THE PLANARITY OF THE STICK AND ARM MOTION IN THE FIELD HOCKEY HIT

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The development of relevant simulation models is one way in which our knowledge of the field hockey hit may be improved. The aim of this study was to test the appropriateness of a planar pendulum model for the motion of the stick and arms during the downswing. The hits of 13 experienced female players were filmed, and swing planes were fitted to the motion of the stickface during the downswing. Low variability in the length of a segment's projection onto the swing plane was taken as evidence for the validity of a planar model. Coefficients of variation of less than 5% for the stick and forearm lengths supported the use of such a model for these segments, but its validity for the upper arms is less certain.

KEY WORDS: field hockey, hit, modelling, swing plane.

INTRODUCTION: Despite its importance for long-range passing and shooting at goal (Anders and Myers, 2008), the field hockey hit is surprisingly poorly understood. Three-dimensional kinematics of the stick and body have been reported only by Chivers and Elliott (1987) and Elliott and Chivers (1988). Improvements in our knowledge of the stroke, which would provide a basis for better-informed recommendations on technique, may possibly come from a combination of further empirical investigations and computer simulation. The most obvious candidate in the latter area might be a planar pendulum model of the kind first popularised for golf by Cochran and Stobbs (1968). For field hockey, Elliott and Chivers (1988) suggested that the left arm and stick function as a double pendulum featuring a single arm segment, but that the right arm would need to be treated as two separate segments.

The validity of planar models for the golf swing has recently been challenged, with a single plane not always being appropriate for the club only, let alone the club *and* the arms (see Coleman and Anderson, 2007, for a summary). For the field hockey hit, and following Cochran and Stobbs' (1968) original definition of the swing plane, Willmott and Dapena (2008) found that the motion of the stickface during the downswing was remarkably planar. This plane might form the basis of a pendulum model for the arms and stick either if these segments move directly within the same plane, or if they share a common axis of rotation that it is perpendicular to the plane. In the latter case, each segment's projection onto the swing plane would be of constant length and would appear to move in the plane (Figure 1).

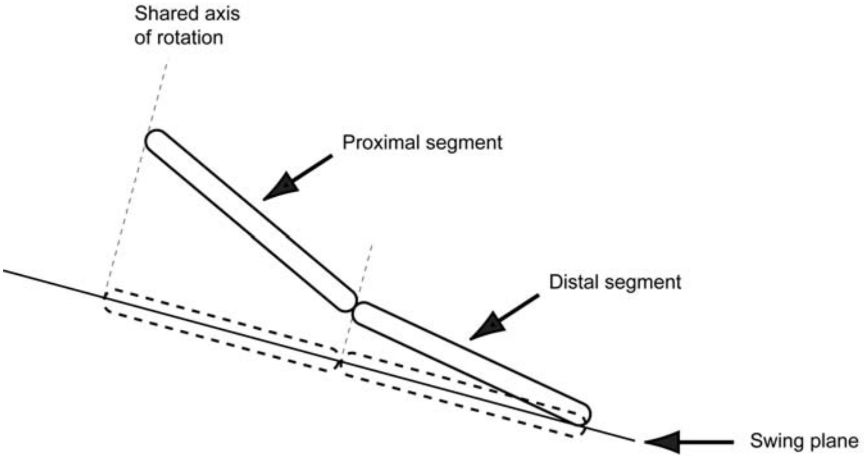

Figure 1. A 'planar' double pendulum model in which the two segments rotate about a shared axis, with their projections (dashed lines) moving in the swing plane.

The purpose of this study was to investigate the validity of a planar model for the motion of the stick and arms during a field hockey hit. This was done by determining the angles at which the stick and arm segments are held relative to the stickface swing plane during the downswing of the field hockey hit. The cosines of these angles are a measure of the length of the projected segments, and the consistency of these projected lengths can be used to test the appropriateness of a planar representation of the hit.

METHODS: Data Collection: Thirteen experienced female field hockey players (height = 1.67 ± 0.06 m; mass = 64 ± 6 kg; mean ± sd) were asked to hit a stationary ball after a single approach step. Six of these players used a straight backswing in which the stickface path was similar to that of the subsequent downswing; the remaining seven players adopted a looped backswing in which the stick was taken back in a pronounced curve above the plane of the downswing. The hits were filmed with two Locam motion-picture cameras at 200 fps, and the DLT method (Abdel-Aziz and Karara, 1971) was used to reconstruct the three-dimensional positions of three stick markers as well as the left and right wrists, elbows and shoulders. The elbows and shoulders were tracked as part of a wider study in which the whole body was digitised in every other frame during the downswing; due to their higher velocities, the wrists and stick markers were digitised in every frame.

The data for all landmarks were smoothed from the start of the downswing to impact using quintic splines. Cutoff frequencies were selected on a subject-by-subject basis, and ranged from 30 to 42 Hz for the stick markers, 22 to 30 Hz for the wrists, and 16 to 18 Hz for the elbows and shoulders. Finally, the three stick markers were used to reconstruct the position of the centre of the stickface and the two ends of the stick shaft at each instant.

Data Analysis: Stroke planes were fitted to the stickface motion using Total Least Squares Regression, as described in Willmott and Dapena (2008). The stickface motion was resampled at 0.10 m intervals to give equal weight to all parts of the downswing, and the motion was considered to be planar where the mean absolute residual between the stickface coordinates and the fitted plane was less than 0.5% of the path length travelled by the stickface. Working backwards from impact, the longest portion of the downswing that met this criterion was selected.

Quintic spline interpolation was used to determine the positions of the shoulders, elbows, wrists and stick shaft endpoints at the instant of each of the resampled stickface positions. The angles between the stroke plane and the following segments were calculated: the stick shaft, the left and right upper arms, and the left and right forearms. Positive angles indicated that the proximal end of the segment was higher than the distal end, relative to the swing plane. The cosine of a segment's angle gave the length of its projection onto the swing plane as a proportion of the true segment length. For each segment, the mean cosine at every stickface position was determined for each backswing group. The consistency of these mean cosines across the downswing was quantified using the coefficient of variation (CV, the standard deviation expressed as a percentage of the mean value).

RESULTS & DISCUSSION: The planar portion of the stickface motion had a length of 2.45 ± 0.28 m for the straight backswing group, covering the entire downswing for five players and 95% of it for the sixth player. The length of the planar portion for the looped backswing group was 2.87 ± 0.29 m, which was 86 ± 8% of the downswing length.

Figure 2 shows how the projected length of each segment varied over the portion of the downswing for which the stickface motion for all members of a particular backswing group was planar: the last 2.1 m for the straight backswing group, and the last 2.3 m for the looped backswing group. The variation in projected lengths was small for the stick (CV <1% for both backswing groups) and the forearms (CV <5%), supporting the use of a planar model for these segments.

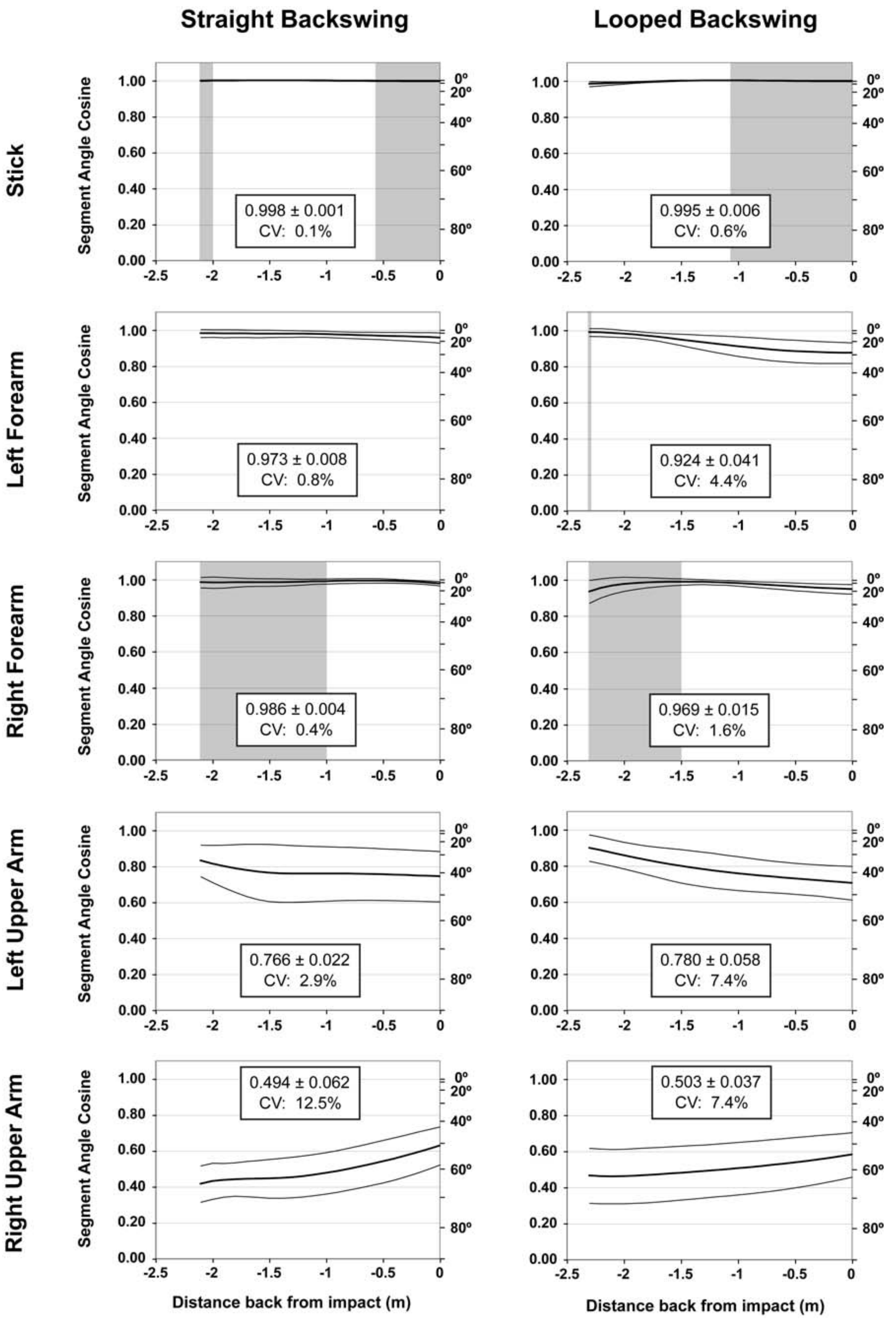

Figure 2. Variation in the cosines of the segment angles relative to the swing plane with increasing distance of the stickface back from impact. The lines shown are the mean ± sd for each group of subjects. The shaded areas represent periods when the angles were negative. The inset boxes show the distribution of each mean cosine and its coefficient of variation.

The variability was greater, in general, for the projected lengths of the upper arms, with the CV reaching 12.5% for the right upper arm in the straight backswing group.

The angles on the right side of each graph in Figure 2 are a guide to the segment angles that correspond to particular cosine values. Given the non-linear relationship between angles and their cosines, however, the variability in the mean segment angles cannot be read directly from Figure 2. The distribution of the values of each mean segment angle across the shared planar section of the downswing is therefore listed in Table 1.

Table 1. The distributions of the mean segment angles, calculated for each backswing group. (mean ± sd, all values in degrees.)

	Straight Backswing	Looped Backswing
Stick	0.0 ± 0.5	1.7 ± 5.0
Left Forearm	12.3 ± 2.2	17.0 ± 9.4
Right Forearm	0.5 ± 5.9	3.6 ± 11.1
Left Upper Arm	38.0 ± 1.9	37.5 ± 5.9
Right Upper Arm	60.0 ± 4.2	59.1 ± 2.5

The stick and the right forearm moved close to the swing plane; the left forearm was maintained at a small positive angle. Large ranges of angles for the forearms in the looped backswing group did not lead to large variation in the projected lengths because the absolute angles were comparatively small, and thus the cosines did not change much. The upper arms were held at considerable angles to the stroke plane: approximately 40° and 60° for the left and right upper arms, respectively.

CONCLUSION: Investigation of the consistency of segments' projected lengths in the swing plane has demonstrated that the motion of the stick shaft and forearms could be approximated by a planar pendulum model. For the stick and right forearm, this is because the segments are moving close to the plane itself; the left forearm is held at a positive angle to the plane but its projected length is very consistent. The validity of a planar model for the upper arms is less certain: these segments are at much larger angles to the swing plane, where small changes in these angles result in larger changes in the projected lengths.

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