International Journal of Sports and Physical Education (IJSPE)
Volume 9, Issue 3, 2023, PP 21-28
ISSN 2454-6380 (Online)
DOI: https://doi.org/10.20431/2454-6380.0903003
www.arcjournals.org

The Effect of Multitasking on Female Soccer Player Jump Landing Ground Reaction Force

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Abstract: *Soccer players experience many injuries during jump landing after heading a ball. Some have attributed these injuries to multitasking during a jump with a header. The purpose of the study was to compare vertical ground reaction force (GRF) during jump landings from a vertical jump to that of a jump with an attempt to head a soccer ball. Fourteen Division II women soccer players (age 19.35 ± 0.93years; weight 569 ± 80 N; height 163 ± 6cm) completed a series of three jump conditions, three times each. These jumps included maximum countermovement vertical jumps (VJ), jumps where they headed a soccer ball (JH), and jumps where they attempted to head a soccer ball but missed (JM).The JH condition was uses for deception as participants were unaware of the JM condition. Data from VJ and JM were compared. Participants showed greater peak GRF and peak loading rate (LR) on the dominant compared to the non-dominant limb for the JM condition ($p<0.05$).*

Injury prevention programs may improve by integrating sport specific multitasking exercises into their routines. Adding different cognitive elements could yield better research representation of what happens during landing in real game situations.

Keywords: *Landing mechanics, Soccer jump landing, Female athlete jump landing*

1. Introduction

Soccer is the most popular sport in the world, with approximately 270 million active players [1].In recent decades, FIFA has made growth and development one of the pillars of the FIFA Women's Football Strategy.[2]Thus, there has been an increase in the number of female players in the sport. There are currently approximately 13.36 million girls and women playing organized soccer [2].This rise in popularity and number of participants is associated with a greater number of soccer injuries. In fact, soccer players experience greater injuries rates than those of other physical demanding sports, such as American football and hockey [3].Most soccer injuries occur in the lower limbs and are primarily sprains, strains, and contusions.[3] Anterior cruciate ligament (ACL) injuries are among the most common injuries in soccer and occur 4-6 times more in women than men [4].ACL injuries commonly occur in non-contact situations,when an individual is attempting to decelerate the body, such as when landing from a jump [5]. Soccer players typically jump when they are attempting to head the ball. Thus, soccer injuries occurring during landing are more likely to occur when a player jumps for a header.

Heading a ball has two features that are likely to make landing different from a typical countermovement jump landing. The first being the heading motion itself and the second being multitasking. Two studies investigated the effect of a soccer heading motion on landing mechanics and reported greater peak vertical ground reaction force (GRF) when doing the heading motion compared to a vertical jump with no heading motion [6, 7].However, in both studies the ball was suspended, thus, not accounting for players visually tracking a moving ball and timing their jump.

Adding multiple multitasking situations to vertical jumps has been investigated but not during a soccer header and in some cases, the added cognitive task was not sports related. One study compared vertical jumplanding mechanics with no additional cognitive condition to landing while counting backwards by one as well as landing while counting backwards by seven [8].The added cognitive task resulted in greater peak vertical GRF but there was no difference between counting backwards by one and counting by seven. However, counting backwards is not a task athletes would do during an athletic performance.A recent study investigated the effect of multitasking on a series of basketball jump shots [9].Participants experienced greater peak vertical GRF and greater peak LRon their dominant side when they had to shoot the ball above a simulated defender compared to no defender. These GRF and LR increased when the players received a pass prior to shooting. Thus, the more complex the task, the riskier the landing. It is unclear if landing after a jump shot would be similar to that following a soccer header. During the basketball task, players were clear on what they needed to perform prior to taking off the ground. However, in soccer, players jump and make decisions in the air based on visually tracking the soccer ball, making it a different skill with possiblydifferent landing mechanics.

Thus, the purpose of this study was to compare vertical landing GRFduring vertical jumps to that during landing after attempting a soccer header, in division II women's soccer players. We hypothesized that players would experience greater peak GRF and peak LR when a heading motion while visually tracking a ball is involved compared to just a vertical jump.

2. METHODS

2.1. Participants

Fourteen female NCAA Division II collegiate-level soccer players (age 19.35 ± 0.93 years; mass58 ± 8.2 kg; height 163 ± 6 cm) participated in the study. Players were excluded if they were not cleared to play by the team athletic trainer. All players practiced four days per week for two hours a day and participated one hour of weight training, twice a week. In addition, they competed in two ninety-minute games aweek.However, playing time in these games varied from players participating the entire game to minimal or no time at all.

2.2. Procedures

All procedures were approved by the university's institutional review board prior to testing. Participants came to an indoor gym during the offseason wearing game wear and team issued sneakers. Allparticipants read and signed an informed consent form. Participants answeredquestions to identify their dominant foot (defined as the foot they kick a soccer ball with), age, and injury history. This was followed by measuring their weight and height. Loadsol force insoles (Novel, Munich, Germany)were then placed in the participants' sneakers to measure ground reaction forces at 100 Hz.Loadsol insoles have been shown to be valid and reliable GRF measuring tools during jump landing at the same sampling rate [10].

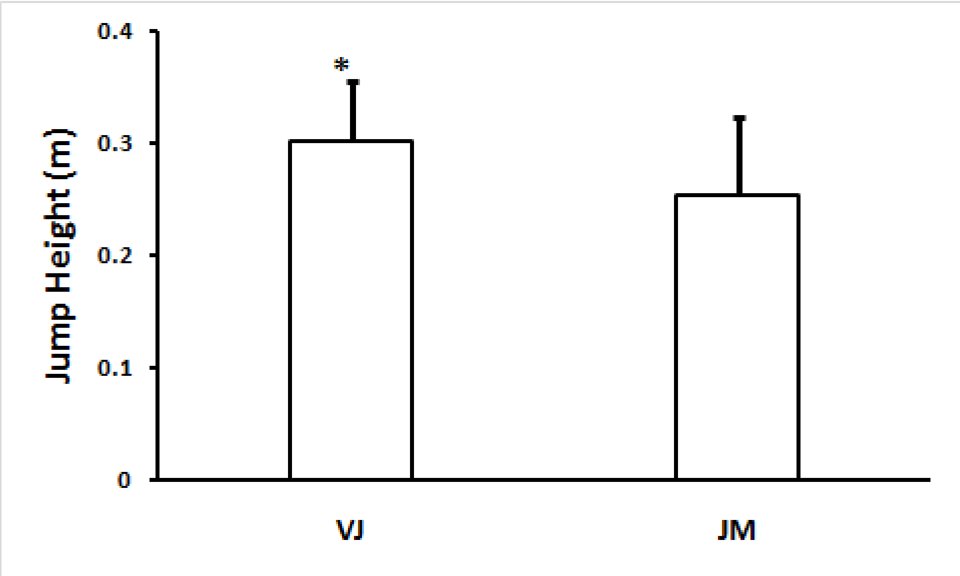
Following a brief warmup, participants were asked to perform a series of nine jumps that included three jump conditions, each conducted three times. Jump trials were conducted in a counterbalanced order. Jump conditions were vertical jump (VJ), jump header (JH), and jump miss (JM). In the VJ condition, participants were instructed to perform a maximum vertical jump. In the JH condition, participants stood facing a researcher who threw a soccer ball from a 24-foot distance towards the participant, in a standardsoccer throw-in technique. Participants were instructed to jump and head the ball out of the air in the forward direction.For the JM condition, the throw was done in the same manner as the JH condition, however, the researcher deliberately threw the ball over the participant's head. The participants were given the same instructions as the JH condition. They were unaware the ball would be too high to head, thus, jumped and attempted to perform a header.For all conditions, no special instructions concerning the upper limbs were given, thus, not restricting their movement and allowing participants to jump as naturally as possible. All trials involving a ball were thrown by the same researcher for consistency. All trials were video recorded qualitative analysis purposes.Custom Matlab (MathWorks, Natick, MA, USA) code was used to determine peak GRF and peak LR during landing and values were confirmed manually. Jump height was calculated from half the time in the air using uniform acceleration motion equations.Dependent variables collected during the JM condition were compared to those from the VJ condition. Data from the JH condition were not used in our analysis as jump height would be difficult to control considering the ball was thrown manually. However, the JH condition was essential as if it was not used, participants would know that the ball would be overthrown and would not track the ball during the JM condition.

Variables analyzed from the ground reaction force data were peak GRF normalized to body weight, peak loading rate, as well as landing height. Peak loading rate was defined as the maximum slope in the GRF curve from the instant of contact to peak GRF [11]. Means of the three trials were uses for statistical analyses.

A series of two-way repeated measures ANOVAs with jump condition (VJ & JM) and side (dominant & non-dominant) as independent variables were used to determine if there is a difference in kinetic variables. Paired t-tests were used to compare landing height between the two conditions as well as compare the total (sum of dominant & non-dominant) peak GRF. Tests with $p<0.05$ were considered statistically significant. SPSS 28 (IBM Inc, Armock, NY), was utilized to complete all statistical analyses.

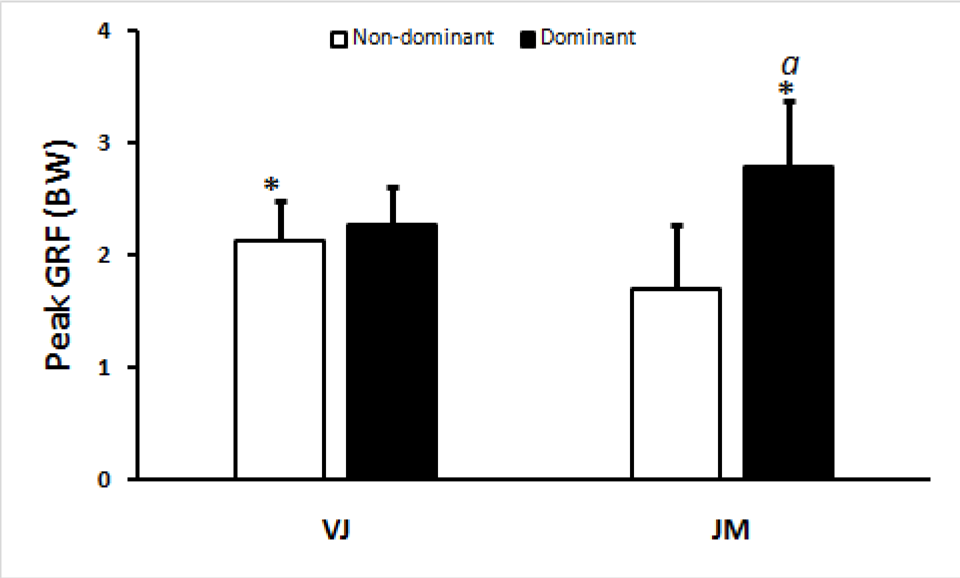
3. Results

Mean and SD jump height for the VJ and JMconditions are presented in Figure 1. Jump height for the JM condition (25 ± 5 cm) was lower than that of the VJ condition (30 ± 5 cm). Dependent t-test showed a significantly greater jump height for the VJ condition ($t = 4.14$, $p<0.01$). Despite the difference in landing height, dependent t-test showed no significant difference in total peak GRF between conditions (4.39 BW and 4.48 BW for the VJ and JM conditions, respectively).



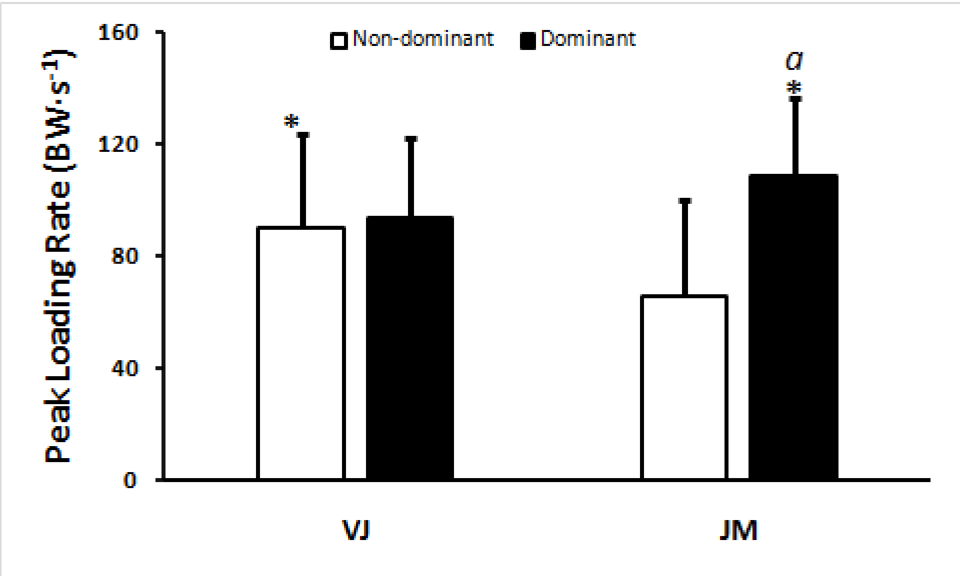
*Mean and s jump heights for the Vertical Jump (JV) and Jump Miss (JM) conditions. * indicates significant difference (p<0.05) between conditions.*

Figure 2 shows mean and SD peak vertical GRF for both dominant and non-dominantsides during both jump types. Participants experienced greater peak vertical GRF on their dominant side compared to non-dominant for both conditions. However,the difference between the two sides was greater in the multitasking condition, as the dominant to non-dominant difference was 0.16 BW during the vertical jump condition and 1.09 BW during the JM condition. Two-way repeated measures ANOVA revealed a significant jump condition by side interaction ($F(1, 13) = 16.64$, $p=0.001$).Simple effects showed participants experienced greaterpeak vertical GRF on the dominant sidecompared to the non-dominant side during the JM condition only ($p<0.05$). Simple effects also showed greater peak vertical GRF on the dominant side during JM compared to that during VJ ($p<0.05$) as well was greater peak vertical GRF on the non-dominant side during VJ compared to that during JM ($p<0.05$).



*Mean and s for peak GRF (BW) for the non-dominant and dominant sides for Vertical Jump (JV) and Jump Miss (JM) conditions. a indicates significant dominant to non-dominant difference (p<0.05), * indicates significantly greater than the same side during the other condition (p<0.05).*

Figure 3 shows mean and SD peak LR for the dominant and non-dominant side during the two jump conditions. Similar to peak vertical GRF, the difference between the dominant and non-dominant sides was greatest in the JM condition. Two-way repeated measures ANOVA revealed a significant jump condition by side interaction (F (1, 13) = 11.86, p=0.004). Simple effects showed significantly greater peak LR on the dominant side compared to the non-dominant during JM only (p<0.05). Simple effects also showed greater peak LR on the dominant side during JM compared to VJ (p<0.05), which was accompanied with greater peak LR on the non-dominant side during VJ compared to JM (P<0.05).



*Mean and s sum of peak GRF Vertical Jump (JV) and Jump Miss (JM) conditions. a indicates significant dominant to non-dominant difference (p<0.05), * indicates significantly greater than the same side during the other condition (p<0.05).*

4. Discussion

The purpose of our study was to compare jump landing ground reaction force following a vertical jump to that following ajump to try to head a soccer ball in division II women soccer players. Before addressing the specific purpose, we need to discuss jump height and how it affected GRFs. We expected participants tojump as high as the VJ during JM considering the ball was too high for their reach and they attempted tohead the ball.However, there was a 17% reduction in jump height during JM. Previous research reported higher jumps when players performed a jump header movement, compared to just a vertical jump [12].However, there are several key differences with our study. In our study, all jumps took place from a standing position, whereas in the other study, they performed a running start. A second difference is gender as our participants were females while their participants were males. Lastly, participants in our study were DII athletes with mean age of 19, compared to semiprofessional and professional players with mean age of 24 years in the other study [12].No difference in jump height between heading a ball and not heading a ball in recreational soccer players (males and females) with mean age of 23 years has also been reported in the liturature.[7] However, other than indicating players were recreational, their level of play was not described. Other research reported lower jump height with multitasking in recreational athletes [8].The difference in participant level of maturity and experience may account for why our participants were not able to jump as high when a ball was involved. With experience, the effect of multitasking overload is reduced, thus, maintaining efficiency in performance [13].Despite the lesser jump height, JM resulted in the same peak total GRF. Had jump height been the same between the two conditions, we would expect greater peak total GRF during the JM condition as observed in other studies [6, 7, 8, 9].

When the jump involved attempting to visually track and head a soccer ball, participants consistentlylanded on their dominant foot, thus, experienced greater peak vertical GRF and peak LR on their dominant side. However, this resulted in lower GRF and LR on the non-dominant side, keeping total force the same. In agreement with our findings, DII basketball players have shown greater increase in both peak vertical GRF and peak LR on their dominant side as the jump shot task got more complicated [9].Similarly, greater peak vertical GRF when drop landingsinvolved a secondary non-sport related visual task have also been reported [14]. Although, GRF data were collected from two force platform, they did not perform and dominant to non-dominant side comparison.

At a lower landing jump and landing height, sum of peak vertical GRF for JM was similar to that of VJ. Previous studies investigating jump landings with heading motion reported greater peak vertical GRF compared to jump landings with no heading motion [6,7].Unlike in our study, this increase in GRF was accompanied by similar landing height for all conditions. However, neither study reported the dominant foot landings observed in our study. This may be attributed to several differences. It is possible that the bias to land on the dominant side is related to visually tracking a moving ball, which was not included in either of the previous studies as the ball was fixed. It is also possible that in our study, the researcher throwing the ball had a bias to one side. However, it seems unlikely considering both right and left footed players landed on their dominant foot. It is also possible that participants in previous studies also landed on one foot but it went unnoticed. In one case it was explicitly mentioned that analyses were conducted on the dominant lower limb only [7].Inthe other case, it was not specified if their data were from one or two limbs [6].Based on the values presented, it is likely they also reported GRF on one side as well. We also need to consider participant level of experience. Participants in our study were DII athletes, whereas in both previous studies, they were DI athletes. Just like with jump height (discussed earlier), overlearning experienced at higher level of performance may result in better maintenance of performance when multitasking [13],which can also apply to maintaining landing mechanics.

The possible influence of jump takeoff on landing should also be considered. Qualitative video observations showed that in JM, participants performed a step-close jump compared a countermovement jump in the VJ. This resulted in distinct GRF patterns prior to takeoff. During VJ, GRF from both feet tended to be coupled from the start of movement. Whereas, during JM, GRF started decoupled but coupled right before takeoff. GRF decoupling enables individuals to reduce bilateral deficit allowing them to reach similar jump height as coupled GRF in lesser time or increase their jump height [15].It is likely soccer players naturally apply a step-close jump to perform a higher or quicker jump compared to a countermovement jump [16].The question remains whether takeoff influenced landing considering GRF was coupled at the instant of takeoff during both conditions. Previous study reported greater pelvic torsion during landing following jumping for a header,it was attributed to push off asymmetry during takeoff and visually tracking the ball in the air [12].However, in that study, participants performed a running vertical jump which typically involves a one-foot takeoff. Nevertheless, pelvic torsion was significantly greater during a running vertical jump with a heading motion compared to that with no heading motion. Thus, takeoff patterns cannot be overlooked and should be further investigated.

Single leg landings with greater peak verticalGRF have been linked to landing injuries. Singled legged landings are recognized as one of two methods for ACL injuries in women team handball players, thus representing a high-risk landing strategy [17].Single leg landings provide a challenge compared to double leg landing, as individuals need to support their body weight and control deceleration of their center of mass on one foot [18].Increased GRF during single leg landings isalso associated with increased knee abduction moments. Since, knee musculature primarily acts in the sagittal plane, these abduction moments are mainly counteracted by knee passive structures including the ACL. Thus, high loads during single leg landings can lead to ACL strain as well as rupture [19].In fact, greater peak knee abduction moment with lesser knee flexion during have been observed with single leg jump landing compared to other forms of single leg landings [20].They argued that single leg jump landings are the most demanding and would serve as a better athlete screening tool.

Not everyone agrees that there is an association between landing from a jump in soccer and ACL injuries. A recent study used video analysis and reported that landing following a jump header is low risk to ACL injury [21].However, their study was conducted on professional women athletes compared to DII athletes in our study. As discussed earlier, dual task interference decreases with experience, which may result in better landing mechanics in higher level athletes [13].Thus, future studies should investigate differences between different age groups and different level athletes.

Our findings show that landing from a vertical jump is a different skill than landing from a jump when a player attempts a header. Thus, when studying landing mechanics in soccer players, it is important to have participants perform the specific task they would typically perform in a game and not just a typical countermovement jump. Jumping tasks that include heading a ball should be used in injury prevention programs. It is important to further investigate heading motion with ball impact as it may not be the same as missing the ball.

4.1. Limitations

In this study, we used Loadsol sensors to collect force data which eliminates the need for participants to focus their attention on landing within the boundaries of a force plate but this limited us to vertical GRF only. Data were collected in a gym with a wooden floor. This was done to avoid winter weather conditions that would have made data collection outside impossible. We speculate that GRF patterns would be similar on a soccer field but with lower magnitudes considering the softer surface. Our participants were DII women soccer players and with mean age of 19 years. Most participants were first- and second-year students. Thus, our findings may not be generalizable outside of this demographic.

Video recordings of the trials allowed us to qualitatively observe movements performed by participants, however, a detailed kinematic analysis was not performed. Thus, it would be recommended for future studies.

Lastly, we recognize that with 14 participants, this study is underpowered. However, we were limited to the players from our university soccer team. In addition, the number of participants is similar published studies [9, 12, 13, 14, 17, 18, 19, 20]. Despite the relatively low number, we were able to find differences between jump conditions.

5. CONCLUSION

Jumping with the intent to head a ball is a different motor skill than jumping without the intent to head a ball resulting in different landing kinetics. When heading the ball was attempted, Division II women soccer players landed on their dominant foot resulting in greater peak GRF and greater peak LR on the dominant side and reduction of these variables on the non-dominant side. To reduce the possibility of injury during landing, prevention programs should include soccer specific jumping and landing tasks that include heading a ball. Future studies should investigate the generalizability of our findings to different populations.

6. Acknowledgement

We would like to thank members of the Southwest Minnesota State University soccer team for volunteering to participate in our study.

We would like to thank Dr Richard Hinrichs, Professor Emeritus at Arizona State University and Dr Jamie Johnston, Neurophysiologist at Alberta Health Services for their contribution to this project.

We would also like to thank Dr Jason Robertson, Research Associate at Nova Scotia Health and Dalhousie University for writing the Matlab code used in this study.

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Citation: *Samuel A. Nascak et al. "The Effect of Multitasking on Female Soccer Player Jump Landing Ground Reaction Force" International Journal of Sports and Physical Education (IJSPE), vol 9, no. 3, 2023, pp. 21-28. DOI:* https://doi.org/*10.20431/2454- 6380.0900303.*