THE RELATIONSHIP BETWEEN FOOT POSITION IN THE TAKE-OFF PHASE AND THE HEIGHT OF THE JUMP SHOT IN BASKETBALL

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The purpose of this study was to identify the relationship between foot position in the take-off phase and the height of the jump shot. The research was conducted on 20 professional basketball players. Each participant performed 9 jump shots on a force plate in laboratory conditions. Jump shots were performed from three different foot positions in random order: 3 from a dominant staggered stance, 3 from a parallel stance, and 3 from a cross-dominant staggered stance. The height of the jump shots from a parallel stance (0.44 ± 0.05 m) were significantly greater than from a dominant staggered stance (0.43 ± 0.04 m) and from a cross-dominant staggered stance (0.43 ± 0.05 m). Therefore, the desirable dominant staggered stance consistent with the reference movement pattern did not prove to be more advantageous in terms of the height of the jump shot compared to other foot placements.

KEYWORDS: foot placement, lower limb, movement pattern, vertical jump.

INTRODUCTION: Basketball is one of the most popular team sport game in the world. Among many motor activities occurring during a basketball game, shooting to the basket is the most important skill that determines the final result (França et al., 2021). The jump shot is the most important shooting technique as it is currently the most used method to score during a game. A two-legged jump shot may account for over 80% of all shots made during the game (Erčulj & Štrumbelj, 2015).

Biomechanical research on the jump shot mainly focuses on the analysis of kinematic variables of the basketball player's upper body and upper limbs (Struzik et al., 2014). There is a relatively small number of studies that analyse the lower limbs motion and mechanics during a jump shot, in particular in relation to the foot placement (Spina et al., 1996; Williams et al., 2016). Guides for basketball coaches present a reference movement pattern for the jump shot performance (Knudson, 1993). Foot position is determined by the shooting upper limb (shooting side). The jump shot stance should be slightly staggered with the shooting side foot forward (dominant foot) and the feet placed approximately slightly less than shoulder width apart. Therefore, for a right-handed player, the dominant foot position is the right foot in front of the left foot (a dominant staggered stance). This dominant foot position is intended to help the athlete maintain balance (by minimizing horizontal displacements of the centre of mass) and the vertical direction of the take-off during the jump shot (Knudson, 1993). Other theoretical benefits of the dominant foot position are less rotation of the shoulder, trunk, and pelvic during the ball release phase (Okazaki et al., 2015). However, in practice, regardless of the reference movement pattern, different foot positions during the jump shot are also encountered. There are three main foot placements (Williams et al., 2016): a dominant staggered stance (DSS, foot of the shooting side in front), a parallel stance (PS, feet placed equal), and a cross-dominant staggered stance (CDS, foot of the shooting side behind).

Previous reports (Spina et al., 1996; Williams et al., 2016) regarding the relationship between foot position and jump shot accuracy (shooting percentage) question the reference jump shot movement pattern in relation to the foot placement. Spina et al. (1996) conducted research on two participants. The advanced basketball player performed jump shots after received a pass with parallel stance (feet placed equal) and scored 6/6, while the amateur used the dominant staggered stance (dominant foot forward by 9 cm) and missed all 6 jump shots. Each participant placed their feet in a position that was comfortable for them, and the advanced basketball player chose a foot position different from those adopted in the reference jump shot movement pattern (Spina et al., 1996). Williams et al. (2016) conducted research on 11 female basketball players from National Collegiate Athletic Association (NCAA) Division I. The participants performed jump shots after received a pass from five different positions (5 m from the basket), adopting a comfortable foot position before each shot. Of the 330 total jump shots attempted, 69.7% were from DSS, 23.9% from PS, and 6.4% from CDS. Shooting percentages were 58.3% from DSS, 62.0% from PS, and 71.4% from CDS. The participants obtained the lowest shooting percentages from the recommended DSS compared to PS and CDS, but DSS was the most commonly used stance (Williams et al., 2016).

Studies on the jump shot do not provide a clear and convincing conclusion about the importance of foot placement in the jump shot performance. So what is the reason for teaching a jump shot from DSS? Why isn't a different foot position (PS or CDS) taught as a reference? Understanding the most effective foot placement for jump shot accuracy will expand the basic knowledge of shooting mechanics and will directly benefit people (players, coaches, experts) interested in developing basketball players.

When it is necessary to counteract aggressive defence, the height at which a shot is performed (release height) turns out to be an important parameter of a jump shot. The factors that affect release height include the body height, jump height and arrangement of body parts (Miller & Bartlett, 1996). Will the theoretically correct foot position allow for greater vertical displacement of centre of mass during the jump shot compared to other foot placements? There are no studies on the impact of different foot positions on the height of the jump shot or even vertical jump height.

Therefore, the purpose of this study was to identify the relationship between foot position in the take-off phase and the height of the jump shot. During which foot position (DSS, PS, or CDS) will the subjects achieve the greatest height of the jump shot?

METHODS: The research was conducted on 20 professional basketball players (body height: 1.94 ± 0.08 m, body mass: 89.4 ± 9.8 kg, age: 24.9 ± 5.6 years, training experience: 13.1 ± 5.5 years). All examined players were right-handed. Participants competed at the highest level of the national league. The tests were performed in the Biomechanical Analysis Laboratory at the Wroclaw University of Health and Sport Sciences, Poland (with PN-EN ISO 9001:2009 certification). Before the tests, each player was familiarized with the research goals, was informed about the purpose of the study and gave written consent to participate in the research. The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Senate's Research Bioethics Commission of the Wroclaw University of Health and Sport Sciences, Poland.

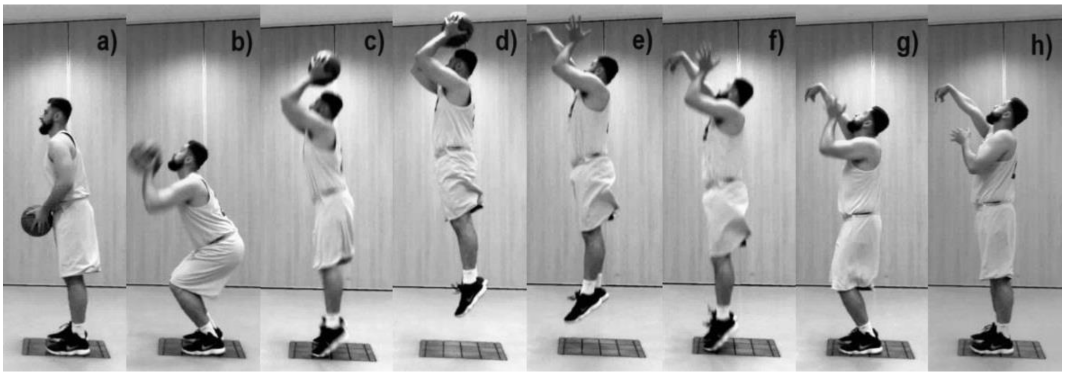

Figure 1: Jump shot in laboratory conditions with the following characteristic body positions: a) starting position, b) countermovement, c) take-off, d) maximum jump height, e) ball release, f) end of the flight phase, g) landing, h) final position.

Jump shots were performed on a force plate in laboratory conditions (Figure1). Each participant performed 9 jump shots with the ball to a person 3 meters away. Jump shots were performed from three different foot positions in random order: 3 shots from DSS, 3 shots from PS, and 3 shots from CDS (Figure 2). All jump shots were to be made as if the defender were jumping to block, i.e. they should have the maximum possible jump height. The intervals between successive jump shots were between 25 and 30 seconds. The trial was repeated if the lower limbs were bent at the knee or hip joints during the flight phase. Before the measurements, the participants performed an individualized warm-up preparing for maximum power effort. From the 9 jump shots performed by each subject, attempts with the greatest height of the jump shot were considered for further analysis (one for each of the three types of foot positioning).

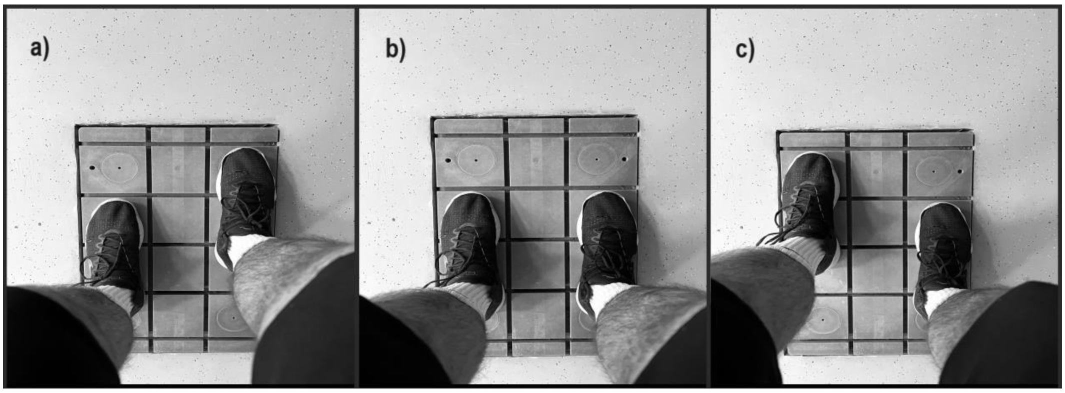

Figure 2: Three different foot placements for a right-handed shooter: a) dominant staggered stance (DSS), b) parallel stance (PS), c) cross-dominant staggered stance (CDS).

Ground reaction forces were measured during jump shots using a Kistler 9281B13 force plate with Kistler MARS Power 2875A software (Winterthur, Swiss). The sampling frequency of the signal from the force plate was 1,000 Hz. Based on the recorded waveforms of the vertical component of the ground reaction force, the height of the jump shot (jump height) was estimated based on the time of the flight phase (Linthorne, 2001):

$$h = g \cdot t_{flight}^2 / 8,$$

where h is the jump height, g is the acceleration due to gravity, and t_{flight} is flight time.
A one-way repeated measures ANOVA (with Tukey's HSD post hoc test) was used to compare the values of the height of the jump shots from three different foot positions (DSS, PS, and CDS). The effect size η^2 was also computed.

RESULTS: Table 1 contains means and standard deviations of the height of the jump shots from three different foot positions (DSS, PS, and CDS). The height of the jump shots from PS were significantly higher than from DSS and from CDS. The η^2 value was 0.28 (large effect size). There were no significant differences in the jump height between the jump shots from DSS and from CDS. The greatest height of the jump shot was achieved by 14 participants from PS, 4 from DSS, and 2 from CDS.

Table 1: Mean and standard deviation values of the height of the jump shots from three different foot positions: a dominant staggered stance (DSS), a parallel stance (PS), and a cross-dominant staggered stance (CDS).

Foot placement	DSS	PS	CDS
Mean (m)	0.43^{a}	$0.44^{a,b}$	0.43^{b}
SD (m)	0.04	0.05	0.04

SD - standard deviation, ^{a} - significant differences at $p < 0.05$, ^{b} - significant differences at $p < 0.01$.

DISCUSSION: The studied group of basketball players obtained the greatest average height of the jump shots from PS. The height of the jump shot from DSS and from CDS were similar. Therefore, the theoretically desirable DSS consistent with the taught reference movement pattern did not prove to be more advantageous in terms of the height of the jump shot (jump height) compared to other possible foot placements. It is not easy to find the causes of the above-mentioned phenomenon, because there are no studies on the impact of different foot positions on the biomechanical variables describing both the jump shot and the vertical jump.
Additionally, and surprisingly, most participants (14 of 20) achieved the greatest height of the jump shot with PS, although of course an average differences of approximately 1 cm between

heights of the jump shots from different foot placements ($\Delta_{PS\text{-}DSS}$ = 0.01 ± 0.01 m, $\Delta_{PS\text{-}CDS}$ = 0.01 ± 0.01 m) may not be considered incredibly high. Therefore, it can be considered, with some caution, that the foot position during the jump shots played a minor role in this group of professional basketball players. Perhaps the observed phenomenon is related to the need to adjust the foot position during the jump shot to the current situation on the court. A professional basketball player must be able to shoot both against the defender and in an unusual position.
So what is the reason for teaching a jump shot from DSS? The cited benefits related to easier maintenance of the body in balance in DSS seem questionable (Knudson, 1993). The slightly staggered stance practically does not affect the base of support, its surface remains relatively the same as in PS (Ryan & Holt, 1989). Parallel positioning of the feet in the take-off phase during a jump shot may, in turn, help maintain the body in balance in the frontal plane (Spina et al., 1996).
The problem of foot placement has so far been considered only in the context of long jump (Mackala et al., 2013). Therefore, it seems advisable to conduct further research on the influence of foot placement on the biomechanical variables that describe the vertical jump and, subsequently, the jump shot. It would also be advisable to consider shooting percentages in further studies. Is there a beneficial foot position when jumping vertically or does it not matter much?

CONCLUSION: The dominant staggered stance did not prove to be more advantageous in terms of the height of the jump shot compared to other possible foot positions. Professional basketball players were able to obtain similar height of the jump shots regardless of foot position, which may indicate the necessary versatility at a high sports level. Therefore, it seems that coaches should pay attention to teaching the jump shot with different foot positions, so that the player can freely adjust them to the situation on the court.

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