliable measure ($r=0.906$) when compared to a 3-camera video system (16). Standing reach was measured prior to the first jump, and the jumping area on the sand court was restored by raking after each jump. Participants performed a minimum of three trials and were allowed additional trials until they completed one trial with no improvement. The highest jump height minus the standing reach was recorded as the vertical jump height.

4 Cone Agility Drill

Participants rested for five minutes after the jump testing prior to starting the agility testing. Two to three practice trials of the agility test were performed at a self-selected pace in order to familiarize the participants with the correct testing procedure (see Figure 1). After the practice trials, participants were asked to complete three trials of the test with maximal effort and a 90 second rest between each trial. Time to completion was recorded using an electronic timing gate (Model IRD-t175, Brower Timing Systems, Draper, UT), beginning when the participant left her stance and stopping when the first part of her body crossed the finish. Heart rate and Rating of Perceived Exertion (RPE) were recorded at the conclusion of each testing trial. Perceived exertion during testing was measured using Borg’s 15 point Ratings of Perceived Exertion Scale (5). Heart rate was recorded every 15 seconds up to 75 seconds after each trial. Heart rate recovery (HRR) was calculated by subtracting HR at 75 seconds from peak HR from each trial. The best time trial was used for statistical analysis. After three trials were performed, participants completed a five minute cool down.
The layout for the 4 Cone Star Agility Test consisted of five cones placed into a cross with three feet in between each cone. Participants started on the right side of the first cone and ran around the left side of the center cone before running counter-clockwise around cone 2. They then ran to the left of the center cone before running counter-clockwise around cone 3. This process was repeated for cone 4. After running around cone 4, participants ran clockwise around the center cone before finishing on the opposite side of cone 1 that they had started (See Figure 1).

Figure 1: 4 Cone Star Agility Test

Statistics
Statistical analysis was performed using SPSS (version 23, IBM, Armonk, New York). A two-by-three repeated measures ANOVA was used to assess differences
between surfaces (sand vs. court) and types of volleyball players (sand, indoor, and hybrid). Significance was set at an alpha level of $p < 0.05$.

**Results**

There were significant differences between indoor and sand conditions for both approach jump trials ($p<0.001$) and agility trials ($p=0.021$). However, there was no significant interaction between sand, indoor, and hybrid volleyball athletes. There were also no significant differences between indoor and sand trials for RPE, maximum heart rate, and heart rate recovery. The ANOVA revealed a trend toward significance between groups for RPE ($p=0.082$). Post hoc tests revealed that significant differences may have existed between indoor and hybrid athletes ($p=0.027$), with a mean difference of $2.0 \pm 1.1$ units. The ANOVA also revealed a trend toward group differences for agility time ($p=0.056$). Post hoc tests indicated that the sand athletes may have performed better than indoor across both surfaces by a mean difference of $0.593 \pm 0.238$ seconds ($p<0.05$), and hybrid players may have performed better than indoor players across both surfaces by a mean difference of $0.553 \pm 0.279$ seconds ($p=0.063$). Descriptive statistics for participants are displayed in Table 1. Means and standard deviations for the dependent variables are presented in Table 2. Significant correlations are presented in Table 3.
Table 1. Participant Characteristics (Mean ± Standard Deviation)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Indoor (n= 6)</th>
<th>Sand (n = 10)</th>
<th>Hybrid (n = 5)</th>
<th>Total (n = 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>19.5 ± 1.2</td>
<td>20.1 ± 1.3</td>
<td>19.4 ± 0.5</td>
<td>19.8 ± 1.1</td>
</tr>
<tr>
<td>Height (centimeters)</td>
<td>181.17 ± 8.94</td>
<td>174.00 ± 6.98</td>
<td>181.66 ± 9.69</td>
<td>178.33 ± 8.43</td>
</tr>
<tr>
<td>Body Mass (kilograms)</td>
<td>80.57 ± 8.80</td>
<td>69.67 ± 6.80</td>
<td>73.18 ± 12.20</td>
<td>73.62 ± 9.63</td>
</tr>
<tr>
<td>Years of Experience Indoor</td>
<td>7.7 ± 2.7</td>
<td>7.0 ± 2.6</td>
<td>7.4 ± 1.1</td>
<td>7.3 ± 2.3</td>
</tr>
<tr>
<td>Years of Experience Sand</td>
<td>2.0 ± 0.9</td>
<td>5.8 ± 3.3</td>
<td>6.0 ± 3.5</td>
<td>4.7 ± 3.3</td>
</tr>
</tbody>
</table>

Table 2. Performance Data (Means ± Standard Deviations)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Indoor (n=6)</th>
<th>Sand (n=10)</th>
<th>Hybrid (n=5)</th>
<th>Total (n=21)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor Approach Jump (cm)</td>
<td>59.69 ± 6.17</td>
<td>56.90 ± 6.33</td>
<td>56.39 ± 7.05</td>
<td>57.57 ± 6.28</td>
</tr>
<tr>
<td>Sand Approach Jump (cm)</td>
<td>53.59 ± 3.53</td>
<td>49.56 ± 5.76</td>
<td>50.91 ± 6.63</td>
<td>51.03 ± 5.47</td>
</tr>
<tr>
<td>Indoor Agility Time (sec)</td>
<td>7.07 ± 0.45</td>
<td>6.42 ± 0.46</td>
<td>6.65 ± 0.46</td>
<td>6.66 ± 0.52</td>
</tr>
<tr>
<td>Sand Agility Time (sec)</td>
<td>7.38 ± 0.73</td>
<td>6.85 ± 0.35</td>
<td>6.69 ± 0.70</td>
<td>6.96 ± 0.60</td>
</tr>
<tr>
<td>Indoor HRR (bpm)</td>
<td>33.5 ± 6.8</td>
<td>36.1 ± 10.5</td>
<td>40.4 ± 13.3</td>
<td>36.4 ± 10.2</td>
</tr>
<tr>
<td>Sand HRR (bpm)</td>
<td>30.5 ± 8.7</td>
<td>38.4 ± 9.6</td>
<td>39.2 ± 11.1</td>
<td>36.3 ± 9.9</td>
</tr>
<tr>
<td>Indoor Peak HR (bpm)</td>
<td>139.2 ± 12.1</td>
<td>139.8 ± 14.1</td>
<td>139.2 ± 10.2</td>
<td>139.5 ± 12.1</td>
</tr>
<tr>
<td>Sand Peak HR (bpm)</td>
<td>142.5 ± 10.6</td>
<td>146.7 ± 12.6</td>
<td>134.2 ± 9.6</td>
<td>142.3 ± 11.9</td>
</tr>
<tr>
<td>Indoor RPE</td>
<td>10.8 ± 1.2</td>
<td>9.3 ± 2.3</td>
<td>8.8 ± 2.3</td>
<td>9.6 ± 2.1</td>
</tr>
<tr>
<td>Sand RPE</td>
<td>10.5 ± 1.8</td>
<td>9.7 ± 2.3</td>
<td>7.4 ± 1.1</td>
<td>9.4 ± 2.2</td>
</tr>
</tbody>
</table>

cm: centimeter; sec: second; HR: heart rate; bpm: beats per minute; HRR: heart rate recovery; RPE: rate of perceived exertion

Table 3. Significant Pearson Product Moment Correlations

<table>
<thead>
<tr>
<th>Variables</th>
<th>Pearson Correlation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indoor Approach Jump &amp; Sand Approach Jump</td>
<td>0.74 (p&lt;0.01)</td>
</tr>
<tr>
<td>Indoor Agility Time &amp; Indoor HRR</td>
<td>-0.597 (p&lt;0.01)</td>
</tr>
<tr>
<td>Sand Agility Time &amp; Indoor Agility Time</td>
<td>0.678 (p&lt;0.01)</td>
</tr>
<tr>
<td>Sand RPE &amp; Indoor RPE</td>
<td>0.610 (p&lt;0.01)</td>
</tr>
<tr>
<td>Sand HRR &amp; Indoor HRR</td>
<td>0.534 (p&lt;0.05)</td>
</tr>
<tr>
<td>Sand Agility Time &amp; Sand HRR</td>
<td>-0.465 (p&lt;0.05)</td>
</tr>
<tr>
<td>Sand HRR &amp; Sand RPE</td>
<td>-0.318 (p&lt;0.01)</td>
</tr>
</tbody>
</table>

HRR: heart rate recovery; RPE: rate of perceived exertion

Discussion

Although approach jump and agility times between groups were not statistically significant, there were a number of parallels and correlations found that are of
importance. There were significant differences for all subjects between indoor and sand jump trials \((p<0.001)\). This showed that the athletes as a whole achieved better scores on the indoor surface when compared to the sand condition (agility mean difference = 0.30 ± 0.46 sec, approach jump mean difference = 6.5 ± 4.3 cm). These data support findings from numerous studies (3, 4, 8, 10) that have reported increased performance on indoor and/or rigid surfaces when compared to sand. The significant correlations reported in Table 3 indicate that athletes who performed better on the indoor surface tended to perform better on sand \((r=0.678, p<0.01\) for the approach jump, \(r=0.678, p<0.01\) for the agility test).

Differences in RPE between groups trended toward significance \((p<0.082)\). When combining data from both surfaces, the post hoc test revealed that the indoor players may have had higher RPE’s by a mean of 2.0 ± 0.8 units when compared to sand players \((p=0.217)\), and sand players may have had higher RPE’s by a mean of 2.6 ± 0.9 units when compared to hybrid players \((p=0.165)\). In addition, indoor players may have had higher RPE’s by a mean of 2.6 ± 1.1 units when compared to hybrid players \((p<0.05)\). Although the main effect for group only trended toward significance, the post hoc results may be explained by the fact that the participants that play both sand and indoor volleyball are familiar with training on both surfaces. Their familiarity and confidence on both surfaces demonstrated the importance of training specificity (10). Athletes will perceive the work to be less difficult when they are familiar with the work they are performing.
Although not statistically significant, there were differences between groups for agility time in both conditions that were trending toward significance ($p=0.056$), with the post hoc test suggesting that there may have been differences between sand and indoor groups ($p<0.05$) and hybrid and indoor groups ($p=0.063$). There were no significant differences between groups for approach jump height; however, the indoor players scored higher than the sand players for both indoor and sand trials (indoor condition: $60.1 \pm 5.1$ and $56.6 \pm 6.7$ cm, respectively; sand condition: $51.5 \pm 6.1$ and $50.8 \pm 5.1$ cm, respectively). It was hypothesized that the sand players would score higher on both indoor and sand jumps, but this was not the case. These findings were in concurrence with Impellizzeri et al., who found that when comparing plyometric training programs in grass versus sand, the grass group improved participants’ vertical jump height significantly compared to the sand group. However, there were no significant increases in sprint time between groups after the training program (8). The data from the present study suggested that training in sand will improve agility time, but similar results were not found for approach jump. These results may be due to the efficiency of the stretch-shortening cycle (SSC). Countermovement jumps are enhanced by the prestretch in the SSC (8). With sand training, increased contact time on the surface and decreased stability equates to use of more stabilization muscles and less GRF. Additionally, findings from Guadino et al. suggest that exercises with change of direction may be better suited to a sand surface, where it is possible to reach higher maximum deceleration values (6). Because of the decrease in GRF and consequent decrease in force development, these neuromuscular patterning changes may lead to decreased performance on an indoor or
rigid surface after an extensive sand training program. Alternatively, the indoor group may have experienced a greater training effect on their fast twitch muscle fibers.

When data from the three groups were combined, negative correlations existed between indoor heart rate recovery (peak heart rate – 75 second recovery heart rate) and indoor best agility times ($r=-0.597, p<0.01$) and sand heart rate recovery and sand agility best times ($r=-0.465, p<0.05$). This suggested that as agility performance improved (a smaller agility time is a better performance), heart rate recovery increased. The negative correlation between sand heart rate recovery and sand agility RPE ($r=-0.318, p<0.1$) suggested that athletes who recovered more quickly from the sand agility trials perceived less effort.

The population tested for this study consisted of a group of elite athletes. Participants were members of either the indoor volleyball or sand volleyball team at the University of Hawaii, where the indoor team finished the season ranked 7th for Division I NCAA Women’s Volleyball, and the sand volleyball team finished 4th in the Division I NCAA National Championship. This was a novel population (elite Division I NCAA volleyball players) when compared to other studies. When comparing means for vertical jump for combined groups, participants scored 21.2 cm higher than the Division I athletes performing a countermovement jump in Barnes et al.’s study; however, this difference should be viewed with caution as different methodologies were used to obtain peak jump heights (2). Similarly, when compared to the athletes from Schaal et al., participants scored 4.8 cm and 10.4 cm higher when compared to Division I athletes and high school players, respectively (16). Participants as a whole from the present study also performed
better in approach jump than Division I players studied by Nesser et al. by 3.1 cm and by 6.1 cm when comparing just indoor players (12). When comparing this elite population to untrained or amateur individuals like those in Impellizzeri et al. (44 amateur soccer players, gender was not identified) and Mirzaei et al. (30 untrained healthy men, college-aged), participants scored 11.4 cm and 6.9 cm higher, respectively (8, 10). The only group with higher jump height results than the participants from the current study was a combined group of Australian state-level volleyball athletes (10 male and 8 female). These athletes jumped 7.3 cm higher on an indoor surface and 4.3 cm higher on sand; however, it should be noted that these data include both male and female athletes (4). All of these findings showed that jumping ability and, presumably, power output were higher for more elite populations. There were a number of factors that may have contributed to this supposition. Elite level athletes tend to have more years of experience both playing their sport and training for their sport. Arazi et al. states that improving muscular performance and function is an important goal for strength and conditioning professionals (coaches) (1). All of the athletes in the present study participated in supervised strength training programs. The ability of more elite populations to perform better on vertical jump tests may have been affected by type of training available and/or by natural selection. It is presumed that elite level athletes will have elite level training as well. NCAA Division I strength and conditioning programs have been shown to enhance sport performance by improving physiological adaptations (16). Elite athletes tend to share common physical traits and may also be older, taller, and have greater lean body mass than non-elite populations. With volleyball specifically, taller players, especially hitters, may perform better because of the specific demands of volleyball and/or an athletic
phenotype. This is supported by research that has reported that more skilled players had greater fat-free mass as well as greater power output when compared to less elite players (16).

An interesting finding was that some players \( (n = 10) \) perceived work on an indoor surface to be more difficult than work on sand when performing the agility test. This included sand \( (n = 5) \), indoor \( (n = 2) \), and hybrid players \( (n = 3) \). One would assume that because of the overall increased external work required for movement in sand due to the athletes’ lack of ability to generate GRFs (11), any movements performed in the sand would seem more difficult. However, for nearly half of the participants, that was not the case. This suggests that playing on a more rigid surface causes more stress on the muscles and joints; therefore, it is perceived as more difficult than playing on a more forgiving surface like sand. This supports the findings from Impellizzeri et al., who reported decreased muscle soreness from training in the sand compared to training on grass (8). Sand training may be a viable option when a main goal of a training program is to decrease pain and muscle soreness or recovering from injury. This may also explain why some participants performed better on the agility test in the sand than on the indoor surface. Unexpectedly, four participants (indoor, \( n = 4 \) ) achieved better agility scores on the sand than on the indoor surface. Decreases in stress to the muscles and joints due to a longer stretch-shortening cycle in sand may be the reason for these differences (8).

Limitations

Limitations of this study may have directly affected the results. Although a strength of the current study was that participants were recruited from elite Division I
NCCA teams, both ranked in the Top 8 nationally, a significant limitation was the small sample size. It is suggested that future research use a larger sample size to further examine the possible differences between groups. Another limitation was lack of consistency with number of days between first and second data collections (9 ± 6 days). Participants who performed with less time between data collections may have been more familiar with the testing procedures and therefore performed better. A standardized number of days between sessions would be ideal for future research.

**Conclusion**

In conclusion, this study demonstrated that there was a significant difference in approach jump and agility performance between indoor and sand conditions \((p<0.001)\), with performance on the approach jump and the agility test being significantly better on an indoor surface than on sand. Data from the present study suggest that training on the sand does not necessarily improve performance. This may be due to the increased SSC in sand, indicating that sand training may not necessarily be beneficial to athletic performance for athletes who play on a rigid surface (8). However, lower RPE scores for sand and hybrid players when compared to indoor players showed that there were positive aspects to training in sand.
PART II

Appendix A: Review of Literature

Introduction
Sand volleyball is a relatively new competitive sport that is quickly expanding. There are numerous differences between sand and indoor volleyball, distinctly the variability of the training surface in sand volleyball. Beach sand, on which sand volleyball is played, is classified as highly absorptive on the surface stiffness scale (4). The differences between beach sand and a traditional volleyball court can affect an athlete’s performance, especially if he or she has not trained on that surface. Optimal performance of the indoor or sand athlete is dependent on the specific movements associated with the sport of interest. Jumping and agility are two of the main components in both indoor and sand volleyball. To best enhance jumping and agility performance, the incorporation of power training is essential for sand and indoor volleyball (13). The ability to tolerate high eccentric loads in elite volleyball players is critical for efficient jump performance (15). Maximal jumps have been reported to be lower when performed on sand compared to rigid surfaces similar to a wood-flooring court. However, a significant positive correlation between jump height on sand and land ($R^2=0.92$ for approach jump) indicates that land-based tests can be utilized for sand players (4).

When training for both sand and indoor volleyball, it is important to implement power, plyometric and agility exercises during training (13). Agile athletes have the capability to change direction and start and stop quickly (3). Strength gains relative to body mass improve performance in explosive lower body movements (13). Because it is
a power-dominated sport, volleyball requires quick and repeated movements to jump and react to the ball (19). When comparing the endurance levels of sand volleyball players versus indoor volleyball players, sand players had higher ratings of perceived exertion and increased heart rate but similar levels of blood lactate while playing (3). Another study found a significant difference in lower-body power between player positions in indoor volleyball, exhibiting the importance of specificity with training (16). Existing research shows that plyometric and agility training on sand have multiple benefits, including an increase in muscular endurance, explosive power, and improved neuromuscular control due to the constant shifting of sand (1, 7, 10).

Previous research has shown the complexities of training in sand and how it differs from training on indoor surfaces. Sand training requires an energy output 1.2 to 1.6 times greater than training on land, resulting in increased oxygen consumption (8, 11, 20). The small particles that compose sand create decreased firmness and friction, acting as a “damper” by absorbing energy and not returning as much back to the limb due to the displacement of the surface with each movement (3, 19). The differences between sand and indoor surfaces exist because of the overall increased external work required for movement in sand due to the athletes’ lack of ability to generate ground reaction forces (GRF), therefore decreasing the efficiency of positive work performed by soft tissue structures of the body and thus vertical jump height (4, 8, 19). Sand training can result in decreased stress on the lower extremity musculoskeletal system (8, 15). This could be one of the factors leading to the decreased rate of lower limb injuries (up to five times) in athletes competing on more forgiving surfaces (8). Numerous studies have shown that
sand-based agility and sport-specific training elicit improved results when compared to training on grass (3) and indoor surfaces (7).

While it is commonly noted that performing exercise on the sand is more difficult than on a rigid land surface (8, 11) no studies have explored the relationship between agility and vertical jump test scores on both sand and indoor surfaces in female elite volleyball players (10). Power and speed are more closely related to agility performance in female athletes than in male athletes (r=0.77 for men vs. r=0.81 for women) (17). More data is needed for sport-specific agility tests (3) and to better understand female elite sand and indoor volleyball performance. Therefore, the purpose of this study is to evaluate elite female collegiate volleyball players’ performances, heart rates, and ratings of perceived exertion after completing agility and vertical jump testing in sand and on an indoor surface.

Volleyball

Volleyball is the third most popular sport for girls (16), and its growing popularity has prompted more research and interest. When discussing indoor volleyball, it is important to note that there are three main positions: front row hitters, setters, and back row defenders. Each position has different demands and utilizes unique footwork and muscle patterns. Back row players are typically shorter than front row players. One study compared the physiological differences between positions and experience level in indoor volleyball using a vertical jump test, T-test, and 150- and 300-yard shuttle. Researchers found that Division 1 players had better test scores than the high school athletes, hitters had higher lower-body power than back row defenders, and the 150-yd shuttle times
coordinate with the 300-yd shuttle times. Although front row players were found to have higher lower-body power than back row players, they did not have significantly higher vertical jump scores. This may suggest that training programs are not specific enough for volleyball athletes and should be customized more based on position (16).

Another study investigated the effect that training surface has on different volleyball skills—passing accuracy, hitting, setting, blocking, and serving (7). For each position, these skills hold different priority levels. The study specifically measured passing accuracy and agility over a 10-week training period on both an indoor and a sand surface. Researchers found both agility and passing skills were significantly better in the sand group than the indoor group at the end of the 10 weeks. The results of this study show that, once again, a greater emphasis needs to be placed on training specificity. Training on the sand has the ability to increase performance in indoor volleyball players because of the increase in relative intensity on sand compared to an indoor surface (7). An additional study found that when compared to jumping on an indoor surface, jump heights were significantly less when performed on sand. This same study, however, showed that tests performed indoors are still valid and reliable for sand volleyball players (4).

In regards to beach volleyball, both players are normally expected to be proficient in a wide range of skills, with a little variation between the partners based on their specific strengths. Specificity in training is still important and still needs to be emphasized because beach volleyball itself holds certain challenges. It is more difficult to
generate ground reaction forces, challenging body stability and balance. The overall variability in beach volleyball creates challenges that are not present in indoor volleyball, specifically the need to cover a greater percentage of the court and to exert more energy to control movements. In sand, a player’s ability to change direction and accelerate is compensated, increasing the demands placed on the body. These different demands suggest that playing on sand consumes more energy than playing on an indoor surface. Exercises for beach volleyball players need to be tailored to assure the athletes are trained properly in regards to demands for their sport (19).

An important topic of discussion with athletes is also overtraining. Nesser et al.’s study examined different performance aspects (approach jump, block jump, and agility test) both before and after an NCAA Division I volleyball team’s two week preseason two years in a row (12). The first year, with 24 practice sessions and 12 resistance-training sessions, researchers found decrements in performance between pre-preseason and post-preseason. The second year, with 17 practice sessions and 10 resistance-training sessions, researchers found no differences in performances between pre-preseason and post-preseason. These findings support the claim that coaches need to be aware of rest and recovery. While conditioning and sport-specific practices are important for success in the sport, a balance is needed to ensure athletes will not be overtrained (12).

With its growing popularity, it is important to continue research on volleyball and the components and training aspects that lead to optimal performance levels. Different positions, in both indoor and on the sand, call for different movements and skills.
Understanding the differences in training effects between sand and indoor volleyball is vital for both players and coaches.

**Agility**

Agility is the ability to change direction quickly and to start and stop quickly (17). It is an important aspect of most sports and is hard to be generally developed throughout strength and conditioning programs because of the many different types of agility (forward and backward, lateral, rotational, etc.). One study aimed to examine how speed, power, and balance are predictors of agility as well as find the difference between agility performance in males and females. They found that power is not significantly correlated to agility performance, but is more significant in females than in males. On the other hand, speed was found to be an important predictor of agility performance, likely because of the similar qualities of these two tasks. The study also showed that balance is an important aspect of agility; this is because performing well with agility tests and sports requiring agility rely on rapid accelerations and decelerations while changing direction. Without good balance, performance will be hindered (17).

Other studies have explored how agility is affected by training surface. Binnie et al. analyzed the influence of sand- and grass-training programs on 20m sprint times. They found that an 8-week sand training program shows a significant improvement in sprint times on both grass and sand surfaces, whereas an 8-week grass program shows improvement on only grass surfaces. Although some criticize that training in sand could compromise training outcomes in rigid-surface sports because of the under-utilization of the stretch-shortening cycle, this study did not find that training in sand negatively
affected performance times on a rigid surface. Binnie et al. suggest that implementing two hours of sand training a week can be beneficial for both sand and indoor sports (3).

Similarly, another study examined the effects of plyometric training on muscle soreness, vertical jump height, and sprinting ability when performed on sand and grass surfaces (8). Injuries are common in sports like soccer, and authors suggested that participating in sand training programs could reduce the chance of injury during preseason training. As they had expected, Impellizzeri et al. found that muscle soreness experienced by the sand training group was lower than the soreness of the grass group. They did not find that training in the sand increased counter-movement jump (CMJ) ability; however, plyometric training on the sand did increase standing jump (SJ) ability (8). These results are consistent with the discussion of Binnie et al., suggesting that training for a movement that requires stretch-shortening of the muscles should be done on a rigid surface (3). The main finding of this study was that training in sand decreases muscular soreness, which is beneficial for all athletes (8).

Researchers have also taken note of how energy expenditure on sand differs from energy expenditure on a rigid surface. Zamparo et al. found that energy cost of moving (walking or running) on sand was 1.2-1.8 times greater than on a more compact surface (20). Similarly, Lejeune et al. found that walking on sand requires 2.1-2.7 times more energy expenditure than walking on a hard surface, and running on sand requires 1.6 times more energy expenditure than running on a hard surface. The reason for these consistent findings when comparing movement between the two surfaces is because of
the mechanical work performed on the sand and a decrease in positive work in the sand (9). When running on sand, the sand acts like a damper, reducing kinetic energy. This is the reason for slower agility times on sand when compared to rigid surfaces and the reason why sand requires a higher energy expenditure (9, 20). Findings from Guadino et al. also showed slower sprint times in the sand than on grass. Researchers suggest that this significant difference may be due in part to the tendency of the foot to slip backwards during the push phase of the stride (6).

There are different factors that contribute to agility performance in the sand. The previously mentioned research shows that movement in the sand requires greater energy expenditure than movement on a rigid surface (9, 20). Gaps in the literature exist that leave room for further research about elite female volleyball players’ movement in the sand and how factors like surface play a role in performance.

Vertical Jump

In volleyball, jumping is a very important skill, especially for front row players in indoor volleyball and for all players in sand volleyball. According to Sheppard et al., counter-movement jump (CMJ) ability and approach jump ability are both critical aspects when determining volleyball performance (18). A CMJ utilizes muscles that cause movement across multiple joints, which leads researchers to believe that multijoint exercises provide the most accurate indication of jump height (13). Numerous studies have been conducted to explore the relationship of jumping ability to factors like agility performance, power, and strength. Barnes et al. examined the relationship between jumping and agility performance and found that counter-movement height jump can be
used to predict agility test times. This makes sense because both maximal jumping and sprinting are dynamic movements that require high muscular power (2).

In addition, Nuzzo et al. found that measures of multi-joint dynamic strength are best for predicting CMJ height. Namely, relative squat 1RM and power clean 1RM tests may be used to predict relative CMJ peak power, CMJ peak velocity, and CMJ height. Once again, researchers found the importance of specificity in training, taking into account the stretch-shortening cycle and how duplicating this movement is the best way to increase vertical jump height. From their study, Nuzzo et al. suggest that strength and conditioning coaches should incorporate dynamic strength exercises to best increase strength and power output (13).

Sheppard et al. discovered that the seven best jumpers in their study also had the highest power output, and the seven worst jumpers had the lowest power output, demonstrating the need for high power generation and velocity production when training for athletics. Sheppard et al. suggest that having the knowledge of factors related to power performance can aid strength and conditioning coaches in creating the best training programs for their athletes. In addition, they found that depth jumping is the best way to develop the stretch-shortening cycle, which is crucial in volleyball and in trying to increase vertical jump height (18).

Plyometric training has been widely used to increase power and vertical jump performance because it has been shown to increase the subject’s use of the stretch-
shortening cycle. Mirzaei et al. examined the influence of 6 weeks of plyometric training on sand on jumping ability, agility, and strength and sprinting performance. Similar to other studies, Mirzaei et al. performed the training program on sand because of the research stating that training on sand decreases muscular soreness when compared to training on a rigid surface. Statistical analysis showed that after the plyometric training, jumping ability increased significantly. Additionally, subjects had minimal muscle soreness and damage to the lower body. From these results, researchers suggest that strength and conditioning coaches design plyometric programs on the sand for their athletes (10).

Similar to studies that have examined energy expenditure while walking or running on sand, studies have also been conducted that examine the energy expenditure of jumping on sand and how it compares to jumping on a rigid surface. Muramatsu et al. had eight collegiate male volleyball players perform 3 sets of 10 CMJ on sand and 3 sets of 10 CMJ on an indoor rigid surface. Differences between the jump heights were not statistically significant, so researchers were able to compare the jumps by saying they were the same height but in different conditions. The oxygen uptake in the sand trials was higher than the oxygen uptake in the indoor trials. Consequently, jumping in sand requires 1.2 times more energy than jumping on a rigid surface (11). This finding correlates with the findings of both Lejeune et al. and Zamparo et al. (9, 20).

Other studies have also taken into account the effects and potential benefits of plyometric training on sand. Arazi et al. used 14 healthy male subjects to compare the
effects of 6-week depth jump training on both and sand and indoor surfaces on muscular performance (1). Results showed that both the sand and rigid surface training programs had significant training effects on the measured factors—jumping ability, agility, strength, and speed. Like similar studies, researchers suggest that strength and conditioning coaches incorporate sand training to increase performance and see even better results (1).

Jumping, one of the most important skills in volleyball, can be affected by a variety of factors. Jumping in sand volleyball creates more variability that changes both the way volleyball players jump and also how high they can jump. Training programs that incorporate plyometrics have been explored to find the best way to train volleyball players to increase jump performance (1, 10, 11). Determining the differences in jump height between sand and indoor volleyball players will show how playing in sand affects vertical jump performance and how coaches can better train their athletes for maximal performance.

**Conclusion**

Existing research has investigated aspects of volleyball and the components that make an exceptional volleyball player—power, strength, agility, and jumping ability. These four areas have been shown to be connected in numerous ways, and the development of each creates a better volleyball player. When it comes to sand volleyball, there is less specific research because of the growing emergence of the sport. Some comparisons have been made between the two sports (4, 7, 19), but these comparisons do not use elite populations or court-specific tests (2). One study examined the difference
between jumping on sand and jumping on a rigid surface (11), while another utilized a training program performed both in sand and on an indoor surface to compare differences (1). However, this study used a male population. The proposed study will use a female elite population and will examine effects of both jumping and agility performance on sand for both sand and indoor volleyball players. This study will add to the existing research and potentially create new guidelines for strength and conditioning coaches of volleyball athletes.
References


Appendix B: Informed Consent Form

Department of Kinesiology and Leisure Science, University of Hawaii at Manoa
1337 Lower Campus Road, PE/A Complex Rm. 231, Honolulu, HI 96822
Phone: 808-956-7606

- **Principle Investigators:** Heather Boyan, BS; Morgan Kocher, MS, ATC; Nathan Murata, PhD; Ronald Hetzler, PhD

- **Title of Study:** Sand vs. Indoor Agility and Vertical Jump Performance in both Beach and Indoor Volleyball Players

- **Purpose of Research:** Sand volleyball is growing in popularity and is a relatively new sport. There is not much existing literature about the differences between sand and indoor volleyball (and none with an elite population) that compares sport-specific movements. For the proper development and training of both indoor and sand volleyball players, it is important to research the best methods of training and which environmental conditions present the best opportunity for improvement. The purpose of this study is to evaluate elite female collegiate volleyball players’ performances, heart rates, and ratings of perceived exertion after completing agility and vertical jump testing in sand and on an indoor surface.

- **Expected Duration for Participants:** Two testing sessions that will be approximately two days apart. Each session will be approximately 30 minutes long.

- **Description of Procedures:** Participants will be asked to complete two different testing sessions, one on a sand surface and one on an indoor surface. Each testing session will include maximal vertical jump testing and agility testing.

Vertical Jump Testing: Vertical jump testing for the three-step volleyball approach will be performed using a Vertec Jump Training System. Participants will be allowed at least three trials, and their testing will be terminated when they complete a trial without any improvement from the last trial. The best trial is used for research purposes.

Agility Testing: Participants will be tested for agility using the 4 Cone Star Drill, which is used in their strength and conditioning program. The procedure for the test will be fully demonstrated, and each participant will be allowed two practice trials at their own pace before completing three timed trials at maximal effort with a minute rest time in between each trial. The fastest trial time will be used for research purposes.
Procedures will be exactly the same for both the sand and indoor surfaces.

- **Benefits**: There are no direct benefits for participating as a research subject.

- **Risks**: Performing maximal vertical jumps and exerting maximal effort on the 4 Cone Star Agility test may cause some muscle fatigue and soreness of lower extremities upon completion. Participants should understand that if they are injured in the course of this research process, they alone will be responsible for the costs of treating any injuries.

- **Confidentiality**: All personal information will be kept confidential to the extent allowed by law. Several public agencies with responsibility for research oversight, including the UH Human Studies Program, have authority to review research records. Research records will be kept in a locked file in the investigator’s office for the duration of the study. All personal information will be destroyed upon completion of the research project.

- **Contact Information**: If participants have any questions or concerns regarding their participation in this study, they may contact any of the key personnel: Heather Boyan at 219.742.8410, Morgan Kocher at 971.237.6903, Dr. Nathan Murata at 808.956.7606, or Dr. Ronald Hetzler at 808.956.3802. For questions about participants’ rights as a research participant, contact the University of Hawaii Human Studies Program by phone at 808.956.5007 or by email at uhirb@hawaii.edu.

I hereby agree to participate in the research study “Sand vs. Indoor Agility and Vertical Jump Performance in both Beach and Indoor Volleyball Players.”

______________________________
Print Name

______________________________   ____________
Signature of Participant        Date

If participants cannot obtain satisfactory answers to their questions or have complaints about their treatment in this study, please contact: Committee on Human Subjects, University of Hawai‘i at Manoa, 2540 Maile Way, Honolulu, Hawaii 96822, Phone (808) 956-5007.
Appendix C: General Health Questionnaire

Name: __________________________
Email: __________________________ Phone #: ________

Please answer the following questions:

• Age:

• Date of Birth:

• Gender: Male   Female

• Height:   ft.    in.

• Weight:   lbs.

• Have you ever been diagnosed with a concussion? Yes   No
  • If yes, how many?

• Which one is your dominant leg? (Which leg do you use to kick a ball?)
  Right   Left

• Have you sustained any lower extremity injuries in the past 6 months? Yes   No
  • If yes, what injury?

• How often do you exercise?

• How long do you usually exercise for each time?

• What kind of exercise do you do?
Appendix D: PAR-Q

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES NO

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

2. Do you feel pain in your chest when you do physical activity?

3. In the past month, have you had chest pain when you were not doing physical activity?

4. Do you lose your balance because of dizziness or do you ever lose consciousness?

5. Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?

6. Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?

7. Do you know of any other reason why you should not do physical activity?

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

• You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.

• Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

• start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.

• take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

Please note: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

“I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction.”

NAME ___________________________ SIGNATURE ___________________________ DATE: ___________________________

SIGNATURE OF PARENT ___________________________ or GUARDIAN (for participants under the age of majority) ___________________________ WITNESS ___________________________ 1:12

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

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