ANALYSIS OF RUGBY PUNT KICK MOTIONS AIMING AT DIFFERENT KICKING DISTANCES

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The purpose of this study was to compare the rugby punt kick motions for different kicking distances of college players, focusing on the motions of the kick leg and hip. A motion capture system (11 cameras, 200Hz) was used to collect three dimensional coordinates data of nine college rugby players, who performed three different punt kicks aiming at 35m, 50m and maximum kicking distances. Pelvis rotation range of motion and approach angle increased significantly with the increase in kicking distance. Significant correlations were found between the pelvis rotation range and swing speed ($r=0.736$, $p<0.01$), and the pelvis rotation range and approach angle ($r=0.690$, $p<0.01$). Two different punt kicking motions with two approach angles were found in college rugby players. For short kicking distance, the straight approach should be used to limit the rotational movement of the pelvis and kick the ball with a straight impact, using the extension of the kicking knee joint as a major contributor. For long kicking distance the diagonal approach should be used to kick the ball with large pelvis rotation, hip flexion, and knee extension.

KEYWORDS: approach angle, hip rotation, 3D motion analysis, swing speed

INTRODUCTION: Rugby is a game in which two teams of 15 players each run with the ball to score points by passing and kicking it across the opponent's goal line. In rugby, the importance of kicking has increased in recent years. In the Rugby World Cup, an average of 46 kicks were made per game, the majority of which were punt kicks (World Rugby, 2019).
Van den Berg and Malan (2010) stated that the punt kicking was one of tactical factors determining a winner. In the game of rugby, the punt kick is used to pass a and/or ball to recover position and area. Koyanagi (2021) described that winning teams used area kicks, grubber kicks and kick passes, and were able to do accurate long kicks. Therefore, one of the key factors required for a successful punt kick would be an appropriate technique to control kicking distance and direction. Sinclair et al. (2016) concluded from the result of regression analysis that the angular velocity of the knee extension of the kicking limb at ball impact and peak angular velocity of the hip flexion were the best predictors of ball velocity. Sayers and Morris (2012) described that skilled kickers might use the rapid axial rotational velocity of the pelvis to generate a stretch-shortening cycle in the hip flexors of the kicking side.
From these facts, it would say that it is essential to increase the angular velocity of the knee and hip joints of the kicking leg to carry a ball for distance and to control the angular velocity of the kicking leg when aiming at various distances. However, there is little scientific information on how players control motions of the kicking leg and hip in punt kicks for various distances. Therefore, the purpose of this study was to compare the rugby punt kick motions for different kicking distances of college players, focusing on the motions of the kick leg and hip.

METHODS: The participants were nine male college rugby players (height, 1.71 ± 0.07 m; weight, 77.7 ± 12.4 kg). Three kinds of punt kicks; a full effort kick for maximum distance, a kick aiming at a 5m square target area which was located at 35m from the goal line and a kick for 50m. They attempted at least five times at each distance. The target area size and distances were decided through pre-testing so that they could adapt the tasks. The trials for motion

analysis were ones in which the ball hit the target area, and were evaluated as 4 on 5 score by the participants' and a coach's subjective and introspective criterion. A motion capture system (11 cameras, 200Hz, Qualisys, Sweden) was used to collect three-dimensional coordinate data of 49 body reflective markers and 4 points on a rugby ball. The three-dimensional coordinate data were smoothed separately before and after ball impact using a Butterworth digital filter with an optimum cut-off frequency (8-15 Hz) (Winter, 2005). The right handed coordinate system was defined: the vertical direction as the Z-axis, the direction of punt kick as the Y-axis, the direction perpendicular to the Y-axis as the X-axis.
The ball velocity, release angle and the swing ankle velocity of the kicking leg as a swing speed were calculated as release parameters. The following motion parameters were calculated for the punt kick: hip flexion angle, hip abduction angle, pelvis rotation angle, knee joint angle, approach angle. The approach angle was defined as the angle between the direction of approach run and the Y axis. The averaged motion of the punt kickers was created from three-dimensional coordinates data after the method of Ae, (2020).
Friedman test and Willcoxon signed rank test were used to test significant differences among three trials. In order to examine relationships between each motion parameter and swing speed, Pearson's correlation coefficient was calculated. The significance level for all tests was set at 5%. SPSS version 27 (IBM Co., Armonk, NY, USA) was used for statistical analysis.

RESULTS: Table 1 shows the ball velocity, swing speed, and release angle of the college male rugby players in the three trials. With the increase in kicking distances, the ball velocity and swing speed significantly increased. However, there was no difference in the release angle.
In the present study, since accuracy of the kick was evaluated only whether a ball hit the target area(5m square) or not, the kicking accuracy was not considered seriously. Only the rate of hitting the target area was shown in Table 1.

Table 1: Release parameters of punt kicks aiming of three different distances.

		35m (n=9)	50m (n=9)	MAX (n=9)	difference	
Ball velocity	[m/s]	21.1 ± 0.6	25.7 ± 1.1	27.8 ± 2.4	35m vs 50m 35m vs MAX 50m vs MAX	p<0.05 p<0.05 p<0.05
Swing speed	[m/s]	14.6 ± 0.6	17.2 ± 0.5	18.3 ± 1.1	35m vs 50m 35m vs MAX 50m vs MAX	p<0.05 p<0.05 p<0.05
Release angle	[deg]	30.9 ± 4.4	35.1 ± 2.7	33.5 ± 3.1	35m vs 50m 35m vs MAX 50m vs MAX	n.s. n.s. n.s.
Accuracy	[%]	82.3 ± 12.6	64.7 ± 9.8	———	35m vs 50m	p<0.05

Table 2 shows the motion parameters of the punt kick in college male rugby players.
With the increase in kicking distances, the pelvis rotation range and approach angle significantly increased. However, there was no difference in knee extension range.
The hip abduction range and hip flexion range significantly increased from the kick for 35 m to 50 m. However, there was no difference between the kick for 50 m and the maximum kick.

Table 2: Motion parameters of punt kicks aiming of three different distances.

		35m (n=9)	50m (n=9)	MAX (n=9)	difference	
Pelvis rotation range of motion	[deg]	19.5 ± 6.0	29.9 ± 4.5	35.5 ± 6.1	35m vs 50m 35m vs MAX 50m vs MAX	p<0.05 p<0.05 p<0.05
Hip flexion range of motion	[deg]	90.1 ± 10.8	104.5 ± 7.6	106.7 ± 8.2	35m vs 50m 35m vs MAX 50m vs MAX	p<0.05 p<0.05 n.s
Knee extension range of motion	[deg]	104.5 ± 12.2	108.2 ± 10.7	101.9 ± 9.2	35m vs 50m 35m vs MAX 50m vs MAX	n.s. n.s. n.s.
Hip abduction range of motion	[deg]	14.5 ± 4.7	25.4 ± 5.6	25.7 ± 5.0	35m vs 50m 35m vs MAX 50m vs MAX	p<0.05 p<0.05 n.s.
Approach angle	[deg]	13.8 ± 7.8	31.4 ± 12.6	38.3 ± 6.7	35m vs 50m 35m vs MAX 50m vs MAX	p<0.05 p<0.05 p<0.05

There was a significant positive correlation between pelvis rotation range and swing velocity ($r=0.736$, $p<0.01$), as well as between hip flexion and swing velocity ($r=0.643$, $p<0.01$), and approach angle ($r=0.690$, $p<0.01$).

Figure 1 shows the stick pictures for 35m, 50m, and the maximum kicking distances.
In the kick for 35 m, the pelvis rotational range of motion and the hip abduction range of motion were the smallest in three kicks, and the kicking foot was swung nearly on the sagittal plane from smaller approach run (13.8 ± 7.8 deg.) than two other kicks.
In the kick for 50 m and maximum kick, more diagonal approach to the kicking direction was used and the abduction and the pelvis rotation of the kicking thigh became larger than the 35m kicks.

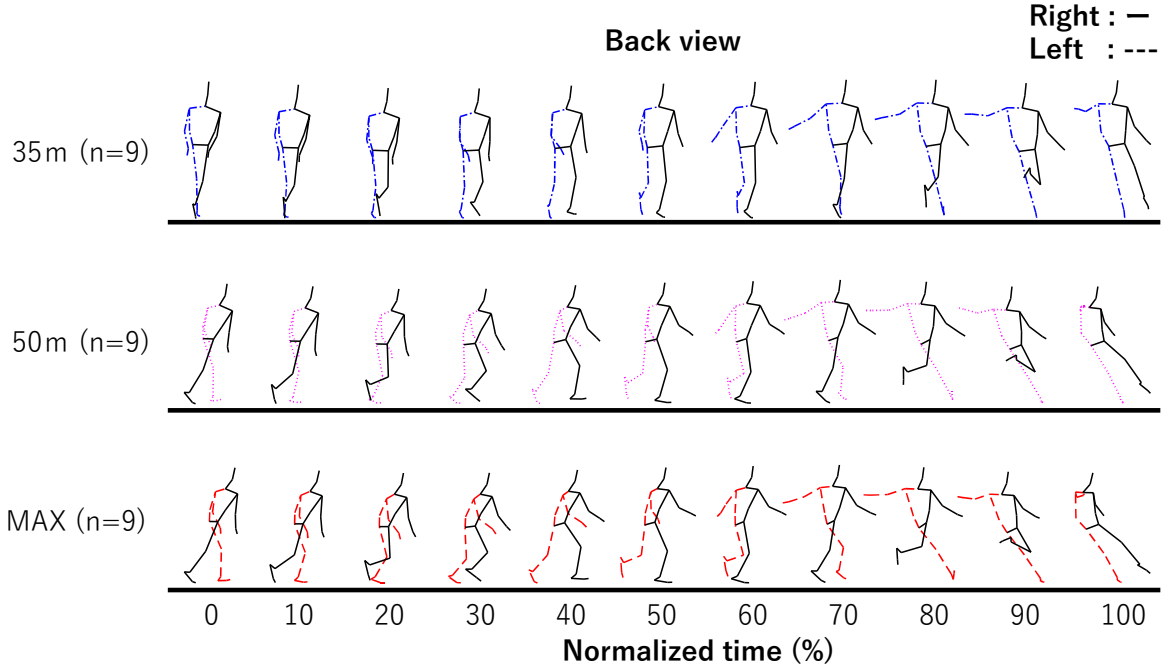

Figure 1: Averaged punt kick motions for the 35m, 50m and maximum distances

DISCUSSION: It was found that there are two types of approach in the punt kicks: a straight approach and a diagonal approach to the kicking direction, based on the approach angle. The pelvis rotation range of motion increased with the increase in kick distances. There was a significant correlation between the swing speed and the pelvis rotation and hip flexion range.

These results indicated that the swing speed induced by using a large pelvis rotation and hip flexion.
In the 35m punt kick, the approach was closer to the kick direction than two other kicks.
The approach angle became more diagonal to the kick direction in the 50m and maximum kicks. The instep kick of soccer, the pelvis rotation range of motion was significantly correlated with the approach angle (Ikeda et al.,1993). In rugby punt kicks, an oblique approach can help to increase the pelvis's rotational range of motion, as well as the case of the soccer kick. These results revealed that in the 50m and maximum punt kicks, the college rugby players increased the pelvis rotation to obtain a large swing speed by using a diagonal approach. The diagonal approach and greater pelvis rotation range of motion would be essential to carry the ball farther and to regain area.
In Australian football goal kicking, accurate goal kickers have used a straight impact on the target and made an accurate kick from straight approach and limiting pelvis rotation range (Blair et al., 2020). In the present study, the college rugby players used a straight approach in the 35 m punt kick and limited pelvis rotation range, which might help an accurate punt kick. Since the 35m punt kick has been used for kick-passing and kicking into space behind the opponent's defenders, it is thought that the kicking accuracy would be emphasised and achieved by using a straight approach and limiting the pelvis rotation range of motion.
The distance of the punt kick could controlled by the following two types of punt kick motions and approach angles. For short kicking distance, the straight approach should be used to limit the rotational movement of the pelvis and kick the ball with a straight impact, using the extension of the kicking knee joint as a major contributor. For long kicking distance the diagonal approach should be used to kick the ball with large range of pelvis rotation, hip flexion, and knee extension.

CONCLUSION: Two different punt kicking motions with two approach angles were found in college rugby players. For short kicking distance, the straight approach should be used to limit the rotational movement of the pelvis and kick the ball with a straight impact, using the extension of the kicking knee joint as a major contributor. For long kicking distance the diagonal approach should be used to kick the ball with large range of pelvis rotation, hip flexion, and knee extension. Therefore, it would be effective to use different kicking motions, depending on objectives and target distances of punt kicking.

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