kinematic analysis of soccer goalkeeper's diving save in penalty: effect of instructional video and laterality on performance

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Abstract

Background: It is essential to develop effective instructional methods to improve the goalkeepers' diving kinematic performances. The present study aimed to analyze the effect of laterality and instructional video on the soccer goalkeepers' dive kinematics in penalty.
Methods: Eight goalkeepers belonging to youth categories (U15, U17 and U20) were randomly divided into control group (CG) and video instruction group (VG). The second performed 20 penalty defense trials on the field with balls thrown by a machine, ten before and after receiving a video instruction to improve the diving kinematics, while the CG only performed the dives. Three cameras recorded the collections. A markerless motion capture technique (OpenPose) was used for the identification of joints and anatomical references. The 2D data were used for 3D reconstruction through the direct linear transformation method. Side preference was collected through an inventory. Two-way ANOVA for repeated measures, common and the Statistical Parametric Mapping (SPM-1D) Student's t test for paired samples methods were applied for statistical analysis. The significance level was set at $p \leq 0.05$.
Results: In the post-instruction situation, the VG presented differences in comparison to the CG in the variables: knee flexion/extension angle, time to reach peak resultant velocity, frontal step distance, and frontal departure angle, which generated greater acceleration during the dive. Regarding laterality, it was found that attempts to the non-dominant leg side had higher resultant velocity during 88.4 – 100% of the diving cycle, different knee flexion/extension angle, and higher values in the frontal step distance.
Conclusion: The instructional video generated an acute change in the diving movement pattern of specialized young goalkeepers when comparing the control and the video instruction group in the post condition. This can be used in training sessions to improve the movement pattern of goalkeeper's dives.

Keywords: goalkeeper, soccer, penalty, biomechanics, kinematic.

1. Introduction

Penalty kick is considered the greatest clear chance of a goal from set play[1,2] as it is a duel only between the penalty kicker and the goalkeeper. Some people say it is a lottery, but science has proven that it is not. The goalkeeper and the penalty taker have factors that influences their performances and strategies that they can benefit from. A revision have pointed out important aspects that influences the players: coping with stressful situations, non-verbal behavior, motivational fit and anxiety[3]. Other factors were also highlighted by different studies: athlete's reputation [4], positioning[5,6], uniform color[7,8], goalkeeper and penalty taker straegies[9–11] and penalty kick direction[3,12.] All these factors influence the the two main actions in the penalty, the kick and the diving save.

The penalty kick kinematic has been studied in many ways, exploring the support leg[13,14], kicking techniques[15,16], approach angle[17], velocity and accuracy in different categories[18] and other factors[19]. But only a few studies focus on the goalkeepers' diving save kinematics. Research with elite goalkeepers concluded that the lower limb contralateral to the diving side has a greater contribution to the goalkeeper center of mass (CM) velocity and specifically the contralateral hip extensors[20–22]. They also did not find differences in performance between the diving sides. Other studies found some laterality effects on the diving kinematics. Lower center of mass (CM) velocity in the ball contact moment was found in dives to the non-dominant side in elite goalkeepers[23]. Greater horizontal and resultant CM displacement was found in dives for the non-dominant lower limb side in amateur and professional goalkeepers[24]. Other attested that the dives to the non-dominant side have greater variability between the performance of consecutive dives in relation to the dominant side but this research used only one voluntary[25].

However, it is worth mentioning that all these diving kinematic researches were carried out in laboratories and only one without stationary balls [21], so field studies need to be developed to verify if the findings reflect in situations closer to those that occur in the game. The use of markless methods for kinematic analysis can make it possible. An example is the OpenPose, a human pose detection library that allows the identification of joints and anatomical points in videos through skeleton detection algorithms, becoming unnecessary the use of artificial markers and providing an accessible and reproducible way for kinematic analysis [26–29]. The use of this type of resource allows data collections in the field and without markers, which is promising and innovative as it allows tasks to be done in the most natural way possible, giving greater ecological validity to the experiment.

The methods to improve the goalkeeper's kinematic dive in penalty are still not yet clear in the literature. A study applied a combined technical and physical 12 weeks training and improved the CoM horizontal velocity and power at the contralateral push-off in the penalty, an increase in the push off feet preparatory stance width and a decrease in the diving time. The technical training was the distance between the feet in the dive preparatory posture adjustment to 75% of the leg length using a personalized stick for the goalkeepers' feet positioning[22]. Studies point to the effect of different instructions on motor skills performance training. Several research about attentional focus instructions on sports showed that the ones with external focus (i.e., body effect on the environment) leaded to better performance improvement when compared to an internal focus group (i.e., own body) or control group. The external instruction benefit has been reported in golf [30,31], basketball [32], dart throwing [33,34], volleyball and soccer [35].

The use of video instructions has already been explored too. Studies comparing oral and video instructions showed that the second is as efficient or better in many sport tasks, as: throwing [36], golf [37], discus, hammer [38], tennis[39] and landing tasks[40]. Some authors also suggested the creation of specific audiovisual materials for learning different motor skills[40]. However, despite the various evidence regarding the benefit of video instructions the literature still lacks studies that analyze the effect of an instructional video on soccer goalkeeper diving performance.

Therefore, the present study aimed to analyze the effect of laterality and video instruction in the diving kinematics of soccer goalkeepers in penalty. The initial hypothesis was that after watching a diving save video instruction the goalkeepers would improve diving performance which would appear in the diving kinematics variables analyzed, and that the dives to the non-dominant lower limb side (NDLL) would present better diving performance when compared with the dominant lower limb side (DLL) trials.

2. Methods

2.1. *Participants*

Eight soccer goalkeepers belonging to the youth categories (U15, U17 and U20) of a club that plays at the A2 series of the São Paulo state championship participated in this study. Participants were randomly divided into a control group (CG) (n = 4; age = 16.9 ± 2.4 years old; mass = 75.9 ± 10.4 kg; height = 1.77 ± 0.09 m; training experience in the position = 6.8 ± 1.9 years; training routine = 5 ± 2 days a week) and video group (VG) (n = 4; age = 16.4 ± 2 years; mass = 84.5 ± 11.2 kg; height = 1.88 ± 0.09 m; training experience in the position = 5.8 ± 4.9 years, training routine = 5 ± 2 days a week). Both groups had 3 righ-footed players and 1 left-footed.

Studies involving goalkeeper diving kinematic analysis tend to have a low number of participants due to the comparatively lower number of athletes playing in this postion20–25,41–43. The School of Physical Education and Sport of Ribeirão Preto Ethics Committee approved all the experimental procedures (CAAE: 24268719.0.0000.5659). Written consent was obtained from the participants and their legal guardian(s).

2.2. Instruments

For data collection, 3 cameras (GoPro HERO 3+ Black Edition) were set at an acquisition frequency of 120 Hz. A camera was placed in front of the goal and the other two arranged on different sides with a diagonal view, all pointing towards the center of the goal (Figure 1). The cameras synchronization was achieved through the GoPro Hero 3+ remote control. In order to identify the volunteer's lateral preference, the Global Lateral Preference Inventory (IPLAG)[44] was used. A notebook played the instructional video for the goalkeepers.

For the soccer kick representation, a soccer ball launcher machine was placed in the penalty mark and a cloth to obstruct the goalkeeper's view of the side where the ball would be thrown were used[43] (Figure 1). This machine was used in order to standardize the ball launch speed and location. Official size balls proposed by the Brazilian Football Confederation[45], with diameter between 68 and 70 cm were used. Despite the adjustments and modifications made by the researchers, the ball launcher machine was not in perfect condition on the collection day, which harmed the ball launching location in some trials that had to be discarded.

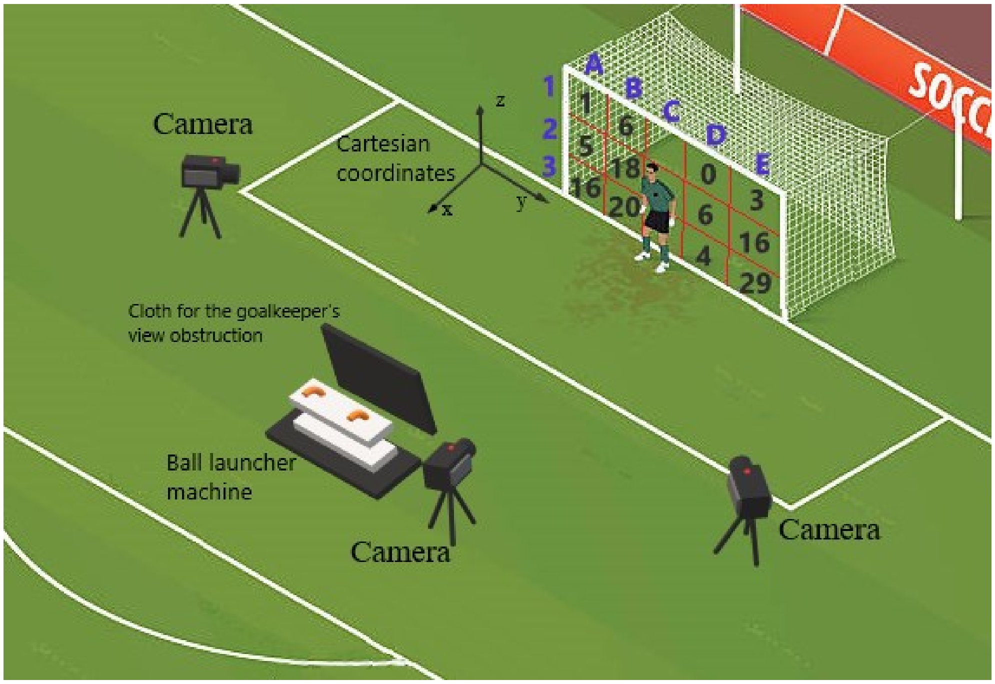

Figure 1. The data collection experimental setup. References of the camera positioning, ball launcher machine, cloth for goalkeeper's view obstruction and cartesian coordinates. Goal divided into 15 quadrants with the number of balls launched in each one.

2.3. Instructional video

A 6 minutes and 20 seconds video containing instructions in order to improve the diving movement pattern of soccer goalkeepers at the penalty was elaborated in an oral Power Point format presentation with language accessible to goalkeepers. Two kind of instructions were used: explicit (with internal and external focus) and by analogy[46–48]. The instructions were written on the slides and accompanied by images, videos, and oral explanation. At the end of the video, a summary was made so that the goalkeepers could remember all the instructions passed. To prepare the instructional video, references from the literature that explored the goalkeeper's diving kinematics on penalty kicks and stretching-shortening cycles of the muscles were used [20,21,23,25,43,49–51], in addition to consultation with biomechanics specialists and goalkeeping coaches.

The tips in the instructional video were: (1) on the support base for the dive keep the feet apart at a distance corresponding to 75% of the leg length (this value was calculated for each VG athlete and they were placed in the suggested position for them to get used to it); (2) use the frontal step with the leg ipsilateral to the dive side at the impulsion moment; (3) seek to reach the highest speed in the shortest possible time; (4) use the muscle elastic component (rapid stretch-shortening cycle) and the arms on the impulse; (5) dive with a front departure angle of 18° (to cover the smallest distance between the center of the goal and the ball trajectory to the goal corners).

2.4. Experimental procedures

The data was collected at the goalkeepers' training site. Initially the cameras, ball launcher and cloth for goalkeeper's vision obstruction was positioned in a standardized setup (Figure 1). In sequence, the volunteers answered to the IPLAG to identify the lower limbs lateral preference. Before starting the dives execution, the goalkeepers realized a 5-10 minutes warm-up structured for the muscles to reach an optimal state for the collection task demand[52]. The final part of the warm-up was the execution of two jumps to the right and two to the left, to familiarize the goalkeeper with the penalty save dynamics with balls launched. For data collection, the goalkeeper was instructed to stay at the center of the goal, facing away from the penalty mark while the ball launcher machine was directed to the side the goalkeeper should jump. Then the goalkeepers were instructed to turn facing the penalty mark and advised that the collection had started and the ball would be launched.

Participants were instructed to perform the dive with maximum impulsion regardless of where the ball is released and were advised that the number of defenses made was not the focus of the study. The final distribution of the balls launch sites in the validated dives are presented in Figure 1. It is worth mentioning that several dives in region B and D were discarded because the ball launch harmed the goalkeepers' impulsion biomechanics. Those who were kept had the balls thrown close to quadrants A and E. In relation to quadrant 1, there were also dives discarded when goalkeepers showed a vertical movement pattern inadequate for the analysis pretended and those who were kept had the ball thrown near quadrant 2. The final height that the balls were launched was close to a normal penalty distribution being respectively: lower third 55.64% and 56.6%, middle 36,29% and 30,4%, and upper third 8.06% and 12.9% (Figure 1) [9].

The VG performed a total of 20 dives, 10 before (VGPRE) and 10 after the video instruction (VGPOST). Totalizing 10 right dives, 5 before and 5 after the instructional video and 10 for the left side with the same number of trials in each condition. The diving execution side order was chosen randomly to not influence the final result. The recovery time between attempts was equal or greater than 90 seconds. During the instructional video execution, VG participants were able to clear any doubts with the researchers and they could perform 2 dives to each side for the instructions given adaptation. The CG performed the same procedures as the VG, however, at the moment that the instructional video would be shown the volunteers had a rest period equivalent to the video's runtime, without receiving any kind of instruction or feedback. In other words, they performed the 10 initial dives (CGPRE), rested and performed another block of 10 trials (CGPOST).

2.5. Data processing

The lower limbs lateral preference was collected by IPLAG. It provides a numerical scale in which: 1 = strongly left-footed; 2 = moderate left-footed; 3 = ambidextrous or without preference; 4 = moderate right-footed; 5 = strongly right-footed. However, to separate the trials between the dominant lower limb side (DLL) and non-dominant lower limb side (NDLL) the volunteers classified as 1 and 2 were grouped in left-footed and the ones classified as 4 and 5 formed the right-footed group. No one was classified in category 3.

For kinematic analysis, the OpenPose, was used. It allows the identification of joints and anatomical points in videos through skeleton detection algorithms (Figure 2). All data were reviewed and when the 2D coordinate obtained by OpenPose was missing from the goalkeeper's body it was manually corrected in the software Dvideow (v. 1.0.0.1). Subsequently, the data were smoothed with a fourth-order digital Butterworth (low-pass) filter with cutoff frequency set on 7 Hz obtained by residue analysis[53]. Finally, the coordinates 2D were transformed into 3D global coordinates using the 3D-DLT method (direct linear transformation) in Python3. The 3D reconstruction was performed with the videos of only two cameras, preferably the two lateral ones. The central camera was used for the reconstructions in the cases when the lateral ones presented error and for the annotation of the quadrants that the ball crossed the goal line.

The calibration was performed using eleven points of the soccer goal corners and the error was calculated by reconstructing the own goal. The error for each axis was: X (anteroposterior) = 0.054 m, Y (mediolateral) = 0.015 m and Z (vertical) = 0.017 m. The anatomical references obtained through OpenPose aimed the delimitation of 14 body segments: head, trunk, arms, forearms, hands, thighs, legs and feet. For this, 25 anatomical references were identified as shown in Figure 2.

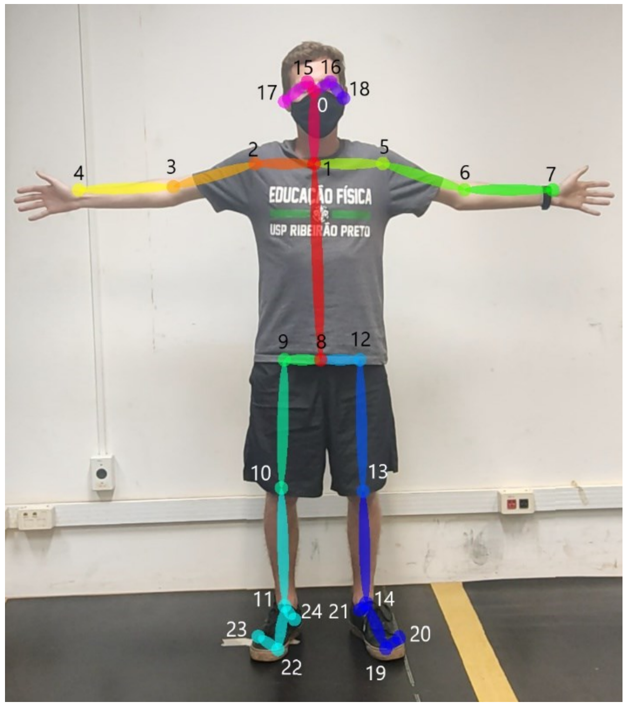

Figure 2. Identification of joints and anatomical points by the artificial neural network OpenPose.

The CM calculation was performed according to the segmental method[54,55]. The volunteers' mass and height measurements together with the 3D global anatomical references coordinate data were used to obtain the mass and center of mass of each body segment, using standardized anthropometric parameters[56]. For analysis, goalkeeper dives were normalized in the time series (0-100%), with the beginning at the moment when the foot ipsilateral to the diving side leaves the ground for the first time and ending at the moment when the CM reaches the resulting peak velocity generated by the impulse. The calculation of the interested variables was performed in Python 3 as follows:

- Peak resultant velocity (PRV) = it was identified the highest value of CM velocity in the time series from the beginning of the dive until the last contact of the leg ipsilateral to the dive side with the ground plus 6 frames. The 6 frames were adopted so that there was no influence from the fall gravity acceleration in the center of mass velocity, which wouldn't correspond to the impulse generated by the goalkeeper which is the study focus. The PRV was used to determine the end of the diving time series.
- Knee flexion/extension angle = it was calculated by the relative angle between the tight and shank segments[57], formed by the points: hip (9 or 12), knee (10 or 13) and ankle (11 or 14) (Figure 2).

- Time to reach peak resultant velocity (TRPRV) = it was calculated through the absolute time between the moment that the lower limb ipsilateral to the dive side leaves the ground the first time and the moment the goalkeeper reaches the peak resultant velocity.
- Frontal step distance (FSD) = it was calculated only on the anteroposterior axis through the difference of the point representing the big toe (19 and 22) (Figure 2) between the first and the last moment the ipsilateral foot leaves the ground.
- Distance between the legs in the preparatory posture (DBLPP) = for this calculation it is necessary to know the leg size of the athletes. It was calculated using the points hip (9 or 12), knee (10 or 13) and ankle (11 or 14). The points of the ankle had their vertical axis extrapolated to the heel point value (21 or 24) to represent the closest point to the ground and greater fidelity to the size of the goalkeeper's leg. Then, the distance between the heels' points (21 and 24) was measured to infer the distance of the legs in the preparatory posture in the first moment that the foot ipsilateral to the dive side made its last contact with the ground. Finally, a relationship was performed between the legs distance in the preparatory posture and leg size and multiplied by 100 to convert to percentage.
- Frontal departure angle (FDA) = it was calculated the angle formed by the center of mass at the first and last moment of contact of the ipsilateral leg to the ground.

A total of 154 dives were processed, and 30 were discarded, leaving 124 validated. Attempts were discarded due to the ball launch location not being ideal for the goalkeepers to perform the dives correctly. Two discarding situations prevailed: (1) when the ball was launched too close to the center of the goal; (2) when the ball was thrown too high, which modifies the goalkeeper's diving movement pattern [20]. All subjects had the same number of validated trials in their pre and post situations. That is, if the participant had 4 valid trials in the pre situation for the DLL side he would have the same amount in the post situation for this same side.

2.6. Statistical analysis

Shapiro-Wilk, Levene and Mauchly tests were performed to identify normality, homogeneity and sphericity of the data, respectively. The results were described in mean and standard deviation, the analyses were performed using a two-way ANOVA for repeated measures, and a Bonferroni post-hoc test. The independent variables were the CG and the VG and the pre and post situations, the dependent ones were the values obtained in the variables concerning the instructional video effect. Paired Student's t test was used to indicate whether there was a difference between the dives to the DLL and NDLL sides. Cohen's d was used to report the effect size of the presented variables (0.2 small, 0.5 medium, > 0.8 large).

Temporal graphs were used to present the resulting velocity and the knee flexion/extension angle. Student's t test for paired samples using the method Statistical Parametric Mapping (SPM) indicated whether there were differences between the pre and post situations in both groups, between the CG and VG in both situations and in relation to the dive sides. This method of statistical analysis makes it possible to identify when in the time series the differences occur and has been used previously for biomechanical analysis [58,59]. In all cases the significance level was $p \leq 0.05$ and the analyzes were conducted in Python 3 and SPSS (v.21.0, IBM Statistics).

3. Results

No significant difference was found in the goalkeepers resulting center of mass velocity normalized in the time series, both in the comparison of pre and post situations of the CG ($p > 0.05$; $t = 2.84$) and VG ($p > 0.05$; $t = 2.77$) (Figure 3) and in the comparison between CG and VG in pre ($p > 0.05$; $t = 2.78$) and post ($p > 0.05$; $t = 2.73$) situations.

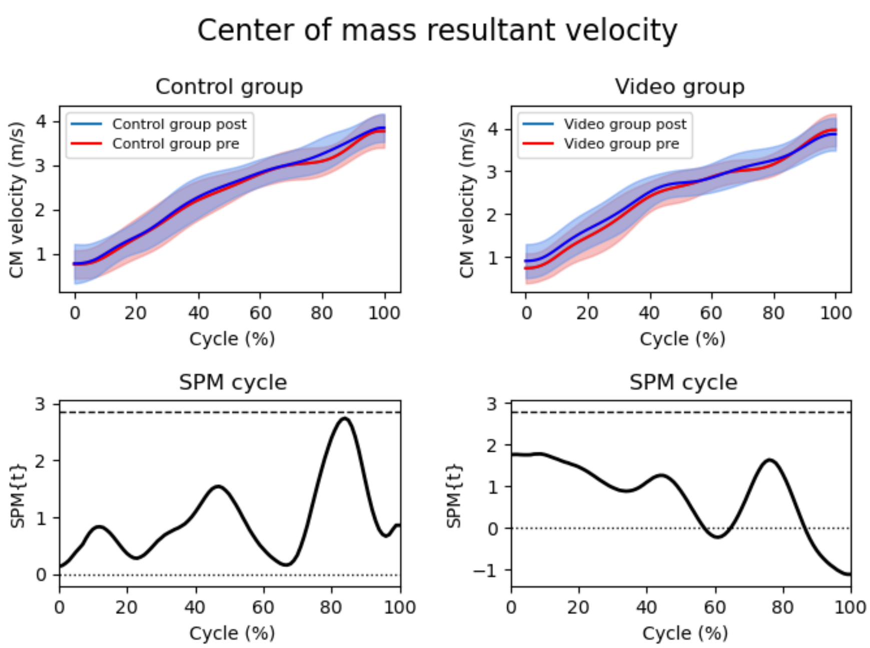

Figure 3. Center of mass resultant velocity between pre and post intervention situations (top) and SPM cycle (bottom) normalized in the time series (0-100%). The upper graphs represent the mean and standard deviation (shaded area) of the center of mass velocity, while the lower graphs represent the SPMt. The shaded area in the lower graphs indicates significance ($p < 0.05$). SPM = Statistical Parametric Mapping; SPM{t} = t value along the diving cycle; CM = center of mass.

Regarding the knee flexion/extension angle ipsilateral to the dive side, there was also no significant difference found between the pre and post situations in the CG ($p > 0.05$; t = 2.72) and VG ($p > 0.05$; t = 2.71) and in the comparison CG and VG in the pre situation ($p > 0.05$; t = 2.69). Although, the VG presented a greater knee flexion/extension angle in relation to the CG in the post intervention situation during 55.3% - 75% of the diving impulse cycle (p = 0.008; t = 2.69) (Figure 4).

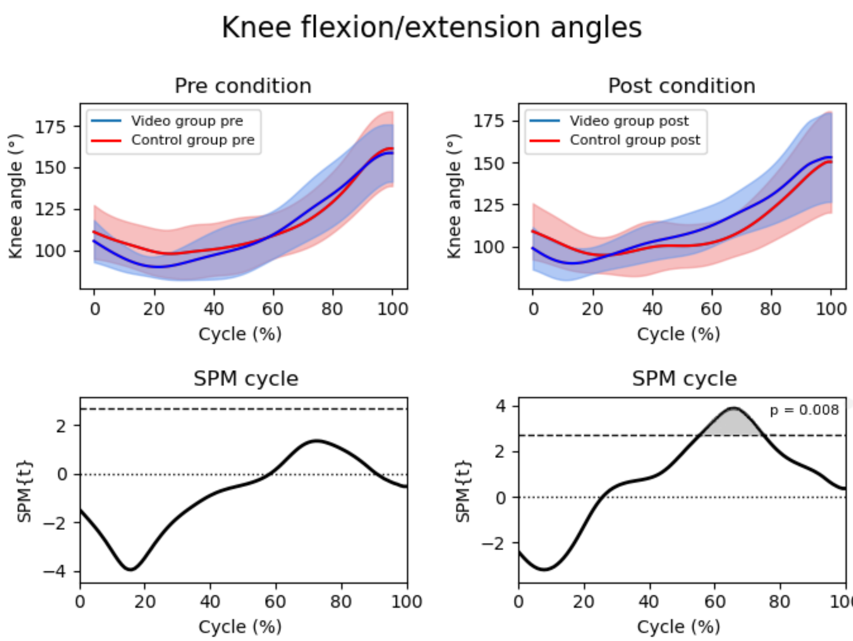

Figure 4. Flexion/extension angle of the knee ipsilateral to the diving side between the control and video groups in the pre and post intervention situations (top) and SPM cycle (bottom) normalized in the time series (0-100%). The upper graphs represent the mean and standard deviation (shaded area) of the knee ipsilateral to the diving side flexion/extension angle, while the lower graphs represent the SPMt. The shaded area in lower graphs indicate significance ($p < 0.05$). SPM = Statistical Parametric Mapping; SPM{t} = t value along the diving cycle.

The two-way ANOVA for repeated measures showed that the VG, in the post situation, obtained higher values when compared to the CG in the same situation in the variables FSD ($p = 0.008$, $d = 0.75$) and FDA ($p = 0.035$, $d = 0.56$) and minor values in TRPRV ($p = 0.01$, $d = 0.69$). In the other comparisons (CGPRE x CGPOST, CGPRE x VGPRE, VGPRE x VGPOST) no significant difference was found between the variables: TRPRV, FSD, DBLPP and FDA ($p > 0.05$) (Table 1). It is worth noting that the CG's FSD in the post situation did not pass the normality test ($p = 0.018$) due to an outlier that, if replaced by the median would show normality ($p = 0.194$) and would continue to show significant difference compared to VG.

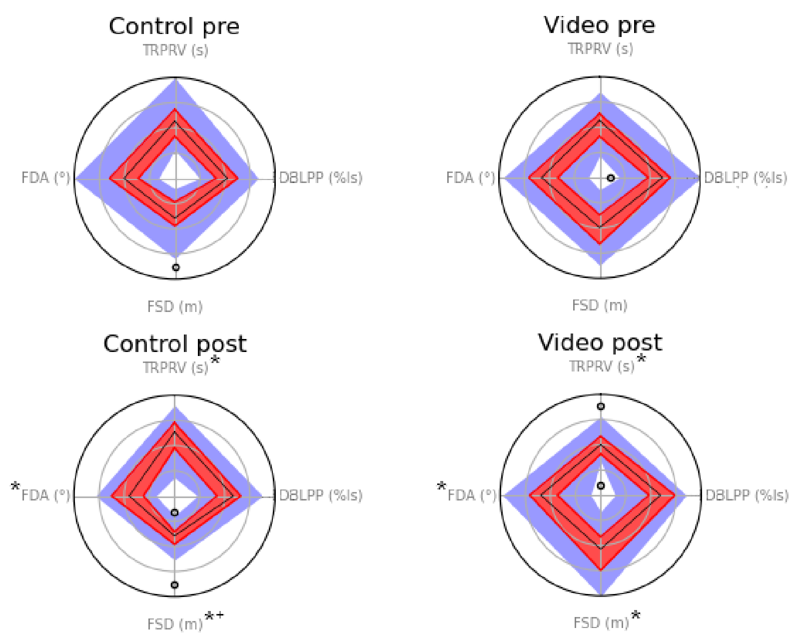

Figure 5. Radarboxplot of the variables collected to verify the instructional video effect on the dives. The inner red region represents the 25-75% percentiles of each variable. The blue area represents the total range. The outliers appears as circles. TRPRV = time to reach peak resultant velocity; DBLPP = distance between the legs in the preparatory posture; FSD = frontal step distance; FDA = frontal departure angle; s = seconds; m = meters; %ls = leg size percentage; ° = degrees; * $p<0.05$. Two-way ANOVA for repeated measures; + did not pass the normality test.

Table 1. Mean and standard deviation of the variables collected to verify the instructional video effect on the dives.

Variables	Control group		Video group	
	Pre	Post	Pre	Post
Time to reach the peak resultant velocity (s)	0.544 ± 0.085	0.572 ± 0.085*	0.535 ± 0.08	0.517 ± 0.075*
Frontal step distance (m)	0.313 ± 0.21	0.336 ± 0.15*+	0.426 ± 0.21	0.49 ± 0.247*
Distance between the legs in the preparatory posture (%ls)	0.728 ± 0.14	0.754 ± 0.144	0.784 ± 0.162	0.799 ± 0.145
Frontal departure angle (°)	13.71 ± 6.706	12.064 ± 6.102*	15.037 ± 6.973	15.708 ± 6.791*

s = seconds; m = meters; %ls = leg size percentage; ° = degrees; * $p<0.05$. Two-way ANOVA for repeated measures; + did not pass the normality test.

Regarding the laterality effect, higher values of CM velocity were found in attempts to the NDLL side during 88.4 – 100% of the diving cycle ($p = 0.018$, $t = 2.68$). Attempts for the NDLL side also showed greater knee flexion/extension angles during 41.3% - 62.6% of the diving cycle ($p = 0.005$; $t = 2.61$) (Figure 6). Student's t test for paired samples indicated that the dives to the NDLL side obtained higher values in the FSD ($p = 0.009$, $d = 0.45$) when compared to the dives to the DLL side.

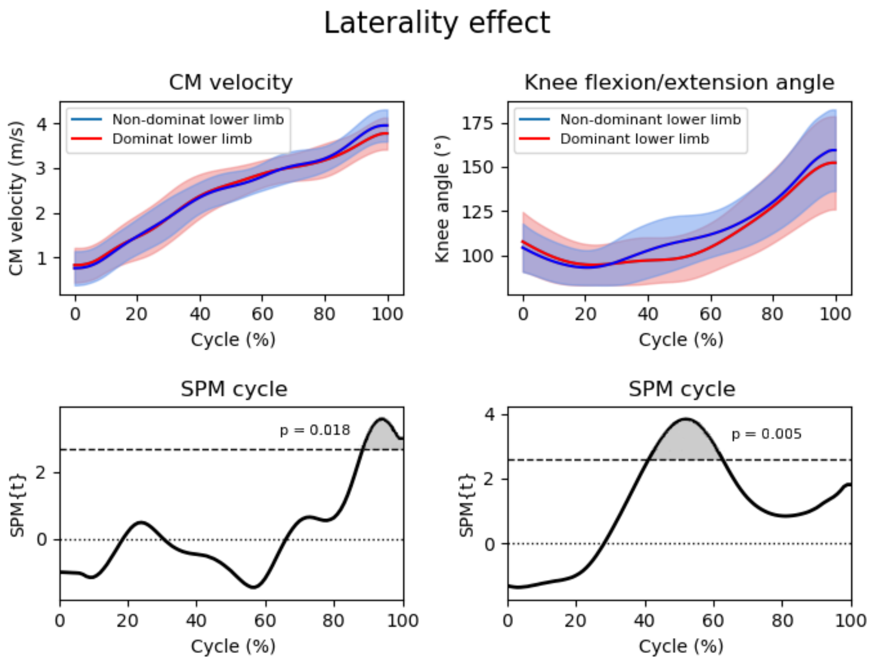

Figure 6. Center of mass resultant velocity and flexion/extension angle of the knee ipsilateral to the diving side between attempts to dominant and non-dominant leg side (top) and SPM cycle (bottom) normalized in the time series (0-100%). The upper graphs represent the mean and standard deviation (shaded area) of the center of mass resultant velocity and the flexion/extension angle of the knee ipsilateral to the diving side, while the lower graphs represent the SPMt. The shaded area in the lower graphs indicates significance ($p < 0.05$). SPM = Statistical Parametric Mapping; SPM{t} = t value along the diving cycle; CM = center of mass.

Table 2. Mean and standard deviation of the variables analyzed in the dives to the side of the dominant and non-dominant lower limb.

Variables	Dominant lower limb	Non-dominant lower limb	*P* value
Time to reach the peak resultant velocity (s)	0.538 ± 0.08	0.546 ± 0.086	0.583
Frontal step distance (m)	0.343 ± 0.181	0.439±0.239	0.009*
Frontal departure angle (º)	12.998 ± 6.686	15.262 ± 6.607	0.051

s = seconds; m = meters; º = degrees; * p<0.05. Student's paired t test.

4. Discussion

The present study objectives were: (1) to compare the diving kinematic performance of soccer goalkeepers at the penalty moment before and after watching an instructional video that contained tips for improving the diving movement pattern, and (2) to verify the effect of laterality on this phenomenon. Although the resulting velocity did not show a significant difference between the different conditions and groups, interesting results were found regarding the instructional video effect on the VG movement pattern in relation to the CG in the post condition.

The VG presented lower TRPRV than the CG only in the post situation. Considering that there was no difference between the resulting velocity reached by the two groups, it can be concluded that the VG reached the same velocity in less time, that is, it obtained a greater acceleration than the CG, which can help the goalkeepers to reach the goals corners faster and possibly increase their chance of making a defense[41]. It is worth noting that the VG had a decrease in the TRPRV from the pre to the post situation, while in the CG there was an increase. This may have been caused by fatigue and the instructional video played an important role in improving the VG diving movement pattern in the post situation, making them present lower TRPRV than the CG.

The differences in the movement pattern between the CG and VG in the post situation could be noticed by observing the different values presented in the variables: angle of knee flexion/extension normalized in the time series, FSD and FDA. It is worth noting that the instructional video had tips for: (1) Use of elastic force in impulsion; (2) use the frontal step in the dive and (3) adopt a frontal departure angle as close as possible to 18º. Therefore, the instructional video acute use changed the VG goalkeepers' movement pattern in the post situation when compared to the CG.

The difference in knee flexion/extension angle demonstrates that the VG presented greater elastic force use in the diving impulse. It can be noted by the normalized time series analysis (Figure 4) that the VG in the post situation realized the knee flexion and extension before the CG that remained with the knee flexed for more time, taking longer to perform the extension and consequently losing part of the elastic energy of the quick movement down (knee flexion) and up (knee extension). The elastic force generated by the quick shortening-lengthening muscle cycle is an important factor for strength development[49,50] and contributed to the VG to present lower values of TRPRV and consequently higher values of acceleration. Another instruction in the video was about DBLPP, no difference was noticed between the groups and conditions. However, it is worth noting that the instructional video tip was to the goalkeepers to spread the legs in a distance as close as possible to 75% of their leg size [51] and they already had a preparatory posture with values close to this in both the CG and VG in pre and post situations (Table 1).

Regarding the laterality effect, the present study demonstrated that the dives to the NDLL side obtained greater resultant velocity during 88.4 – 100% of the diving cycle. This happened due to the better use of elastic force when compared to the DLL side dives. It can be noticed by the similar knee flexion/extension angle behavior difference that occurred between the CG and VG in the post situation (Figures 4 and 6). In addition, FSD may also have contributed to this higher velocity generation[24] (Table 2).

The authors suggest that the goalkeepers that participated in this study may have a stronger DLL when compared to the NDLL and this could be another factor that helps explaining the greater velocity values in the trials to the NDLL side. That would happen because the lower limb contralateral to the dive side contributes more than the ipsilateral to the velocity obtained by the CM [20]. The velocity results obtained differ from others studies that obtained greater values in the dives to the DLL side[23] and no differences between the velocities obtained in the dives to both sides[20,25]. However, it is important to highlight that all of these studies were carried out in a laboratory and with static balls, while the present study was carried out in the field with balls in movement, which provides greater ecological validity to the results obtained.

The present study's main limitation was the fact that the ball launching machine was not in perfect condition on the collection day. It made some balls to be thrown in places that harmed the goalkeepers' dive causing the discard of 30 trials. In addition, in the current study only the acute effect of the instructional video was tested, future researches should be done to verify if there is retention of the new movement pattern performed by the athletes. The low number of participants is also a limitation but it is in accordance with other goalkeeper diving save studies. The authors believe that the current study opens doors for future researches because it demonstrated that it is possible to: (1) perform kinematic analysis without the need for attached markers to the athletes' body, (2) carry out all the collection in the field for greater ecological validity and (3) use balls in movement for kinematic analysis of goalkeepers diving saves.

Despite the study limitations, kinematic analysis proved to be an important tool to understand the goalkeepers’ diving save, indicating where are the athletes' advantages, deficiencies and limitations in their diving movement pattern are and examining these in relation to laterality. The video instruction can be an important tool to make refinements in specialized and experienced goalkeepers movement pattern and be used alongside with strength and power training methods based on the recent findings in goalkeeper diving save kinetics and kinematics to improve the athlete's performance[22]. The diving acceleration improvement can give the goalkeepers more time to decide which side to dive, permitting them to collect more information about the penalty taker kicking movement technique improving their chance to anticipate correctly[60–63]. All of this can contribute to increase the success rate in penalty save attempts.

5. Conclusion

This study demonstrated that the instructional video was effective in generating an acute change in the diving movement pattern of specialized young goalkeepers in the groups' comparison. In the post situation the video instruction group showed a difference concerning the control group in the variables: knee flexion/extension angle, time to reach peak resultant velocity, frontal step distance and frontal departure angle which generated a greater acceleration in the dive. In relation to laterality, it was found that attempts to the non-dominant lower limb side showed greater resultant velocity during 88.4 – 100% of the diving cycle, different patterns in the knee flexion/extension angle and higher values in the frontal step distance.

6. Contributions

Contributed to conception and design: RLMM, PRPS
Contributed to acquisition of data: RLMM
Contributed to analysis and interpretation of data: RLMM, PRPS
Drafted and/or revised the article: RLMM, CCAS, PB, DL, TGR, AKT, AGC, PRPS
Approved the submitted version for publication: RLMM, CCAS, PB, DL, TGR, AKT, AGC, PRPS

7. Data and Supplementary Material Accessibility

The datasets generated in the current study, the code for the data analysis and the instructional video, the original and with English subtitles, are available on:

https://github.com/rafaellmmonteiro/FAPESP_2020-14845-6-Instructional_video_goalkeeper (As on april. 2023).

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