Landing patterns in netball: analysis of an international game

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The passing and landing patterns among netball players were investigated by examining all the 595 passes in an international match between Australia and New Zealand. Intra-class correlations were used to test inter-observer reliability. The independence of two variables was tested using a Pearson χ^2 test and a contingency coefficient was used to assess the degree of association between variables. An inter-rater reliability in the identification of movement patterns was 0.99. Most of the landings observed in this match were on the forefoot and not the hindfoot as generally reported in controlled experiments. Only 14% of the players leapt to receive a pass compared with 76% reported earlier under controlled environments. The distribution of passing techniques unexpectedly showed that approximately 50% of all the players did not reach for the ball as it was thrown directly to them. However, over 70% of the players threw straight passes which were mainly received in the chest quadrant and other types of passes such as loop, bounce and rebound were used less frequently. Nearly 50% of all players used a right-handed pass to dispose of the ball, while the next most popular pass was to use both hands (40.2%). Landing and passing patterns differed between players in different positions. Footfall patterns on landing after a catch were associated with the trajectory of the ball.

Keywords: Netball, injury, footfall patterns, landing patterns

Netball is a dynamic, fast, skilful and predominantly female team sport. In Australia it attracts more than half a million registered players from the young to the middle-aged and from the unskilled to the internationally highly skilled player. Many of the skills involve explosive movements, quick changes of directions, different types of passes plus a variety of ways to receive and dispose of the ball within a 3-s time frame. Despite the fact that landings have been associated with both acute and chronic injuries as a result of the large forces on each foot^{1,2}, landing techniques have received far less attention than the mechanics of other skills in the game³.

Landing techniques are complex as they are

influenced by both extrinsic and intrinsic factors. The extrinsic factors include the position of the team and opposition players, height and direction of movement towards the ball, footfall patterns, receipt and disposal of the ball, and the relationship between the court surface and the shoe. Besides these external factors, the player is also required to integrate the intrinsic demands of neuromuscular coordination, spatial orientation and proprioception during this complex task of landing. The ultimate movement is restricted by the footwork rule of a maximum of one-and-a-half steps while in possession of the ball. Therefore, upon landing after receiving the ball, a player must decelerate rapidly and assume a position which affords sufficient stability so that the footwork rule is not infringed⁴.

Attempts to investigate different landing patterns and passing techniques associated with footwork rules have been limited to the controlled laboratory environment. In early laboratory studies, Steele and Milburn carried out kinematic and kinetic analyses of landing patterns by examining the footfall patterns of 21 skilled centre-court netball players using four different types of footwear^{5,6}. Different footfall patterns of landing were demonstrated by the players during a typical attacking movement. The most frequent footfall pattern demonstrated for all conditions was impact of the ground with the heel of the foot (83.6%). The forefoot made initial contact with the ground in 6.3% of landings while the midfoot made contact in 2.5% of landings.

In the same study, Steele and Milburn⁵ also found that players varied their approach to receive the ball from a typical netball pass. Most of the subjects (75.9%) performed a leap approach to receive the ball as compared with the 16.5% who used a hop approach. A further 7.6% used a mixture of the leap and hop approach. Moreover, the subjects consistently used one approach technique on the dominant limb and a different technique for landing on the non-dominant limb.

In a later study to examine the footfall patterns after receiving a high pass, Steele and Milburn² found that seven of the ten subjects landed on the forefoot while only three subjects made initial contact with the heel of the foot. Steele and Lafortune⁴ also concluded that further research must be conducted into the footfall patterns on impact loadings in netball.

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To date, no research has addressed the integration of landing techniques with footfall patterns, different positional plays, type of pass, movement patterns to receive and dispose of the ball, in the game situation. The purpose of this study was therefore to identify at an international level: (1) the typical landing pattern and the type of passing technique used; (2) the association between each of the landing patterns and passing technique variables with different positional play; (3) the three-way relationship between typical passing technique, landing pattern and position of the player.

Methods

Subjects

An Australian Broadcasting Corporation videotape recording of the tritest series was used to analyse the match between Australia and New Zealand on 14 May 1986 in Sydney, Australia. Sixteen international players were studied (seven from the Australian team and nine from the New Zealand team, as two players were substituted due to on-court injuries). The match consisted of two 20-min halves.

Procedure

A National NV G25 video with a variable-speed playback and freeze-frame facility was used to analyse the individual passing and landing patterns.

In the game, each pass was analysed by observing:

1. The position of the player receiving the pass;
2. The team of that player;
3. Variables related to passing and receiving the ball:
 - (a) type of pass
 - (b) direction of movement towards the ball
 - (c) height of the catch (in relation to the player's body)
 - (d) receipt and disposal of the ball (catch and throw handedness);
4. Variables related to landing patterns:
 - (a) footfall pattern
 - (b) movement pattern towards the ball
 - (c) side of landing (footfall).

Under the category 'movement pattern towards the ball', a hop was defined as landing on the take-off limb and a leap was defined as landing on the foot opposite to the take-off limb⁵. Both a hop and a leap indicate a stride with elevation. On the other hand, a jump is confined to elevation rather than a stride. A skip is a movement which usually involves sideways motion with little elevation and almost a two-foot landing where one foot lands followed almost immediately by the other foot. A run differs in that the player continues the running motion on receiving the pass whereas a step is performed at a walk-pace with minimal elevation.

The pass was not counted when an infringement occurred or when a catch was not completed. Landings after the ball was tossed-up by the umpire were not included in the analysis. One observer

analysed all the passes. Another observer then analysed six randomly selected 5-min intervals from the videotape to establish inter-observer reliability.

Statistical analysis

The intra-class correlation was used to measure inter-observer reliability⁷. Frequency tables were used for descriptive purposes. The independence of two variables was tested by using the Pearson χ^2 test. The contingency coefficient was used to assess the degree of association between variables. The above statistical techniques were used because of the unordered categorical nature of the data collected. All hypotheses were tested at the 5% significance level.

Results

The inter-rater reliability for the study sample was 0.99. This high degree of agreement between the two observers was probably a result of the precise and clear definition of passing and movement types made before the study.

A total of 595 passes were observed in the game. The proportion of passes made by the two teams and by each position are reported in Table 1. The result was a win for the Australian team by 35 goals to 19. The number of passes made by the New Zealand team (39.3% of total) was less than that of the Australian team. The defence players (goal defence and goal keeper) of both teams had fewer passes than attacking (goal shooter and goal attack) and mid-field players (wing attack, centre and wing defence).

The distributions of landing patterns and passing techniques are presented in Table 2. Forefoot landing was the most preferred landing pattern (57.3%) with only a small percentage (8.1%) landing on their hindfoot. Landing on the right foot (32.4%) was slightly more frequent than left foot landings (26.1%). Symmetrical landings were common when players landed on two feet (23.9%). Although most of the approaches to receive the ball involved horizontal elevation (i.e. hop and leap 29.4%), 25.0% of the passes were received with the foot planted, and a similar 24.7% caught the ball following a jump. Low-elevation movements (i.e. skip and run) toward the ball were observed 15.8% of the time.

The most frequent type of pass was straight (73.1%) where the ball was thrown in a horizontal

Table 1. Percentage passes by team and by position ($n = 595$)

Team	Australia	60.7
	New Zealand	39.3
Position	Goal shooter	18.5
	Goal attack	16.0
	Wing attack	18.5
	Centre	20.0
	Wing defence	11.3
	Goal defence	11.3
	Goal keeper	4.4

Table 2. Distributions of landing patterns and passing techniques ($n = 595$)

Landing	Footfall pattern	
	Forefoot	57.3
	Hindfoot	8.1
	Planted	24.7
	Outside border	2.5
	Un sighted	7.4
	Side of footfall	
	Right foot	32.4
	Left foot	26.1
	Two-foot symmetrical	23.9
	Two-foot asymmetrical	13.6
	Un sighted	4.0
	Movement pattern (approach to catch)	
	Hop	15.1
	Leap/step	14.3
	Jump	24.7
	Skip	8.2
	Run	7.6
	Planted	25.0
	Un sighted	5.0
Passing	Type of pass	
	Straight	73.1
	Loop	10.3
	Bounce	8.9
	Rebound	1.9
	Un sighted	2.0
	Direction of movement to ball	
	Straight	49.9
	Forward	10.3
	Backwards	0.8
	Right	21.5
	Left	15.8
	Un sighted	1.7
	Height of catch	
	Overhead	22.7
	Head/shoulder/chest	62.4
	Waist and below	13.3
	Un sighted	1.7
	Handedness of catch	
	Two hands	94.1
	Right hand	2.4
	Left hand	2.5
	Un sighted	1.0
	Handedness of throw	
	Two hands	40.2
	Right hand	48.7
	Left hand	5.9
	Un sighted	5.2

Values are percentages

direction to the player compared with the other types of passes such as a loop (10.3%), bounce (8.9%) and rebound (1.9%).

Players' movements to reach the ball demonstrated an interesting pattern. Almost half (49.9%) of the passes were directed at the players so that they did not have to reach for the ball. Of the other passes, players generally had to reach to either the right (21.5%) or left (15.8%) sides to catch the ball. Only 10.3% of the catches required the player to move forward towards the direction of the pass to receive the ball.

Most of the passes were caught in the chest-shoulder-head quadrant (62.4%) with 22.7% passes being caught overhead. Players used both hands to catch the ball on almost every occasion (94.1%) but

they predominantly used their right hands (48.7%) or both hands to dispose of the ball (40.2%).

Table 3 shows the cross-tabulation of passing and landing patterns by positional play where only those variables significantly associated with position are reported. The two passing/receiving variables which were not significant and therefore were not included in the table were reach ($\chi^2_8 = 11.14$, $P = 0.194$) and hand-catch ($\chi^2_4 = 4.08$, $P = 0.395$).

From Table 3, it can be seen that straight passes were the favoured technique of almost all players (72.8% of total passes for all players). Compared with attacking and mid-field players, defensive players caught the ball more often from rebounds (8.7%) as would be expected. Bounce passes were more frequently used than the loop passes by attacking players (13.3% *versus* 5.0%).

The link between height of pass and positional play is obvious. On average, mid-fielders caught the ball between the head and waist more often (67.5%) than other players. On the other hand, defensive players caught more overhead passes (34.0%) than other players, while attacking players received more passes below the waist (18.5%) than for other positions.

Throwing patterns in both the attack and mid-field positions showed that two-handed (47.7% and 47.2% respectively) and right-handed (47.7% and 44.5% respectively) passes were almost equally favoured, whereas defensive players preferred the right-handed pass (81.3%).

Table 3 also shows that defence players very often landed on their right foot but very seldom landed on both feet. Attacking and mid-field players landed on both feet significantly more than defensive players. These landings were generally symmetrical for attacking players and a similar percentage of symmetrical and asymmetrical landings were recorded for mid-field players.

Although landing on the forefoot was the most commonly used technique by the players irrespective of their position, the 48.6% of forefoot landings for attacking players was not as high as those by mid-field (67.6%) and defensive players (68.7%). Attacking players, who are responsible for shooting goals, had more landings with a planted foot when receiving the ball (43.4%).

While a jump pattern was the most commonly observed way to approach the ball by mid-field and defensive players, 42.5% of the movements towards the ball by attacking netballers were with one foot in a planted position. Other common movement patterns used were a hop (19.4%) by mid-fielders and leap (20.7%) by defensive players. Both of these positions demonstrated a similar preference to a skip or running (19.7% and 18.4% respectively) approach to the ball.

Table 4 shows the significance and degree of association (contingency coefficient) between the landing and the passing/receiving variables by positions. A general pattern is observed, namely that, regardless of position, there is a significant association between (1) direction of movement and all the landing variables, (2) type of pass and all landing variables except footside, (3) height of the catch and all landing variables except footside. It must be

Table 3. Distributions of landing and receiving patterns by positions (read percentages down each column for each landing/receiving variable)

	Position			χ^2	P
	Attack	Mid-field	Defence		
<i>Receiving/passing</i>					
Type of pass				38.25	0.000
Straight	80.1	74.2	64.1		
Loop	5.0	12.9	13.0		
Bounce	13.3	12.9	14.1		
Rebound	1.6	0.0	8.7		
Sample size	181	310	92		
Height of catch				12.72	0.013
Overhead	22.8	19.6	34.0		
Head to waist	58.7	67.5	51.1		
Below waist	18.5	12.9	14.9		
Sample size	179	299	87		
Hand throw				41.42	0.000
Two hands	47.7	47.2	16.5		
Right	47.7	44.5	81.3		
Left	4.7	8.3	2.2		
Sample size	172	301	91		
<i>Landing</i>					
Side				51.16	0.000
Right	27.6	30.1	58.0		
Left	28.2	26.2	28.4		
Two-symmetrical	34.8	23.5	9.1		
Two-asymmetrical	9.4	20.2	4.6		
Sample size	181	302	88		
Movement pattern				44.61	0.000
Hop	10.1	19.4	17.2		
Leap	11.7	15.1	20.7		
Jump	26.3	24.8	31.0		
Skip/run	9.5	19.7	18.4		
Planted	42.5	21.1	12.6		
Sample size	179	299	87		
Fall				48.79	0.000
Fore	48.6	67.6	68.7		
Hind	6.4	9.8	10.0		
Out	1.7	1.7	8.8		
Plant	43.4	21.0	12.5		
Sample size	173	296	80		

Some of the observations were unclear due to the angle of the video camera

mentioned here that the significance of a correlation coefficient depends not only on its magnitude but also on the sample size. In this study, as would be the case in many game situations, there were many more passing/receiving plays by mid-fielders (296) than by defensive players (94). Hence, the two contingency coefficients in Table 4 considered practically not significant could be regarded as practically significant because they are both 0.4 or above, which is higher than almost every other coefficient in the table but not statistically significant only because both were demonstrated by defence players. On the other hand, the two coefficients considered practically significant should be treated practically as not significant as they are both below 0.25 which is lower than all other coefficients in the table, but statistically significant because the sample sizes were relatively large for these comparisons.

The significant associations found in Table 4 between landing and passing/receiving patterns were investigated further and presented in Table 5. The breakdown by positional play was not necessary as significance was consistent between different positions. No χ^2 statistic was shown in Table 5 as the associations are all significant.

Footfall patterns varied for different types of pass. A player who received a straight or looped pass was more likely to land on their forefoot (66.3% and 82.8% respectively) than any other part of the foot, whereas a player receiving a bounce pass landed with the foot planted (58.2%). On the other hand, when a player had to catch the ball from overhead or the region of the chest, she was more likely to land on her forefoot (88.4% and 62.4% respectively), but catching the ball below the waist was usually performed with one foot planted. The most likely footfall pattern

Table 4. Contingency coefficient between landing and passing variables by position

Passing variables	Position	Landing variables		
		Footfall	Foot side	Movement pattern
Type of pass	Attack	0.309 (0.016)	n.s.	0.353 (0.022)
	Mid-field	0.348 (0.000)	0.223 (0.023)*	0.390 (0.000)
	Defence	0.472 (0.006)	n.s.	0.532 (0.001)
Direction of movement	Attack	0.373 (0.002)	0.381 (0.001)	0.402 (0.009)
	Mid-field	0.271 (0.040)	0.276 (0.025)	0.415 (0.000)
	Defence	0.396 (0.246)†	0.447 (0.037)	0.497 (0.099)†
Height of catch	Attack	0.444 (0.000)	n.s.	0.526 (0.000)
	Mid-field	0.332 (0.000)	n.s.	0.430 (0.001)
	Defence	0.511 (0.000)	n.s.	0.504 (0.001)
Hand catch	Attack	n.s.	n.s.	n.s.
	Mid-field	n.s.	n.s.	n.s.
	Defence	n.s.	n.s.	n.s.
Hand throw	Attack	n.s.	n.s.	n.s.
	Mid-field	0.244 (0.040)*	n.s.	n.s.
	Defence	n.s.	n.s.	n.s.

Values in parentheses are *P* values; *practically significant; †practically not significant; n.s., not significant

when a player moved to reach for a straight pass was a two-foot symmetrical landing (33.9%). When a player was forced to move forward, backward and to the right, the footfall landing pattern was also on the right side.

Table 5 also shows the relationship between the type of pass and movement patterns. Straight passes were mostly received by either a jump (29.7%) or a planted foot (24.2%) whereas a hop was used more frequently (35.6%) to receive a loop pass. When a player moved straight or forwards to the ball, the foot was most frequently planted (35.6% and 29.3%, respectively). A hop (29.0%) was used more often when a player moved to the right to reach the ball, but when moving to the left they mainly executed a leap/step (22.8%) approach. Movement patterns appeared also to be influenced by the height of the catch, 58% of overhead passes being caught by jumping. Passes received from the head and below were more frequently received with the foot planted.

Discussion

Generally, the types of landings recorded in the game environment were not the same as those found under controlled simulated laboratory testings. Landing on the forefoot (57.3%) was the most commonly used

technique by most of the players. Hindfoot landing was unexpectedly rare for all players, irrespective of their position. These findings are different from the laboratory experiment reported by Steele and Milburn⁵ where 83.6% of the landings were on the hindfoot, whereas forefoot contact with the ground only accounted for about 6% of all landings. The findings, however, were more in line with those reported by Steele and Milburn² where 70% of the subjects in a laboratory-based experiment adopted a forefoot landing pattern.

The 14.3% of players who leapt to catch the ball in this study was substantially less than the 75.9% reported in the laboratory study by Steele and Milburn⁵. Most players approached the ball with a hop (15.1%), jump (24.7%) or had one foot planted on the ground (25.0%).

Type of pass and direction of movements to receive the pass observed in this study were also different from the typical netball attacking movement patterns selected by Steele and Milburn⁶ for their laboratory study. In the controlled experiment, subjects were required to run forward, 'break' to a specified side to catch the ball, land on one leg, pivot and throw the ball to the catcher positioned 5–6 m away. In this match, nearly half of the passes were directed towards the players. Movement to the right or left was only required in 21.5% and 15.8% of the catches respectively.

There is evidence from this study that a variety of landing strategies are required for different positional play. Attacking, mid-field and defence players often landed on different sides of their feet. In addition, landing appeared to be affected by the type of pass, height of the catch and direction of movement. However, apart from the fact that far more forefoot landings were observed in this international match, no 'landing by position' comparison can be made as landing patterns have not previously been studied for different court positions.

The tactics of playing netball might have changed. Straight and relatively higher passes were used commonly in the game. This is certainly a contrast to the typical low passes used by Australian players more than a decade ago⁸. Our findings also indicated that overhead passes often resulted in forefoot landing but catches with one foot planted were used more than average for passes caught below the waist. This is consistent with data obtained by Steele and Milburn² who reported that most of the players (70%) made initial contact with the forefoot upon landing when receiving a high pass, while only three of the ten players made initial contact with the heel of the foot on receiving this type of pass. Results from this study were also similar to results from Valiant and Cavanagh⁹ who found that in basketball the height of pass influenced the footfall patterns executed on landing.

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Table 5. Distributions of football patterns*

	Landing variable: footfall			n
	Fore	Hind	Plant	
Type of pass				
Straight	66.3	8.7	25.1	403
Loop	82.8	5.2	12.1	58
Bounce	26.9	14.9	58.2	67
Rebound	100.0	0.0	0.0	5
Direction to catch pass				
Straight	59.6	3.7	36.8	272
Forward	51.0	19.6	29.4	51
Backward	100.0	0.0	0.0	6
Right	72.9	15.3	11.9	118
Left	67.4	11.6	20.9	86
Height of catch				
Overhead	88.4	5.8	5.8	121
Head to waist	62.4	10.2	27.4	343
Below waist	25.7	8.6	65.7	70

	Landing variable: side of footfall				n
	Right	Left	Two-symmetrical	Two-asymmetrical	
Movement direction					
Straight	28.3	22.7	33.9	15.0	286
Forward	40.3	35.5	17.7	6.5	62
Backward	50.0	33.3	16.7	0.0	6
Right	48.8	23.6	12.2	15.5	123
Left	23.7	39.8	19.4	17.2	93

	Landing variable: movement pattern						n
	Hop	Leap/step	Jump	Skip	Run	Plant	
Type of pass							
Straight	15.9	13.3	29.7	9.7	7.1	24.2	421
Loop	35.6	13.6	22.0	8.5	8.5	11.9	59
Bounce	2.7	27.4	1.4	1.4	13.7	53.4	73
Rebound	11.1	0.0	88.9	0.0	0.0	0.0	9
Direction to catch pass							
Straight	8.5	6.0	31.7	11.3	7.0	35.6	284
Forward	17.2	25.9	17.2	3.5	6.9	29.3	58
Backward	33.3	50.0	16.7	0.0	0.0	0.0	6
Right	29.0	21.8	24.2	5.7	8.0	11.3	124
Left	20.7	22.8	18.5	6.5	12.0	19.6	92
Height of catch							
Overhead	16.0	14.5	58.0	2.3	3.8	5.3	131
Head to waist	18.8	15.1	19.6	10.9	9.0	26.6	357
Below waist	3.9	14.3	2.6	6.5	10.4	62.3	77

No χ^2 -squares reported as all associations are significant (Table 4). *Read percentage across each row

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