

## Posture-reading by men's football goalkeepers and other factors in saving penalty kicks

### Leitura pelo goleiro da postura do cobrador de pênaltis no futebol masculino e outros fatores na defesa

Lectura por el golero de la postura del ejecutante de penales en el fútbol masculino y otros factores en la atajada

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#### Keywords:

Soccer;  
Training programme;  
Goalkeeper;

#### ABSTRACT

Penalty kicks are often decisive in football matches. Therefore, any technique that yields an advantage either in scoring or saving them is of great importance. Here we show the influence of a training programme for goalkeepers on the probability of defending penalties in men's football. Virtual training was used through an app that shows the shooter at the moment of setting the support foot on the ground and requiring the answer of which side (right or left) the ball will be directed at. Complemented with physical training, four sub 21 professional goalkeepers from Santarém, Brazil, developed the ability to correctly choose the side (left or right) at which the ball will be aimed. Sets of 800 penalties were kicked before (acting as control group) and after the training programme and it was found that, after training, the chances of saving penalty kicks or, at least, choosing the correct side, increase dramatically. It is concluded that the training programme improved the goalkeeper's ability to choose the correct side. Other factors (laterality and height) were not found to be statistically significant.

#### Palavras-chave:

Futebol;  
Cobrança de pênalti;  
Goleiro;  
Software para treino

#### RESUMO

Os pênaltis são frequentemente decisivos em partidas de futebol. Portanto, qualquer técnica que produza uma vantagem tanto para marcar como para salvá-los é de grande importância. Aqui mostramos a influência de um programa de treinamento de goleiros na probabilidade de defesa de pênaltis no futebol masculino. O treinamento virtual foi utilizado por meio de um aplicativo que mostra o chutador no momento de colocar o pé de apoio no solo e exigir a resposta de qual lado (direito ou esquerdo) a bola será direcionada. Complementado com treinamento físico, quatro goleiros profissionais sub 21 de Santarém, Brasil, desenvolveram a habilidade de escolher corretamente o lado (esquerdo ou direito) para o qual a bola seria direcionada. Conjuntos de 800 pênaltis foram chutados antes (agindo como um grupo de controle) e depois do programa de treinamento e verificou-se que, após o treino, as chances de salvar pênaltis ou, pelo menos, de escolher o lado correto aumentam drasticamente. Conclui-se que o programa de treinamento melhorou a habilidade do goleiro em escolher o lado correto. Outros fatores (lateralidade e estatura) não mostraram ser estatisticamente significativos.

#### Palabras clave:

Fútbol;  
Software de  
entrenamiento;  
Golero;  
Arquero;  
Portero

#### RESUMEN

Los tiros penales suelen ser decisivos en los partidos de fútbol. Por lo tanto, cualquier técnica que proporcione una ventaja, ya sea para anotar o para atajarlos, es de gran importancia. Aquí mostramos la influencia de un programa de entrenamiento para góleros sobre la probabilidad de atajar los penaltis en el fútbol masculino. Se utilizó entrenamiento virtual a través de una aplicación que muestra al tirador en el momento de poner el pie de apoyo en el suelo y que requiere la respuesta de hacia qué lado (derecho o izquierdo) se dirigirá el balón. Complementado con entrenamiento físico, cuatro góleros profesionales sub 21 de Santarém, Brasil, desarrollaron la capacidad de elegir correctamente el lado (izquierdo o derecho) al que se dirigiría el balón. Se lanzaron series de 800 penales antes (actuando

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como un grupo de control) y después del programa de entrenamiento y se encontró que, después del entrenamiento, las posibilidades de atajarlos o, al menos, elegir el lado correcto, aumentan drásticamente. Se concluye que el programa de entrenamiento mejoró la capacidad del golero para elegir el lado correcto. Otros factores (lateralidad y estatura) no mostraron ser estadísticamente significativos.

## INTRODUCTION

Football association (soccer in some English-speaking countries) is undisputedly the most popular of sports and has become a subject of scientific research in the last decades (Reilly et al., 1988, and Harvey, 2005). The game is peculiar in using feet instead of hands. Its collective nature renders skill less important than in other disciplines, often replaced by right decisions of the players and spatial intelligence (Leite and Guerra, 2004). However, biomechanics and science of movement in general (Kuhn, 1988; Belda Maruenda, 2009) are useful in a situation with controlled variables and more depending on technique: the penalty kick (Memmert et al., 2013). In this dramatic, face-to-face duel by only one player of each opposing team (shooter and goalkeeper), strict rules must be heeded (Arruda, 2013): the goalkeeper can move sideways but without leaving the goal line, the shooter must kick the ball in a forward direction towards the goal and cannot touch it again until another player does.

Since it is scored in 82% of the cases (FIFA, 2017), this is often a decisive event. Several factors affect its outcome, like the region of the goal the shot is aimed at (Fariña et al., 2013), the moment of the match (Almeida et al., 2016) and which major league is observed (Jamil et al., 2020). Moreover, many championships, including 4 out of 16 matches in the knockout stage of the last World Cup, decide draws through the shooting of penalty kicks following the FIFA rule.

Thus, decision making is paramount: behaviours of the two players involved as adopting an ecological dynamics perspective (Lopes et al. 2008). Also, the respective strategies are a typical example of escalation in evolutionary game theory (Shubik, 1971), in which the delay in making the decision allows the anticipation of the opponent's action (Wilson et al., 2018).

Furthermore, a cause-effect relationship is here proposed (Carvalho et al., 2013): if biomechanics can help the goalkeeper in interpreting the shooter's posture and the diving can be performed in time and to the correct side (right or left) the ball is kicked at, the skill needed to optimise performance can be learnt (Carvalho et al., 2013; Izzo et al., 2019) using a specifically created software (Morya et al., 2005; White et al., 2020).

The software is based on usual principles of visual perception training (McGuckian et al., 2018): if the goalkeeper, when the support foot of the shooter is on the ground, can acquire the capability of reading the inclination of the trunk (which coincides with the side the ball will be aimed at) and dive to that side within 0.5 seconds, the chances of saving are improved.

Other factors of potential importance will be assessed too. For instance, laterality is likely relevant in training (Stöckel & Carey, 2016) since the goalkeeper's movement involves moving to the side as fast as possible: reaction times of right and left hands in individual sports are influenced by laterality (Badau et al., 2019). Diving to the side of the preferred limb is significantly faster than to the other side (Rebello-Gonçalves et al., 2016).

Among other anthropometric and physiological variables (Ziv & Lidor, 2011), the height of the goalkeeper (usually the tallest of football players; Leão et al., 2019), might also be important for enhancing performance at saving penalty kicks (Müller et al., 2018) - it seems likely that a taller person can reach more distant areas of the goal, as in the classic argument of Hill (1950).

Incidentally, well-reputed goalkeepers are thought to be taller by penalty kickers (Müller et al. 2018) but reputation was not considered here because our subjects were rather in the beginning of their careers (see Material and Methods). Also, the goalkeepers' position (i.e., slightly to one side from the centre of the goal) was not included as a variable, despite its demonstrated importance (Noël et al., 2015; Wood & Wilson 2011). Hence, our results are valid when goalkeepers stand in the very centre of the goal in penalty kicks.

## MATERIAL AND METHODS

The research was experimental, exploratory, descriptive and explanatory of a quantitative nature.

Three goalkeepers and two other players from the reserve team of the São Francisco Esporte Clube (SFEC, a professional club that participates in the under-20 championship of the Pará State) were observed in the field of the Associação de Funcionários do Instituto Brasileiro do Meio Ambiente (ASSIBAMA), Santarém, Brazil.

Following Bar-Eli and Azar (2009), the goal of official dimensions was divided in 15 regions (Figure 1) that were printed in a fabric adjusted to the goal using hooks. The players dressed in uniforms with visible marks on shoulders, elbows, wrists, hips, knees and ankles.

Using 4 official Penalty™ footballs, 960 penalties were kicked once a week from February to April 2014 in two 30-minute sessions per week of 40 shots after the usual training of the SFEC. Experiments, i.e., penalty kicks following the rules, were filmed with three previously calibrated and prepared cameras (Samsung digital camcorder SC MX 10A NTC, digital camera Samsung HZW, Nikon Coolpix Full HD Movie).

The movements of the players were decomposed with the software Kinovea. In frame-by-frame analyses of the players' movements, distance, time and angle of the shot as well as the direction of the ball were measured. The instant in which the kickers impacted the ball and the goalkeepers started their reaction movements were recorded.

The second phase of the experiment included two sessions per week of five 10-penalties series for each of the professional first division goalkeepers from São Raimundo and São Francisco teams in the Barbalhão and the Panterão stadiums in Santarém. As a complement of the observations on movements, those experienced goalkeepers were asked about the strategy used for saving penalties for enhancing the development of the training programme. Their opinions about the programme were also recorded.

In the third phase, goalkeepers were trained with the programme developed that included the use of computer simulations showing the view of a kicker about to shoot and the request of answering whether a dive to the left or to the right was needed (Tubino, 1984; Weineck, 2004; Orloff et al., 2008; Bompa and Buzzichelli,



**Figure 1.** Beginning of the run towards the ball in a penalty kick. The goal area is divided as in Bar-Eli & Azar (2009).

2015). Then, a new series of 800 penalties was kicked in the previously described order and arrangement.

## STATISTICAL ANALYSIS

The data were analysed with the Student *t*-test. The null hypothesis ( $H_0$ ) implied that differences regarding the number of times goalkeepers chose the correct side before and after the training were explained by random variations not related to training. Similar analyses were performed to assess the contribution of the goalkeeper's laterality (ie, whether they were more successful while diving towards their preferred side or not) and height (ie, whether taller goalkeepers were more successful at saving penalties or not).

## RESULTS

Tables 1 and 3 show data before and after training and Tables 2 and 4, the coincidences between the side to which the ball was aimed at and the side to which the goalkeeper moved to (Figures 2-5).

The reaction time for the goalkeeper to correctly decide which side to dive at with chances to make the save (incidentally, in coincidence with the time at which the kicker's support foot touched the ground) was congruent with published values: 0.5 sec (Bar-Eli and Azar, 2009).

In 28% of the cases, the goalkeepers chose the appropriate side before training and 63% after training, an increase of over two-fold (Figure 6), with differences in the coincidences being significant in both cases (left,  $t = -6.57$ ,  $p = 0.05$ ; right,  $t = -10.39$ ,  $p = 0.05$ ).

The height of the goalkeepers and the proportion of saves before and after the training was established to have tended to improve their performances to some extent although not significantly.

All goalkeepers in this study are right-handed and right-footed. They tended to dive more to their right side both before and after the training values. After the training, the coincidence of the correct diving towards their right increased.

**Table 1.** Penalties shot before training.

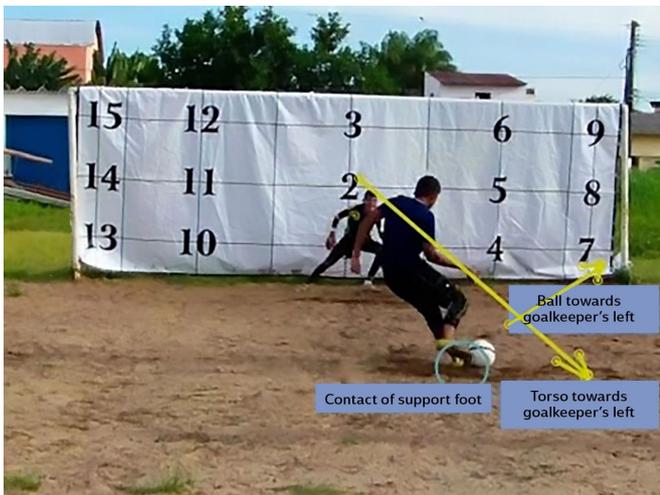
Goalkeeper	Goalkeeper 1	Goalkeeper 2	Goalkeeper 3	Goalkeeper 4	Total
Number of penalties	200	200	200	200	800
Ball to the right	85	83	83	82	333
Ball to the centre	44	34	46	47	171
Ball to the left	71	83	71	71	296
Goalkeeper to the right	92	92	85	92	361
Goalkeeper to the centre	22	16	32	38	108
Goalkeeper to the left	86	92	83	70	331
Right/right coincidence	38	26	23	41	128
Lef/left coincidence	24	27	19	29	99

**Table 2.** Coincidences between the side at which the ball was shot and the side to which the goalkeeper dived before training.

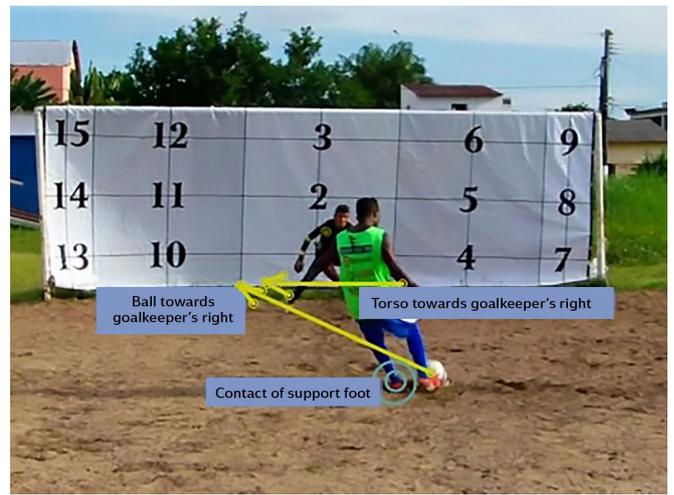
Total coincidences	Right-Right	Left-Left
227	128	99

**Table 3.** Penalties shot after training.

Goalkeeper	Goalkeeper 1	Goalkeeper 2	Goalkeeper 3	Goalkeeper 4	Total
Number of penalties	200	200	200	200	800
Ball to the right	89	90	92	93	347
Ball to the centre	35	30	40	39	174
Ball to the left	76	80	68	68	279
Goalkeeper to the right	96	112	104	104	417
Goalkeeper to the centre	14	07	15	12	54
Goalkeeper to the left	90	81	81	84	329
Right/right coincidence	67	60	78	75	280
Lef/left coincidence	60	50	52	65	227



**Figure 2.** As the ball is impacted, the shooter's body leans to the left side of the goalkeeper.



**Figure 4.** Moment of impact on the ball be aimed at the right side of the goalkeeper. Shooter's body inclines towards his left (right, as seen by the goalkeeper).



**Figure 3.** Same shot a fraction of a second later, with the goalkeeper diving towards his left side after correctly reading the shooter's posture.



**Figure 5.** Wrong diving of the goalkeeper towards his left side.

Table 5 provides the data of the contingency table computing showing the improvement after the training when the right decision is made before and after the programme, grouped by side kick/side chosen.

## DISCUSSION AND CONCLUSIONS

### SIDE CHOICE

The shots in penalty kicks are non-rotational (Nakamura et al., 2018), with the foot following a straight trajectory before hitting the ball. As predicted by

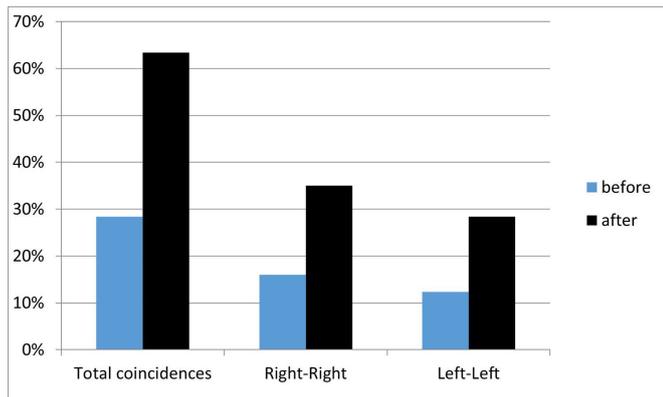


Figure 6. Coincidence comparisons of proportions of shots and dives before and after training.

Table 4. Coincidences between the side at which the ball is shot and the side to which the goalkeeper dives after training.

Total coincidences	Right-Right	Left-Left
507	280	227

conservation of the angular moment, it is biomechanically necessary, when the support foot touches the ground, to incline the trunk towards the same side the ball will be kicked at (Bar-Eli et al., 2007; Navarro et al., 2012; Nakamura et al., 2018; Biswas, 2018; Blair et al., 2018). Thus, for a left footed kicker that will direct the ball to the left of the goalkeeper, the (left) kicking foot should be closer to the support foot. In compensation, the trunk will balance on the right hip joint, swinging to the right (seen as to the left by the goalkeeper). If, however, a left-footed shooter aims at his left side, the ball must be impacted on a point that is closer to his body, usually by abducting the foot. The support foot must be placed farther away from the ball, which makes the trunk to be leaned to the left.

The shooter then reaches a non-return moment when the support foot lands and the kicking foot is swinging to hit the ball. The goalkeeper, after properly reading the posture of the shooter, has about 0.5 seconds to start the dive to the correct side (Kuhn, 1988), so increasing his chances of impeding the scoring (Lees et al., 2010).

It must be stressed that this game is basically endless (Campos, 2009) and this enhanced performance is meant to be ephemeral, as a counterstrategy will be eventually developed for shooters to beat the approach proposed here for goalkeepers.

### LATERALITY

Known in old fossils far in the past of human evolution (Faurie et al., 2016), laterality is of general importance in sports practice in many ways (Loffing et al., 2016; Faurie et al. 2016), with fighting interactions (including sports as a way of physical confrontation, ritualised or not; Tirp et al., 2014; Harris 2016). Even other

Table 5. Results of computing the performance before/after the training grouped by side kick/side chosen when correct decision is made.

Type of coincidence		Goalkeeper				Total shots by side
		Goalkeeper 1	Goalkeeper 2	Goalkeeper 3	Goalkeeper 4	
BEFORE	Right/Right	38	26	23	41	333
	Left/Left	24	27	19	29	296
AFTER		Goalkeeper				
Type of coincidence		Goalkeeper 1	Goalkeeper 2	Goalkeeper 3	Goalkeeper 4	Total shots by side
Right/Right		67	60	78	75	364
Left/Left		60	50	52	65	292
Percentages of correct decisions		Goalkeeper				Mean
	Coincidence	Goalkeeper 1	Goalkeeper 2	Goalkeeper 3	Goalkeeper 4	
BEFORE	Right/Right	11,4%	7,8%	6,9%	12,3%	9,6%
	Left/Left	8,1%	9,1%	6,4%	9,8%	8,4%
AFTER	Right/Right	18,4%	16,5%	21,4%	20,6%	19,2%
	Left/Left	20,5%	17,1%	17,8%	22,3%	19,4%

mammals show lateral preferences for their movements and with differential performance (Murphy & Arkins 2006) which is revealed early in life in humans (Gabbard & Iteya, 1996).

The dominance of one limb over the other, even in regard to the essential task for a goalkeeper of positioning the arms (Imanaka et al., 1995; van der Kamp and Masters, 2008), becomes a concerning factor when the movement pattern of an athlete is adversely affected, especially from the point of view of biomechanics (Parrington & Ball, 2016), including performance as well as injury prevention. Also, in the decision making of the kicker, our results suggest that correctly perceiving the laterality of the goalkeeper (Moore et al., 2017) is of importance in the success of scoring a penalty kick.

Studies on laterality in football have focused mainly on field players rather than on goalkeepers (Petro & Szabo, 2016). Anyway, insight can be obtained for the case of the movement; the differential speed of the extremities in football players differ significantly (27.68 m.s<sup>-1</sup> for the execution of the kick with the preferred leg vs. 23.49 for the non-preferred leg; Vaverka et al. (2003), so rendering this disparity as a proxy of goalkeeper's performance when using his legs to dive to the side of their preferred leg or the other.

Players are found to be faster on the rotation of the contralateral side (Zouhal et al., 2018). Differences for movement times between right and left footed players in elite football players are significant ( $p = 0.039$ , effect size = 0.413, small) for both left and right rotation and only for the right rotation in amateur players.

Including specific training for laterality enhances performance in juvenile footballers (Pietsch and Jansen, 2018), According to Grouios (2004), sports have become a fertile area for laterality research, due either to the innate superiority of some motor dominance or the strategic advantage.

## STATURE

Goalkeepers are the tallest among football players but no clear increased performance was observed for the tallest among them. Preliminary observations did not corroborate the previous idea that taller goalkeepers tend to perform better when the ball is directed to the areas more distant from the centre of the goal.

## FINAL REMARKS

Further studies with more goalkeepers of varied statures as well of such other factors like the reaction times and the power in the jump. Also, binomial models are expected to shed new light on this process.

We claim that this training procedure is likely to be important also for female goalkeepers to some extent. However, the differences in the female pelvis are likely to influence the biomechanical requirement for female

shooters to incline their trunks as described here for male players.

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## CONFLICTS OF INTEREST

The authors report no conflict of interest.

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