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ABSTRACT

Objectives The lower limb is widely reported as the most commonly injured body part in the field of hockey, more specifically lateral ankle sprains and internal knee injury. Despite this, there remains limited understanding of how the biomechanics of the sport could be adapted to minimise injury. The aim of this study was to propose a foot position during the hockey hit that results in the smallest joint angles and moments, from a total of four different foot positions: 0°, 30°, 60° and 90°, which may correlate to injury risk.

Method Eighteen players from the local University Ladies Hockey Club participated in this study. Each player was required to perform a hit with their lead foot in four different positions: 0°, 30°, 60° and 90°, where 0° was a lead foot position perpendicular to the direction of motion of the ball. Angles and moments were calculated with the Vicon system using force plates and motion analysis.

Results Significant differences ($p<0.05$) were found between the angles and moments of the four foot positions tested, indicating that foot angle can influence the degree of angulation, and moments, produced in the lower limb joints during the hockey hit.

Conclusion There is a relationship between lead foot position and the angles and moments produced in the lower limb joints during the hockey hit, and this may correlate with injury risk.

What are the new findings?

- Lead foot position influences the angles and moments produced in the lower limb joints during the hockey hit.
- Overall, a lead foot position in line with the rest of the body whilst performing the hockey hit, defined as 30° in the present study, produced the lowest angles and moments in the most significant planes of motion.
- Foot position may correlate with injury risk to the lower limb during the hockey hit.

INTRODUCTION

Field hockey is a fast-paced stick and ball sport played in 132 countries worldwide.[1] Players must withstand forces generated from fast running and sharp turns while also using their upper body to control and strike the ball.

Although contact injuries from the stick and ball are more common and can have serious consequences, non-contact mechanisms are significant, particularly among female players.[2] The lower limb is of particular interest; Barboza *et al*[3] carried out a systematic review of injury data and found that this was the area of the body most commonly injured during hockey, more specifically the knee and ankle with the literature vague on whether the injuries occur through hitting or running. The complex cutting manoeuvres and high-power swing motions required to distribute the ball create a high risk of overuse injury, particularly to the ligaments of the knee and lateral ankle.[4] However, limited literature exists on the biomechanics of the sport and how this relates to non-contact injury mechanisms.

Degree of angulation and magnitude of moments around a joint are factors known to correlate with the risk of injury, as they play a key role in the biomechanics of the joint.[5–7] Since the lower limb joints allow limited degrees of angulation, particularly in the coronal and transverse planes,[8] a foot position that results in angulation of the foot close to its maximum angle, in the respected plane of motion, will increase the risk of injury. Furthermore, there are a number of factors that influence how the magnitude of a force will affect the joint, such as the strength of surrounding muscles. Therefore, there is not a particular magnitude of moment that can be stated as the threshold for injury, making it difficult to quantify the risk of injury. However, through comparison of the four positions against one another, the one that produced the smallest moments the most often, and largest moments the least often, could be said to carry the smallest risk of injury.

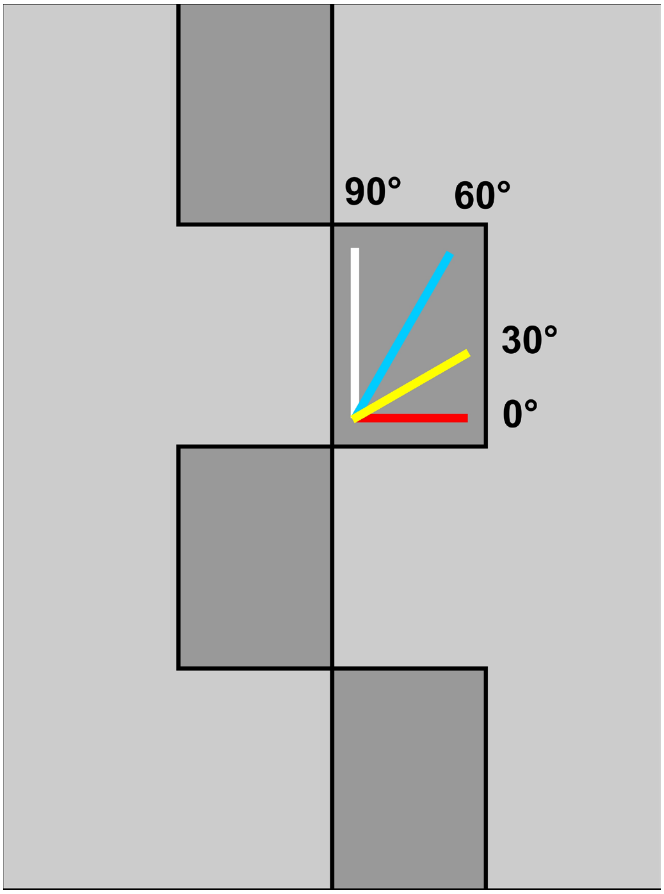

Figure 1 Foot positions.[11]

There were four foot positions tested in the present study: 0°, 30°, 60° and 90°, relative to the axes of the force plate used to gather motion analysis data. In hockey, a side on stance is common, with the front foot placed at a diagonal to the line of movement of the ball. In this position, the front-foot faces in a similar direction to the rest of the body, with minimal rotation of the ankle joint relative to the body. In the present study, this foot position was defined as 30°. In order to gather motion analysis data with both a smaller and larger degree of angulation at the ankle, a further three foot positions, defined as 0°, 60° and 90° were also tested.

A foot position of 90°was the highest degree included because this results in the foot pointing in the direction of movement. A fourth angle of 60° was included for a more thorough comparison of foot positions between the two extremes of 0° and 90°.

The effect of foot position during a drag flick, a type of stroke performed in hockey when shooting at goal, was investigated by Wild *et al*.[9] The authors proposed that an externally rotated lead foot position during this stroke increases the force at the ankle joint. The hit, which was analysed in the present study, is relevant to a wider range of hockey players than the drag flick, as it is used in all aspects of the game. Therefore, understanding the biomechanics of this stroke is highly relevant.

It appears that adaptation of foot orientation is possible through appropriate training. A recent study involving a neuromuscular training programme for hockey players classed as having unstable ankles resulted in a positive effect on the participants' ankle positioning.[10]

This study aimed to propose a lead foot position during the hockey hit that results in the smallest joint angles and moments, from a total of four different foot positions: 0°, 30°, 60° and 90°. The null hypothesis of this study was that no relationship exists between lead foot position and the angles and moments produced during a hockey hit.

MATERIALS AND METHODS

Patient and public involvement

Twenty female hockey players were recruited from the local University Ladies Hockey Club. Volunteers were recruited through a poster being displayed in the hockey club and were given a participant information sheet prior to the study commencing. Participants were required to have played a minimum of one season of competitive hockey and have no significant injuries that precluded them from playing the year before the study was conducted.

Procedure

Motion analysis data were collected using the Vicon Nexus system V.2.6.1 (using 14 MXF40 cameras and 4 AMTI force plates BP600400). Coloured tape was used to mark the four foot positions on one of the four force plates, as shown in figure 1.

Before collecting data, each participant was provided with a standardised pair of hockey shoes in the appropriate size to minimise any variations that could be attributed to footwear. Anthropometric data were recorded. Sixteen retroreflective markers were then attached at the following bony landmarks: anterior superior iliac spine, sacral dimple, medial and lateral femoral epicondyle, medial and lateral malleoli, posterior calcanei and between the first and second metatarsal heads. A further four wand markers were placed on each lateral thigh and calf (figure 2). Following calibration of the laboratory, participants were provided with a ball and a standard hockey stick that matched their height and asked to practice performing the hit until the participant and lead investigator agreed that they were familiar with the experimental setup. The hit was then performed while stepping onto the force plate. The trial was considered successful if the motion was performed correctly, with their whole foot on the force plate, and at the required angle. Data were collected until five successful trials at all four foot positions were recorded, from each participant.

Data analysis

Vicon software was used to label successful trials. Trials were disregarded if any of the markers were missing, if the foot position was not at the required angle, or if the foot was not completely within the boundary of the force

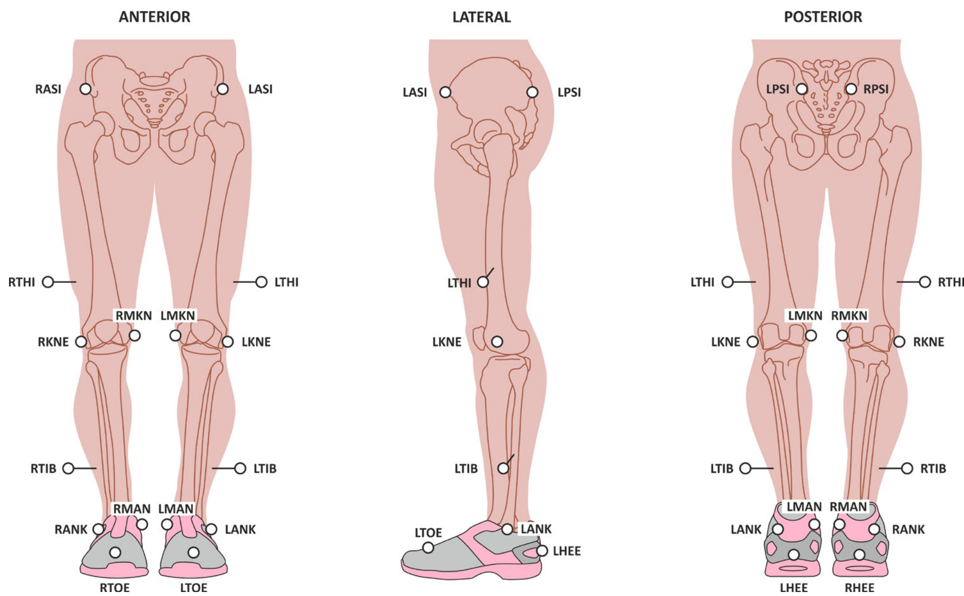

Figure 2 Marker placement.[12]LANK, left ankle (lateral); LASI, left asis; LHEE, left heel; LKNE, left knee (lateral); LMANK, left ankle (medial); LMKNE, left knee (medial); LPSI, left psis; LTHI, left thigh; LTIB, left tibia; LTOE, left toe; RANK, right ankle (lateral); RASI, right asis; RHEE, right heel; RKNE, right knee (lateral); RMANK; right ankle (medial); RMKNE, right ankle (medial); RPSI, right psis; RTHI, right thigh; RTIB, right tibia; RTOE, right toe;

plate. This was the case for two participants, so data from eighteen participants was analysed.

Statistical analysis

The SPSS system V.22 was used to analyse the data. Analysis and comparison between foot positions was carried out using the general linear model and pairwise comparisons. Four groups were formed using information from all 18 participants at each foot position. A significant difference was reported if the p value was<0.05.

RESULTS

Of the 18 participants whose data were analysed, the mean age was 20 years (SD 1.0); the mean height was 167 cm (SD 5.2) and the mean mass was 64.2 kg (SD 5.7).

Graphs were created to clearly display the trends of angles and moments between the foot positions.

Due to lateral ankle sprains and internal knee injury being the most common injuries in hockey, particular focus was paid to the planes of motion in which these could occur. Statistically significant differences (p<0.05) were found between the angles and moments of all four foot positions tested.

The effect size, CIs and p values for all comparisons made are shown in tables 1 and 2, for ankle and knee data, respectively.

Ankle

Plantarflexion

Angles

The maximum plantarflexion angles were lowest at a foot position of 30° with a mean of 15.3°, and highest at 60° with a mean of 20°. The only significant difference was between 30° and 60° (p<0.05).

Moments

Angle 0° produced the lowest maximum plantarflexion moment of the four foot positions (121 Nmm/kg), and this degree was significantly different (p<0.001) from the other three, of which 30° produced the highest result (273 Nmm/kg). There were no significant differences between 30°, 60° or 90°.

Inversion

Angles

As seen in figure 3, the two foot positions that produced the lowest maximum inversion angles were 0° and 30°, between which no significant difference was found. Foot positions of 90° and 60° produce the highest inversion angles and no significant difference was found between them. However, significant differences were found between 0° and both 60° and 90°, and 30° and both 60° and 90° (p<0.001).

Moments

Figure 3 shows that 30° and 60° produced the smallest inversion moments of the four positions and were not significantly different from each other. The maximum moment at 90° (113 Nmm/kg), which was the highest of the four positions, was significantly different from 0° (p<0.05) and of greater significant difference from 30° and 60° (p<0.001). No significant differences were found between 0°, 30° and 60°.

Table 1 Ankle data

Event type			Mean difference	SE	P value	95% CI for difference	
						Lower bound	Upper bound
Plantarflexion angles (degrees)	0	30	1.381	2.162	0.526	5.718	2.956
		60	3.288	1.970	0.101	0.663	7.238
		90	0.919	1.736	0.599	2.563	4.401
	30	0	1.381	2.162	0.526	2.956	5.718
		60	4.669*	1.607	0.005	1.445	7.893
		90	2.300	1.647	0.168	1.003	5.603
	60	0	3.288	1.970	0.101	7.238	0.663
		30	4.669*	1.607	0.005	7.893	1.445
		90	2.369	1.364	0.088	5.105	0.367
	90	0	0.919	1.736	0.599	4.401	2.563
		30	2.300	1.647	0.168	5.603	1.003
		60	2.369	1.364	0.088	0.367	5.105
Plantarflexion moments (Nmm/kg)	0	30	151.735*	27.226	0.000	97.127	206.344
		60	148.726*	28.901	0.000	90.757	206.694
		90	133.799*	29.298	0.000	75.035	192.562
	30	0	151.735*	27.226	0.000	206.344	97.127
		60	3.009	18.310	0.870	39.735	33.716
		90	17.936	13.642	0.194	45.299	9.427
	60	0	148.726*	28.901	0.000	206.694	90.757
		30	3.009	18.310	0.870	33.716	39.735
		90	14.927	14.173	0.297	43.354	13.500
	90	0	133.799*	29.298	0.000	192.562	75.035
		30	17.936	13.642	0.194	9.427	45.299
		60	14.927	14.173	0.297	13.500	43.354
Inversion angles (degrees)	0	30	0.329	0.665	0.623	1.663	1.006
		60	3.260*	0.609	0.000	4.480	2.039
		90	3.718*	0.621	0.000	4.964	2.472
	30	0	0.329	0.665	0.623	1.006	1.663
		60	2.931*	0.499	0.000	3.932	1.930
		90	3.389*	0.473	0.000	4.339	2.440
	60	0	3.260*	0.609	0.000	2.039	4.480
		30	2.931*	0.499	0.000	1.930	3.932
		90	0.458	0.370	0.221	1.202	0.285
	90	0	3.718*	0.621	0.000	2.472	4.964
		30	3.389*	0.473	0.000	2.440	4.339
		60	0.458	0.370	0.221	0.285	1.202

Continued

Table 1 Continued

Event type			Mean difference	SE	P value	95% CI for difference	
						Lower bound	Upper bound
Inversion moments (Nmm/kg)	0	30	13.662	9.341	0.149	5.074	32.398
		60	7.296	11.515	0.529	15.800	30.392
		90	35.935*	10.993	0.002	57.984	13.885
	30	0	13.662	9.341	0.149	32.398	5.074
		60	6.366	9.668	0.513	25.757	13.026
		90	49.597*	9.965	0.000	69.584	29.609
	60	0	7.296	11.515	0.529	30.392	15.800
		30	6.366	9.668	0.513	13.026	25.757
		90	43.231*	8.481	0.000	60.242	26.220
	90	0	35.935*	10.993	0.002	13.885	57.984
		30	49.597*	9.965	0.000	29.609	69.584
		60	43.231*	8.481	0.000	26.220	60.242
Internal rotation angles (degrees)	0	30	1.543	1.587	0.335	1.641	4.726
		60	10.446*	1.944	0.000	6.548	14.345
		90	19.196*	2.235	0.000	14.713	23.680
	30	0	1.543	1.587	0.335	4.726	1.641
		60	8.904*	2.197	0.000	4.497	13.310
		90	17.654*	2.245	0.000	13.152	22.156
	60	0	10.446*	1.944	0.000	14.345	6.548
		30	8.904*	2.197	0.000	13.310	4.497
		90	8.750*	2.070	0.000	4.598	12.902
	90	0	19.196*	2.235	0.000	23.680	14.713
		30	17.654*	2.245	0.000	22.156	13.152
		60	8.750*	2.070	0.000	12.902	4.598
Internal rotation moments (Nmm/kg)	0	30	4.677	12.595	0.712	29.939	20.584
		60	29.925*	12.834	0.024	55.665	4.184
		90	25.776	14.033	0.072	53.923	2.371
	30	0	4.677	12.595	0.712	20.584	29.939
		60	25.247	13.000	0.057	51.322	0.828
		90	21.099	14.327	0.147	49.835	7.638
	60	0	29.925*	12.834	0.024	4.184	55.665
		30	25.247	13.000	0.057	0.828	51.322
		90	4.148	12.844	0.748	21.614	29.911
	90	0	25.776	14.033	0.072	2.371	53.923
		30	21.099	14.327	0.147	7.638	49.835
		60	4.148	12.844	0.748	29.911	21.614

*Highlights data: p<0.05.

Internal rotation

Angles

In the transverse plane, internal rotation angles decreased from a foot position of 0° to that of 90°, with mean angles of 48.7° and 29.5°, respectively. Significant differences were found between all four foot angles (p<0.001) except between 0° and 30°, which produced the highest degrees of internal rotation and were not statistically significant from each other.

Moments

Furthermore, 60° produced the highest internal rotation moments (295 Nmm/kg) and this result was significantly different from that of 0° (p<0.05), which produced the lowest (265 Nmm/kg). However, there are no significant differences between any of the other positions.

Table 2 Knee data

Event type			Mean difference	SE	P value	95% CI for difference	
						Lower bound	Upper bound
Flexion angles (degrees)	0	30	0.445	1.053	0.674	2.556	1.667
		60	4.027*	1.124	0.001	6.282	1.772
		90	6.149*	1.390	0.000	8.937	3.360
	30	0	0.445	1.053	0.674	1.667	2.556
		60	3.582*	1.150	0.003	5.889	1.276
		90	5.704*	1.147	0.000	8.005	3.403
	60	0	4.027*	1.124	0.001	1.772	6.282
		30	3.582*	1.150	0.003	1.276	5.889
		90	2.122*	1.020	0.042	4.167	0.076
	90	0	6.149*	1.390	0.000	3.360	8.937
		30	5.704*	1.147	0.000	3.403	8.005
		60	2.122*	1.020	0.042	0.076	4.167
Flexion moments (Nmm/kg)	0	30	37.741	43.019	0.384	48.545	124.027
		60	98.725	55.467	0.081	12.527	209.977
		90	196.787*	53.372	0.001	89.736	303.838
	30	0	37.741	43.019	0.384	124.027	48.545
		60	60.984	45.334	0.184	29.944	151.913
		90	159.046*	42.688	0.000	73.424	244.668
	60	0	98.725	55.467	0.081	209.977	12.527
		30	60.984	45.334	0.184	151.913	29.944
		90	98.062*	46.029	0.038	5.740	190.384
	90	0	196.787*	53.372	0.001	303.838	89.736
		30	159.046*	42.688	0.000	244.668	73.424
		60	98.062*	46.029	0.038	190.384	5.740
Extension moments (Nmm/kg)	0	30	98.843*	33.914	0.005	30.822	166.865
		60	254.436*	44.212	0.000	165.759	343.114
		90	323.881*	46.311	0.000	230.993	416.769
	30	0	98.843*	33.914	0.005	166.865	30.822
		60	155.593*	37.923	0.000	79.529	231.657
		90	225.037*	46.053	0.000	132.666	317.409
	60	0	254.436*	44.212	0.000	343.114	165.759
		30	155.593*	37.923	0.000	231.657	79.529
		90	69.445	43.330	0.115	17.464	156.353
	90	0	323.881*	46.311	0.000	416.769	230.993
		30	225.037*	46.053	0.000	317.409	132.666
		60	69.445	43.330	0.115	156.353	17.464

Continued

Table 2 Continued

Event type			Mean difference	SE	P value	95% CI for difference	
						Lower bound	Upper bound
Adduction angles (degrees)	0	30	3.888*	0.759	0.000	5.409	2.366
		60	8.088*	0.727	0.000	9.547	6.630
		90	10.787*	0.784	0.000	12.360	9.214
	30	0	3.888*	0.759	0.000	2.366	5.409
		60	4.201*	0.536	0.000	5.277	3.125
		90	6.899*	0.669	0.000	8.241	5.558
	60	0	8.088*	0.727	0.000	6.630	9.547
		30	4.201*	0.536	0.000	3.125	5.277
		90	2.699*	0.560	0.000	3.821	1.576
	90	0	10.787*	0.784	0.000	9.214	12.360
		30	6.899*	0.669	0.000	5.558	8.241
		60	2.699*	0.560	0.000	1.576	3.821
Adduction moments (Nmm/kg)	0	30	163.446*	32.442	0.000	228.516	98.376
		60	389.585*	33.304	0.000	456.385	322.786
		90	499.924*	45.099	0.000	590.381	409.466
	30	0	163.446*	32.442	0.000	98.376	228.516
		60	226.139*	28.605	0.000	283.513	168.766
		90	336.478*	37.265	0.000	411.222	261.733
	60	0	389.585*	33.304	0.000	322.786	456.385
		30	226.139*	28.605	0.000	168.766	283.513
		90	110.338*	33.314	0.002	177.158	43.518
	90	0	499.924*	45.099	0.000	409.466	590.381
		30	336.478*	37.265	0.000	261.733	411.222
		60	110.338*	33.314	0.002	43.518	177.158
Abduction angles (degrees)	0	30	2.527*	0.543	0.000	3.616	1.438
		60	4.398*	0.760	0.000	5.923	2.873
		90	5.317*	0.702	0.000	6.725	3.910
	30	0	2.527*	0.543	0.000	1.438	3.616
		60	1.871*	0.536	0.001	2.946	0.796
		90	2.790*	0.528	0.000	3.850	1.730
	60	0	4.398*	0.760	0.000	2.873	5.923
		30	1.871*	0.536	0.001	0.796	2.946
		90	.919*	0.432	0.038	1.786	0.053
	90	0	5.317*	0.702	0.000	3.910	6.725
		30	2.790*	0.528	0.000	1.730	3.850
		60	.919*	0.432	0.038	0.053	1.786

Continued

Table 2 Continued

Event type			Mean difference	SE	P value	95% CI for difference	
						Lower bound	Upper bound
Abduction moments (Nmm/kg)	0	30	101.129*	34.395	0.005	170.117	32.141
		60	203.261*	35.802	0.000	275.071	131.450
		90	329.079*	33.256	0.000	395.782	262.376
	30	0	101.129*	34.395	0.005	32.141	170.117
		60	102.131*	37.945	0.009	178.240	26.023
		90	227.950*	31.780	0.000	291.692	164.207
	60	0	203.261*	35.802	0.000	131.450	275.071
		30	102.131*	37.945	0.009	26.023	178.240
		90	125.819*	35.845	0.001	197.714	53.923
	90	0	329.079*	33.256	0.000	262.376	395.782
		30	227.950*	31.780	0.000	164.207	291.692
		60	125.819*	35.845	0.001	53.923	197.714
Internal rotation angles (degrees)	0	30	1.570*	0.547	0.006	0.473	2.667
		60	2.038*	0.801	0.014	0.431	3.645
		90	4.184*	0.862	0.000	2.455	5.912
	30	0	1.570*	0.547	0.006	2.667	0.473
		60	0.468	0.595	0.435	0.726	1.662
		90	2.613*	0.694	0.000	1.222	4.005
	60	0	2.038*	0.801	0.014	3.645	0.431
		30	0.468	0.595	0.435	1.662	0.726
		90	2.146*	0.639	0.001	0.864	3.427
	90	0	4.184*	0.862	0.000	5.912	2.455
		30	2.613*	0.694	0.000	4.005	1.222
		60	2.146*	0.639	0.001	3.427	0.864
Internal rotation moments (Nmm/kg)	0	30	17.640	9.194	0.060	36.081	0.800
		60	61.764*	10.622	0.000	83.068	40.459
		90	71.546*	11.499	0.000	94.610	48.482
	30	0	17.640	9.194	0.060	0.800	36.081
		60	44.123*	10.839	0.000	65.863	22.384
		90	53.906*	11.606	0.000	77.185	30.626
	60	0	61.764*	10.622	0.000	40.459	83.068
		30	44.123*	10.839	0.000	22.384	65.863
		90	9.783	12.459	0.436	34.773	15.207
	90	0	71.546*	11.499	0.000	48.482	94.610
		30	53.906*	11.606	0.000	30.626	77.185
		60	9.783	12.459	0.436	15.207	34.773

Continued

Table 2 Continued

Event type			Mean difference	SE	P value	95% CI for difference	
						Lower bound	Upper bound
External rotation angles (degrees)	0	30	4.151*	1.243	0.002	1.658	6.644
		60	8.640*	1.222	0.000	6.188	11.091
		90	10.109*	1.295	0.000	7.511	12.707
	30	0	4.151*	1.243	0.002	6.644	1.658
		60	4.489*	1.121	0.000	2.239	6.738
		90	5.958*	1.209	0.000	3.534	8.383
	60	0	8.640*	1.222	0.000	11.091	6.188
		30	4.489*	1.121	0.000	6.738	2.239
		90	1.470	1.116	0.194	0.769	3.709
	90	0	10.109*	1.295	0.000	12.707	7.511
		30	5.958*	1.209	0.000	8.383	3.534
		60	1.470	1.116	0.194	3.709	0.769
External rotation moments (Nmm/kg)	0	30	1.964	14.036	0.889	–26.188	30.117
		60	–12.391	15.724	0.434	–43.930	19.148
		90	–15.810	12.942	0.227	–41.769	10.149
	30	0	–1.964	14.036	0.889	–30.117	26.188
		60	–14.355	12.183	0.244	–38.791	10.080
		90	–17.774	11.806	0.138	–41.455	5.907
	60	0	12.391	15.724	0.434	–19.148	43.930
		30	14.355	12.183	0.244	–10.080	38.791
		90	–3.419	12.410	0.784	–28.311	21.473
	90	0	15.810	12.942	0.227	–10.149	41.769
		30	17.774	11.806	0.138	–5.907	41.455
		60	3.419	12.410	0.784	–21.473	28.311

*statistically significant (p <0.05)

Knee

Flexion

Angles

For flexion at the knee, 0° and 30°produced the lowest angulation (44.6° of angulation for 0° foot position), and there was no significant difference between them. The highest mean flexion was recorded from 90° with a mean angle of 50.7°. Very significant differences were found between 90° with both 0° and 30° and also with 60° and 0° (p<0.001). Significant differences were also found between 60° and both 30° and 90° (p<0.05).

Moments

For flexion at the knee, a foot position of 90° produced the lowest maximum flexion moments with a mean of 1282 Nmm/kg, while 0° produced the highest with a mean of 1479 Nmm/kg. The result for 90° was significantly different to that of 60° (p<0.05) and of greater significant difference to 0° and 30° (p<0.001).

Extension

Angles

No knee extension angles were recorded.

Moments

For extension at the knee, a foot position of 90° produced the highest maximum extension moments, with a mean of 591 Nmm/kg. This result was significantly different from the maximum moments produced at foot positions of both 0° and 30°, of which the mean extension moments were 267 Nmm/kg and 366 Nmm/kg, respectively (p<0.001).

Adduction

Angles

Very significant differences were found between adduction angles of all foot positions (p<0.001), the lowest resulting from 0° and the highest from 90°.

Moments

A foot position of 0° produced the lowest adduction moments (683 Nmm/kg) and 90° produced the highest (1183 Nmm/kg). A significant difference was found between 60° and 90° (p<0.05) and greater significant differences were found between all other foot positions (p<0.001).

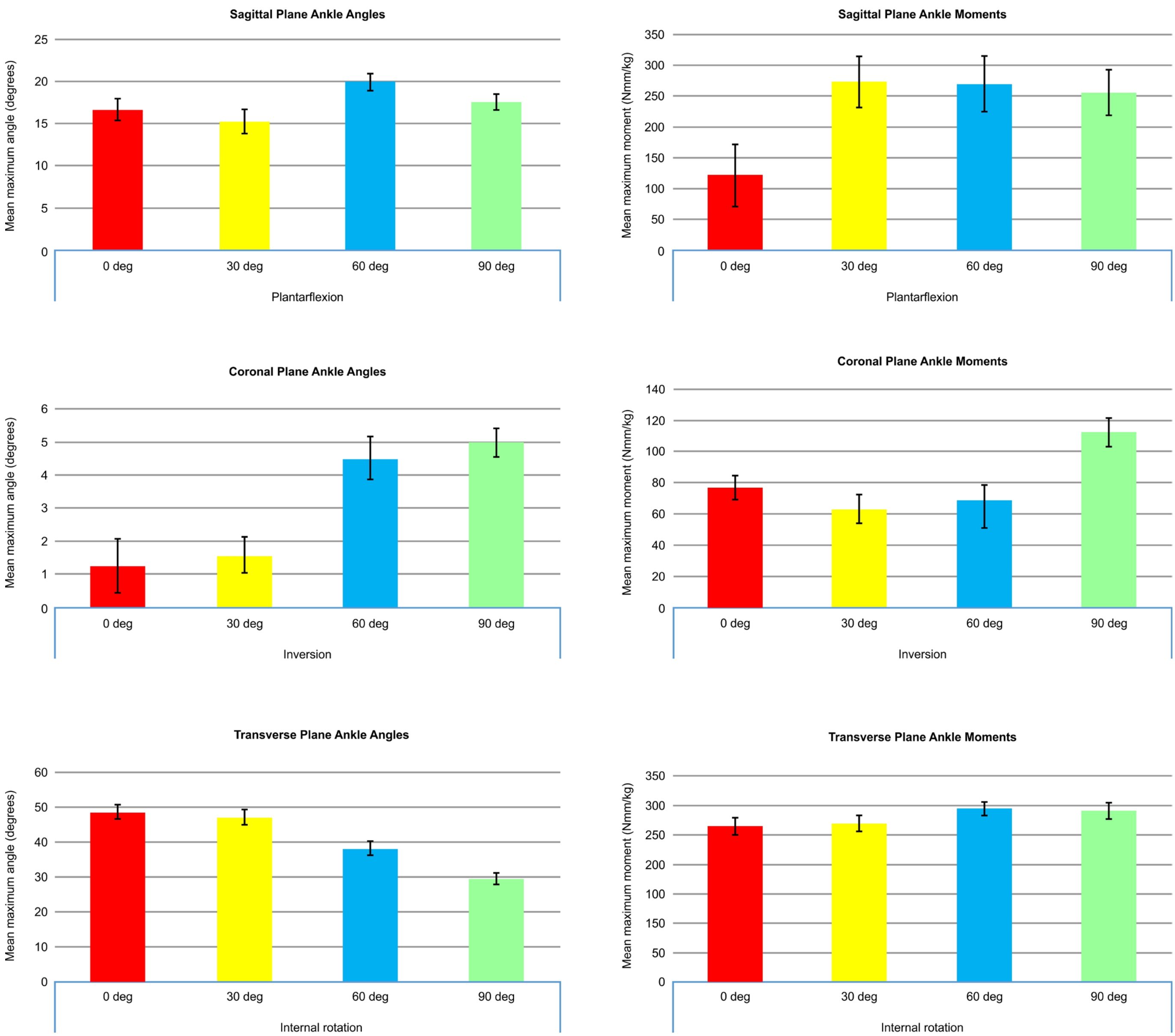

Figure 3 Ankle graphs.

Abduction

Angles

For abduction, 90° produced the lowest angulation of 6.3° and 0° produced the highest of 11.6°. A significant difference was found between 60° and 90° ($p<0.05$) and very significant differences were found between all other foot positions ($p<0.001$).

Moments

For abduction, the trend followed the opposite direction, with the highest moments at 0° (539 Nmm/kg). Significant differences were found between 30° and both 0° and 60° ($p<0.05$). Even greater significant differences were found between 60° and both 0° and 90°, and between 90° and both 0° and 30° ($p<0.001$).

Internal rotation

Angles

Figure 4 displays a trend of decreasing internal rotation angles from 0° to 90°. For internal rotation angles, very significant differences were found between 90° and both 0° and 30° ($p<0.001$). Significant differences were also found between 0° and 30° and also 60° with both 0° and 90° ($p<0.05$).

Moments

The foot positions that produced the lowest internal rotation moments were 0° and 30°, with no significant difference between them. The lowest was 0° with a mean moment of 202 Nmm/kg. The highest internal rotation moments were produced at 60° and 90°, with no significant difference between them. The highest was 90° with a mean moment of 274 Nmm/kg. Significant differences

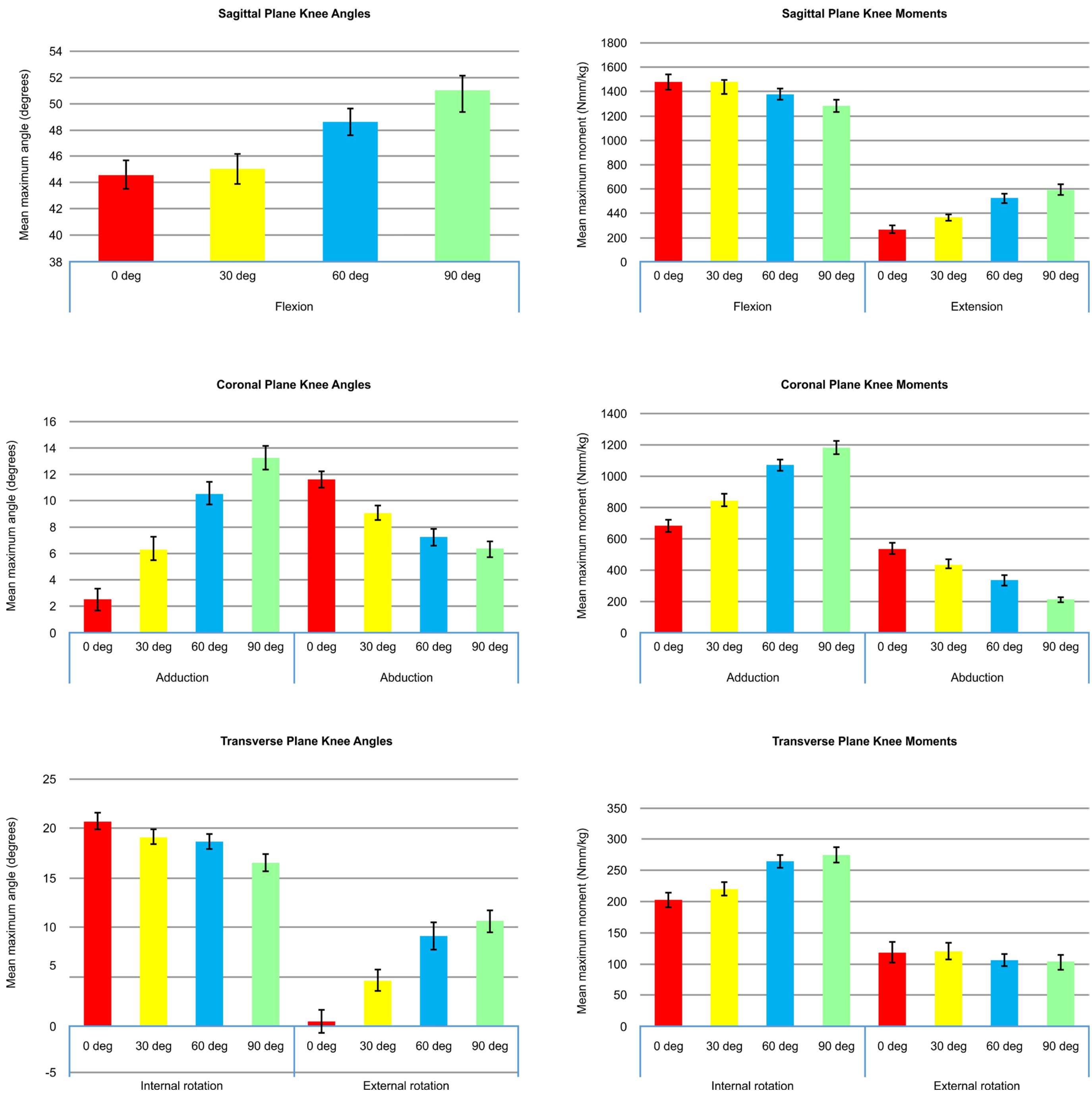

Figure 4 Knee graphs.

were found between both 0° and 30° with both 60° and 90° ($p<0.001$).

External rotation

Angles

The lowest external rotation angle was found to be at 0° with a mean of 0.5°, and the highest angle was found at 90° with a mean of 10.6°. A significant difference was found between 0° and 30° ($p<0.05$). Very significant differences were found between all other foot positions ($p<0.001$), except between 60° and 90°, where there was no significant difference.

Moments

No significant differences were found for external rotation moments between any of the four foot positions.

DISCUSSION

This study investigated which foot position (0°, 30°, 60° or 90°) produced the smallest and largest degrees of angulation and moments, in the lead ankle and knee joints, during the hockey hit.

Ankle summary

Ankle injury in hockey most commonly involves the lateral ligaments[3] which usually occurs when the foot is inverted, internally rotated and plantarflexed.[5] The highest degrees of ankle inversion were found at foot positions of 0° and 90° and that of internal rotation was found at a foot position of 0°. Although 0° consistently produced the highest angulation, 90° caused the most significantly high moments. Therefore, rather than one particular foot position, it seems that the extremes of foot position collectively lead to larger degrees of angulation and magnitudes of moment. In contrast, 30° was the foot position that most consistently produced the lowest degrees of angulation and moments.

Knee summary

For the knee, moments in the coronal plane were significantly higher at foot positions of 0° and 90° compared with 30° ($p<0.001$), and moments in the transverse plane were significantly higher at both 60° and 90° than 0° and 30° ($p<0.001$).

Limitations

This study is an exploratory study to aid future research and hence the relatively low number of participants. While the surface on which the hit was performed did not replicate normal playing conditions, the key focus of the study was to propose the best foot position from the four positions investigated. As such, the surface was constant throughout the study, hence the four foot positions could be directly compared against one another. Furthermore, the proposed foot position of 30° may not be the most appropriate for all hockey players and it is not expected that a player would be able to consistently implement this into their play. However, alignment of the lower limb could become a more prominent aspect of hockey coaching and could be of particular relevance to players with a history of injury.

CONCLUSION

The aim of this study was fulfilled, indicating that lead foot position is related to the angles and moments produced in the lower limb joints during the hockey hit, and the null hypothesis can, therefore, be rejected. A lead foot position of 30° resulted in the smallest degrees of angulation, and magnitude of moment, the most often, and the largest the least often. This correlates to a lead foot that is in line with the rest of the body, while carrying out the hockey hit. The idea that this may be correlated with injury risk would require testing via either an intervention or epidemiological study, and if this idea was confirmed, a specific intervention associated with foot position during the hockey hit may decrease the risk of injury.

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