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Influence of video instruction on soccer kick velocity in young players

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Abstract

Soccer is a sport that necessitates proficiency in motor control and cognitive abilities, with kicking serving as a fundamental action. Improving kicking performance is vital for player advancement, leading to the inquiry: "How can video instruction promptly optimize kicking technique in young players?". This research aimed to investigate the immediate effects of an instructional video on the kinematic variables of kicking to induce an acute alteration in the movement pattern. A cohort of 26 male youths, aged between 10 and 15 years, partook in the study and were segregated into an instruction group (IG) and a control group (CG). The IG received exposure to a video containing specific kicking instructions, while the CG viewed a video lacking such guidance. Both groups were recorded performing penalty kicks before and after viewing the video. Kinematic analysis was carried out utilizing the OpenPose artificial intelligence neural network for pose detection and subsequent 3D reconstruction. The primary discovery was that the length of the last stride (LS) notably increased in the IG following the instructional video. This outcome indicates that video instructions hold promise in promptly enhancing particular aspects of kicking technique in young soccer players.

Keywords

Kinematics, openpose, artificial intelligence, young soccer, football, penalty kicks

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Introduction

The action that often determines the outcome of a soccer game is the kick. The kinematics of the lower limbs are closely linked to kicking success, especially in terms of transferring speed to the ball.[1] To increase the chances of scoring a goal, players need to achieve the highest possible ball speed, which depends on various factors such as foot speed at impact and the quality of the ball strike at the moment of foot contact.[2–5] Furthermore, a faster kick reduces the likelihood of the goalkeeper or opposing player having enough time to react.[6–8] Identifying indicators that contribute to success in this skill is one of the most important issues in applied biomechanics in soccer.[9]

In the literature, studies regarding ball speed have focused on players aged over 15 years.[10–14] In contrast, variables such as the length of the final stride[15–17] and the distance between the supporting foot and the ball[12,14,15,17] have been relatively underexplored in young players, despite their importance. These variables are crucial because they influence the energy transfer needed to increase ball speed.[1] This energy transfer is affected by several factors, including the length of the final stride in the kick, the distance between the support foot and the ball, and the speed of the foot.[18] The correlation between ball speed and foot speed serves as an indirect measure of the quality of impact between the foot and the ball during the kicking motion.[10] As highlighted in a study by Asai et al.,[2] the nuances of the foot-ball impact are pivotal to kicking proficiency. The nuances of these variables warrant further investigation, particularly in younger age groups, to better understand and enhance kicking performance. One

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factor that can affect kicking performance is the set of instructions given to players.

One of the many ways to instruct students to perform the most proficient movement for the task they are performing is through video demonstration. Theoretically, an individual's movement pattern emerges from the interaction between individual, environmental, and task constraints.[19] Change (learning) can be seen as a search process, where the practitioner seeks, among the available movement possibilities, those that best satisfy the task objective.[20,21] In other words, the learner in the kicking task seeks among the available information those that best assist in achieving the most efficient kick. Exploration is a fundamental process from this approach; however, due to a very stable initial pattern, it can limit the search process, causing the practitioner never to find a more suitable pattern for the motor action being performed.[22] Therefore, "forcing" the practitioner to explore new patterns can be beneficial for change. External information such as feedback, verbal instruction, demonstration by a model, or via video, would serve as task constraints, guiding the practitioner to explore within a certain range of possibilities.[23] Lafe and Newell[24] observed that verbal instruction alters the exploration of coordination patterns in a bimanual force task. Therefore, video instruction could yield similar results, guiding the individual to another coordination pattern.

Different approaches can be used during video instruction, such as directing attention through video-based information,[25] such as, simply showing a video of a proficient individual performing the task (e.g. Al-Abood[26]) highlighting some specific aspects of the video by a point of light (e.g. Horn et al.[27]), or guiding the individual to attend to different visual information in the video (e.g. the trajectory of the ball in a video of the kick. Hodges et al.[28]). A review performed by Pacheco et al.[29] showed that in some cases, only the demonstration video was not enough for the individual to learn a new movement pattern, it is necessary to add some other variables (e.g. verbal cue, visual cue, or feedback).

The concept of video-based training encompasses a specific practice phase wherein presented stimuli demand perceptual-cognitive responses from participants.[30,31] Diverse approaches are employed, including the strategic direction of attention through video-based information,[25] enabling learners to engage in skill practice without the actual execution of the task.[32] Particularly in sports requiring sustained involvement, such as soccer, this methodology has the potential to expedite experiential learning and enhance the perceptual-cognitive development process.[33] Although the visual model provides all the necessary cues for reproducing the response, individuals may not employ effective search strategies to acquire these cues. Thus, it may not be the content of the suggestion itself, but rather the signaling function that favors the use of verbal cues. If this is indeed the case, then the presence of visual cues may achieve the same goal as verbal cues (i.e. directing attention to the most critical aspects of the task). Alternatively, verbal cues also provide additional information not available through visual observation – specifically, augmented narration with explicit instruction, which cannot be conveyed through visual cue protocols. The addition of verbal information allows the observer to verbally encode the movement, a process less likely to occur without verbal input. Consequently, the combined use of verbal and visual cues is expected to facilitate attention to critical cues and enhance the retention of observed actions through the formation of more elaborate visual and verbal codes.[34]

The temporary retention of information in working memory is fundamental for various cognitive tasks, such as planning, verbal competence, spatial orientation, mental manipulation of objects, and others.[35–37] According to the Baddeley[38] and Hitch model, working memory consists of several components, including one responsible for the temporary storage of information in modality-specific buffers and a central executive component intended to maintain the active representation of memory, control attention, and preserve it from interference by irrelevant stimuli.[39,40] This working memory capacity is crucial in the context of video-based training, as the combination of verbal and visual cues can help maximize the retention and use of presented information.

In the study conducted by Cowan et al.,[41] working memory capacity was evaluated through various verbal and visual tasks, with moderate to strong correlations with standardized working memory measures. Regarding visual working memory, capacity was observed to gradually increase throughout development, with an average capacity of 3.5 items at ages 7 and 8 years, 4.4 items at ages 9 years and 10, 4.8 items at ages 11 and 12 years, and 5.7 items in college students.[41,42]

The literature review conducted by Zhao et al.[43] examined the immediate effects of training interventions employing videos across four distinct studies.[44–47] One study involved elite athletes,[46] while two studies included novice participants,[44,47] and one study encompassed both novices and elite athletes.[45] All four studies were conducted in a controlled laboratory environment under the supervision of a structured training program.[44–47] Furthermore, participants in all four studies viewed soccer-related videos from a "first-person" perspective.[44–47]

An effective method for evaluating the impact of video instruction on kick coordination is through kinematic analysis. Typically conducted in a laboratory setting using optical cameras and retro-reflective markers, this traditional setup is not inherently designed for outdoor applications. Recent advancements in deep neural networks now enable the estimation of joint angles without the need for retro-reflective markers.[48] Markerless motion estimation algorithms, such as

Table 1. Participants demographic data mean, standard deviation (SD), and *p*-value of the variables for the control group (CG) and the intervention group (IG).

Variables	CG (*n* = 13)		IG (*n* = 13)		*p*-value
	Mean	SD	Mean	STD	
Age (years)	12	±0.92	13	±1.47	0.05
Weight (kg)	41.2	±8.09	52.69	±12.95	0.01*
Height (m)	1.53	±0.11	1.59	±0.11	0.17
Training experience (years)	6.31	±2.74	6.62	±1.65	0.73
Training frequency (days/week)	3.85	±1.92	3.69	±1.94	0.83

$^{*}p < 0.05$.

OpenPose,[49] present a promising solution for the analysis of video data, allowing for the extraction of kicking kinematics in a potentially less time-consuming, more cost-effective, and non-invasive manner. Some studies have utilized OpenPose as a tool for kinematic evaluations in soccer fields for tasks such as kicking[50] and goalkeeper jumping.[51]

In Palucci Vieira et al.,[50] they aimed to compare a markerless automatic motion estimation algorithm (OpenPose) with manual digitization and found that the global calibration errors were 0.9, 1.1, and 1.8 cm, respectively, in the x (anteroposterior), y (media-lateral), and z (vertical) directions, indicating that the error values were within the range reported previously. The study concluded that the OpenPose tracking method may be a reliable tool for evaluating soccer kicking kinematics in youth soccer under grassy field conditions, providing data compatible with those obtained from traditional frame-by-frame manual digitization. However, retraining based on their own dataset contributed to further reducing errors arising from possible algorithm false detections, and they acknowledged the relatively small sample size as a limitation in evaluating the performance of the markerless algorithm. In Monteiro et al.,[51] they aimed to analyze the effect of laterality and instructional video on the soccer goalkeepers' dive kinematics in penalty saves using OpenPose. As limitations, the study only analyzed the acute effect of the instructional video and noted that manual corrections were necessary when using OpenPose. This requirement for manual intervention highlights a broader challenge within the field of markerless motion analysis, as also shown in Palucci Vieira et al.[50] Despite the limitations and need for manual correction pointed out, OpenPose presented a small measurement error that compensates for its use in evaluations outside the laboratory.

The progress in computational sciences, particularly in computer vision and image processing, has significantly enhanced the analytical techniques and measurement systems employed in human movement research. These innovations have contributed to a more profound understanding of the three-dimensional (3D) kinematic and kinetic characteristics of soccer kicking.[1] Within the repertoire of tools available for scrutinizing kicking movement performance, video analysis stands out as capable of providing objective and sensitive kinematic metrics, aspects not always fully captured through visual assessments alone.[52]

Based on the above, the current study aims to assess, through in-field data collection, whether the presentation of an instructional video can immediately enhance ball speed, the length of the final stride, and kicking foot speed at the moment of ball contact. Conversely, it aims to investigate if this presentation can decrease the distance between the supporting foot and the ball.

Our working hypothesis posits that, following instructional video exposure, young participants will demonstrate enhanced ball speed, an increased length of the final stride, a reduced distance between the supporting foot and the ball, heightened kicking foot speed at the moment of ball contact, and a greater ratio between ball speed and kicking foot speed at the moment after watching the video, as compared to the moment before watching the video. These differences are also anticipated when comparing the experimental group to the control group.

Methods

Participants

A cohort of 26 young soccer players, aged between 10 and 15 years, devoid of any surgical history or lower limb injuries within the preceding 6 months, and engaged in soccer training at least once a week, constituted the participants for this study. The age of the participants was chosen for convenience, as they were already part of a university extension project open to the community with a soccer school for children aged 10–15 years before the research. Employing the online platform Research Randomizer,[53] participants were randomly assigned to either the control group (CG) or the instruction group (IG). The participants demographic data are presented in Table 1. It is noteworthy that only one participant in the control group exhibited left-footed kicking, while all other participants were right-footed. Ethical approval for the experimental procedures was obtained from the Ethics Committee at the School of Physical Education and Sport of Ribeirão

Figure 1. Experimental setup for kick data collection, featuring the penalty mark, two synchronized cameras (C1 and C2), and the display location for recorded videos.

Preto (CAAE: 26288119.8.0000.5659). Before the commencement of the study, written consent was obtained from each participant and their legal guardian(s).

Instruments

Kinematic data for both the kick and ball were acquired through two GoPro Hero 10 Black Edition cameras (GoPro, Inc., USA), configured at a resolution of 2720 × 1530 pixels and a frame rate of 120 Hz. Positioned 2 m from the penalty mark and with a 7 m separation between them, the cameras were oriented toward the penalty mark at a 45° angle, providing a comprehensive diagonal view of the kicking action, as illustrated in Figure 1.

The cameras were synchronized using "GoPro The Remote for HERO 8/9/10/11 Black & MAX 360." In this study, synchronization was rigorously verified by cross-checking the total number of frames and identifying the precise frame capturing the foot's contact with the ball on each camera. This meticulous process ensured the accuracy and consistency of the kinematic data for subsequent biomechanical analysis. While the synchronization method employed in this study is unique, validation of the GoPro cameras' capability for synchronized 3D kinematic analysis is supported by research conducted by Johnson et al.,[54] Palucci Viera et al.,[50] and Monteiro et al.[51]

To maintain consistency in assessments across different age groups, specific ball sizes were employed. Participants aged 10 and 11 years used a ball with a circumference ranging from 0.635 to 0.66 m, while those aged 12–15 years utilized a slightly larger ball with a circumference between 0.685 and 0.695 m.

Videos presented

Participants were randomly allocated to either the IG or the CG, with each group exposed to a specific instructional video. In the IG, participants watched a 30-s video only once, which presented four instructions through verbal cues accompanied by animations created using Unity software (version 2019.4.16f1, USA). The four instructions included: (A) Extending the last step; (B) Keeping the foot beside the ball; (C) Making contact with the "instep" of the foot; (D) Continuously moving until the kick is executed. Only four instructions were chosen due to working memory capacity limitations. These instructions were familiar to the participants due to their previous experience in the soccer school, ensuring better understanding and compliance. In Figure 2 we present screenshots from the video demonstrating each instruction.

Conversely, participants in the CG watched a different 30-s video only once, which provided information on the importance of physical activity, anatomical aspects, and health. Notably, this video did not contain any specific guidance or instructions related to the kicking technique.

Experimental procedures

The experimental protocol was conducted on an official soccer field with natural grass, conforming to FIFA standards (100 m × 70 m; goal dimensions, 7.32 m × 2.44 m), situated at the Physical Education, Sports, and Recreation Center (CEFER) of the University of São Paulo. Participants received detailed instructions outlining the procedures and commenced the session with a familiarization test. During this phase, they

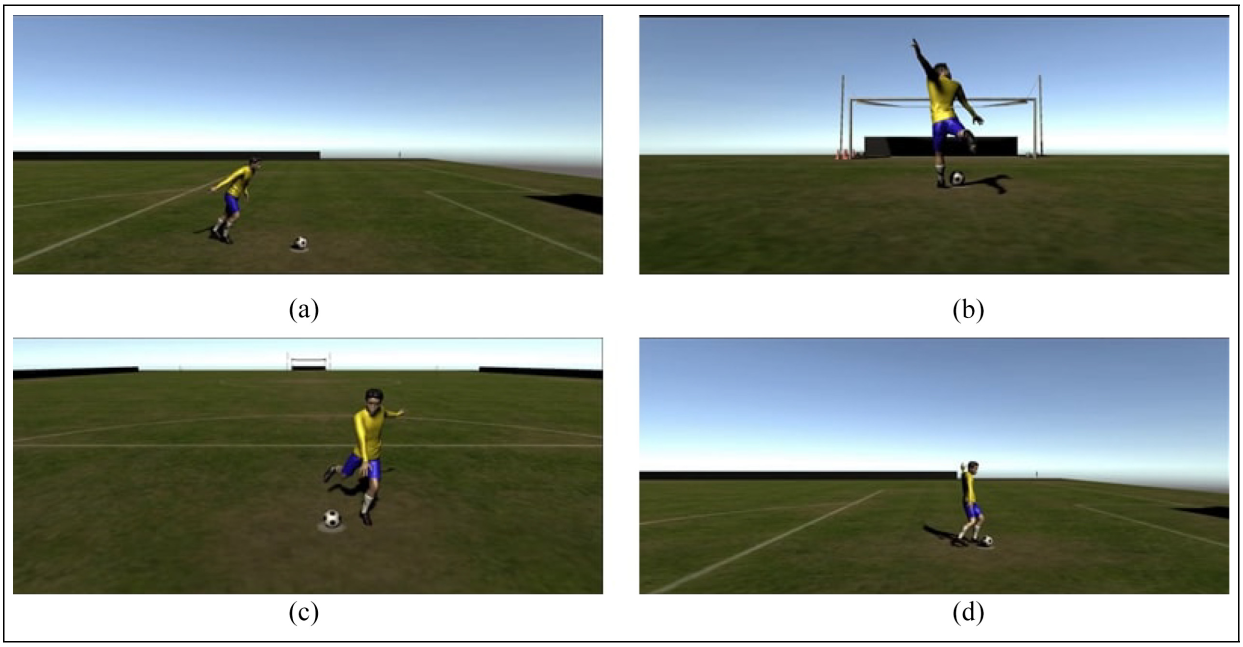

Figure 2. Screenshots from the video with the instructions as follows: (a) extending the last step, (b) keeping the foot beside the ball, (c) making contact with the "instep" of the foot, and (f) continuously moving until the kick is executed.

executed five sub-maximal penalty kicks to enhance their comprehension of the task and adapt to the ball.

Following the familiarization, participants performed five penalty kicks with explicit instructions to exert maximum force, aiming to score a goal. The acceleration approach was personalized for each participant, with no restrictions on running patterns or approach angles. Importantly, there were no restrictions on which part of the foot to use to kick the ball, allowing participants to choose their preferred technique. The success criteria for the kicks required the ball to enter the goal; only successful attempts were analyzed and counted.

Subsequently, participants were randomly assigned to view either the Instruction Group (IG) or Control Group (CG) video. The assigned video was presented on a 15″ monitor of an Eurocom notebook (Eurocom Corporation, Canada) and, in both groups, participants simply watched the 30-s video seated in front of the monitor, without any interaction or control over the playback. Immediately after viewing the video, each participant conducted a new series of five penalty kicks to compare with their previous attempts.

Data processing

Each kicking attempt was meticulously recorded, and only successful goals were considered valid; shots hitting the goalpost or going wide were excluded from subsequent analysis. Post-recording, videos underwent careful editing, with the initiation of the participant's first movement and the conclusion of the assessment defined as ten frames after the participant's contact with the ball. To enhance the validation of kicks during the assessment, a strategically positioned camera at the edge of the penalty area, focused on the goal line, was employed.

For the evaluation of kinematic variables related to each kick, videos of the kicking attempts were subjected to analysis using the OpenPose artificial intelligence neural network.[49] This advanced network facilitates the identification of joints and anatomical points in videos, providing screen coordinates of the recognized points through a skeleton detection algorithm, as depicted in Figure 3.

At certain points during the execution of OpenPose, partial occlusion of segments of the lower limb led to incorrect keypoint identification. To address this, we used the Dvideow software (v. 1.0.0.1), developed by researchers at the University of São Paulo, Brazil,[55,56] to manually correct the misidentified keypoints, but only in the specific frames where these errors occurred.

For the evaluation of ball-related variables, we utilized the DeepLabCut toolbox, developed by researchers at Harvard University, USA, and Ècole Normale Supèrieure, France.[57,58] This toolbox harnesses the capabilities of an artificial neural network to estimate the marker-less pose of objects. Specifically, in our study, the network was trained to provide screen coordinates of the estimated center of the ball using a detection algorithm. Similar to the approach applied to kicking kinematics, instances with inaccurate screen coordinates underwent manual correction. This correction process involved identifying and rectifying the erroneous screen coordinates to accurately determine the center of the ball.

A total of 260 kicking attempts underwent evaluation, and the subsequent dependent variables were computed for each validated kicking attempt:

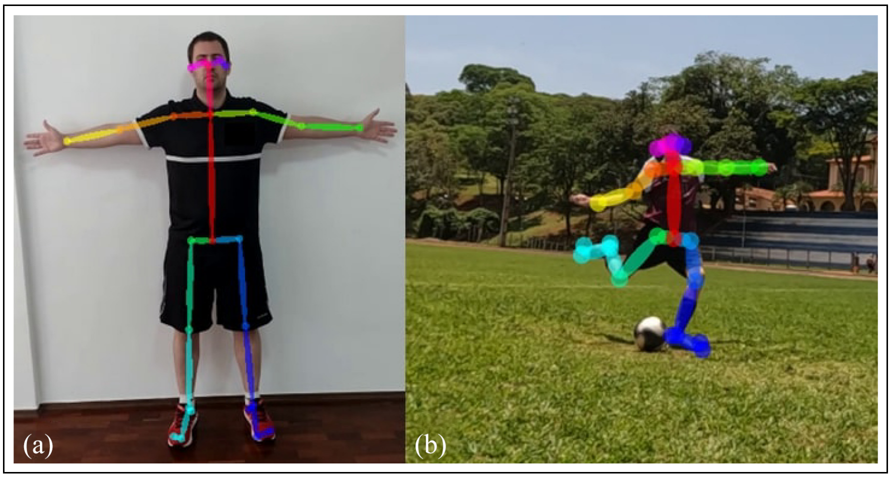

Figure 3. (a) Demonstration of OpenPose detection and (b) application of OpenPose to the kicking task.

- Length of the Last Step (LLS)[15,16]: This metric is defined as the Euclidean distance between the location where the hallux of the kicking foot loses contact with the ground and the heel of the support foot upon landing during the final step.
- Distance between the Support Foot and the Ball (DSB)[12,14,15]: Representing the Euclidean distance between the centroid of the support foot and the estimated center of the ball at the moment of foot-ball contact.
- Speed of the Kicking Foot at Ball Contact (SKF)[11,59]: Defined as the instantaneous speed of the dominant foot's centroid at the moment of ball contact.
- Ball Speed (BS)[60,61]: Signifying the instantaneous speed of the estimated center of the ball ten frames after foot-ball contact.
- BS / SKF Ratio: Computed as a dependent measure,[17] it serves as an indirect indicator of foot and ball impact quality.[10]

The kicking and ball kinematic data underwent a comprehensive pipeline of pre-processing, processing, and analysis facilitated by custom routines developed in the Python programming language. Screen coordinates acquired from OpenPose of the two cameras underwent smoothing using the LOWESS method with a delta of 0.1 and alpha of 0.1. Subsequently, these coordinates underwent further transformation into 3D global coordinates using the Direct Linear Transformation (DLT) method.[62] This step involved converting the 2D coordinates obtained from the OpenPose analysis of the two cameras into the 3D global coordinates. For the DLT method, we utilized the known 3D coordinates of a trihedron constructed from iron bars, each with vertices measuring 1 m, extending along the x, y, and z axes at right angles to each other. This trihedron was equipped with distinct markings visible to the camera, positioned at intervals of 0.25, 0.5, 0.75, and 1.0 m along each axis, thus ensuring spatial reference.

Figure 4. Difference in Euclidean distance for pole length during 3D reconstruction over time.

Subsequently, a Python routine was employed to compute the LLS, DSB, SKF, BS, and BS/SKF kinematic variables for each participant's kicking attempt. Additionally, the DeepLabCut toolbox[57,58] was utilized to assess the error associated with the DLT method. For this purpose, the detection algorithm was configured to provide screen coordinates for the base and the highest point of a topographic pole. As illustrated in Figure 4, a detection instance is shown, highlighting ten screen coordinates with the top of the pole marked in purple and the base in yellow.

To evaluate measurement accuracy, a video capturing the complete traversal of the topographic pole across the entire data collection area was employed. Subsequently, 3D reconstruction was conducted using the DLT method and the same calibration setup. Measurement accuracy was assessed by computing the Euclidean distance between the top and base of the topographic pole. The actual distance between the pole's ends was 1.925 m, while the average Euclidean distance between the

Table 2. Mean (± standard deviation) and *p*-value (effect size) of the length of the last step (LLS), distance between the support foot and the ball (DSB), speed of the kicking foot at ball contact (SKF), ball speed (BS) and ball speed/speed of the kicking foot at ball contact ratio (BS/SKF) for the control group (CG) and the intervention group (IG) at pre and post-video viewing time points.

Variables	CG			IG		
	Before	After	*p*-value (power)	Before	After	*p*-value (power)
LLS (m)	1.31 (±0.23)	1.32 (±0.23)	0.22 (0.06)	1.27 (±0.26)	1.31 (±0.21)	0.04* (0.14)
DSB (m)	0.32 (±0.06)	0.32 (±0.07)	0.69 (0.05)	0.32 (±0.05)	0.31 (±0.05)	0.13 (0.21)
SKF (m/s)	10.37 (±1.67)	10.18 (±1.58)	0.14 (0.12)	10.84 (±1.36)	10.77 (±1.38)	0.51 (0.05)
BS (m/s)	17.64 (±4.56)	17.29 (±4.63)	0.25 (0.08)	18.13 (±3.30)	18.34 (±3.34)	0.47 (0.06)
BS/SKF	1.69 (±0.31)	1.69 (±0.3)	0.83 (0.02)	1.68 (±0.26)	1.71 (±0.27)	0.36 (0.08)

*$p < 0.05$.

reconstructed top and base of the pole measured 1.94 m. This difference indicates an average error of approximately 0.02 m.

Statistical analysis

Statistical analyses were conducted using custom routines developed in the Python programming language. Mean and standard deviation values were computed, and the normality of the sample was assessed through the Kolmogorov-Smirnov and Shapiro-Wilk tests.

The participants characteristics in the control and instructional video groups were compared with *T*-tests. Tests with a *p*-value < 0.05 were deemed statistically significant. Subsequently, the pre- and post-intervention time points for each kicking variable in both the control and instructional video groups were compared, considering the data distribution. Tests with a *p*-value < 0.05 were deemed statistically significant. *T*-tests for dependent samples and the Wilcoxon test were employed based on the normality of the data. Only in the analysis of the pre- and post-moments of the LLS and SKF variables of the control group was the Wilcoxon test applied, as these variables did not present a normal distribution. To determine effect size, G*power software (version 3.1.9.7) developed by researchers at the University of Düsseldorf, Germany[63] was utilized, with values less than 0.2 considered a small effect, values between 0.2 and 0.7 indicate a medium effect, and values greater than 0.7 denote a large effect.

Results

The mean, standard deviation (SD) and *p*-value of the participants characteristics for the control group (CG) and the instructional group (IG) are presented in Table 1. Among the participant demographic variables, only weight showed a statistically significant difference between the groups. The other variables did not show significant differences, with age being a borderline case.

The mean (±standard deviation) and *p*-value (effect size) of the kicking variables for both the control group (CG) and the instructional group (IG) are presented in Table 2.

Furthermore, Figure 5 illustrates a radar plot depicting the mean values of kinematic variables for both groups at various time points, both before and after the intervention.

In the comparative analysis of kicking variables between the pre- and post-intervention periods, a statistically significant difference was identified solely in the IG for the LLS, with a *p*-value less than 0.05 ($p = 0.044$). However, it is noteworthy that the effect size in this instance was small. For the remaining variable comparisons, no statistically significant differences were observed when evaluating the pre- and post-intervention periods in both groups.

Discussion

In soccer, the kicking action holds paramount significance. Studies adopting an ecological approach to assess kinetic and kinematic variables in kicking tasks are crucial for advancing our understanding of the activity and refining the performance of young soccer players. These evaluations empower physical education professionals and coaches to monitor individual progression and specific demands more effectively. Existing research in soccer frequently emphasizes video training for game situation perception and decision-making.[43,64–67] However, our study aims to fill a gap by understanding the immediate kinematic effects of video instructions on kicking performance.

A statistically significant difference was found in the change in LLS before and after video presentation, specifically in the IG ($p = 0.044$), although the effect size was small. No other statistically significant differences were observed before and after the video for both CG and IG regarding the remaining variables. This outcome was not initially anticipated and is likely due to study limitations.

Given the pivotal role of kicking in soccer and the importance of variables such as BS, DSB, LLS, and SKF, we conducted a literature search for similar analyses. However, we did not find studies using video

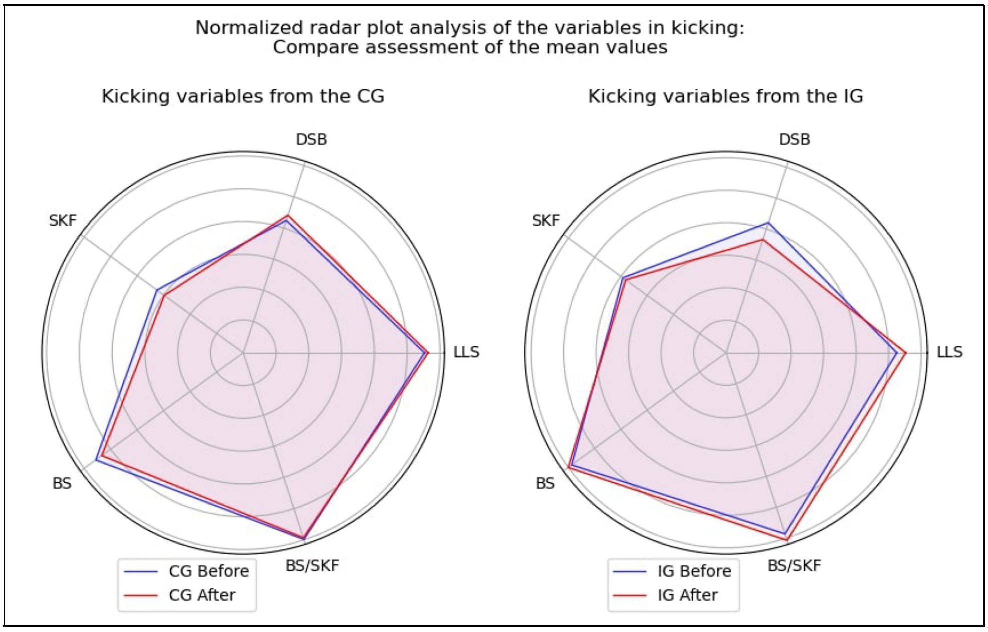

Figure 5. Radar plot illustrating normalized average values of kinematic variables for the CG and the IG. Before values are represented in blue, and after values in red.

instruction to analyze changes in kicking kinematics. Therefore, we compared our data to existing literature values for practitioners of similar ages, ensuring our values align with previously reported literature for these variables. Studies regarding BS have predominantly focused on players aged over 15 years.[10–14] The observed improvement in BS with age might be attributed to increased practice time as young players mature.[68] In contrast, variables such as LLS[15–17] and DSB[12,14,15,17] have been relatively underexplored in young players.

Upon analyzing the mean values of these variables, we found that the data for LLS, DSB, and BS in both the CG and IG align with the findings of Vieira et al.,[17] who studied players over 13 years old, approximating the average age of our study. Notably, our results show lower BS values compared to the studies by Rodrèguez-Lorenzo et al.,[69] who evaluated 46 players in the U-14 category or younger of a professional first division club, and Cerrah et al.,[70] who focused on 10 players aged 12 and 13 years of a professional first division club.

Furthermore, our results show lower DSB values compared to those found in the study by Kapidvzic et al.,[15] which analyzed 13 youth players from a professional first division club. The values of SKF and the BS/SKF ratio in our study differed from those reported by Vieira et al.,[17] exhibiting lower SKF values and consequently higher BS/SKF ratio values. This disparity can be attributed to the criterion adopted in the study by Vieira et al.,[17] where participants were required to have initiated regular practice at the age of six, a criterion not applied in our study. Additionally, the marking of keypoints in their study was done manually, which may have altered the point locations used for comparing variables.

The primary difference between the present study and the cited ones is that, unlike Vieira et al.,[17] which does not specify, the participants in the other studies were part of elite soccer teams. In our study, participants were not required to be part of professional or elite soccer clubs, which may explain the differences in the results. Nonetheless, there are still notable similarities in some kinematic data between groups within the same age range.

For coaches and physical educators, the integration of contemporary technologies and evidence-based approaches into training programs is imperative. This integration not only elevates athletes' performance but also fosters a deeper comprehension of the cognitive and biomechanical processes inherent in sports. Souissi et al.[71] contend that delivering guidance solely through verbal feedback, without video feedback or with video feedback lacking additional cues, has minimal impact on skill acquisition. Consequently, it appears that the effects of video and verbal feedback are synergistic. This assertion aligns with the findings of Nunes et al.,[72] where simple video feedback alone did not significantly enhance golf putting kinematics performance in elderly individuals. Motor learning research has consistently shown that active participant engagement in the learning process enhances performance.[73,74] Notably, the group that received combined video feedback and verbal instruction demonstrated improvements in movement kinematics. Therefore, while our data did not show statistically significant differences, the inclusion of instructional videos, as implemented in this study, may still have a positive effect on the kinematic development of soccer practitioners.

These observations underscore the notion that the effects of video and verbal feedback may be additive. The integration of both modalities offers a more comprehensive approach to skill acquisition, especially in complex motor tasks. This observation aligns with the premise that a multimodal approach, encompassing both visual and auditory cues, contributes synergistically to the learning process, potentially yielding more profound and sustained improvements in motor performance.

In the study by Monteiro et al.,[51] participants who watched instructional videos demonstrated changes in kinetic and kinematic variables compared to the control group. This discrepancy with our study may be attributed to the different durations and formats of the instructional videos used. Monteiro et al. provided a comprehensive 6-min and 20-s instructional session, including a PowerPoint presentation and oral explanation, followed by a summary of the instructions. In contrast, our study presented a much shorter 30-s video, designed to fit within the limitations of working memory.

Strategies employed in educational videos have also been a focus of investigation, with evidence supporting the effectiveness of segmentation into smaller units[75] and control over the presentation pace.[76] These approaches tend to positively impact learning outcomes compared to continuous video viewing, leading to a reduction in cognitive load during video consumption[77,78] and facilitating smoother cognitive processing.[76] This strategy of using smaller video units with controlled presentation speed was applied in our study but not in others.

The incorporation of technologies such as virtual reality and interactive videos in athlete training offers an immersive experience, facilitating a more profound understanding and retention of complex motor skills.[33,65] When combined with video feedback, these tools have the potential to enhance athletes' self-efficacy and decision-making in game situations.[34,74] In this study, the application of more immersive technologies aimed to assist in task explanation for participants, including changes in camera position and image zoom to improve task visualization. However, this approach did not yield significant results in our study.

Strategies employed in educational videos have been a focus of investigation, with evidence supporting the effectiveness of segmentation into smaller units[75] and control over the presentation pace.[76] These approaches tend to positively impact learning outcomes compared to continuous video viewing, leading to a reduction in cognitive load during video consumption[77,78] and facilitating smoother cognitive processing.[76] This strategy of using smaller video units with controlled presentation speed was applied in our study but not in others.

The incorporation of technologies such as virtual reality and interactive videos in athlete training offers an immersive experience, facilitating a more profound understanding and retention of complex motor skills.[62,65] When combined with video feedback, these tools have the potential to enhance athletes' self-efficacy and decision-making in game situations.[34,74] In our study, the instructional video was a 30-s clip designed to fit within the limitations of working memory, presenting four key instructions through verbal cues and animations. Unlike the more immersive technologies involving virtual reality and interactive components, our approach focused on concise and clear guidance for immediate application. This difference in the level of immersion might explain why our approach did not yield significant results compared to studies using more advanced technologies.

In addition to the reported results, this study has certain limitations. The primary constraint is the relatively small number of participants, which limits the broad generalization of findings to the wider population. Furthermore, the conducted tests revealed small effect sizes. Additionally, the data collection process relied on only two cameras, resulting in a reconstruction methodology with an average measurement error of 0.02 m, which could affect the comparison of results before and after the intervention. This error is consistent with those reported in the soccer literature using OpenPose, where Viera et al.[50] found an OpenPose measurement error of 0.03 m. Meanwhile, the study by Monteiro et al.[51] reported errors of 0.054 m in the anteroposterior axis, 0.015 m in the mediolateral axis, and 0.017 m in the vertical axis during 3D reconstruction of goalkeepers using OpenPose. It is essential to acknowledge this error, especially when comparing it with "gold standard" measurements, which typically exhibit errors within the millimeter range.

Hence, we recommend that future research endeavors prioritize the assessment of the long-term effects of the video-based training model, incorporating comprehensive kinematic evaluations in the kicking task. Additionally, the adoption of advanced technologies such as OpenPose or other neural networks for human pose detection, coupled with an increased number of cameras for image capture, may be essential to minimize measurement error and maintain a more ecologically valid approach to studying the kicking task. The inclusion of a calibration system with more points may also be necessary to reduce error in the 3D reconstruction method.

Conclusion

The acute demonstration of instructional videos specifically improves the last stride length (LLS) of young soccer players. However, it is important to note that the statistical significance of these findings was low, indicating that even the improvements in LLS should be interpreted with caution. This finding highlights the need for a careful and measured approach when considering the acute effectiveness of video instruction. While LLS showed some improvement, other kinematic variables did not demonstrate significant changes. Therefore, the overall impact of acute video-based training may be limited, and further research is necessary to explore its broader implications and effectiveness.

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Data availability statement

The data that support the findings of this study are available from the corresponding author, Santiago, P.R.P., upon reasonable request.

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