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ANALYSIS OF THE MOVEMENT INTENSITY OF NATIONAL LEVEL BASKETBALL GUARDS AND CENTRES IN DEFENCE AND OFFENCE – A CASE STUDY

ANALIZA INTENZIVNOSTI GIBANJA BEKOV IN CENTROV V OBRAMBI IN NAPADU NA KOŠARKARSKI TEKMI – ŠTUDIJA PRIMERA

ABSTRACT

McInnes, Carlson, Jones, and McKenna (1995) reported that players change movement category every 2 seconds and only 15% of live time was spent in high-intensity activity. A case study of one guard and centre was analysed during ball in play time. Frequency, average time duration and distance covered were analysed for the time spent in each of four velocity categories – walking, slow run, fast run and sprint. A new approach was also used to assess the transitions between the velocity classes.

The results showed that more time was spent in the lowest velocity classes, although the amount of time spent walking and fast running seemed to differ in offence and defence. The players made 1.06 (centre) and 1.14 (guard) transitions between velocity classes per second.

Analysis of these relatively rapid changes in velocity classes seems to be more indicative of the intense nature of basketball and offers a potential methodology for future research.

Keywords: basketball, velocity classes, distance covered, offence, defence, SAGIT

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POVZETEK

McInnes, Carlson, Jones in McKenna (1995) so ugotovili, da se struktura in intenzivnost gibanja košarkarjev na tekmi v povprečju spreminjata vsaki 2 sekundi, pri čemer predstavlja delež visoko intenzivnega gibanja 15% aktivnega dela igre. Na vzorcu dveh košarkarjev na tekmi Državnega prvenstva Slovenije, smo analizirali frekvenco, povprečni čas in pot gibanja obeh igralcev znotraj aktivnega dela igre.Hitrost gibanja je bila opredeljena s 4 hitrostnimi razredi - hoja, počasen tek, hiter tek in šprint. Intenzivnost gibanja je bila analizirana na osnovi števila prehodov med posameznimi hitrostnimi razredi.

Intenzivnost gibanja igralcev je bila najpogosteje opredeljena z nižjimi hitrostnimi razredi, vendar se je čas gibanja v hoji in hitrem teku razlikoval v napadu in obrambi. Frekvenca prehajanja med različnimi hitrostnimi razredi je bila 1.06 pri centru in 1.14 prehodov v sekundi pri branilcu.

Pogosti prehodi med različnimi hitrostnimi razredi bi lahko bili boljši indikator intenzivnosti gibanja v košarki in zato bi bilo s tem metodološkim pristopom smiselno nadaljevati.

Ključne besede: košarka, hitrostni razredi, pot gibanja, napad, obramba, SAGIT

INTRODUCTION

Basketball is one of the most popular team sports and is characterised by some specialised movement patterns. These patterns include different types of movement such as shuffling, dribbling and jumping as well as more common movements such as walking, jogging, running and sprinting. Knowledge of the physical demands on players during a match is very important since this information can help players and coaches develop appropriate training regimes and consequently optimise players' performances during the game. Time-motion analysis has been used on many occasions to evaluate a player's performance and also to define activity profiles for different types of players in basketball. McInnes, Carlson, Jones, and McKenna (1995) analysed the movement patterns of basketball players by using different movement categories with a specific interest in the form and intensity of movements. They reported that players change movement category every 2 seconds and that 15% of live time (the period when the game clock is running) was spent engaged in high-intensity activity. In a very similar study by Ben Abdelkrim, El Fazaa, and El Ati (2007), the mean frequency of all movement categories was found to be 1,050 activities where the mean duration of movement categories never exceeded 3 seconds. Further, players spent 5.3% of live time sprinting and 22% in low to moderate-intensity running with differences found amongst guards, forwards and centres for the percentage time spent in high-intensity running. Taking a slightly different approach, Narazaki, Berg, Stergiou, and Chen (2009) evaluated female and male players' performances by analysing movement classified in just four types. Their results showed that players spent 34.1% of the time running and jumping, 56.8% walking and 9% standing. By employing a computer vision technique, Erčulj, Vučković, Perš, Perše, and Kristan (2008) analysed the average velocity of different types of players and found that during the live time of the game the velocity differed significantly among guards, forwards and posts (1.92 m/s, 1.87 m/s and 1.74 m/s, respectively). Stimulated by such a low speed of movement, Vučković et al. (2010) analysed players' movement intensities with respect to different velocity classes. They found that all types of players spent more than 60% of the time in low intensity movement swith a speed less than 1.4m/s. These findings came as a surprise and suggested a different approach was needed to analyse movement intensity in basketball. Therefore, the aim of this study is to analyse the frequency, duration and distance covered when players transit between different velocity classes.

METHODS

Design

The sample of participants contained 8 players who were classified with regard to their playing role (4 guards; age 24±3.2, height 187.8±3.4 and 4 centres; age 24.5±3.1, height 205.8±3.9). One guard (in this case always a point guard who played in position 1 and was responsible for carrying the ball and co-ordinating the team offence)and one centre (who always played in position 5 and was responsible for close range shooting and co-ordinating the team's defence (Drinkwater, Pyne, & McKenna, 2008) were then selected for analysis in this paper on the basis that both players had to be on court at the same time. This meant that a meaningful comparison of each player's movements could be undertaken since both spent the same amount of time in defence and offence situations. The data were collected in one match between two teams during the final stages of the Slovenian National Championship (2005/06).

Movement intensity was classified in four different velocity categories as suggested by Šibila, Vuleta and Pori (2005):

- walking (up to 1.4 m/s);
- slow run (1.4 – 3.0 m/s);
- fast run (3.0 – 5.2 m/s); and
- sprint (above 5.2 m/s).

Movement intensity was analysed within live time only, which refers to the time the game clock for attack (24 sec) was running, with separate analyses for offence and defence periods of the game. The data were analysed on four levels:

1. Level 1
2. The frequency, average time duration and distance covered by each player were analysed for the time spent in each velocity category.
3. Level 2
4. The frequency, average time duration and distance covered by each player were analysed during the transition between two different velocity categories. In this case, the time was calculated from the start of one velocity category until the end of the next velocity category. All possible transitions were analysed: accelerations (walking-slow run, slow run-fast run, fast run-sprint) and decelerations (sprint-fast run, fast run-slow run and slow run-walking).
5. Level 3
6. This level contained transitions between the three velocity categories: accelerations (walking slow run-fast run, slow run-fast run-sprint) and decelerations (sprint-fast run-slow run and fast run-slow run-walking).
7. Level 4
8. On this level, transitions between all four velocity categories were included: acceleration (walking-slow run-fast run-sprint) and deceleration (sprint-fast run-slow run-walking).

Procedure

All quarters were recorded with two video cameras (Ultrak CCD Color KC 7501 CP,Japan)at 25 video frames per second, thus obtaining 25 positions for each individual player for every second of the game. The cameras were fastened to the ceiling; each located above one half of the pitch in a vertical plane above the free throw line. This enabled the entire playing surface to be captured using a fixed zoom with a varifocal 2.8 mm lens (Ultrak KL2814IS, Japan). All quarters were recorded directly onto a DVD and then transferred to the computer's hard drive.

Digital images were processed by the SAGIT tracking system (Perš, Bon, Kovačič, Šibila, & Dežman, 2002). This system allows properly aligned motion and annotation data to be exported to other computer applications and processed by using SQL queries (Perš, Vučković, & Kovačič, 2005). In this study, custom data processing algorithms written in Matlab were applied.

Statistical analysis

In order to assess differences in the times spent at different work rates, non-parametric tests (Kruskall Wallis) were employed as the distributions of time and distance were positively skewed. Chi square tests of independence were used to assess the frequencies related tothe velocity categories.

RESULTS

This analysis represents 23 minutes and 12.2 seconds of ball in play time during which the centre and guard were on court together. During this time, both centre and guard positions tended to spend more time in the lowest velocity classes irrespective of the state of the game i.e. whether they were playing defence or offence (Figure 1). A chi square test for independence found that in defence both centre and guard positions were more frequently in velocity class 1 (33.5%, 36.7%, respectively) but less frequently in velocity class 3 (17.9%, 14.6%, respectively) than when in offence (Chi square = 41.59, df = 9, p < .001).

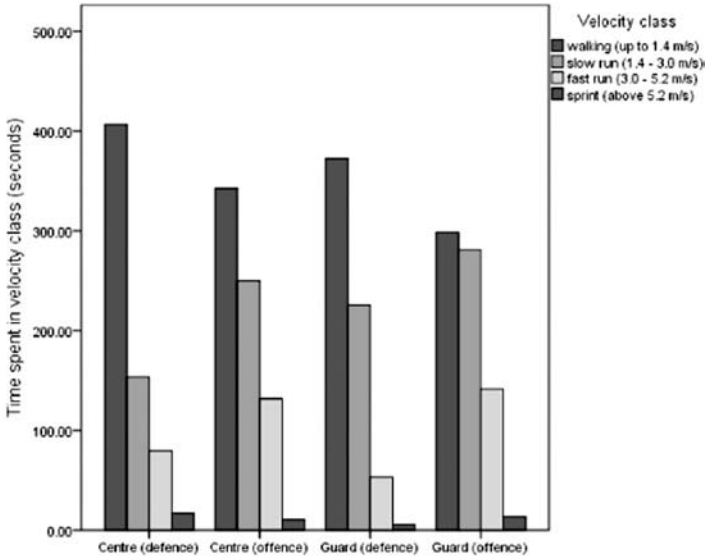

Figure 1: Time spent in each velocity class during ball in play time

Whilst the quantitative data show differences in time spent in the different velocity classes they do not show the associated trajectories. The SAGIT system enables this and Figures 2 and 3 illustrate the differences in directions taken by the centre and guard.

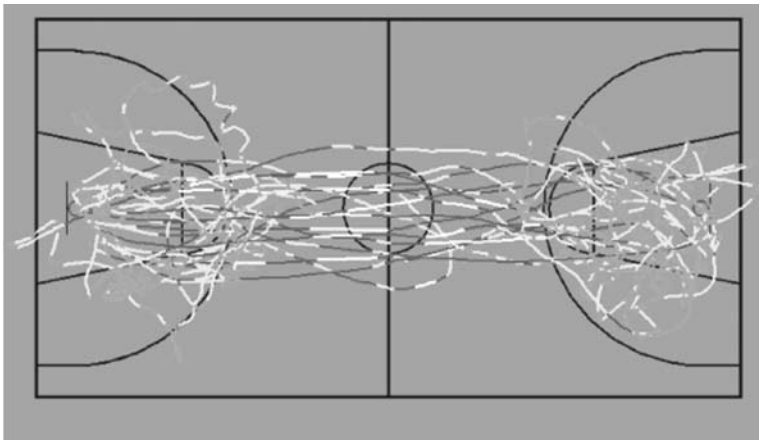

Figure 2: Velocity path for the centre during 449 seconds in the 1st quarter

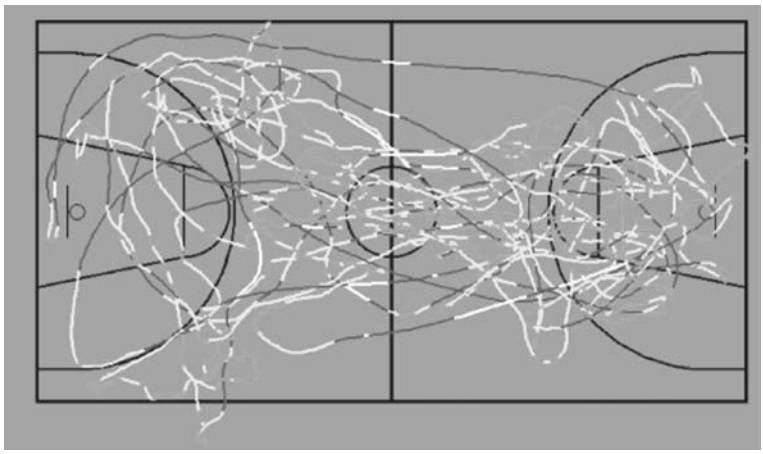

Figure 3: Velocity path for the guard during 449 seconds in the 1st quarter

It was also apparent that more distance was covered in offence compared to defence (Figure 4) although 156.24 seconds more time was spent in offence.

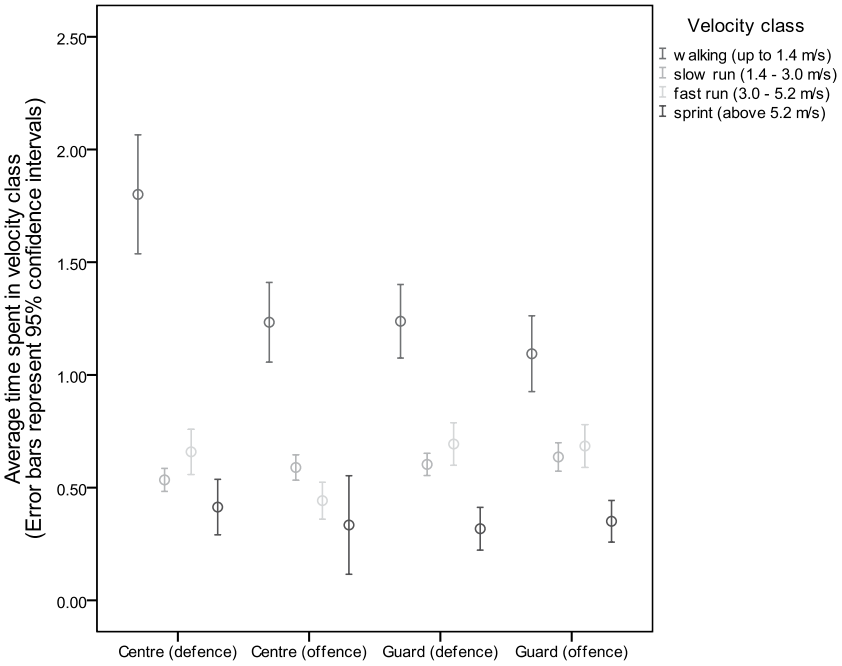

Figure 4: Total distance covered in each velocity class during ball in play time

Kruskall Wallis tests showed that the average time spent in velocity class 1 (chi square = 15.59, df = 3, $p < .01$) and 3 (chi square = 10.31, df = 3, $p < .05$) differed depending on the player position and whether the player was playing in defence or offence (Figure 5). No differences were found for the time spent in velocity classes 2 (chi square = 0.48, df = 3, $p = .92$) and 4 (chi square = 6.18, df = 3, $p = .10$).

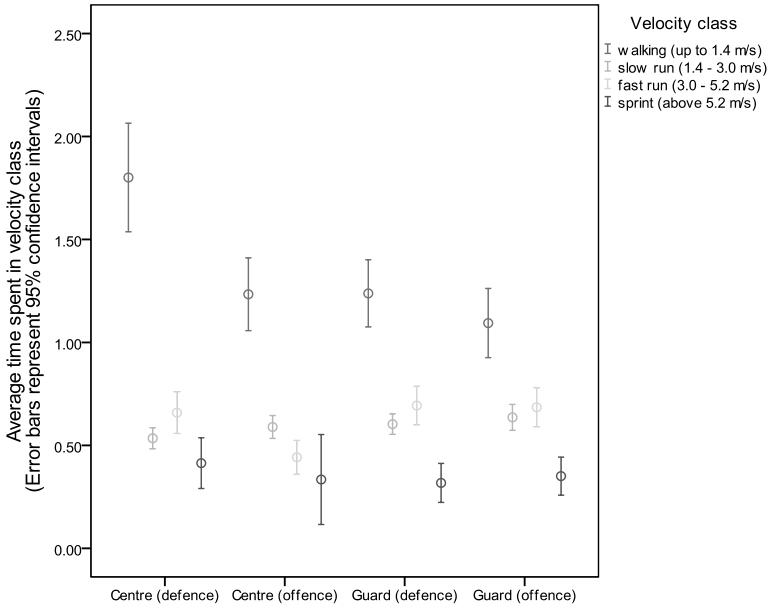

Figure 5: Average time spent in each velocity class during ball in play time

Kruskall Wallis tests showed that the average distance covered in velocity class 1 (chi square = 24.67, df = 3, $p < .001$), 2 (chi square = 11.42, df = 3, $p < .05$) and 3 (chi square = 25.03, df = 3, $p < .001$) differed depending on the player position and whether the player was playing in defence or offence Figure 6). No differences were found for the average distance covered in velocity class 4 (chi square = 2.47, df = 3, p = .48).

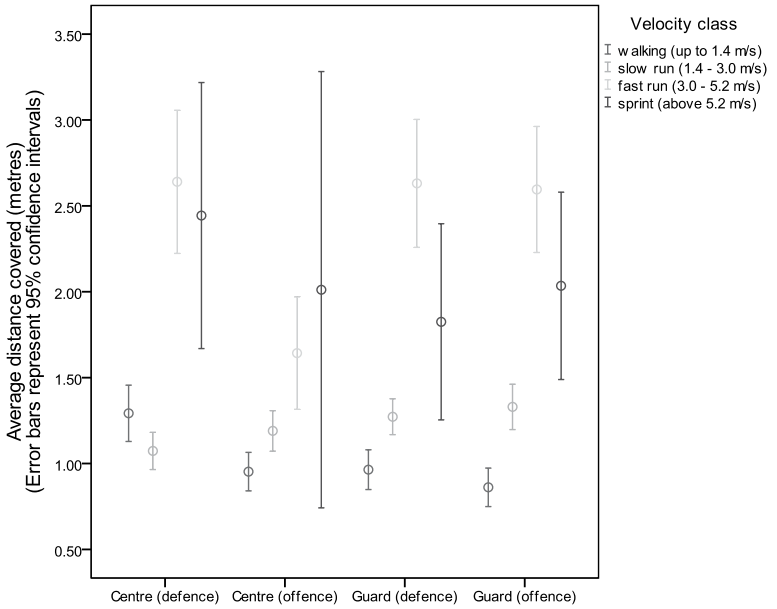

Figure 6: Distance covered in each velocity class during ball in play time

The difference in distance covered (and associated trajectories) is best presented by another SAGIT output (Figure 7) where it is evident that less movement closer to the ring occurred in defence (the right side of the figure) compared to greater movement and at a greater distance from the ring in offence (the left side). This difference was more apparent for the guard than the centre which is due to the guard's tactical role.

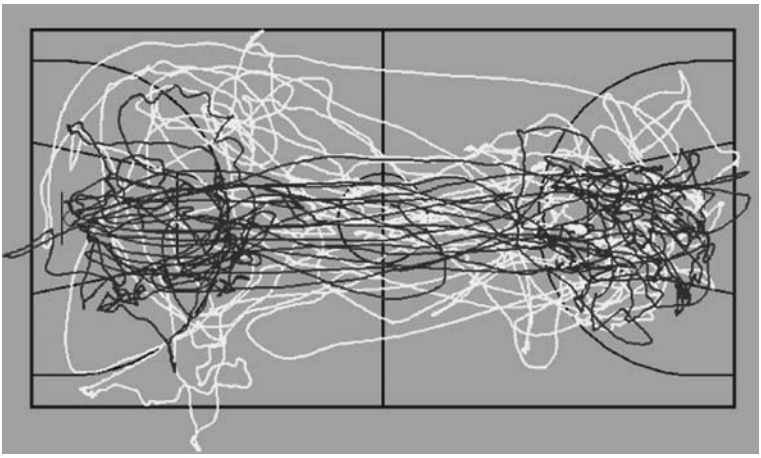

Figure 7: Trajectories of the centre (red) and guard (yellow) during the same 449 seconds in the 1st quarter

The above analyses give a breakdown of the work undertaken in the different velocity classes but do not show how often there are changes in velocity classes. The following analyses attempt to demonstrate the frequency at which transitions between velocity classes take place since frequent accelerations and decelerations will place higher workloads on a player than more constant velocities.

The centre made 1,476 transitions between velocity classes, meaning that these transitions took place 1.06 times every second. Similarly, the guard made 1,591 transitions (1.14 times every second). The time taken and distance covered for each transition was calculated (Table 1) using the start time of the transition as the point in time when the player entered the starting velocity class and the finish time of the transition as the point in time when the player exited the finishing velocity class.

Table 1: Transitions between two velocity classes

Transition		N	Mean time	(SD)	Mean distance	(SD)
VC 1 to 2	Centre	434	2.11	1.86	2.31	1.61
	Guard	487	1.70	1.50	2.02	1.49
VC 2 to 3	Centre	214	1.19	0.81	3.76	2.81
	Guard	243	1.16	0.81	3.50	2.62
VC 3 to 4	Centre	72	0.94	0.63	4.60	3.01
	Guard	54	0.85	0.61	4.12	2.89
VC 2 to 1	Centre	452	2.08	1.80	2.32	1.60

Transition		N	Mean time	(SD)	Mean distance	(SD)
	Guard	499	1.80	1.68	2.15	1.67
VC 3 to 2	Centre	229	1.26	0.76	3.98	2.76
	Guard	254	1.27	0.97	3.72	2.94
VC 4 to 3	Centre	75	1.02	0.67	4.89	3.12
	Guard	54	0.85	0.60	4.06	2.70

There were no differences in the pattern of accelerations and decelerations between the guard and centre for offence (chi square = 1.51, df = 5, p = .91), whereas in defence the guard tended to make more transitions between velocity classes 1 and 2 and 2 and 3 than the centre (Figure 8) but less transitions between velocity classes 3 and 4 (chi square = 34.96, df = 5, p < .001).

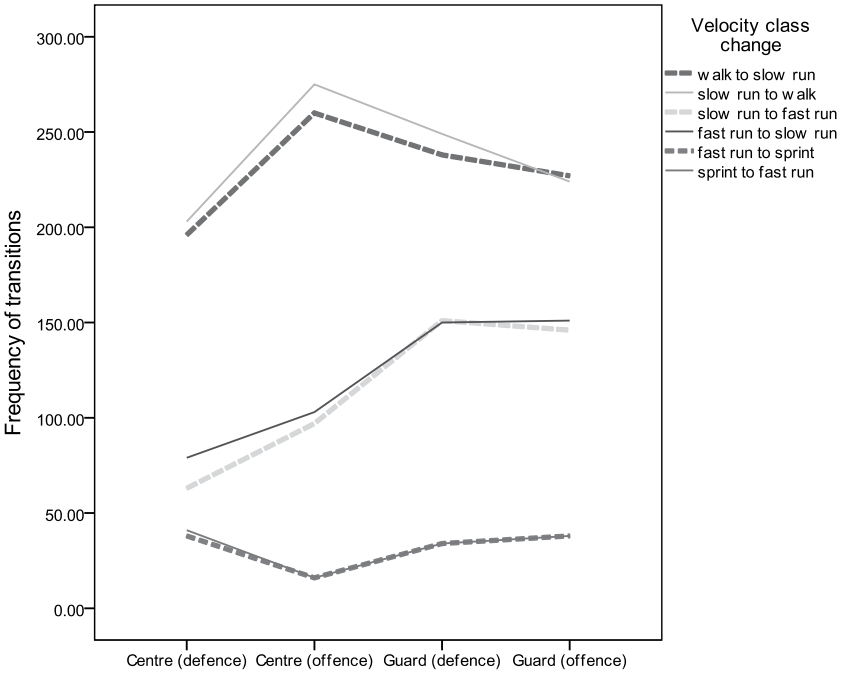

Figure 8: Frequency of velocity class transitions during ball in play time

Players were also able to accelerate and decelerate involving two or three transitions between velocity classes (Table 2). Chi square tests showed that the frequency of these transitions were independent of playing position and state of the game, although the guard tended to complete these transitions in less time and distance.

Table 2: Transitions between three or four velocity classes

Transition		N	Mean time	(SD)	Mean distance	(SD)
VC 1 to 2 to 3	Centre	65	2.67	1.98	4.97	3.03
	Guard	100	2.28	1.49	4.59	3.05

Transition		N	Mean time	(SD)	Mean distance	(SD)
VC 2 to 3 to 4	Centre	26	1.46	0.90	5.91	3.54
	Guard	38	1.45	0.81	5.54	3.19
VC 1 to 2 to 3 to 4	Centre	9	2.12	1.13	6.74	3.36
	Guard	13	2.00	0.83	5.79	2.66
VC 3 to 2 to 1	Centre	91	2.77	1.91	4.91	2.83
	Guard	119	2.56	2.01	4.88	3.73
VC 4 to 3 to 2	Centre	36	1.56	0.96	6.02	3.53
	Guard	39	1.54	0.91	5.42	3.07
VC 4 to 3 to 2 to 1	Centre	20	3.43	2.08	8.48	4.30
	Guard	24	2.83	1.93	6.43	3.49

DISCUSSION

Basketball is known as an intensive and dynamic team sport, although many studies show that players spend most of the time in low intensity movement such as standing, walking and jogging (Vučković et al., 2010; Narazaki et al., 2009). Although some previous studies investigated the frequency and duration of different locomotive actions executed by basketball players (Ben Abdelkrim et al., 2007; McInnes et al., 1995), to our knowledge this is the first to have investigated the frequency, average duration and distance covered during the transitions between different movement intensities.

Similar to previous studies, the guard and centre in this study spent most time in the slowest velocity class (walking). The proportionate time spent in each velocity class was similar for both offence and defence, although there was an increased time spent fast running, and a corresponding decrease in walking, when in offence compared to defence. This resulted in a greater distance being covered in offence compared to defence as the players were moving faster. However, in this study the period of play being analysed consisted of more time spent in offence which accentuated the distance differential. Kruskall Wallis tests showed that the increased time spent in offence resulted in differences in time and distance for walking and fast running only, suggesting that it is these velocity classes that differentiate offence and defence play. From the tactical perspective, offence is characterised by the greater movement of players as they try to move into space so they may receive the ball and create passing lines, whereas in defence players move less as their objective is to defend the ring (as shown in the SAGIT output, Figure 7).

Since the basketball court is relatively small compared to some other sports fields, for example soccer, it is not surprising that basketball players are unable to reach the same maximum velocities as seen in sports like soccer. Due to the limiting factor of pitch size on movement intensities, we thought that some measure of the change in velocity (here we used transitions between velocity classes) may be a better method for discriminating and describing movement intensity in basketball. The players in this study made 1,476 (centre) and 1,591 (guard) transitions, that is a change between velocity classes 1.06 and 1.14 times per second, respectively. This is considerably less than the 2 seconds reported by McInnes et al. (1995), although this may be due to methodological differences between the two studies. Our method consisted of adding the times spent in the two velocity classes involved in the transition. Consequently, the number of transitions is

related to the size of the velocity class such that if we had made the velocity classes smaller we would have had more transitions. This raises the question of the appropriateness of the velocity classes although this is only likely to be addressed adequately through an academic study. The velocity classes used here resulted in average transition times of 1.72s (SD = 1.56s) for the centre and 1.52s (SD = 1.39s) for the guard which shows that agility and speed, as suggested by Ziv and Lidor (2009), are important indicators of players' performances. Since these times were positively skewed, it should be noted that 87.02% of the transition times occurred in under 3 seconds. It seems sensible to suggest that it is the rapid nature of these changes in velocity class that provides a clue as to how to measure the intensive nature of basketball players' movements.

Only small differences were found in the pattern of accelerations and decelerations between the guard and centre, and this was only in defence. In this situation, the guard tended to make more transitions in the slower velocity classes (walking, slow run and fast run) but fewer higher speed transitions (between fast run and sprint) than the centre. From the tactical perspective, centres tend to be more static in defence than guards which would explain the lower frequency of transitions in the slower velocity classes. It seems counterintuitive that the centre had more transitions between a fast run and sprint, although this can be explained by the movement in the transition phase between offence and defence and vice versa. The guard's trajectories were seen to exhibit greater variability (Figure 3), probably as a consequence of carrying the ball and being slowed down by the defensive player's actions. Another explanation of this finding is that guards tend to move from one free throw zone to the other, which is a shorter distance than for the centres who tend to run from basket to basket. The extra distance covered by the centre would make it easier to develop higher speeds and thus move into the sprint category.

CONCLUSION

Movements in basketball are categorised as predominately slow paced. However, it is obvious to anyone watching or playing basketball that this does not accurately portray the intense nature of physical activity in basketball. This paper reports how a case study of national level players found that changes between velocity classes occurred 1.06 (centre) and 1.14 (guard) times per second. This relatively rapid change seems to be more indicative of the intense nature of basketball and offers a potential methodology for future research into the movement characteristics of basketball. More work is needed to discover which velocity classes are appropriate for basketball as these will determine the frequency of transitions between velocity classes. An alternative approach would be to consider acceleration data in relation to velocity data. Whilst differences in movement characteristics were found between the guard and centre position and when in offence and defence roles, there was also some evidence to suggest that movements during the transitions between offence and defence and defence and offence, perhaps differing in relation to whether a basket was scored or not, may need to be analysed separately in future. It would be reasonable to use the same approach of analysing a player's intensity at present since new rules were applied in October 2010 (Official Basketball Rules, 2010).One of the major differences is the new shape of the restricted area which is also 2% bigger. Consequently, to some extent this might influence a player's movement patterns.

Finally, it would seem sensible to consider the effect of team tactics on movement patterns and intensities. For example, different defence strategies e.g. zone, man to man or pressing from the

initiation of the attack to affect a turnover, would each result in very different movement patterns in both offence and defence as those in the offence are likely to change their tactics in response to the defence strategy.

REFERENCES

Ben Abdelkrim, N., El Fazaa, S., & El Ati, J. (2007). Time-motion analysis and physiological data of elite under-19-years-old basketball players during competition. *British Journal of Sports Medicine,* 41, 69-75.

Drinkwater, E. J., Pyne, D.B., & McKenna, M.J. (2008). Design and interpretation of anthropometric and fitness testing of basketball players. *Sports Medicine,* 38, 565-576.

Erčulj, F., Vučković, G., Perš, J., Perše, M., & Kristan, M. (2008). Establishing basketball players' velocity and distance covered during a basketball match with the sagit computer tracking system. *Journal of Coimbra Network on Exercise Sciences, 4, 50-59.*

McInnes, S.E., Carlson, J.S., Jones, C.J., & McKenna, M.J. (1995). The physiological load imposed on basketball players during competition. *Journal of Sports Sciences,* 13, 387-397.

Narazaki, K., Berg, K., Stergiou, N., & Chen, B. (2009). Physiological demands of competitive basketball. *Scandinavian Journal of Medicine & Science in Sport,* 19, 425-432.

Official Basketball Rules. (2010). Retrieved 15March 2011 from http://www.fiba.com/downloads/Rules/2010/OfficialBasketballRules2010.pdf

Perš, J., Kovačič, S., & Vučković, G. (2005). Analysis and pattern detection on large amounts of annotated sport motion data using standard SQL. In *Proceedings of the 4th International Symposium on Image and Signal Processing and Analysis,* (edited by S. Lončarić, H. Babić and M. Bellanger), pp. 339-344. Zagreb: Faculty of Electrical Engineering and Computing.

Perš, J., Bon, M., Kovačič, S., Šibila, M., & Dežman, B. (2002). Observation and analysis of large-scale human motion. *Human Movement Science,* 21, 295-311.

Šibila, M., Vuleta, D., & Pori, P. (2004). Position-related differences in volume and intensity of large-scale cyclic movements of male players in handball. *Kinesiology,* 36 (1), 58-68.

Vučković, G., Dežman, B., Perše, M., Kristan, M., Perš, J., Kovačič, S., & James, N. (2010). An automatic tracking analysis of the movement velocities of national level basketball guards, forwards and centres. In V. Koprivica, & I. Juhas(Eds.), *Zbornik radova* (p. 97-101). Beograd: Fakultet sporta i fizičkog vaspitanja.

Ziv, G., & Lindor, R. (2009). Physical attributes, physiological characteristics, on-court performances and nutritional strategies of female and male basketball players. *Sports Medicine,* 39, 547-568.