Movement Classification

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Abstract
The Bloomfield Movement Classification (BMC) allows speed agility quickness requirements as well as injury risk of activity in team games to be characterised. A limitation of previous applications of the BMC is that frequencies of movement types can be over-estimated while duration of movement instances can be under-estimated. This is because a movement instance composed of segments performed in different directions and / or turning activity will be presented as separate movement instances even if the same locomotive movement type is being performed. The current paper proposes a method of processing data captured using the BMC to address this. The method not only recognises movement instances composed of multiple segments but also allows movements to be characterised by the number of turns and direction changes performed within the movement instances. The netball movement data used in the current investigation has limited reliability and the results should only be considered in the knowledge that reliability is limited. However, the way in which the results are presented here are a good example of how the BMC can be used in future investigations of movement in different sports where a greater level of reliability is achieved.

Keywords: Time-motion analysis, agility.

1. Introduction

The Bloomfield Movement Classification (BMC) is a detailed time-motion analysis technique that allows sports behaviour to be characterised by the profile of locomotive movements performed, direction of movement, turns, swerves, on-the-ball movement and intensity of movement (Bloomfield *et al*., 2004). There are different variants of the BMC that have been used on different commercial computerised analysis systems. The original BMC that was used to analyse elite soccer performance (Bloomfield *et al*., 2007a) represented turns as instantaneous events of no duration. There are a variety of ways of analysing such data to provide meaningful information about the nature of the sport of interest. For example temporal patterns that exist within movement sequences may be repeated often within the game (Bloomfield *et al*., 2005), the activity performed when players turn (Bloomfield *et al*., 2007b), accelerate or decelerate (Bloomfield *et al*., 2007c) may be of interest. A modified version of the BMC used by Williams and O'Donoghue (2005) to investigate injury risk of netball activity considered turns to be performed over a period of some duration while some other locomotive activity was being performed. The modified version of the BMC used by O'Donoghue and Williams (2005) also excluded intensity of movement and game related skills.

The investigation of elite soccer undertaken by Bloomfield *et al.* (2007a) implemented the BMC using the Observer Pro package Version 5.1 (Noldus Information Technology, The Netherlands). The importance of this is that modifiers (such as locomotive movement, intensity and direction) can be analysed by the package together or in isolation. Where modifiers are considered in isolation, the frequencies and mean durations reported recognise that some instances of locomotive movements are composed of different segments where the locomotive movement is performed in different directions or at varying intensity. The investigation of injury risk in netball undertaken by Williams and O'Donoghue (2005) implemented their modified version of the BMC using the Focus X2 package (Elite Sports Analysis Ltd, Dalgety Bay, Fife, Scotland). The data exported from this package was then processed in Microsoft Excel to determine frequencies and durations of movement instances. However, the way in which the data was processed considered consecutively recorded events of the same movement type to be different instances where direction changes or turn occurred within the locomotive movement being performed. This lead to an over-estimation of the frequency of locomotive movements and an under-estimation of mean duration of locomotive movements. Indeed most of the results for locomotive movements reported by Williams and O'Donoghue (2005) were percentage of observation time rather than frequency and duration. Therefore, the purpose of the current investigation was to apply a modified version of the BMC, implemented in Focus X2, to the analysis of movement in an exemplar sport (netball) in a manner that addressed the problem of movement instances involving multiple segments performed in different directions, with or without turning.

2. Methods

2.1. Pilot

The Focus X2 category set used in the current investigation was the same as that used by Williams and O'Donoghue (2005). However, there was still a need for the authors to familiarise with the category set and its use to analyse netball. The pilot study was undertaken analysing 6 minutes of video recording of a netball player's performance using Focus X2 and confirmed the suitability of the modified version of the BMC for netball without further refinements. The pilot study revealed that operating the Focus X2 package with this detailed category set required over 30 minutes to analyse each minute of player's performance.

2.2. Modified Bloomfield Movement Classification

The modified version of the BMC (Williams and O'Donoghue, 2004) was comprised of three categories; movement type, direction of movement and turning during movement. There were 12 movement classes which are defined as follows:

- Stationary- Staying in one spot
- Stepping- Raising and replanting of foot
- Walking- Moving slowly by stepping

- Jogging- Moving at a slow monotonous pace (slower than running, quicker than walking)
- Running- Manifested purpose and effort, usually when gaining distance
- Shuffling- Moving with a very short stride length, for example readjusting footwork or stumbling
- Skipping- Moving with small bound-like movements
- Hop- Taking off and landing on the same foot
- Jump- Propulsion from one/ both feet with definite landing position that differs to running / jogging movements
- Leap- Jumping with greater effort, to achieve maximal height or distance
- Lunge- A sudden thrust to an outstretched position
- Braking- Sudden deceleration from high intensity movement

There were 18 different directions of movement with respect to the direction faced by the player's torso. These were forwards, backwards, left, right, vertical, four diagonal directions, eight arced directions as well as not applicable (remaining in one place, not travelling in any direction). Turning during movement was classified as turning to the left or right, up to 90^o, 90^o or more or no turning occurring.

2.3. Reliability

The system was tested by the authors independently analysing 5 minutes 15.88s of the movement of a netball player recorded during a training match. A supplementary analysis system to determine the kappa statistic (O'Donoghue, 2005) was applied to the timed sequences of movements recorded by the two independent observers. Table 1 shows the amount of the observed movement deemed to be performing each movement type by the two observers. There was a good strength of agreement for movement type (κ = 0.6343). Table 2 and Table 3 show the direction of movement and turning activity performed within movement respectively that were recorded by the 2 independent observers during the reliability investigation. Direction of movement had a moderate strength of agreement (κ = 0.4399) while turning during movement had a fair strength of agreement (κ = 0.2724). However, Table 3 shows that a minority of time where each observer recorded any kind of turn was agreed by the other observer. Turning during movement was therefore considered to be unreliable within the current investigation and not analysed within the paper.

Table 1. Type of movement recorded during the inter-operator reliability study.

Observer 1	Observer 2											
	Stat	Walk	Step	Jog	Skip	Shuf	Jump	Lunge	Run	Brake	Leap	Total
Stationary	10.00	1.72	5.32	0.00	0.48	5.68	0.36	0.56	0.24	0.00	0.20	24.56
Walk	1.12	97.40	4.16	1.68	3.08	1.12	0.00	0.00	0.48	0.72	0.00	109.76
Step	3.24	10.32	12.48	0.72	0.80	4.32	0.00	0.40	0.00	0.00	0.00	32.28
Jog	1.08	1.32	0.56	27.84	0.80	0.16	0.24	0.60	0.00	0.08	0.00	32.68
Skip	0.00	0.48	3.80	2.16	24.16	1.64	0.00	0.68	1.24	0.16	0.00	34.32
Shuffle	1.80	1.44	5.48	1.52	5.00	27.84	0.08	0.00	6.00	0.76	0.00	49.92
Jump	0.12	0.00	0.12	0.32	0.00	0.24	3.20	0.00	1.00	0.00	0.00	5.00
Lunge	0.00	0.44	0.00	0.00	0.72	1.12	0.92	1.76	0.00	0.16	0.00	5.12
Run	0.04	0.44	0.24	0.00	0.00	0.68	0.00	0.04	16.92	0.08	0.00	18.44
Brake	0.00	0.00	0.00	0.28	0.92	0.00	0.04	0.00	1.80	0.76	0.00	3.80
Leap	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	17.40	113.56	32.16	34.52	35.96	42.80	4.84	4.04	27.68	2.72	0.20	315.88

Table 2. Direction of movement recorded during the inter-operator reliability study.

Observer 1	Observer 2																	
	FWD	BWD	Left	Right	FLD	FRD	BLD	BRD	FLA	FRA	LFA	RFA	LBA	RBA	BLA	BRA	Vert	N/A	Total
FWD	57.72	2.24	1.76	0.60	5.64	13.24	5.80	0.60	1.40	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.20	1.84	91.12
BWD	7.84	37.12	2.28	0.04	0.28	0.76	8.44	2.76	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	59.88
Left	0.68	3.16	9.40	0.48	1.32	0.00	0.76	1.04	0.32	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.24	1.24	19.04
Right	0.76	0.48	1.52	6.88	0.00	1.64	0.48	0.00	0.00	1.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.96	14.24
FLD	3.36	1.24	3.72	1.28	14.56	1.64	0.92	0.60	0.28	0.00	0.00	0.00	0.40	0.00	0.00	0.00	0.88	0.08	28.96
FRD	4.20	0.00	0.88	0.40	0.96	6.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.96	14.12
BLD	1.08	1.92	0.60	0.00	0.00	0.00	9.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.32	13.00
BRD	2.20	1.40	0.00	0.24	0.00	0.72	0.00	5.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	10.40
FLA	2.40	0.04	1.44	0.44	1.72	0.00	0.28	0.00	2.16	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.32	8.84
FRA	1.48	0.00	0.04	0.32	3.24	2.08	0.00	0.00	0.00	2.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9.68
LFA	0.00	0.20	1.52	0.00	0.00	0.00	0.00	0.04	0.00	0.00	1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.04
RFA	0.20	0.00	0.00	1.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.48
LBA	0.32	0.00	0.36	0.00	0.08	0.00	1.20	0.00	0.48	0.00	0.00	0.00	1.24	0.00	0.00	0.00	0.00	0.00	3.68
RBA	0.56	0.12	0.96	3.04	0.00	0.12	0.00	1.92	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.72
BLA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BRA	0.00	0.48	0.00	0.00	0.00	0.00	0.00	1.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.08
Vert	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N/A	5.72	2.32	2.92	0.76	0.76	3.24	1.48	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.36	10.36	28.60
Total	88.52	50.72	27.4	15.76	28.56	30.16	28.44	14.36	4.64	5.08	1.36	0.00	2.08	0.00	0.00	0.00	1.68	17.12	315.88

Table 3. Turning recorded during the inter-operator reliability study.

Observer 1	Observer 2					
	Left<90	Right<90	Left>90	Right>90	N/A	Total
Left<90	12.20	2.68	1.92	0.44	11.64	28.88
Right<90	5.92	12.00	0.96	0.20	6.76	25.84
Left>90	2.16	0.32	7.28	1.40	3.92	15.08
Right>90	0.24	1.44	0.76	4.12	4.52	11.08
N/A	26.12	24.00	16.96	11.20	156.72	235.00
Total	46.64	40.44	27.88	17.36	183.56	315.88

2.4. Data Collection

Eight female subjects (2 Goal Attacks and 1 from each of the 6 other positions), who were part of the Welsh senior netball squad in 2006, were observed. Each of the subjects was filmed for 4 to 6 minutes during a Welsh squad training match using a Panasonic NV-GS120 digital video camera. The total volume of video recorded data was 40 minutes 11.12s. This video recording was captured on computer disc at 25 frames per second using Focus X2 package's video capture facility. Focus X2 provides a fine position control feature allowing the start of each movement to be located to the nearest 0.04s. The movement type, direction and any turning within each movement was tagged at the start of each event with Focus X2 also recording the start time of each movement.

2.5. Data analysis

The timed sequence of movements with direction and turning modifiers was exported so as a Matlab 7.0.1 subroutine could determine the frequency, mean duration and percentage time for each movement class. This algorithm traversed the series of time-motion records in chronological order. As it did so, adjacent records of the same movement type were combined into single movement instances. The number of originally recorded time-motion records that made up each movement instance were captured. This resulted in the correct frequency of movement instances being reported and divided into the total observation time spent performing these movements when determining mean durations. There were no inferential statistics used in the current investigation as most positions were only represented by a single subject.

3. Results

There were 1385 movement records exported in total for the 8 players. However, when the analysis system identified consecutively recorded records of the same movement type, the actual number of movement instances was 1171 as shown in Table 4.

Table 4. Frequency of movements.

Movement	Number of additional segments within movement instance							%with more than one segment
	1	2	3	4	5	6	All	
Braking							84	0.0
Jogging	12	2					115	12.2
Jumping							54	0.0
Leaping							18	0.0
Lunging							26	0.0
Running	10						131	7.6
Shuffling	9	3		1			72	18.1
Skipping	16	3		1			117	17.1
Stationary							205	0.0
Stepping	12	1					139	9.4
Walking	63	12	8	3	1	1	210	41.9
All	122	21	8	5	1	1	1171	13.5

When the observation time for each movement class is divided by the frequency values determined using the analysis system, longer durations are calculated avoiding the under-estimates reported by Williams and O’Donoghue (2005). This is shown in Table 5. Table 6 shows the time spent performing movements in different directions. It is evident that 20% of observation time was spent not moving, 32% was spent in a forward direction, which means that 48% was spent moving in other directions such as backwards and diagonal. Walking was mainly performed in a forwards (48.9 %) or backwards (25.1%) direction. Jogging was mainly performed in a forwards direction (60.5%) and large amount of shuffling and skipping were performed in a sideways direction (39.8% and 48.9% respectively).

Table 5. Mean duration and %time for different movements.

Movement	Total time (s)	Mean duration of instance (s)	%Time
Braking	33.0	0.4	1.4
Jogging	242.4	2.1	10.1
Jumping	45.6	0.8	1.9
Leaping	12.4	0.7	0.5
Lunging	17.8	0.7	0.7
Running	199.7	1.5	8.3
Shuffling	106.2	1.5	4.4
Skipping	194.3	1.7	8.1
Stationary	481.3	2.3	20.0
Stepping	191.4	1.4	7.9
Walking	887.2	4.2	36.8
All	2411.1	2.1	100.0

Table 6. Time spent performing movements in different directions (s) with percentage of individual movement time in parenthesis.

Movement	Direction									
	Fwd	Fwd Diag	Fwd Arc	Sideways	Sideways Arc	Bwd	Bwd Diag	N/A	Vertical	Total
Braking	13.4 (40.5%)	2.2 (6.6%)		6.7 (20.4%)		0.5 (1.6%)	0.6 (1.8%)	9.6 (29.1%)		33.0 (100.0%)
Jogging	146.5 (60.5%)	59.5 (24.5%)	14.0 (5.8%)	4.2 (1.7%)	3.8 (1.6%)	8.0 (3.3%)	6.3 (2.6%)			242.4 (100.0%)
Jumping	4.6 (10.0%)	0.5 (1.1%)		1.9 (4.1%)	0.4 (1.0%)	1.9 (4.2%)	1.2 (2.5%)		35.1 (77.1%)	45.6 (100.0%)
Leap	7.2 (58.1%)	0.8 (6.8%)		3.1 (25.2%)			1.2 (10.0%)			12.4 (100.0%)
Lunging	6.2 (34.9%)	3.6 (20.0%)	4.8 (27.3%)			1.2 (7.0%)	1.9 (10.8%)			17.8 (100.0%)
Running	84.3 (42.2%)	74.0 (37.1%)	12.7 (6.4%)	19.1 (9.6%)	0.6 (0.3%)	3.0 (1.5%)	6.0 (3.0%)			199.7 (100.0%)
Shuffling	11.2 (10.5%)	8.7 (8.2%)		42.2 (39.8%)		12.3 (11.6%)	12.8 (12.0%)	19.1 (18.0%)		106.2 (100.0%)
Skipping	12.9 (6.7%)	23.6 (12.1%)	2.8 (1.5%)	94.9 (48.9%)	1.4 (0.7%)	23.0 (11.9%)	35.6 (18.3%)			194.3 (100.0%)
Stationary	13.5 (2.8%)	1.2 (0.2%)		1.1 (0.2%)		3.7 (0.8%)		461.8 (96.0%)		481.3 (100.0%)
Stepping	40.3 (21.1%)	32.1 (16.8%)		68.9 (36.0%)		29.6 (15.5%)	17.9 (9.3%)	2.6 (1.3%)		191.4 (100.0%)
Walking	433.4 (48.9%)	89.6 (10.1%)	27.4 (3.1%)	48.6 (5.5%)	9.8 (1.1%)	222.7 (25.1%)	55.6 (6.3%)			887.2 (100.0%)
Total	773.5 (32.1%)	295.7 (12.3%)	61.8 (2.6%)	290.8 (12.1%)	16.1 (0.7%)	306.1 (12.7%)	139.1 (5.8%)	493.0 (20.4%)	35.1 (1.5%)	2411.1 (100.0%)

The turning activity performed within movements could not be considered to be reliable. Therefore, Table 7 should be viewed as an example of how turning results can be presented when using the modified version of the BMC. Some movements are shown when performed forwards and when performed in other directions separately.

Table 7. Number of movements where turns of different angles are performed.

Movement	Turn				Total	Frequency	%with turns
	L<=90°	L>90°	R<=90°	R>90°			
Braking	6	2	3	3	14	84	16.7
Jogging	10	11	13	10	44	115	38.3
Jogging-Fwd	*8*	*8*	*10*	*9*	*35*		
Jogging-Other	*2*	*3*	*3*	*1*	*9*		
Jumping	6	9	4	5	24	54	44.4
Leaping	2	3		5	10	18	55.6
Lunging	5	1	1	1	8	26	30.8
Running	21	14	19	13	67	113	51.1
Running-Fwd	*20*	*9*	*17*	*10*	*56*		
Running-Other	*1*	*5*	*2*	*3*	*11*		
Shuffling	3	1	11		15	72	20.8
Skipping	19	25	14	17	75	117	64.1
Skipping-Fwd	*5*	*4*	*4*	*2*	*15*		
Skipping-Other	*14*	*21*	*10*	*15*	*60*		
Stationary	6	2	2	3	13	205	6.3
Stepping	23	12	25	18	78	139	56.1
Walking	35	33	28	40	136	210	64.8
Total	136	113	120	115	484	1171	41.3

Tables 8, 9, 10 and 11 show the activity performed before and after braking, jumping, leaping and lunging movements. This is based on the ideas of Bloomfield *et al.* (2007c). Table 8 shows that that there were 20 occasions where the 8 players followed a braking action with an acceleration into a running movement. Tables 9 and 10 show that running is commonly performed before jumps and leaps respectively. Table 11 shows that 12 of the 26 lunges were followed by the player accelerating into a jog or run.

Table 8. Movements performed before and after braking actions.

Before	After										
	Jog	Jump	Leap	Lunge	Run	Shuffle	Skip	Stationary	Step	Walk	Total
Jogging	2				1		1		2	6	12
Jumping					4	1	1	1	1	1	9
Leaping	1	1				1		1	1	1	6
Lunging										1	1
Running	7	2			11	1	9	5	6	1	42
Shuffling			1								1
Skipping	1	1		1	4		2		1	2	12
Walking						1					1
Total	11	4	1	1	20	4	13	7	11	12	84

Table 9. Movements performed before and after jumps.

Before	After									
	Brake	Jog	Lunge	Run	Shuffle	Skip	Stationary	Step	Walk	Total
Braking	1	1						1	1	4
Jogging	1						3	1	1	6
Running	6	4	2	4		1	2	4		23
Shuffling		2	1					2	1	6
Skipping					1		1	3	1	6
Stationary							2	3	1	6
Stepping	1			1						2
Walking							1			1
Total	9	7	3	5	1	1	9	14	5	54

Table 10. Movements performed before and after leaps.

Before	After								
	Brake	Jog	Lunge	Run	Shuffle	Skip	Stationary	Step	Total
Braking	1								1
Jogging					1			1	2
Running	5	1	1	1	1	1	1	2	13
Skipping		1							1
Stationary				1					1
Total	6	2	1	2	2	1	1	3	18

Table 11. Movements performed before and after lunges.

Before	After								
	Brake	Jog	Run	Shuffle	Skip	Stationary	Step	Walk	Total
Braking							1		1
Jogging		2	1				1		4
Jumping	1	1					1		3
Leaping							1		1
Running			1						1
Shuffling		1					2		3
Skipping		1	3		1		1		6
Stationary					1			1	2
Stepping		1	1	1		1	1		5
Total	1	6	6	1	2	1	8	1	26

4. Discussion and Conclusions

The particular results of the current investigation should be viewed with some caution due to the limited reliability of observation. The kappa values for inter-operator agreement show a lower strength of agreement than when Williams and O'Donoghue (2005) used the same method for the analysis of netball. Unsurprisingly, the reliability of netball observation was also lower than that of soccer observation (Bloomfield *et al.*, 2007d). Netball is played by teams of 7 and so each player is involved in the game for a greater percentage of match time (Loughran and O'Donoghue, 1999). The movement with the most turns and direction changes within instances was walking with one instance performed by the Wing Defender made up of 7 segments with 6 direction changes and 3 changes in turn attribute performed. All three changes of turning attribute coincided with 3 of the 6 changes of direction. The fact that the current investigation recognised that the 344 walking records came from 210 walking instances made a difference of being able to report a mean duration of walking movements of 4.2s rather than an under-estimate of 2.6s. The frequency, mean duration and percentage time results give an overall view of the distribution of match time allowing speed agility quickness requirements (Bloomfield *et al.*, 2007a) and injury risk (Williams and O'Donoghue, 2005) to be estimated. However, a full understanding of the nature of movement performed in sport requires temporal analysis of movement patterns (Bloomfield *et al.*, 2005). The results shown in the Tables 8 to 11 allow a fuller analysis of jumping, leaping, lunging and braking movements in a manner similar to that pioneered by Bloomfield *et al*. (2007c). The importance of reliably being able to record turning is that turning during movement is an important aspect of movement in team games (Bloomfield et al., 2007b; Grehaigne *et al*., 1997).

In conclusion, the current paper has proposed a method of analysing BMC data that allows direction changes and turning within movement instances to be recognised and reported. Such information is important to our understanding of movement in sport, especially speed agility quickness requirements. Future time-motion analysis research should apply this technique to the analysis of movement team and individual games using reliable data collection and sufficient subject numbers to allow results to be generalised.

5. References

Bloomfield, J., Polman, R.C.J. and O'Donoghue, P.G. (2004), The 'Bloomfield Movement Classification': Motion analysis of individuals in team sports. **International Journal of Performance Analysis of Sport-e**. 4(2), 20 - 31.

Bloomfield, J., Jonsson, G.K., Polman, R.C.P., Houlahan, K., and O'Donoghue, P.G. (2005). Temporal Pattern Analysis and its Applicability in Soccer. In: **The Hidden Structure of Social Interaction. From Genomics to Cultural Patterns** (Edited by L. Anolli, S. Duncan, M. Magnusson, and G. Riva), Amsterdam: IOS Press B.V. pp. 237-251.

Bloomfield, J., Polman, R. and O'Donoghue, P.G. (2007a), Physical demands of different positions in FA premier league soccer, **Journal of Sports Science and Medicine,** 6, 63-70.

Bloomfield, J., Polman, R. and O’Donoghue, P.G. (2007b), Turning movements performed during FA Premier League soccer matches, World Congress of Science and Football VI, Antalya, Turkey, January 2007.

Bloomfield, J., Polman, R. and O’Donoghue, P.G. (2007c), Deceleration movements performed during FA Premier League soccer matches, World Congress of Science and Football VI, Antalya, Turkey, January 2007.

Bloomfield, J., Polman, R. and O’Donoghue, P.G. (2007d), Reliability of the Bloomfield Movement Classification, **International Journal of Performance Analysis of Sport-e**, 7(1), 20-27.

Grehaigne, J.F., Bouthier, D. and David, B. (1997), A method to analyse attacking moves in soccer, In **Science and Football III** (Edited by Reilly, T., Bangsbo, J. and Hughes, M.), London: E&FN Spon, 258-264.

Loughran, B.J. and O’Donoghue, P.G. (1999), Time-motion analysis of work-rate in club netball. **Journal of Human Movement Studies**, 36**,** 37-50.

O’Donoghue, P.G. (2005), An Algorithm to use the kappa statistic to establish reliability of computerised time-motion analysis systems, 5th International Symposium of Computer Science in Sport, Hvar, Croatia, 25th-28th May 2005.

Williams, R. and O’Donoghue, P. (2005), Lower limb injury risk in netball: a time-motion analysis investigation, **Journal of Human Movement Studies**, 49, 315-331.