KINEMATICS OF SOCCER INSTEP KICKING: A COMPARISON OF TWO-DIMENSIONAL AND THREE-DIMENSIONAL ANALYSIS

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The influence of two- and three-dimensional filming procedures on the calculation of soccer instep kicking kinematics was examined in this study. The knee angular velocity calculated three-dimensionally was compared with the data obtained from the following two procedures: 1. the angular velocity vector was computed as a perpendicular component to the sagittal plane (2D projection); 2. the angular velocity was computed only from the two-dimensional coordinates (2D standard). A distorted changing pattern was produced by the 2D standard approach which was most likely caused by computing segmental angular velocities from quasi-planar projection. It is suggested that researchers treat with caution any comparisons in the literature between three-dimensional angular kinematics and those computed two-dimensionally.

KEY WORDS: 2D, 3D, knee angular velocity, thigh angular velocity, shank angular velocity.

INTRODUCTION: The instep kick of soccer players has been dealt with in detailed biomechanical analyses. At first glance, sagittal plane motion forms the foundation of this skill, though the kicking leg also rotates around the frontal and longitudinal axes of the body (Roberts and Metcalfe, 1968; Plagenhof, 1971). However, in the past most studies (Luthanen, 1988; Putnam, 1991; Barfield, 1995; Lees, 1996) applied a two-dimensional procedure, thereby ignoring the motions out of the sagittal plane. Even in recent investigations this method was still applied. (Andersen, et al., 1999; Dörge, et al., 2002).
The three-dimensional nature of the instep kicking kinematics has been established (Levanon & Dapena, 1998; Nunome et al., 2002). However, up to now the effect of the filming procedures (two-dimensional vs. three-dimensional) on the calculation of kicking kinematics has never been systematically examined. It is obvious that the influence of the out-of-plane motion on the kicking kinematics must be scrutinized. Thus it could be clarified to which extent the knowledge obtained from past two-dimensional analyses is applicable to the examination of the actual three-dimensional kicking motion. Such information would furthermore clarify whether the previous two-dimensional data might be compared to the newly updated three-dimensional data. The purpose of this study, therefore, was to systematically quantify the influence of the two-dimensional procedures on the results of soccer instep kicking kinematics through a comparison with the three-dimensional analysis.

METHOD:

Data Collection:
Five highly skilled club players (age: = 16.8 ± 0.4 yrs; height: = 176.2 ± 6.1 cm; mass: = 70.6 ± 7.2 kg) volunteered to participate in this study. Informed written consent was obtained from each participant. After an adequate period of warm-up, the players were instructed to perform instep kicks with maximum force aiming at a target located at the centre of a goal 11 m in front of the ball. All participants performed at least five attempts with the right leg so that two shots with both a good foot-to-ball impact and adequate targeting could be selected. Two electrically synchronized video cameras were used to capture the lower limb motion at 200 Hz (exposure time was 1/2000 s). A digitizing system was used to manually digitize body landmarks including: right hip, knee, ankle, heel and toe. The centre of the ball was also digitized in its initial stationary position and in all available frames after it left the foot. The direct linear transformation (DLT) method was used to obtain the three-dimensional coordinate of each landmark.

Data Analysis:
In the present study, the knee angular velocity was chosen for comparison because both its two- dimensional and its three-dimensional nature were widely discussed in the literature.
To illustrate how the conventional two-dimensional procedures influence the data of the knee angular kinematics, the knee angular velocities were computed according to three different approaches. First, using methods similar to those reported by Sprigings et al. (1994), the absolute angular velocity vector was calculated for thigh and shank. The knee angular velocity vector was computed by substracting the absolute angular velocity vector of the thigh from that of the shank. For computing the anatomical-relevant knee angular velocity, a unit vector (rotational axis) perpendicular to the plane was defined by the longitudinal axis of the thigh and shank. The magnitude of the knee angular velocity was calculated as a parallel component to the unit vector (3D). Second, the magnitude of the knee angular velocity was computed as a perpendicular component to the sagittal plane (2D projection). Finally, the knee angular velocity was calculated only from the two-dimensional (the Y and Z) coordinates (2D standard) to resemble a conventional filming procedure in the literature.
The positive (+) and negative (-) values correspond to extension and flexion of the knee joint, respectively. To avoid systematic distortion of the data caused by ball impact, the angular velocities were computed from unsmoothed raw coordinates until two frames before ball impact. No smoothing procedure was applied to the kinematic data.

RESULTS:

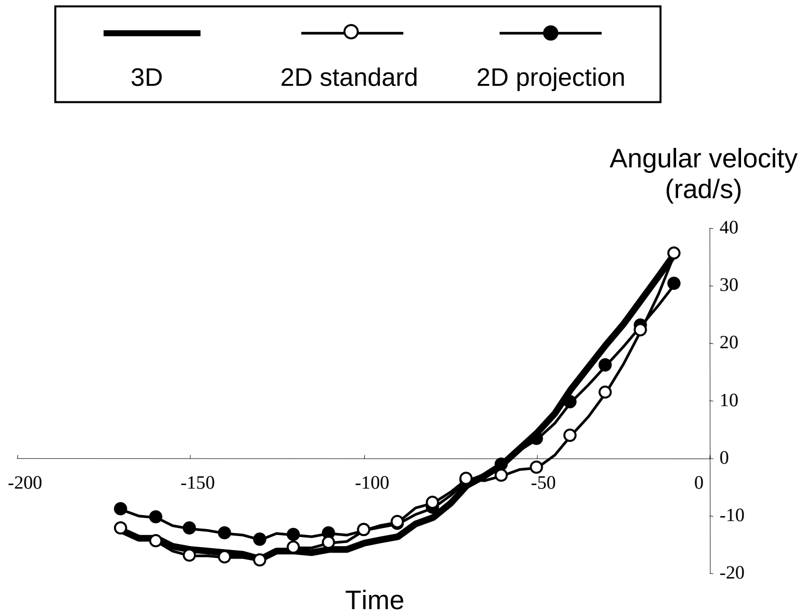

Figure1: Mean angular velocity of knee according to three different procedures.

The average changes of the knee angular velocities obtained from the three different processing procedures are shown in Figure 1. In the graph, the curves start just after right toe off and end immediately before ball impact (the time of 0 corresponds to the moment of ball impact). The effect of these procedures on the curves and magnitudes of the knee angular velocity was quite consistent among all participants. Although the general pattern of the knee angular velocity was basically similar across the three approaches, parts of the curves were distorted in the two-dimensional analyses.
It can be seen that the 2D standard approach produced a distorted changing pattern of the knee angular velocity. This seems to be initiated approximately 50 ms before ball impact. In contrast, the 2D projection approach results in the consistent underestimation of the magnitude of the knee angular velocity throughout the kick.

DISCUSSION: The present study systematically examined the effect of two- and three-dimensional filming procedures on the results of knee angular kinematics during soccer instep kicking. As shown in Figure 1, the magnitude was consistently underestimated during 2D projection and a distorted changing pattern was observed in the 2D standard analysis.

In order to explain how the knee angular velocities have been distorted in 2D standard, the angular velocity of the thigh and shank were computed because the knee angular velocity was computed by substracting the angular velocity of the thigh from that of the shank. These two segmental angular velocities were computed as a perpendicular component to the thigh-shank plane as is done in the 3D approach; and their two-dimensional angular velocity was also computed as is done in the 2D standard approach. The positive (+) and negative (-) values correspond to counter-clockwise and clockwise rotation of the thigh and shank, respectively.

Figure 2 shows the average change of the thigh and shank angular velocities measured according to the two different approaches (3D and 2D standard). As shown, the 2D standard procedure caused an irregular distortion of the two segments' angular velocities. In particular, the 2D standard's thigh angular velocity was partially overestimated around 50 ms before ball impact while a distinctive underestimation of the shank angular velocity occurred simultaneously . These two factors would account for the distinct distortion of the knee angular velocity curve that occurred in the last 50 ms before ball impact.

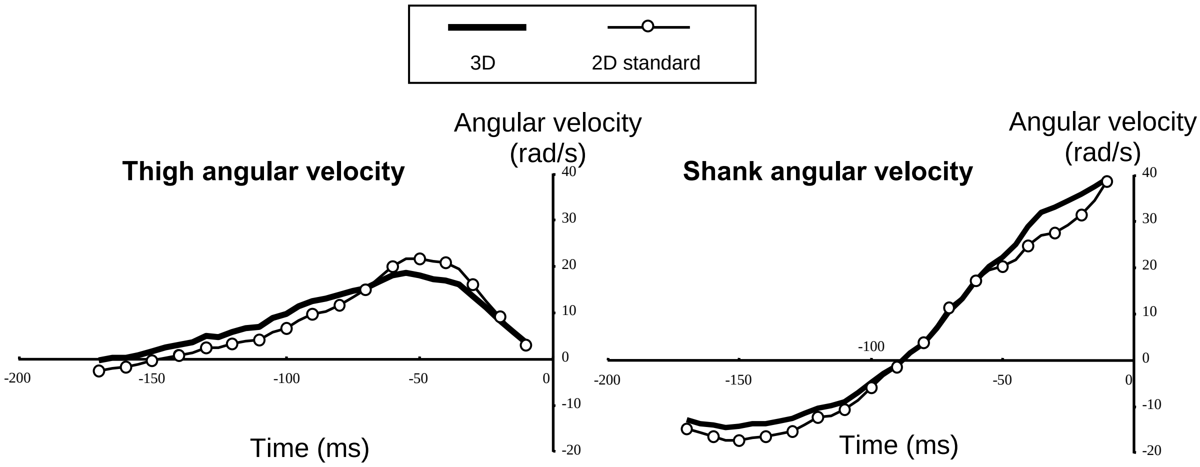

Figure2: Mean angular velocity of thigh and shank in 3D and 2D standard analyses.

From the comparison between the 2D approaches (2D projection vs. 2D standard), it can be concluded that the 2D standard's computing process of the angular velocity is most likely responsible for its distorted changing pattern of the knee angular velocity. Figure 3 shows the concept of underestimation (panel (a)) and overestimation (panel (b)) of the segmental angular velocity when the angular velocity is calculated from the projection image (bottom) and the actual swing plane (top). In general, the projected image of the sagittal plane is expected to be reduced in the vertical direction. When a segment is mostly oriented horizontally like panel (a), its velocity vector in the projection image (**V'**) is reduced whereas its length (**r'**) is mostly maintained. This will result in underestimation of the segment's angular velocity (**ω'**). In the other case, which is illustrated by panel (b), the length of the segment (**r'**) is reduced in the projection while the velocity vector (**V'**) is mostly maintained. This will result in overestimation of the segment's angular velocity (**ω'**).

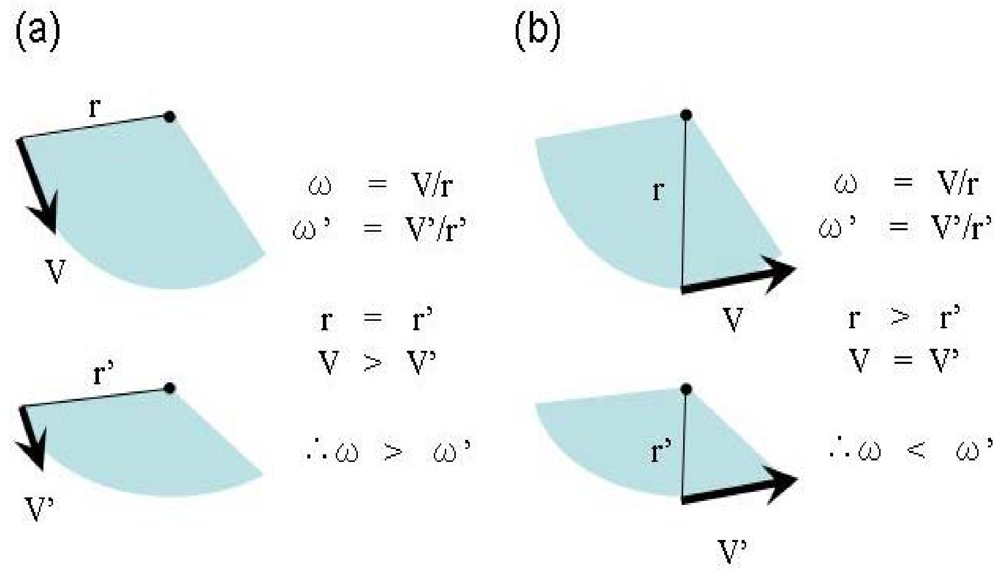

Figure3: Scheme of under- and overestimation of angular velocity in the projection.

CONCLUSION:
A distinct, distorted pattern of knee angular velocity was produced when it was computed from the conventional quasi-planar procedure that has been used in the majority of previous studies. This was most likely due to a computing process of segmental angular velocity from a quasi-planar projection image. Thus, researchers should compare three-dimensional angular kinematics with those computed two-dimensionally in the literature with caution.

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