THE EFFECT OF WIDE PREPARATORY STANCE ON DIVING SAVE PERFORMANCE IN FEMALE GOALKEEPERS

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The purpose of this study was to investigate the effect of a wider preparatory stance on diving save performance in female goalkeepers. Five national-level goalkeepers performed dives from preferred and wide (75% of leg length) preparatory stance. Repeated measures ANOVA showed no effect of preparatory stance on dive time. Statistical parametric mapping 2-way repeated measures ANOVA was performed on the centre of mass (CoM) velocity, legs contributions, and contralateral power curves. It was found that the wider stance width required more contribution from the contralateral and less from the ipsilateral push-off, but this effect did not manifest in an improved CoM velocity or contralateral power generation. Coaches are recommended to evaluate the physiological and biomechanical differences before translating research findings between gender.

KEYWORDS: football, soccer, kinematics, kinetics, coaching, strength and conditioning.

INTRODUCTION: Most of goalkeeper biomechanics research, to date, has been performed on male goalkeepers (Spratford et al., 2009; Ibrahim et al., 2019a; 2019b; 2020; 2023). They were found to use a proximal-to-distal contralateral-to-ipsilateral coordination sequence in lower limb joints power generation (Ibrahim et al., 2020) and use their contralateral leg as the main contributor to the centre of mass (CoM) velocity (Ibrahim et al., 2019a). Furthermore, they were found to generate more horizontal momentum than vertical momentum in high and low dives (Ibrahim et al., 2019a). They were also found to benefit, in terms of a reduced dive time, from a wider preparatory stance (≈75% of leg length) than their preferred one (≈45% of leg length; Ibrahim et al., 2019b; 2023). Female and male goalkeepers are asked in matches to cover the same distances (same goal dimensions), while they are different in anatomical (e.g., body height) and physiological characteristics (e.g., muscular force capacity). This poses some uncertainty regarding the degree at which the previous literature from male goalkeepers can be applied to females in coaching and physical preparation. Although the importance of the horizontal momentum, the contralateral leg push-off, and the proximal-to-distal joint power generation could be also true for female goalkeeper, it is questionable to what extent the wider preparatory stance could be beneficial. Based on Ibrahim et al. (2019b), the wider stance will orient the contralateral leg in a more favourable position to develop forces that are aligned with the CoM and the ball. However, it will load more the contralateral leg in the push-offs, which poses the question from the perspective of muscular capacity in females, in terms of rate of force development (McMahon et al., 2017) and maximum power capacity (Nuell et al., 2019). Therefore, the goal of this research was to clarify the effect of a wider preparatory stance on the diving save performance (dive time) of female goalkeepers. Despite limited muscle capacity, we hypothesized that female goalkeepers would benefit from the wider preparatory stance width by reducing dive time and improving CoM velocity toward the ball.

METHODS: Five female national-level goalkeepers from the Dutch league 'Eredivisie Vrouwen' participated in this study (age 20.5 ±3 years, mass 67.3 ±6.3 kg, height 173.9 ±5.9 cm). The research protocol was approved by the Ethics Committee of the Faculty of Behavioral and Movement Sciences at the Vrije Universiteit Amsterdam.
Two force platforms (AMTI 400600, USA) embedded under artificial grass were used to measure at 1000 Hz the ground reaction forces (GRF) applied on each foot. A passive marker optoelectronic system (Vicon 612, Oxford UK), consisting of nine infrared cameras, was used

to capture at 200 Hz the 3D position of 26 markers attached to the thorax (6), feet (4 per foot), hands (3 per hand), and balls (3 per ball). The protocol consisted of diving to save high (180 cm off the ground), and low (50 cm off the ground) balls on the right and left side of the goal. Goalkeepers started on the force platforms, in the middle of the goal, and reacted to a visual stimulus produced by an LED board with 4 lights indicating the height and side of the ball that needs to be 'saved' as fast as possible. The goalkeeper had at all time one ball suspended at high height on one side and another ball suspended at low height on the other side. Balls were attached with a magnet to a rope suspended 1 m in front of the goal line and 1 m inside the side post. Each goalkeeper completed a total of 24 dives, 3 dives per height (high, low), side (left, right), and condition (preferred stance, wide stance). For the wide stance conditions, goalkeepers had tape markers on the ground indicating the position of the feet that corresponds to a stance width equal to 75% of their leg length.

All kinematic and kinetic analyses were carried out using custom software in MATLAB (R2023b, MathWorks Inc., United States). The dive onset instant was detected for each trial using a custom algorithm based on the Approximated Generalized Likelihood-Ratio (Ibrahim et al., 2019b). Ipsilateral take-off was defined as the moment when the second toe-tip marker vertical position started to increase, and ball contact instant was determined when a shift in the ball's markers position was detected. Dive time [s] was calculated as the time between dive onset and ball contact instants. The dive that had the shortest time per side, height and condition was selected for further analysis, ending up with 8 dives per goalkeeper. The analysis of thorax's CoM velocity and total body CoM were used interchangeably based on previous evidence of high correlation between the two in goalkeeper's diving save (Ibrahim et al., 2020; 2023). The contribution of each leg to the total body CoM velocity was calculated by quantifying the resulting velocity of each GRF (Ibrahim et al., 2019a):

$$v_j = \int_{t_0}^{t_{takeoff}} \left(\frac{F_j}{m} - \frac{g}{2}\right) dt \qquad \textbf{(Equation 1)}$$

In Equation 1, *v* is the CoM velocity [m/s] resulting from each leg *j*. t_0 and $t_{takeoff}$ are the light instant and the moment of ipsilateral take-off, respectively. *F* is the GRF acting on the respective leg, *m* is the body mass of the goalkeeper, and *g* is the gravitational acceleration.

Finally, the generated power [W] from the contralateral leg push-off was calculated by multiplying the contralateral GRF by the thorax's CoM velocity.

All kinematic and kinetic variables were segmented from light instant to take-off, and time normalized to the median of dive time across all participants. Two-way repeated measures ANOVA was used to compare the effect of height (high, low) and stance width (preferred, wide) on dive time. To explain the mechanism behind the results of dive time, two-tailed 1D statistical parametric mapping (SPM) two-way repeated measures ANOVA was also used to compare the CoM velocity, the contralateral and ipsilateral contribution to CoM velocity, and the contralateral power curves in both horizontal and vertical directions, between heights (high, low) and stance widths (preferred, wide). All statistics were conducted in MATLAB using the open-source software package spm1D 0.4.9 (Pataky, 2012; https://spm1d.org/). The significance level for all statistical tests was set a priori to <0.05.

RESULTS and DISCUSSION: Female goalkeepers dived from their preferred stance width (44 ±4% of leg length) and saved the ball within 1.239 ±0.085 s and 1.098 ±0.076 s, for high and low balls respectively. Whereas the dive times for the wide conditions were 1.271 ±0.143 s for high balls, and 1.095 ±0.074 s for low balls. Two-way repeated measures ANOVA showed that there was only a main effect of dive height ($p<0.001$) on dive time, as diving to save low balls was on average 0.159 s faster than high balls. Contrary to our hypothesis a wider stance did not influence diving save performance in female goalkeepers. In a previous study on male goalkeepers, a wider preparatory stance resulted in a reduction of the ipsilateral sidestep length, allowing more time for force development rather than sidestepping to increase stance width, and resulting in a shorter dive time (Ibrahim et al., 2019b). In the current study, female goalkeepers did reduce their ipsilateral sidestep in wide stance conditions by around 24 cm, but without any effect on dive time.

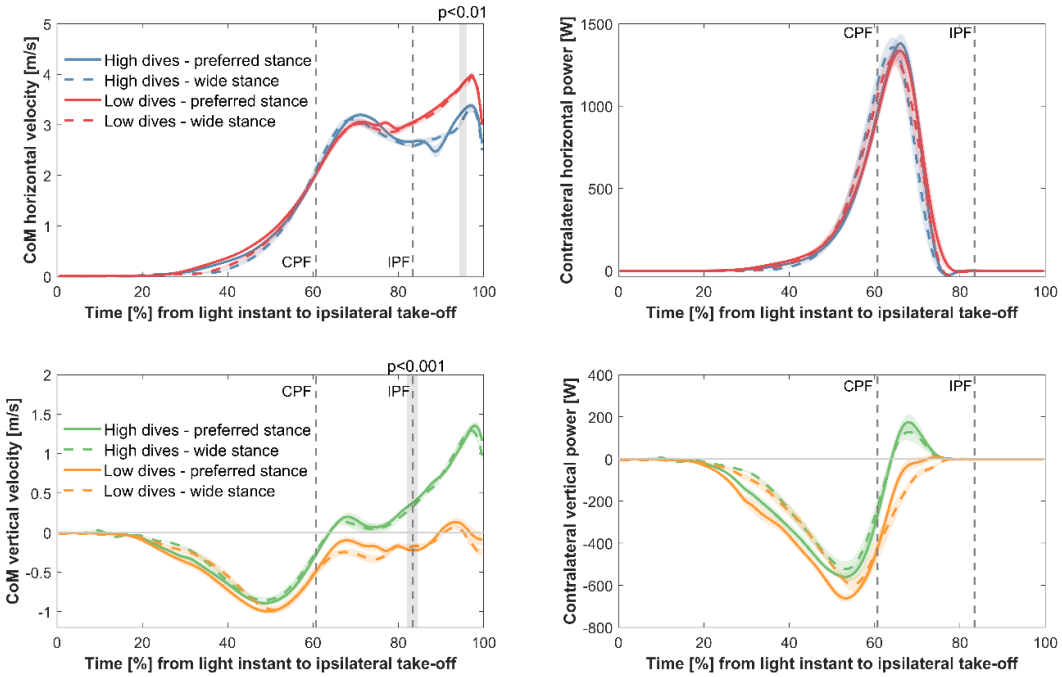

Figure 2: Thorax's CoM velocity (left plots) and contralateral power (right plots) time registered from light to take-off instants. Standard error is in coloured shading and statistical parametric mapping significance area for the independent variable 'height' is in grey shading with the corresponding p value above. The dashed vertical lines correspond to the contralateral peak force (CPF) and ipsilateral peak force (IPF) instants.

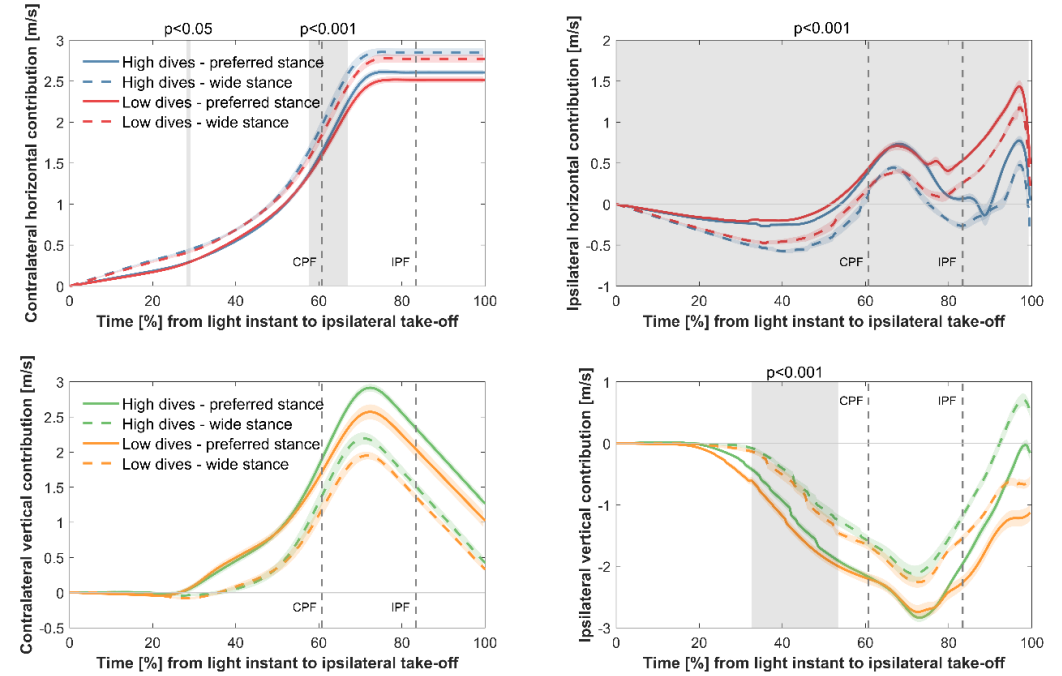

Figure 3: Contralateral (left plots) and ipsilateral (right plots) leg contribution to thorax's CoM velocity, time registered from light to take-off instants. Standard error is in coloured shading and statistical parametric mapping significance area for the independent variable 'stance width' is in grey shading with the corresponding p value above. The dashed vertical lines correspond to the contralateral peak force (CPF) and ipsilateral peak force (IPF) instants.

SPM with two-way repeated measures ANOVA design revealed a main effect for height on horizontal (from 94.3 to 96% of normalized time (NT), $p<0.01$) and vertical (from 81.9 to 84.6% of NT, $p<0.001$) CoM velocities (Figure 2). In line with the literature (Ibrahim et al., 2019b; 2023), the wider preparatory stance increased the reliance on the contralateral leg by inducing a significant increase in its contribution to horizontal CoM velocity during the contralateral push-

off, from 57.7 to 67.0% of NT (mean difference of +0.3 m/s, $p<0.001$; Figure 3). This extra reliance on the contralateral leg was not translated into improved CoM velocity and contralateral power (Figure 2). In the 57.7 – 67% time interval, female goalkeepers were able to generate an average contralateral power of 1064 ±247 W from the preferred stance, compared to 1136 ±183 W from the wide stance. However, the average horizontal CoM velocity, over the time series from 57.7 to 67% of NT, did not differ between preferred stance (2.236 ±0.413 m/s) and wide stance (2.279 ±0.421 m/s).

SPM with two-way repeated measures ANOVA design also revealed a main effect of stance width on ipsilateral contribution to both horizontal (from 0 to 99% of NT, $p<0.001$) and vertical (from 32.7 to 53.4% of NT, $p<0.001$) CoM velocity (Figure 3), without interaction effect between stance width and dive height. The ipsilateral leg contribution to horizontal CoM velocity has dropped significantly throughout the dive (from 0 to 99% of NT). This drop is more significant in length than the resulting improvement in contralateral contribution to horizontal CoM velocity (99% vs. 9.3%), manifested in greater negative contribution before and smaller positive contribution after contralateral peak force (Figure 3). Therefore, another reason for the lack of significant difference in horizontal CoM velocity toward the ball is because the improvement that was gained at the contralateral push-off when starting wider was lost at the ipsilateral push-off. This explains the absence of any effect from preparatory stance on dive time and CoM velocity. Female goalkeepers seem to be dependent on both push-offs, and the contralateral leg alone is not capable to generate enough push-off power that can overcome the drop of the ipsilateral contribution when starting from a wider stance width. In other studies, male goalkeepers did show an improvement in contralateral push-off power and CoM velocity that outlasted any decrease in performance at the ipsilateral push-off (Ibrahim et al., 2019b; 2022). This might be due to the difference in physical capacity between both genders (McMahon et al., 2017; Nuell et al., 2019). The small sample size could be a limitation to the study results. It is a common issue in research on elite athletes, and we recommend future studies to tackle this problem by relying on markerless motion tracking. The latter allows easy measurement in bulk of goalkeeper movements in their natural environment without any interference of sensors or markers.

CONCLUSION: Starting the dive from a wider preparatory stance did result in the expected technical changes in females (i.e., more reliance on the contralateral push-off, and better contralateral contribution to CoM velocity). However, in contrast to previous findings in male goalkeepers, it did not induce an increase in physical performance (i.e., CoM velocity, push-off power, and dive time). Future studies are recommended to perform direct comparisons between male and female goalkeepers, to unravel the limitations and the discrepancy in the biomechanics of the skill.

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