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The Effect of Modular vs. Traditional Playing Surface on Landing Impact

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Abstract

International Journal of Exercise Science 19(1): 1009, 2026. Youth female volleyball athletes often compete year-round on varying surfaces—wood during high school and synthetic during club seasons—potentially affecting mechanical stress. This study compared landing impact and jump height on wood versus artificial flooring. Varsity athletes (n = 15) were monitored using validated wearable sensors to measure landing impact (G-force), stress percent, and jump height during training sessions that included a structured warmup and two-set scrimmage. By surface type there was a difference for G-force ($p < 0.01$), but no difference for stress percent (wood = 16.4 to 21.0%, $p = 0.49$), or average jump height ($p = 0.96$). Specifically, no difference was found for G-force during the warmup (wood = 3.8 ± 0.5, artificial 3.5 ± 0.5 $m \cdot s^{-2}$, $p = 0.10$) or set one (wood = 3.6 ± 0.6, artificial 3.3 ± 0.6 $m \cdot s^{-2}$, $p = 0.05$), but values during set two were higher on the wooden floor (wood = 4.2 ± 0.3, artificial 3.5 ± 0.4 $m \cdot s^{-2}$, $p < 0.01$). These results suggest synthetic flooring may reduce impact forces, particularly during prolonged play. Athletes appear capable of maintaining performance across surfaces, likely through biomechanical adaptation. Coaches and athletic trainers should consider surface type when managing athlete workload and recovery.

Keywords: Gym floor, performance, shock absorption, training load

Introduction

Volleyball involves the repetitive and rapid application of large amounts of force on the lower limb musculature, which can lead to cumulative microtrauma and overuse injuries. As load is applied and impact force is placed on the joints, the body must respond with shock attenuation measures, which are affected by the surface on which athletes are playing.[1,2] Synthetic playing surfaces, or modular flooring, were introduced in the 1960s with the goal of increasing durability and versatility to enable multi-sport use, and to reduce the harshness of take-offs and landings in athletic activities.[1,3] Artificial surfaces have been incorporated into indoor sports due to durability and the cost effectiveness of upkeep. This expansion of use is cause for further research on performance when dealing with modular playing surfaces.

In the United States, many youth volleyball athletes engage in training or competition activities up to six days a week during the season, and those who participate in both school and club seasons, may be actively playing for over 48 weeks per year.[4] To date, jump counts have been the primary measure for assessing physical demands in volleyball.[5–7] Charlton et al. estimated that high school-aged male volleyball players jump 650 times in training per week, not including jumps performed during competition.[5] It has been estimated that during the competitive season female Division I collegiate volleyball athletes perform 12-16 jumps per set, average 97

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jumps per match, and complete 85-119 jumps per practice.[8,9] As the intensity and competitive level increase, the physical demands also rise which leads to a greater number of jumps being executed during both training and gameplay.[10] Kupperman et al. divided jump height data into low (< 20 cm), medium (20-40 cm), and high (> 40 cm) bands to distinguish the intensity of jumps performed.[6] Low band jumps were mostly observed in liberos and defensive specialists for serving, exaggerated shuffling, and diving. Setters accrued the highest total jump count, most of which were in the medium band. Middle blockers and pin hitters performed mostly high band jumps due to the blocking and attacking activities that characterize these positions.[6]

Synthetic flooring materials like linoleum, vinyl, or rubber composites provide a range of performance characteristics, but hardwood has still largely been identified as the material of choice due to increased shoe-surface friction.[11-15] Pasanen, et al. recognized surface hardness and friction between the sports shoe and the surface, or the shoe-playing surface interface to be highly involved in surface-related injuries.[12] Research has found that traumatic pivoting injury risk, including non-contact ACL injury, was higher on artificial floors than wooden floors.[11,12]

Thickness and stiffness are critically important characteristics to consider when discussing synthetic playing surfaces.[15] Artificial turf includes a permanent shock-absorbing layer that ranges from 0.79 to 3.81 cm thick.[16] Alternatively, indoor sports surfaces involve the placement of a synthetic material of thickness ranging from three to 12 mm on top of a concrete layer.[16] Stiffness, or the extent to which a material resists deformation in response to an applied force, is a principle by which surface affects landing impact. From an engineering perspective, impact forces are influenced by alteration of the material properties of sports surface.[15] Coefficient of restitution, defined as a ratio of the velocity of separation (post impact) to the velocity of approach (pre impact), is recognized as a preferred parameter for understanding energy loss of motion in one direction, and is affected by surface material characteristics.[17] A higher value indicates a more elastic collision with less energy lost. Floor thickness, stiffness, surface hardness, and friction are considered for the durability, cost, and portability of indoor playing surfaces, but considerations for jumping performance and landing impacts have yet to be evaluated for indoor playing surfaces.

Research about artificial flooring is dominated by studies of turf, with a limited number of studies examining landing movement biomechanics on synthetic surfaces, and even fewer examining these principles in the scope of indoor sports.[18] Given the concerns about sport specialization in volleyball[4] and the high volume of jumping and landing in the sport,[8,9] it is prudent to evaluate if there are differences in landing impact and jump height among the different playing surfaces. The purpose of this study was to examine landing impact and jump height on both traditional wood and artificial modular playing floors in youth female volleyball athletes. Specialized athletes compete on both surfaces throughout the year, thus understanding how surface type influences landing forces is critical. Survey data were collected to understand sport specialization characteristics exhibited in participating athletes. This study employed wearable technology to provide an ecological evaluation of mechanical loads. We hypothesized that there would be a difference in measured landing impact between the types of surfaces.

Methods

Study Design

This prospective study compared the landing impact and jump heights of youth female volleyball players (n = 17), during two identical training sessions on two flooring types: traditional wood and Taraflex. Jump height and landing impact were measured using VERT wearable devices (Fort Lauderdale, FL). Training sessions included both controlled and uncontrolled components. Athletes began with a structured dynamic warm-up including hitting lines and serving. The warm-up was followed by a two-set scrimmage, with each set being played to 25 points. Athletes were asked to wear the same shoes for both training sessions. This study was approved by the Sam Houston State University institutional review board (IRB-2024-2045) and carried out fully in accordance with the ethical standards of the International Journal of Exercise Science.[19]

Participants

Participants were youth female volleyball players between the ages of 14 and 17 who were active members of club volleyball teams at the participating club. Participants were excluded if they were injured and waiting to be cleared by a physician. All participants were provided with informed consent and completed an assent, along with permission from their parent or guardian. An *a priori* power analysis (using SPSS) for a repeated measures analysis of variance for within participant comparison across two surfaces with an alpha level of 0.05 and effect size of 0.5 indicated that a total n-size of 17 was needed to achieve 80% power based upon stress percentage values.[4]

Protocol

Coefficient of restitution was measured on both floors using a drop test according to the procedures outlined by Haron & Ismail.[17] Three trials were taken on each floor, with the same ball used during both sessions. The ball was dropped from the same initial height (50 cm) across each trial, and the height of the first bounce was recorded. Recorded heights were put into the equation $e = (h_2/h_1)^{1/2}$ an average of the three trials was taken as the coefficient of restitution value for each flooring type.

Before the first training session, athletes were given a validated survey on sport participation and specialization with the following questions: 1) Have you quit other sports to focus on one sport? 2) Can you identify a primary sport? and 3) Do you train or participate in your primary sport more than 8 months out of the year?[13] Responses were summed (yes = 1, no = 0), with a score of 3 classified as highly specialized, 2 being moderately specialized, and 1 or 0 being lowly specialized.[20,21]

Training sessions included both a structured warm-up and a two-set scrimmage, each played to 25 points. The warm-up consisted of movements similar to that which Barbosa et al.[22] and Adevesian et al.[23] found to be effective and included approximately five minutes of hitting lines followed by two minutes of serving. After warming up, athletes split into two teams and scrimmaged for two sets to 25 points.

Athletes wore VERT devices (Fort Lauderdale, FL), which are valid and reliable in measuring jump loads during training and competition in volleyball with a coefficient of variation of 7.8% and count accuracy of 99.3%.[5] The VERT device is a wearable sensor that contains a 3-axis accelerometer, 3-axis gyroscope, and 3-axis magnetometer that provides a reflective measure of external load using the Ldlx algorithm.[5,24] VERT devices were turned on and connected to the VERT app through an iPad (Apple, Cupertino, CA) prior to the onset of data collection. No calibration procedures of the VERT devices were necessary. The device was worn in a VERT belt around participants' waist, placed near the umbilicus. It was ensured that athletes used the same VERT device across both sessions, and it was placed in the same location, with the same tightness. The devices were linked to the VERT Team System app on an iPad. Team sessions were started in the app prior to the start of activity, and data collection was terminated upon completion of the final point of the second scrimmage. Data on the devices was uploaded into the app and shared to the myVERT cloud. Data were downloaded from the cloud, organized by session type (i.e., controlled warm-up, scrimmage one, or scrimmage two) and playing surface for analysis. The variables of interest obtained from the VERT device were G-force (defined as a measurement of instantaneous acceleration recorded during the landing action of a movement), stress percent (defined as peak G-force associated with each landing or attenuation of impact from ground contact up the kinetic chain to the center of mass), and average jump height (cm).

Statistical Analysis

The dependent variables were stress percent, jump height, and G-force. An average was calculated for each variable, for each athlete across each timepoint (warm-up, set 1, and set 2) on both flooring types. Analysis was conducted using SPSS, with an alpha level of 0.05 to determine differences. A Shapiro-Wilks test determined that all variables were normally distributed. Data were analyzed via a 2 (surface) x 3 (timepoint) repeated measures multivariate analysis of variance (RM-MANOVA). Upon a significant main effect, univariate analyses were used to indicate specific differences. Partial eta-squared effect sizes (ES) were calculated to determine the magnitude of the effect and interpreted as small (0.01), moderate (0.06), and large (0.14). Due to a reduced n-size, a post hoc analysis of power was also conducted.

Results

The coefficient of restitution was 0.75 for the wooden floor and 0.66 for the synthetic floor. A higher coefficient of restitution suggests less absorption of the surface with harder landing and improved bounce or takeoff for jumping.

Figures 1-3 show the means and standard deviations of stress percent, average jump height, and G-force, respectively, for each surface type and timepoint. The RM-MANOVA indicated a main effect for surface (Lambda(6,23) = 9.313, $p < .01$, ES = 0.518, large; observed power = 0.991), timepoint (Lambda(6,23) = 5.595, $p < 0.01$, ES = 0.593; large, observed power = 0.982), and an interaction of surface x timepoint (Lambda(6,23) = 5.615, $p < 0.01$, ES = 0.594, large; observed power = 0.983). The univariate tests revealed a timepoint difference for G-force ($F = 7.519$, $p < 0.01$, ES = 0.212, large), but no differences for stress percent ($F = 2.694$, $p = 0.83$, ES = 0.088, moderate), or for average jump height ($F = 1.841$, $p = 0.17$, ES = 0.062, moderate). By surface type there was a difference for G-force ($F = 10.06$, $p < 0.01$, ES = 0.264, large), but no difference for stress percent ($F = 0.491$, $p = 0.49$, ES = 0.017, small), or average jump height ($F = 0.003$, $p = 0.96$, ES = 0.000, trivial). There were no specific surface x timepoint interactions for stress percent ($F = 2.581$, $p = 0.09$, ES = 0.084, moderate), average jump height ($F = 0.578$, $p = 0.56$, ES = 0.020, small), or G-force ($F = 3.005$, $p = 0.06$, ES = 0.097, moderate). Paired t-tests for G-force indicated that set 2 elicited higher landing impacts than the warm-up ($t(29) = -2.274$, $p = 0.02$) and set 1 ($t(29) = -3.742$, $p < 0.01$), but no difference between the warm-up and set 1 ($t(29) = 1.330$, $p = 0.10$). As shown in Figure 3, athletes experienced higher G-forces on the traditional wood floor during each timepoint.

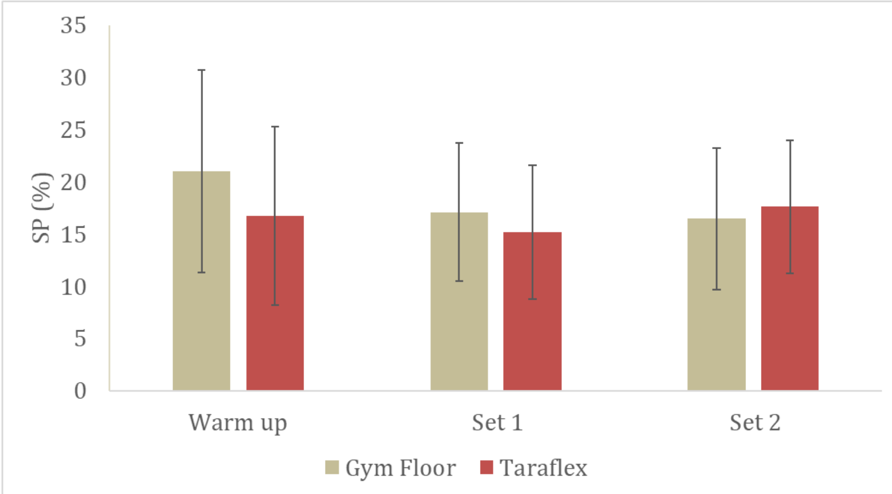

Figure 1. Means and standard deviations of stress percent (SP) for each flooring type across all three time points.

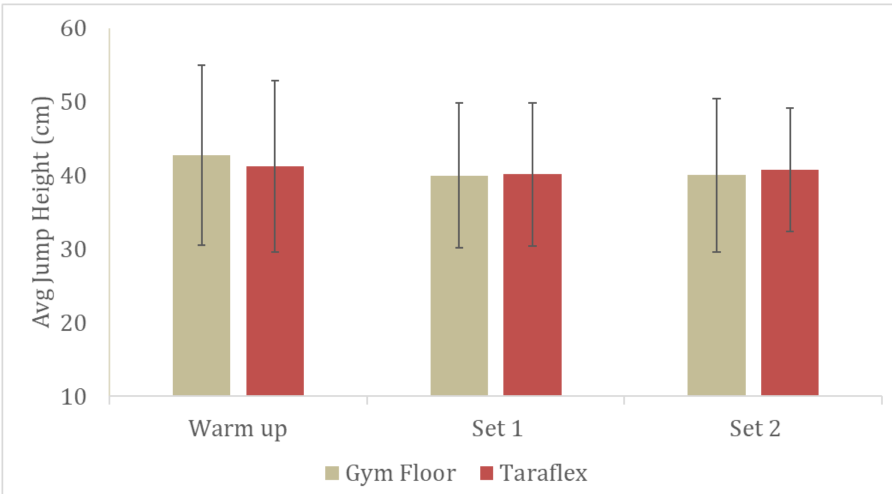

Figure 2. Means and standard deviations of jump height for each flooring type across all three time points.

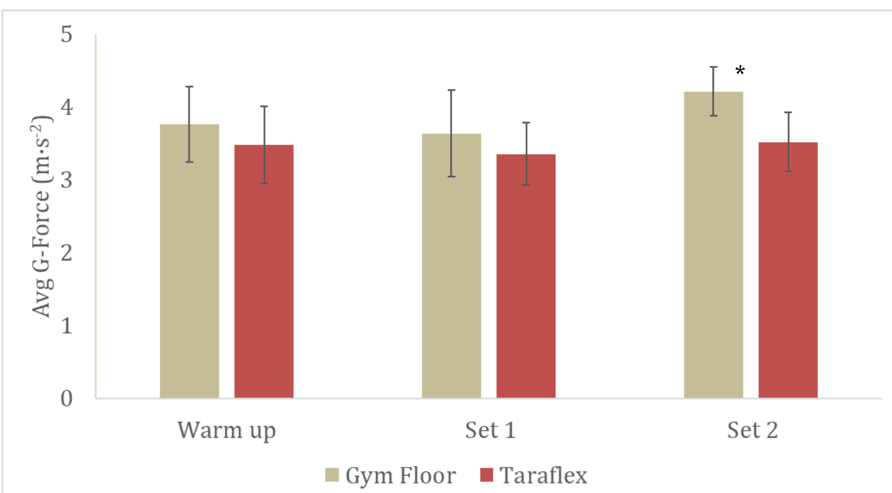

Figure 3. Means and standard deviations of G-force experienced during jumping and landing for each flooring type across all three time points. * indicates a difference by flooring type, $p < 0.05$.

Discussion

This study examined landing impact and jump height differences between traditional wooden and synthetic gym floors in youth female volleyball athletes. The highly specialized nature of their participation, as indicated by their questionnaire responses, shows that these are the types of athletes who not only train and compete year-round, but are also playing on various surfaces. As modular flooring and other artificial playing surface materials continue to gain popularity, it is critical to understand the implications on injury risk and performance. The results revealed notable differences in G-force, and no differences in stress percent and jump height. G-force monitoring has the potential to offer valuable information about jump load volumes. Higher G-forces result in increased stress on joints and soft tissues, potentially leading to fatigue and injury over time.[25] Measured G-force values were higher in set two compared to set one, which may be explained by accumulated fatigue and resultant compensation.[26]

Modular sport surfaces are commonly composed of materials such as linoleum, vinyl, and rubber composites, each of which provide a unique set of performance characteristics, one of the most important being shock absorption.[15] The Taraflex® floor, which is comprised of a combination of PVC sheets and reinforced with fiberglass grids and a foam backing,[27] appeared to mitigate impact forces more effectively than the wood floor. The observed difference in G-force values aligns with the higher coefficient of restitution exhibited on the traditional wooden floor. The lower coefficient of restitution value of the Taraflex® floor indicates a greater energy absorption, and therefore lower G-force values experienced by athlete.[17] Although stress percent, or peak G-force values, were higher on the traditional wooden floor during warm-ups, there was no difference found for sets one or two. Synthetic playing surfaces, like Taraflex®, often include a cushioning layer which may reduce peak impact forces experienced by athletes.[1,27] This is particularly meaningful as youth volleyball athletes play and train for the majority of their high school season on a wooden floor and have variable surfaces, mostly modular, for their club seasons. Previous literature has shown that athletes experience an increase in the landing force as measured by stress percent during training as the high school season progressed.[4] These data were all collected on a wooden floor. This accumulating effect may pose increased stress on joints and soft tissues. There are not yet comparable longitudinal data for the club season. Volleyball players, regardless of position, experience heavy landings from both jumping and diving. Injuries to the knees and back are often associated with hard landings in volleyball and are generally attributed to synthetic floor surfaces rather than wooden floors.[11,12] However, the results of the present study do not support that these injuries are associated with landing impact, but may instead be associated with surface friction. These findings underscore the need for further investigation into material properties and force distribution as synthetic flooring use continues to increase.

No substantial differences in jump height were revealed between flooring types, which may be explained by the ability of athletes to adjust their jump biomechanics and generation of power to maintain performance on different playing surfaces.[28] The consistency in performance is supported by the findings of Çimelni et al., that jump performance in elite volleyball players remains consistent across various training surfaces. Existing literature on surface impact and landing techniques supports the idea that flooring characteristics influence shock attenuation and the incurred risk of injury.[29] Studies have demonstrated that synthetic surfaces may reduce peak impact forces while maintaining performance metrics, which align with the findings of the current work.[30] Included participants were moderately to highly specialized volleyball athletes, whose training and competition occur on both wooden and Taraflex® floors. They play on wood for approximately four months of the year and approximately eight months on the Taraflex®.[4] This experience with both surfaces may also have contributed to the lack of difference observed in jump height performance.

Limitations to this study include the small sample size and lack of specificity in exploring positional differences. The low sample size limits the generalizability of the results. Not examining positional differences does not account for variations in movement patterns between players. Understanding impact forces requires studying not just the landing phase of jumps, but also the diving activities carried out by defensive players on the back row. The present study did not randomize the order of playing surfaces. This likely did not affect the results given that sessions were conducted one week apart and on the same day of the week. However, future research should incorporate a larger and more diverse participant pool, randomize the order of playing surface conditions, and include positional- and fatigue-based analyses to better capture the varied physiological demands across match play and training. Future investigations should also examine surface-specific factors such as coefficient of friction, with attention to how these properties influence neuromuscular loading, movement efficiency, and injury risk. Expanding this work with a stronger integration of existing biomechanical and physiological literature may help clarify the mechanisms underlying the observed performance differences across surfaces.

Practically, the findings of this study are relevant to athletes, coaches, and even parents, particularly those in specialized sports environments. Coaches may use this information to make decisions about playing surfaces to be used in their gymnasiums, with the goal of optimizing performance and reducing overuse injury risk. Parents and athletes alike may benefit from possessing a higher level of awareness of the implications of the surfaces on which they are playing and how they treat their bodies. Play on different surfaces necessitate different recovery measures to promote healthy and safe training and competition. While synthetic flooring is commonly associated with volleyball, its use extends to other high-impact indoor sports, so it is essential to understand surface material properties and their influence on movement mechanics, associated injury risk, and performance.[18] Coaches, parents, and athletes may also be more aware of the accumulation of mechanical loads according to surface type and alter recovery and workload accordingly.

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