



Comparative Analysis of Kinetic Responses and Injury Risk During Landing from 45 cm Height: A Study of Barefoot vs. Sports Shoes Conditions

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Abstract: Jumping and landing biomechanics are closely related to the risk of acute injury due to prolonged exposure to high-ground reaction forces in basketball-like sports, which can lead to lower-limb musculoskeletal injuries in the hip, knee, and ankle. Footwear greatly impacts jumping mechanics, but going barefoot provides a unique perspective on how the human body interacts with the ground. This study aims to find out the kinetic responses during drop landing from 45 cm height with and without sports shoe conditions. Twenty-five healthy young adults were volunteers for this study. Kinetic parameters were recorded and processed by using Quattro Jump force plat and Mars Quarter performance analysis software. Data were presented as mean \pm SD values and statistical analysis was performed using statistical software package SPSS-26. The drop landing data of with and without shoe shows scattered parameters with maximum forces of 4706.12N and 5393.04N at 45 cm height, indicating a 66% and 75% risk of metatarsal injury. The stabilization force was 632.64N and 623.64N at 45 cm, reached at 0.58s and 0.66s respectively. Time from Max Force to MFBS Regression analysis indicated a low R-squared value and a random fit plot. In barefoot (without shoe) conditions, the initial contact force, and maximum force were 85.71% and 13.60% higher (250N and 5393.04N respectively) compared to landing with shoes (100N and 4706.12N). However, the stabilization force was higher (632.64N) when landing with shoes compared to landing barefoot (623.64N). As a result, the risk of musculoskeletal injuries and joint stress was higher when landing barefoot due to the higher initial contact force and maximum force. On the other hand, landing with shoes enhances balance and stability due to the higher stabilization force.

Keywords: Sports injury, Kinetic Response, Drop landing, Barefoot, Sports Shoe Kinetics

1. Introduction

Landing maneuvers are one of the basic exercises in high-risk sports like volleyball, handball, or basketball. These activities are most commonly linked to injuries related to the musculoskeletal system of lower limbs, such as joints (hip, knee, and ankle). Non-contact injuries during participation in dynamic activities are common and two of the most frequent examples are anterior cruciate ligament (ACL) injuries, sometimes such as ankle sprains. Jumping and landing biomechanics have been associated with the risk of acute injury because of repeated exposure to high-ground reaction forces (GRF) in previous reports (Agel *et al*, 2006). Muscle control, muscle fatigue, flexibility,

and musculoskeletal stiffness were variables associated with landing biomechanics, but these components characterize an individual's overall landing technique as being one of the most important factors related to injury potential (Myers & Hawkins 2010). When the landing force is too high, with less physiological absorbance will cause explosive knee valgus and lower extremity injuries (Simpson & Kanter, 1997). All these risks of landing injuries are related to loads to the musculoskeletal system. In terms of landings, primary loading occurs in the lower limbs and trunk. The lower knee and spine force distribution increased in high-performance sports that utilize jumping as the main strategy relative to other athletic activities, risking



more serious injuries caused by larger forces (Leppänen, *et al* 2017). The landing strategy is also adjusted to the surface on which the landing takes place, which leads to differences in muscle activation patterns (Arampatzis *et al*, 2001). Jump landing, which is an essential movement in basketball games. Each player performs 70 jumps in one game and impact is up to nine times body weight on the landing phase of each jump (McClay *et al*, 1994) Failure to damp these repetitive impacts would ultimately result in excessive loads on low extremity tissues (Iwamoto & Takeda 2003; Riemann & Lephart 2002).

Tibial stress fracture (TSF) is one of the common overuse injuries observed in basketball players, with approximately 10 injuries in every 1000 games (Iwamoto & Takeda 2003; Meeuwisse *et al*, 2003). Previous Literature also indicates that TSF is associated with higher levels of tibial shock (Crowell & Davis 2011), impact peak, and loading rate in running population (Milner *et al*, 2006). Basketball Players perform multiple jump activities for layups, shot-blocking, and shooting during a game (Zhang *et al* 2008; Nin *et al*, 2016), resulting in different intensities of impact loading (e.g. associated with height and distant movements) on landing movement as well across it (Nin *et al*, 2016). Landing height and footwear properties (e.g. midsole densities) are risk factors that have been quantified in the basketball literature (Nin *et al*, 2016; Zhang *et al*, 2005) [13, 14].

In brief, lower landing heights and softer midsoles would reduce the loading on the lower extremities. Another study reported basketball had the highest risk of severe knee injuries in non-contact sports (Jones *et al* 2000) [15]. In another study of competition-level adolescent basketball players from Cape Town, 41% of knee injuries over one season were as a result of landing incorrectly following jumping Louw *et al* 2003. Stacoff *et al.* 1998 reported that the F1 value of the vertical component of ground reaction force (GRF) in landings after blocked volleyball block jump was 1000–2000 Newtons (N), and for a second peak (F2) values ranged from 1000 to 6500 N in landings after a volleyball block jump.

Footwear has a huge impact on our jumping mechanics, but going barefoot provides a unique perspective on how the human body interacts with the ground. Research findings on injury risk without footwear have also sparked an interest in barefoot activities (Barker 2018; Baus *et al*, 2020). A previous study by Hootman *et al.* 2007 demonstrated that barefoot sports like gymnastics have a significantly

higher prevalence of knee injuries such as those to the anterior cruciate ligament (ACL) compared with shod sports, including volleyball and basketball. (Baitch 2005) also found that barefoot dancers were injured (65%) of the time compared to those wearing shoes (49%). In addition, beach volleyball involves barefoot landing on soft sand surfaces, there is a notable risk of acute and overuse knee injuries, which is comparable to that of indoor volleyball (Aagaard *et al* 1997; Reeser *et al* 2006). The injury risk associated with barefoot landing during sporting activities is crucial to determine how the kinematics, kinetics, and energetic form of shod landing differ from that in barefoot landing. The athletic shoe wear consists of soft compressive support surface interfaces engineered to attenuate sports injury mechanisms from large ground reaction forces (GRF), though GRF mechanics do not change significantly compared with a barefoot athlete as the athletes morph the compliant interface into a thinner-stiff form for higher stability (Robbins & Waked 1997). Chiu and Shiang also showed that insoles can absorb impact energy up to 32% among sports shoes. In summary, this study indicated that cushioning systems in athletic shoes can play a role in shock absorption and thus reduce the injury risk of athletes (Chiu & Shiang 2007).

The intense research aims to bridge the gap with and without shoe landing from 45 cm height by focusing on kinetic responses across varying elevations. This study investigates Initial Contact Force (N), Max Force (N), Min Force before Stabilization (N), Stabilization Force (N), and Time from Max Force to Stabilization force (S) during descent. The present study is focused on the data collection process through lab simulations, as real-time data collection in basketball or volleyball players is not possible. By dissecting these kinetic variables, this study can identify critical factors contributing to injury risks and inform evidence-based strategies for injury prevention. The study aims to shed light on injury prevention strategies and improve performance based on the kinetic responses with and without shoe landing from 45 cm height. This data will be considered a standard value requiring design, development, and identifying the best sports footwear to reduce injury risk. The hypothesis of this study's findings will have practical implications for athletes, fitness enthusiasts, and kids engaging in with and without shoe activities. By elucidating the kinetic responses during jumps and landing, this study's results can tailor jump-specific exercises to optimize performance and reduce injury risks.

2. Materials and Methods

2.1 Participants

Twenty-five (n=25, male:11, female:14) healthy, physically fit young adults with no foot deformities or musculoskeletal abnormalities in the lower limbs, no history of musculoskeletal disorders or fractures on the lower extremity and vestibular system were selected. The mean age, height, and weight of the male participants were 19.35 ± 1.027 years, 172.48 ± 5.508 cm, 60.80 ± 9.996 kg, and female participants were 19.42 ± 1.060 years, 163.23 ± 8.951 cm, 59.58 ± 10.091 kg respectively.

Before beginning the study, the participants were informed about all the necessary information and the study protocol, also they had completed an informed permission form. The subjects had the freedom to withdraw their participation at any point during the experiment.

2.2 Ethical clearance

The present study protocol on human use as an experimental subject and the entire principles of the experiment outlined by the Declaration of Helsinki Protocol, 1964, and as per approved ethical clearance No. HMC/ IEC/ FDDI/ 01.

2.3 Selection of Sports Shoes and Features

Before initiating the study, a detailed survey was conducted to gain a better understanding of sports footwear preferences and types commonly/regularly used by young adults for playing sports activities. It was observed that most of the adults used sports footwear with these features- Sock liner for ventilation and support for gearing up against the competition, non-marking rubber outsole for grip and durability on indoor surfaces, Lightweight Construction for Improves agility and speed, EVA Midsole for Providing cushion and shock attenuation, Durable Toe Cap for all those ollies, kickflips and scratches. The extended durability of the sole is due to this tough compound used in high-wear regions. Wrapped, padded collar and tongue to Provide additional comfort and support around the ankle, Lace Closure for secure and adjustable fit. The participants used the best-fit size of the footwear during experiments. However, size 8 was best fit for males and size 5 was best for female participants.



Figure 1. Sports shoes used in the study

2.4 Selection of landing height

The landing height of 45 cm was selected for this study based on the typical jump heights observed in basketball players, which generally range from 36 to 54 cm often landing on their toes, particularly during dynamic movements like layups, rebounds, and dunks (de *et al* 2023). This height was chosen to represent or simulate similar conditions that reflect the lower end of the jump heights commonly achieved by basketball players during games. By focusing on a 45 cm landing height, the study aims to closely simulate the conditions under which basketball players might land during actual performance, allowing us to accurately assess the kinetic responses without exposing participants to excessive risk.

The results can then be used to better understand the demands placed on the forefoot during these critical movements and to inform strategies for injury prevention and performance enhancement. When landing from this height, the forefoot is subjected to significant kinetic forces as it is the first point of contact with the ground. These forces are crucial in decelerating the body and stabilizing the landing. The forefoot, specifically the toes and metatarsals, plays a pivotal role in absorbing the impact and distributing the load across the foot.

2.5 Data Collection

A week prior to the study, participants were habituated to drop from 43, 44, 45, 46, 47 and 48 cm height tool on forefoot with and without shoes, to assess comfort in the laboratory. Subjects were

reported that, they were feeling safe and comfortable landing from 45 cm height. This preference shows that 45 cm is an excellent choice for examining forefoot landing kinematics, since it provides a realistic and comfortable challenge in a controlled environment.

A balanced order experiment was followed during data collection to reduce the bias effect. First barefoot data was collected from 1 to 25 serial no. of participants and then with shoe data was collected from the same participants but in reversible way like serial no. 25 to 1. During experiment kinematic responses such as Initial Contact Force (N), Initial Contact Time (S), Max Force (N), Max Force Time (S), Stabilization Force (N), Time from Max Force to Max Force Before Stabilization (S), and Time from Max Force to Stabilization force (S) were recorded during drop landing from 45 cm height without and with wearing sports shoes (Figure 2). All these recorded parameters by using Quattro Jump force plate (Model 9290DD, M/s Kistler Instrument AG in Switzerland) and Mars Quarter performance analysis software was used for data processing and analysis. All the experiment was conducted in laboratory at 25°C - 27°C temperature and 50% - 55% relative humidity,

respectively at the Footwear Design and Development Institute (FDDI) in India.

2.6 Statistical Analysis

Data were presented as mean \pm SD values. Shapiro-Wilk normality test signified that the parameters were not normality distributed. So, the Mann-Whitney U test was done to compare the means of two conditions (with and without shoe) kinetic parameters. The significant level was considered at 0.05 levels. The statistical software package SPSS-26 was used to analyze the data.

3. Results

The scatter plot compares Initial Contact Force (N) with Initial Contact Time (S), Max Force (N) with Max Force Time (s), and Stabilization Force (N) with Time from Max Force to Max Force before Stabilization (S). Additionally, it includes a Radar chart of the Stabilization force and Line Plot of Time from Max Force to Max force reach before stabilization. These visualizations demonstrate the balance and stability dynamics of with and without shoe landing.

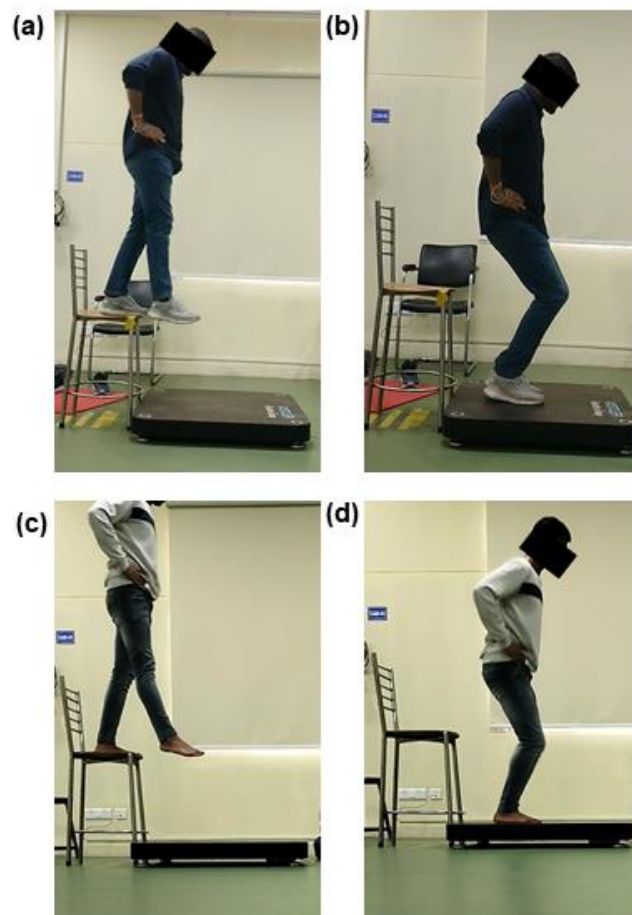


Figure 2. Drop landing from 45 cm height, with (A & B) and without shoe (C & D) condition

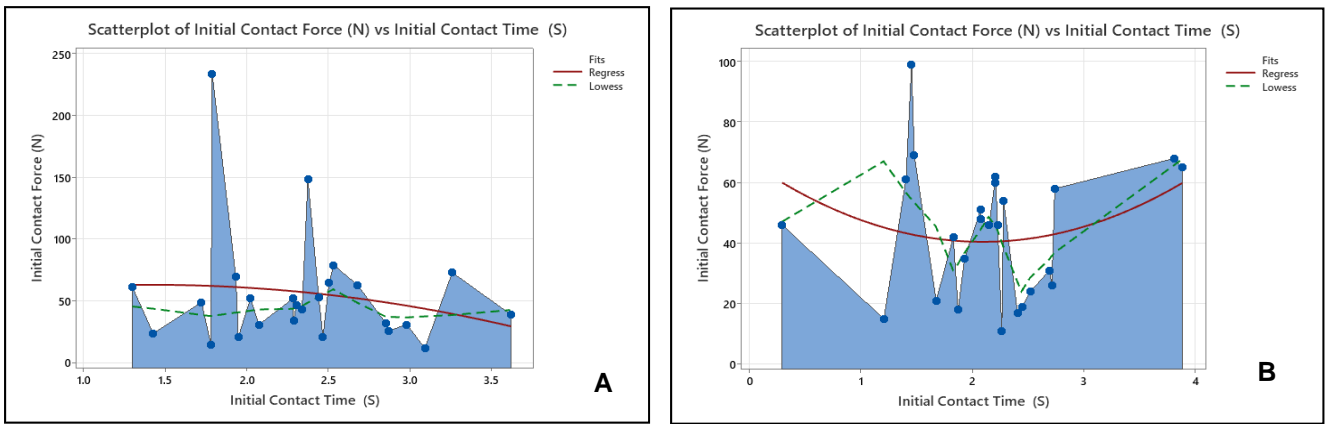


Figure 3. A and B: Representation of scatter plot of Initial Contact Force v/s Initial Contact Time with Regress and Lowes fit model- without and with Shoe condition. The scatter plot of Initial Contact Force (N) vs Initial Contact Time (S) illustrates the relationship between the force applied during initial contact (e.g., stepping on a jump force plate) and the time it takes for that force to occur. The points on the scatter plot form an upward-sloping pattern, indicating that higher initial forces tend to occur earlier.

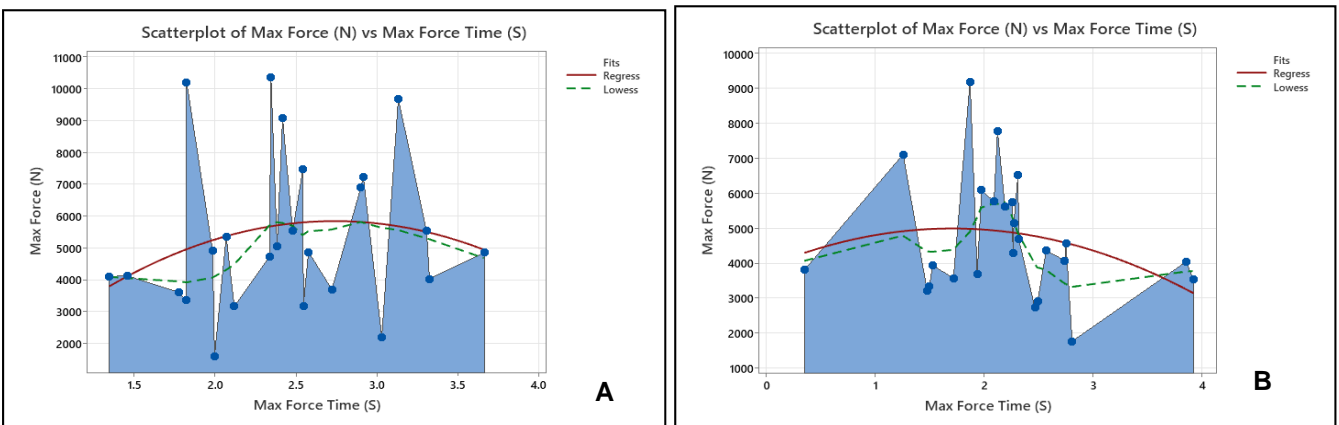


Figure 4. A and B: Representation of scatter plot of Max Force v/s Max Force Time with Regress and Lowes fit model- without and with Shoe condition. The maximum force (N) was higher in the without shoe condition compared to the shod condition. These results suggest that shoes absorb some of the impact force, thereby reducing the peak force experienced. Max Force Time (S) was slightly lower in the shod condition than without shoes condition. It indicates that wearing shoes may help the players to achieve maximal force more quickly, likely due to the increased stability provided during impact.

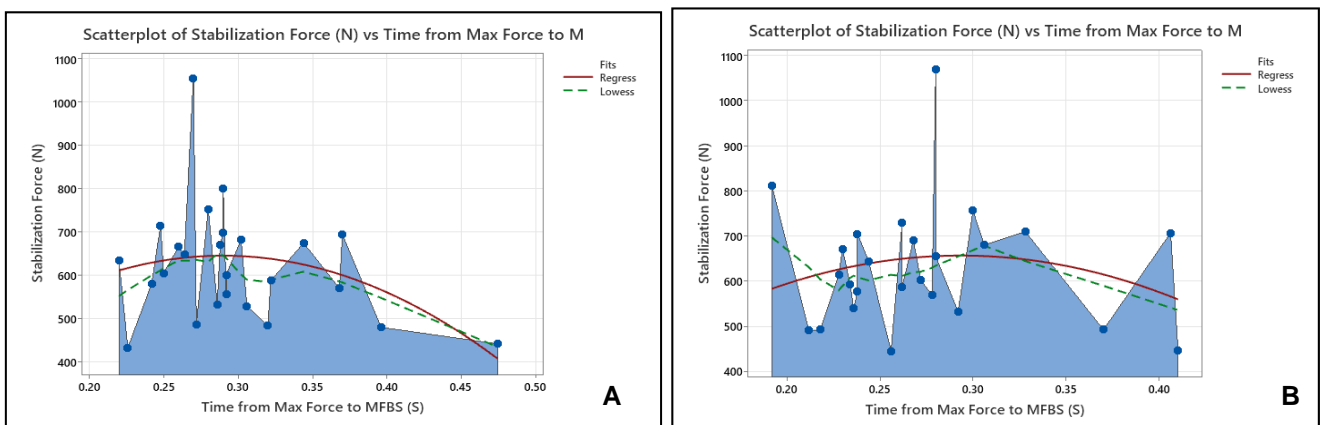


Figure 5. A and B: A Representation of scatter plot of Stabilization Force v/s Time from Max Force to Maximum Force Before Stabilization with Regress and Lowes fit model- without and with Shoe condition. When force fluctuates, the overall pattern reveals a gradual decrease over time. Graph A has a higher variation in force peaks than Graph B. The regression lines show a downward trend, while the Lowess lines show smaller local variations.

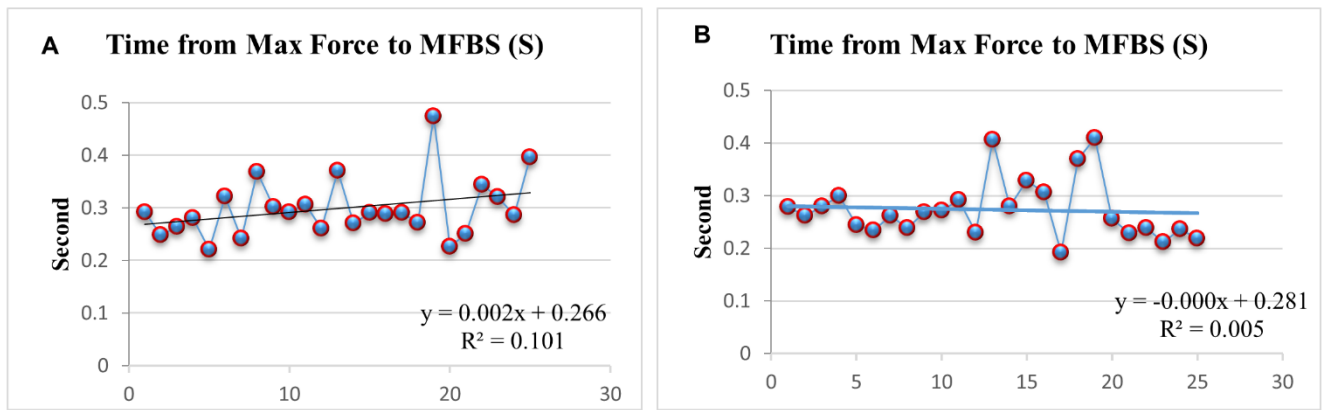


Figure 6. A and B: Representation of Line Chart of Time from Max Force to Maximum Force Before Stabilization of two different conditions- Barefoot and Shoe respectively. This line plot shows how the time from maximum force to reaching another specific stabilization point changes over time. The slope of the line indicates the rate of change, while a flat line suggests a constant time interval.

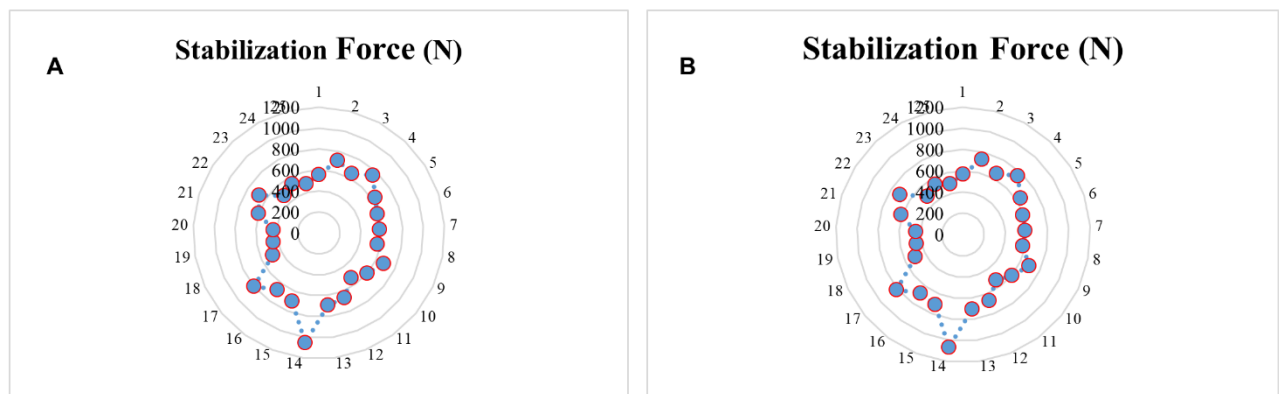


Figure 7. A and B: Representation of Rader Chart of Stabilization force of without and with Shoe condition at 45 cm landing height. The ability to stabilize (e.g. maintaining balance after a sudden force) is associated with the time it takes to regain stability after experiencing maximum force. To maintain balance and stability after jumping, there should be a negative correlation. The Stabilization Force radar chart displays different aspects of stabilization force, such as lateral and anterior-posterior stability. The shape of the radar chart gives an overall picture of stabilization force across these dimensions.

All the illustration of the figure demonstrates with and without shoe landing dynamics and stability over 45 cm landing height. These dynamics data represent the future design dimension achieving better balance and stability.

Table 1. Mean ± Standard Deviation of Kinetic Responses during Vertical Landing from 45 cm falling height without and with Shoe condition (n=25)

Parameters	45 cm (N=25)		Mann-Whitney U test	Asymptotic Sig. (2-tailed)
	Without shoe condition Mean ± SD	With Shoe condition Mean ± SD		
Initial Contact Force (N)	54.96 ± 46.487	43.68 ± 21.769	280.50	0.53 *
Initial Contact Time (S)	2.36± 0.563	2.16 ± 0.744	247.00	0.20*
Max Force (N)	5393.04 ± 2416.093	4706.12 ± 1704.613	266.00	0.36 *

Max Force Time (S)	2.44 ± 0.593	2.20 ± 0.743	241.00	0.16 *
Stabilization Force (N)	623.64 ± 131.975	632.64 ± 133.731	291.00	0.67 *
Time from Max Force to MFBS (S)	0.30 ± 0.057	0.27 ± 0.056	214.50	0.05 *
Time from Max Force to Stabilization force (S)	0.66 ± 0.259	0.58 ± 0.139	275.00	0.46 *

(*) = Not significant

Mann-Whitney U test was conducted to observe the variation between without and with shoe landing from 45 cm height on studied parameters. In without shoe condition, values of Initial Contact Force (N), Initial Contact Time (S), Max Force (N), Max Force Time (S), Time from Max Force to Max Force Before Stabilization (S), and Time from Max Force to Stabilization force (S) was higher than with shoe condition except Stabilization Force (N). In this study, no statistically significant difference was found between with and without shoe condition at $p < 0.05$ level. N= Newton, S= Second.

4. Discussion

Present study aimed to investigate the variations in displayed toe kinetic variables at with and without shoe circumstance at 45-cm drop height to provide insights into balance and balance dynamics while with and without shoe landing. To understand extraordinary mechanical demands in laboratory, the drop Height (DH) differed significantly in various research. Hoffren *et al.* 2007 studied drop landing from a 10-cm DH, even as Zhang *et al.* 2008 [28] measured GRF of landing from a 103-cm DH. The DH range becomes so big that PvGRF turned into additionally broadly disbursed. Even for the same DH of 60 cm as an example, the suggest PvGRF ranged from 2.38 to 4.91 times Body weight (BW) (Dufek & Bates 1990; Pflum *et al.* 2004). According to the present study this information may be essential for the future design and development of shoes. These results proven that with and without shoe balance dynamics supplied a clean photograph of balance and stability, which is important for designing shoes that efficiently absorbs forces for the during jumping activities and prevents them before reaching the threshold limit. The most essential regulatory component that affects landing is leg stiffness, which is because of the segmental configuration at some point of touch-down as well as neuromuscular activation Hoffren *et al.* 2007.

Initial contact is the moment in which your foot impact on the ground and generates a ground reaction force that shapes what happens during next phases of the jump. This force can be broken down into magnitude and direction that in turn impact the

subject's ability to battle gravity out of a vertical lift. A greater initial force also helps the body to get high into the air and moving forward, which is essential for jump height and travel.

In without shoe condition, Initial Contact Force (ICF) varies significantly across certain Initial Contact Times (ICT), with forces ranging from approximately 0 to 250 N, demonstrating that factors other than time may influence ICF. The regression line reveals a vulnerable negative trend, with ICF falling slightly as ICT will rises, although the well-known lowess line exhibit oscillations that could imply periodic patterns or clusters of better forces, possibly inspired by using precise situations or outliers. Variability was also found in the shoe situation particularly at shorter ICTs, with forces ranging from close to 0 to over 100 N (Figure 3). The regression line suggests a non-linear courtship, with ICF to begin with decreasing and then growing over time. The lowess line demonstrates this trend, with a lower as much as about 2 seconds, followed by way of an increase. Notable variances around the 1st and 2nd marks imply ability outliers influencing higher forces. During landing, the peak contact force is higher during initial contract in without shoe (54.96 N) than in shoe condition (43.68N), which reduces by roughly 11.28 N when wearing shoes; this decrease is thought to be related to the cushioning and shock absorbing capabilities of a shoe that increase area over which force may dissipate (An 2002). Thus, in without shoe condition, initial contact time was 2.36 s. Conversely, with shoes the initial contact time was somewhat reduced to 2.16 seconds This might suggest a faster transfer from initial contact to the remainder of gait, perhaps due to the more solid and supportive nature

provided by the shoes. Devita & Skelly (1992) were found landing with a higher ICF increased joint forces particularly in the knee and ankle, raising injury risk. In turn, lower magnitude of ICF protected subjects from injuries better as they could distribute forces more adequately (Devita & Skelly 1992). Zhang *et al.* (2000) was found that high initial contact force during landing was associated with a higher injury risk due to greater joint loading problems as well to the occurrence of injuries in high impact sports. They emphasized the importance of training to improve landing mechanics as an injury prevention strategy which could lower ICF. McNitt-Gray (1993) was observed that increased initial contact times (ICTs), which were associated with a greater ability to dissipate energy and decrease peak forces during landing reduced the likelihood of impact-related injuries in activities such as repetitive jumping.

High initial contact forces (ICF) during landing leading to musculoskeletal injury through the generation of excessive stress with joints and related structures. This can result in acute, mechanism-induced injury (e.g. sprain or fracture), and chronic overuse injuries such as osteoarthritis. Lower ICF helps to reduce the risk of injury by making it easier on our body to absorb and distribute impact. However, if the ICF is too low it may indicate an inadequate engagement of muscle and lack of joint stability affecting balance or increasing fall risk, especially under rapid transition decelerations/accelerations.

These results support the idea that footwear can alter foot-ground interaction during various activities and emphasize potential consequences, as both initial contact force and time were related to gait-related pathologies. In barefoot, due to a lack of cushioning, there is a direct impact on the ground that results in higher initial contact forces (Wright *et al.* 2000).

The force-time curve reveals how subjects accelerate during take-off phase, demonstrating the significant contribution of initial contact force in stabilizing on landing. Balanced movement, less likely to lead to control loss and injury without creating proper force distribution. Imbalanced force distribution to contact time relationship leads directly into chaotic and suboptimal jumps. We need to understand the relationship between these two parameters in order to provide more targeted training for increasing balance during time-series high jump actions. This with and without shoe connection influences sports as well as kids' feet, an important relationship for either setting. The fitted regression line in without shoe condition

was slightly slanting to positive direction, which means that Max Force would also increase with increasing max force time but this relationship could be considered weak at best. Max Force ranges from about 2000 N to >10,000 N indicating that Max Force is affected by other factors (Figure 4). The lowest line shows real local fluctuations - it goes up to about 2 seconds first, and then exhibits a more variable behavior with no statistically acceptable trend. On the other hand, In the shoe condition, we see a downward trend in the regression line whereas force time increases magnitude of max force decreases. Similarly, Max Force exhibits tremendous variability from approximately 1,000 N to nearly 10,000 N — indicating that other factors are at play here as well. The Max Force decreases up to about 2 sec (lowest line) and then shows more variability where it even increased, contrary the regression trend. The maximum force in without shoe condition was 5393.04 N, and the time at which recorded was at 2.44 seconds while the maximum force in shoe condition decreases to 4706.12 N, and the time also decreases to 2.20 seconds at the 45 cm drop height, which was 75.6% and 66% closer to the values associated with metatarsal fractures. Mayank Kalra *et al.* investigate the impact energies, forces and deformations that could lead to metatarsal fractures during workplace impact loading in which they reported second metatarsal as most common fracture site. Maximum energy, force and displacement at fracture were in the average of 46.6 J, 4640 N and 28.9 mm respectively. By using survival analyses, they found that there was 50% fracture probability associated with 35.8 J of impact energy and 3562 N of impact force (Gribble *et al.* 2012). Chappell *et al.* (2005) identified shorter maximum force time during landing in short distance for female athletes as a critical factor associated with higher ground reaction forces and therefore greater risk to sustain an ACL injury. Thus, the emphasis on balancing performance or injury prevention by targeting MFT in training and footwear design. Yeow *et al.* (2011) found that higher ground reaction forces (GRF) and loading rates, increasing knee stress and the risk of ACL injuries were linked with shorter initial contact times (ICTs).

A high MFT will also help attenuate forces thereby taking care of impact absorption, joint alignment and reduce the acute injuries but at immediate expense to power based activities such as jumping or sprinting. Landing with high force increases the possibility of acute injuries and joint stress, which can become chronic if not properly tempered from a shock absorption level. A low MFT suggests rapid force

application, good for explosive movements but this is associated with an increased incidence of muscle strains and stress fractures. This can increase the number of injuries associated with passive shock absorption. Less force decreases injury potential but also can decrease performance in ballistic movements by impairing the ability to store and release energy.

Stabilization force was responsible for energy moving from the ground up in a straight line directly into your body causing maximal upward trajectory and minimal injury susceptibility to both take-off and landing. Correct stabilization ensures alignment, balance, and control so as not to overload greater structures such as muscles, tendons, and ligaments. This efficient energy transfer maximizes the amount of force that is utilized during triple extension and adds to vertical propulsion (Kalra *et al* 2023). There was also a large variation in the square of gravitational attempts generated by stabilization force over a while, with more than 1000 N peaks at about 0.25 seconds while without shoe condition. The regression line indicates an uptrend, while the lowess follows its specific fluctuations closely. On the other hand, regarding shoe state dataset shows more ground truth forces spread between 600 — 700 N that has a very mild change in slope over time. The lowess line shows more intricate changes, but the general trend was much less volatile than without shoe condition.

The stabilization force was 623.64 N without shoe condition and 632.64 N when in shoe condition. Shoes required less time (0.58 sec) to stabilize than barefoot (0.66 sec) (Figure 5). A reason for this small difference in stabilization force might be that footwear's cushioning and impact dissipation properties have minimal impact on the body's ability to stabilize post-peak loading (Hibbert *et al*, 2008). The reduced time to stabilization in the shoe condition and higher stabilization force, suggests support and proprioception may be enhanced by an external device as one adapts quicker from a less stable state to stabilized locomotion. Such findings are in align with previous research that suggests shoes may mitigate high-impact phases while possibly decreasing the injury risk through alterations of gait mechanics on a global level (Nigg *et al*, 2003).

The radar chart analysis indicates that unstable forces in both conditions are grouped around 600–800 N, but without shoe condition was more clustered and very stable while the shod condition seems to be highly variable (Figure 7). However, the largest force distribution across body each direction is

maintained within a consistent edge through both conditions, even if there are fluctuations. Earlier studies have demonstrated that variations are small between the stages from contact force to max. force and from max. Force to stabilization, but a deviation could increase risk of acute ankle injuries/sprains in addition to fractures (Devita & Skelly 1992). McNitt-Gray (1993) indicates, variations of forces during drop landings, including stabilization force, affect injury risk and performance. Paterno *et al.* (2010) found application of stabilization force in preventing re-injury as well as improving landing mechanics following ACL reconstruction.

The higher stabilization force enhances better control during landing, preventing falls and increasing stability-crucial for a sport like basketball. A high top also helps in making sure that the energy transfer is highly efficient; this increases prowess during jumps or instantaneous switch of directions. Moreover, significant stabilization force keeps proper alignment of joints preventing excessive load on the muscular system and tendons/ligaments drastically reducing dangers for getting -damage in form of acute injuries such a sprain or fracture. In addition, lower stabilization force can result in improper joint alignment which could significantly increase the risk of danger such as ankle sprains and knee injuries. It also results in not only less than optimal energy transfer for explosive movements but also leads to quicker fatigue and reduced agility.

Throughout jumping activities, the Time from Max Force to Maximum Force before Stabilization (TTS) was such an important measurement as it tells us how long it takes for that individual to regain stability after landing. Minimizes injury risk by reducing excessive forces or misalignment & allows for energy to be transferred efficiently in the propulsive phase. TTS may be useful for sports that require rapid transitions from landing to take-off (basketball and volleyball) or landing with many single-leg actions in contact support phase (gymnastics), (Lieberman *et al* 2010; Wagner & Blickhan 1999). The scatter plot chart of without shoe condition reveals a mixed distribution pattern centered on an approximately positive linear association between variables (Figure 6. A). The regression equation $y = 0.002x + 0,266$ and an R^2 value of 0.101 correspond to a weak upward trend in the data regarding time from maximum force to MFBS as a function of the independent variable is indicated with a very low correlation between both variables. In the shoe condition, the data points are also fairly

randomly scattered but have a very slight downward slope. The regression equation is $y = -0.000x + 0.281$, and the too-small of an R^2 value is 0.005 (Figure 6. B). As the regression line is flat essentially, changes in the independent variable explain none of or very little variability in time from max force to MFBS. In without shoe condition Time from Max Force to Maximum Force before the Stabilization of the present study was 0.30 seconds, whereas in shoe condition it was 0.27 seconds while landing from 45 cm height. It was considerably lower than data reported by [Flanagan *et al.* \(2007\)](#) of approximately 0.97 seconds, landing from 30 cm height. Another study conducted by [Wikstrom *et al.* \(2004\)](#) examined the time from Max Force to Maximum Force before Stabilization after landing from a height of 70 cm and found that TTS was approximately 2.2 seconds. This finding was significant in the field of sports like basketball as it provides insights into how long it takes for an individual to achieve balance and stability after experiencing peak forces during landing. The finding of the present study was aligned with other studies that propose core stability enhances dynamic performance and balance, the force-time relationship found provides a limited effect on transition time from maximal strength to stabilization [Hennig & Milani \(1999\)](#).

A higher TTS increases the higher risk for acute injuries like sprains, and fractures. It can also lead to chronic issues such as patellofemoral pain syndrome. These activities also impair quick changes in direction and joint loading during sports. Whereas a lower TTS supports quick stabilization with minimum risk injuries and also enhances the efficiency of movement. This rapid stabilization suffices to facilitate the transfer of force, neuromuscular control, and energy optimization required for reduced fatigue.

The present study suggests that shoes are associated with a decreased time to initial contact, maximum force peak, and stabilization when compared to barefoot: this may be the result of rubber tread soles. The feature of rubber-treated sole material of the shoes may have an important role in impulse absorption, resulting in lower peak forces and it might lessen injury risk. More core stability could promote better dynamic performance and balance/stability in subjects with higher values.

6. Conclusion

The present study revealed that landing without a shoe from a height of 45 cm exerts more

impact on the forefoot as compared to with a shoe landing on studied parameters. In barefoot (without shoe) conditions, initial contact force, and maximum force were higher at 85.71% (250N) and 13.60% (5393.04 N) respectively compared to shoe landing conditions (100N and 4706.12N). However, stabilization force was 1.43% higher (632.64N) in landing with a shoe in comparison to landing in barefoot condition (623.64N). Hence, the risk of musculoskeletal injuries and joint stress was higher in without-shoe conditions due to higher initial contact force and maximum force; whereas landing with wearing shoes enhanced balance and stability as well as prevented risk of falls due to higher stabilization force. The present study also stated that kinetic responses and risk of injuries are 75.6% (5393.04 N) without a shoe and 66.0% (4706.12N) landing with shoe condition based on threshold values of metatarsal fractures 3562 N which indicates a 50 % chance of injuries. This observation of the present study is to be utilized for the design and development of sports footwear with special reference to basketball players to enhance performance and minimize the risk of injuries by improving the impact/ force absorption capacity of sports shoes. The current study is restricted to a small sample size, one landing height, and a narrow age group (19.42 ± 1.060 years). In the future, a details study will be conducted with a larger sample size, Age and gender variation, different heights, and different types of sports footwear.

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Author Contribution Statement

Ayan Maity - Data processing, Analysis, Statistical analysis and interpretation, Manuscript preparation.

Bawa Resume Chauhan - Conducted experiment, Data collection, Processing, Review of literature.

Hardik Juneja - Involved data collection, processing, Review of literature. **Mohit Kumar** - Involved in data collection and processing, Review of literature.

Madhusudan Pal - Conceptualization, Experimental design and finalization of study protocol, Overall supervision of study, Editing of final manuscript. All authors read and approved the final manuscript.

Ethics Approval Statement

The present study protocol on human use as an experimental subject and the entire principles of the experiment outlined by the Declaration of Helsinki Protocol, 1964, and as per approved ethical clearance No. HMC/ IEC/ FDDI/ 01.

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Informed Consent

The consent form was signed before the commencement of the study.

Data availability statement

The data supporting the findings of this study can be obtained from the corresponding author upon reasonable request.

Conflict of Interest

The authors declare that there was no conflict of interest.

Does this article pass screening for similarity?

Yes

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