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(Article begins on next page)

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Running head: Time-motion analysis of women’s basketball

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ABSTRACT

The aim of this study was to assess elite women's basketball game performance. Five elite women's games (3 Italian 1st division and 2 Euroleague) were analyzed for individual and team time-motion analyses. The individual analysis evaluated the players' movement patterns with particular focus on high intensity activity (HIA), sprint activity, and repeated sprint events (RSEs). Team analysis included live time (LT), stoppage time (ST), and their ratio, transfer (TR) phases, half court and full court actions. The frequency of occurrence of changes of activities was n=576 ± 110, one every 2.56 s of LT. Total HIA was 8.5 ± 1.8% of LT and no significant differences between quarter-periods were observed. In general, players performed linear sprints (48.3 ± 2.9%) over 1-5 m distance (56.8 ± 5.6%). The occurrence of RSE was 4.4 ± 1.7, with 58.6 ± 18.5% passive recovery between sprints. Team analysis showed no significant difference between games for LT and ST phases (ratio = 1.18 ± 0.25). For game analysis, LT and ST were 43.4 ± 7.8% and 51.1 ± 8.4%, respectively. A difference between games was found for half court actions ($p<0.01$) and TR phases ($p<0.05$). Moreover, 1TR and 2TR were the most performed (45.3% and 23.9%) actions. These results encourage coaches to include repeated sprint ability with mainly linear and short sprints into a comprehensive training program.

Key words: match analysis, movement patterns, sprint activity, repeated sprint ability, agility

INTRODUCTION

The first women's basketball game was played in 1893, when Senda Berenson adapted James Naismith's basketball rules for women (40). However, women's basketball has been included in the Olympic Games since 1976 and the professional Women's National Basketball Association (WNBA) was founded in 1996, receiving a large interest worldwide (40). Conversely, the scientific literature on women's basketball is still limited, particularly regarding performance parameters.

Video analysis is one of the most common methods used to evaluate the performance of both the individual players and the teams during a competition (20). More specifically, notational analysis is considered an objective way to quantify in a valid and consistent manner key elements of a performance (28). According to the Hughes and Franks' classification (21), notational analysis can be used for: 1) technical and tactical evaluations; 2) educational uses with coaches and players; 3) development of databases and performance models; and 4) analysis of movements, commonly referred as time-motion analysis. To date, the majority of the studies in basketball have focused on physiological aspects of performance (14,29,30,31) rather than the analysis of movements during competition (41). While the physiological parameters could inform on the metabolic demands of a game, time-motion methodologies could provide crucial information regarding the occurrence, duration and typology of sport-specific movements to help coaches in designing sound training programs.

Basketball is an open-skill sport characterized by different activities, varying from low-intensity running and walking to maximal sprints and jumps. According to the literature on elite men's basketball players perform around 1000 changes of movement every 2.0 s (5,26), with a 1:3.6 work to rest ratio (4). In particular, high intensity activities occur 15-16% of live time, with 55-105 sprints occurring every 21-39 s and lasting <2 s (5,26). In addition, a decrease in the amount of high-intensity activity has been reported during the second and fourth quarters compared to the first and third ones, probably due to fatigue effect or different team tactical strategies adopted (3,5).

In general, a relevant component for team sport performances is the player's capability to sustain repeated sprints (i.e., repeated-sprint-ability, RSA) with minimal recovery between sprint bouts (7,36). Requiring team sport players to perform repeated straight sprint tasks, several authors focused on the physiological parameters related to RSA (6,7,19,36,39) and only few studies investigated the frequency of occurrence of repeated sprint activities during actual games (9,17,37). Even though RSA is considered particularly crucial for basketball performance (3,10,33), it has been investigated mainly during basketball training (10,34) with only one study analyzing RSA during official men's basketball games (12). No information is available on women's competitions. In general, basketball players perform not only straight sprints but also short sprints with rapid changes of direction and velocity, which is commonly known as agility (35). Although agility is considered an important component for both male (1) and female (15) basketball players, this aspect has been investigated only during rugby competitions (18).

Information on movement patterns during women's basketball is limited. Examining a practice game of college female players, Narazaki and colleagues (27) considered only four categories of movement (i.e., stand, walk, run, jump). The authors reported that running and jumping activities account for 34% of live time. Investigating a female team of the British University Sports Association (BUSA) Premiere League, Matthew and Delextrat (25) reported that players perform 652 ± 128 movements, one every 2.8 s, and spend 5.7% of live time at high intensities. A higher occurrence of movement changes (1752 ± 156) has been reported for Australian state-level basketball players (32). These discrepancies could be ascribed to methodological differences between studies, which need further investigation to establish sound evidence. Finally, to provide a comprehensive picture of the demands of basketball game, it is crucial to combine individual and team time-motion game analyses (28), which could be helpful for strength and conditioning coaches to plan their training sessions. Because of the situational nature of basketball, it is essential to consider also possible differences in individual and team behaviors among games in relation to the duration of the game phases and individual and team movements between and within basketball games. Unfortunately, no study on basketball provided both individual and team analyses.

Therefore, the present research aimed to investigate elite women's basketball performance by combining individual and team time-motion analyses. Specifically, this study examined players' movement patterns, with particular reference to the number of repeated sprint events (RSE), and high intensity activities (HIA) that occurred during the games. Team analysis focused on the number and duration of live time (LT) and stoppage time (ST) phases, and total and half court actions. The hypotheses of our study were that: 1) the time spent by players in HIA decreased throughout the game; and 2) the LT, ST, transfer phases (TR) and half court actions have a different distribution between games.

METHODS

Experimental approach to the problem

The Institutional Research Board approved the study aimed to analyze individual and team women's basketball performances. Written consent was obtained from the players giving them a detailed written and verbal consent explaining aims, benefits and risks involved with the investigation. This study examined a women's team competing in the 2011-2012 season in both "Serie A1" and Euroleague. Serie A1 represents the women's Italian first division basketball championship and includes the best 12 women basketball Italian teams. The top eight teams qualify for the play-off stage. The winner and the second classified of the Italian national competition qualify for the women's Euroleague championship of the following season. The Euroleague is the Europe's premier basketball tournament for women including the best 23 European teams. According to the International Basketball Federations rules, games consist of four 10-min quarters, with two 2-min breaks between the first and last two quarters and a 10-min break between the second and third quarters. A total of five home games (3 by Serie A1 and 2 by Euroleague) were selected for this study. Data were collected from November 6th 2011 to January 8th 2012 during the 2011-2012 regular seasons of both Serie A1 and women's Euroleague championships. According to the official games schedules, the Italian games (Serie A1) were scheduled on Sunday at 6 p.m., while the European games (Euroleague) were played on Thursday at 8.30 p.m. The team won four games and lost only one.

Players' movement patterns were analyzed by means of time motion analysis technique (5,25,26). In particular, individual analysis focused on the occurrence and duration of sprint activity, RSE and HIA. Team analysis evaluated the number and duration of LT, ST, TR and the half court actions. Both individual and team variables were analyzed to give a comprehensive description of the women's basketball performance. Furthermore, the percentage of time spent by players in HIA was used as dependent variable for comparisons between game quarter periods. Team analysis evaluated LT, ST, TR and half court actions were considered dependent variables to verify whether differences occurred between games and within each class of frequency of each variable.

Subjects

An Italian elite (1st division) female basketball team consisting of twelve players (age: 27 ± 4 years; height: 1.84 ± 0.09 m; body mass: 77.5 ± 15.1 kg) volunteered for the study. All players had competed in the European national and international competitions, and in the WNBA professional league during the previous 3 years and were coached by a staff with at least 7-year experience at Serie A1 level. Athletes were involved in eight 120-min training sessions and two games per week. According to the literature (5,25,26), inclusion criteria for individual player analysis the players had to: a) be member of the team from the entire pre-season period (from August to September 2011); b) have played ≥20 $min \cdot game^{-1}$. Therefore, 6 players (2 guards, 2 forwards and 2 centers) were individually analyzed.

Procedures

Video recordings of all games were collected using a fixed camera (Sony HD AVCHD HDR-CX115, Tokyo, Japan), positioned at the midline 8-10 m away from the sideline and elevated 10-12 m to allow a full coverage of the court. The footage was analyzed using the software Dartfish 6.0 (DartfishTM Fribourg, Switzerland), which allowed a frame by frame analysis (with an accuracy of 0.02 s) of each playing sequence by choosing the velocity of footage's reproduction. To avoid inter-observer variability, a single experienced observer scored all the games. Before the study, the observer scored two quarters of the same game 2 months apart, reporting high test-retest reliability (Intraclass Correlation Coefficients = 0.88-0.99).

According to the literature (26), individual movement patterns were divided into 8 activity categories: 1) standing/walking (SW); 2) Jogging (JOG); 3) Running (RUN); 4) Sprinting (SPRINT); 5) Jumping (JUMP); 6) Low- (LM), Moderate- (MM) and High- (HM) intensity specific movements (shuffling, rolling, reverse and cross-over run activities). Also picking and positioning were considered (3). In particular, HMs, JUMPs and SPRINTs performed with and without the ball were recorded, and their sum was used to represent HIAs. The SPRINT category was divided in linear sprint (LS), curved sprint (CS), and sprint with well defined change of direction (CODS). The frequency of occurrences and duration of movements, and the amount of live time spent in each category were considered for the analysis. Finally, sprinting distances were organized into 1-5 m, 6-10 m, 11-15 m, 16-20 m, and >20 m classes, respectively.

In considering the number and duration of sprint repetitions, and the duration and type (active/passive) of recovery, a minimum of three sprints with mean recovery between sprints <21 s was required to be considered a RSE pattern (37). In particular, passive recovery included SW activity, while all the others activities were considered as active recovery. Moreover, the occurrence of high intensity efforts (JUMPs and HMs) was measured during the RSE recovery phases.

Team analysis considered the duration of LT and ST according to 5 time categories: 1-20s; 21-40s; 41-60s; 61-80s; and >80s. Then, the LT/ST ratio was calculated. Furthermore, actions played during LT phases were classified in half and full court, respectively. A half court action occurred when the action started and finished in the same half court. A full court action occurred when action started in one half court and finished in the other half court, with at least 3 team-members crossing the mid-court line. A single TR was counted when those players crossed the mid-court line (23). For full court team movements, the number of consecutive TRs occurring during a single LT phase was collected. Then, TR has been categorized in five classes of frequency (1TR; 2TR; 3TR; 4TR; and >4TR).

Statistical analysis

For each variable, descriptive statistics (mean, SD, frequency of occurrence and percentage) were calculated. To verify differences between quarter periods for LT spent at HIA, an ANOVA for repeated measurements was applied. Chi square tests of independence were applied to assess differences between games in the occurrences of LT, ST and TR, whereas chi-square goodness of fit tests were used to verify differences in the distribution of half court actions between games and to assess differences in LT, ST and TR classes. Statistical analyses were conducted using the statistical package SPSS (version 20.0, Institute Inc., Cary, NC, USA), and the criterion for significance was set at a 0.05 alpha level.

RESULTS

The analysis of activities of individual players showed that total LT and game time were 1477 ± 309 s and 2667 ± 608 s, respectively. During a game, each player performed 576 ± 110 (range 363-759) changes of activity. Table 1 reports the occurrence and duration of individual activities. In general, a change of activity was observed every 2.56 s and 4.63 s for LT and total time, respectively. The highest values emerged for SW, whereas HIA occurred 8.5% ± 1.8 of LT. No differences in time spent by players in HIA were found between quarter-periods.

Insert Table 1

Regarding HIA, SPRINT occurred every 33.3 s of LT and 60.2 s of total time, respectively. The relative picture for HM was 16.6 s and 29.9 s for LT and total time, respectively. Table 2 reports the relative proportion of HIA categories performed with and without the ball. When each category was analyzed separately, both SPRINT (82.9 ± 3.2%) and HM (85.9 ± 3.4%) without the ball were higher than their relative conditions with the ball (SPRINT: 17.1 ± 3.2%; HM: 14.1 ± 3.4%), whereas a more balanced occurrence emerged for JUMP (without the ball: 55.6 ± 5.2%; with the ball 44.4 ± 5.2%).

Insert Table 2

The majority of sprints were for distances <10 m (Figure 1) accounting for 86.7% of the overall number of sprints. The most common sprint was between 1 and 5 m. Overall, more LS were performed than CS and CODS (Table 3). Sprinting without the ball (LS: 94.6 ± 3.1%; CS: 67.4 ± 4.3%; COD: 78.6 ± 4.4%) occurred more frequently than sprinting with the ball (LS: 5.4 ± 3.1%; CS: 32.6 ± 4.3%; COD: 21.4 ± 4.4%).

Insert Figure 1 and Table 3

Over the five games, the analyzed players performed 130 RSE. During a match, 26.0 ± 7.6 RSEs were observed, with 4.3 ± 2.7 performed individually. Within each RSE, the number of sprints was 4.4 ± 1.7, with 15.4 ± 4.5 s between sprints, often in passive recovery (58.6 ± 18.5%). During the active recovery between sprints at least one HM (57.7%) or at least one JUMP (48.5%) occurred.

On 38 occasions, corresponding to 29.2% of the total RSEs, both a HM and a JUMP occurred between two sprints.

For team analysis, no differences emerged between games for the frequency of occurrence of LT and ST, whereas differences were found for the frequency of occurrence for half court actions (p<0.01) and TR phases (p<0.05) (figure 2). Moreover, differences (p<0.001) were found within LT, ST and TR classes of frequency. Regarding the duration of LT, higher occurrences were always found for the 1-20 s (33.4 ± 12.7) and 21-40 s (21.6 ± 4.7) actions respect to those with durations >41s (41-60 s: 10.0 ± 1.6; 61-80 s: 4.8 ± 1.6; >80s: 5.2 ± 3.3). Table 4 reports the percentages of occurrence of LT and ST time categories. The mean game LT/ST ratio was 1.18 ± 0.25, with 1.69 ± 0.78; 1.02 ± 0.26; 1.34 ± 0.58; 1.13 ± 0.28 for the 1st, 2nd, 3rd and 4th quarter, respectively. Furthermore, 35.2% and 64.8% of LT phases were played on half and full court, respectively. The majority of TRs occurred in 1TR (45.3%) and 2TR (23.9%) categories.

DISCUSSION

This is the first study focusing on individual and team time-motion analyses of elite women's basketball games. The main findings were: 1) the repeated-sprint activity is a significant component of elite women's basketball, primarily characterized by linear and short sprints, mostly performed without the ball; 2) no differences were found between game quarters in the live time HIA; and 3) team analysis showed no different distribution for LT and ST phases between games, while a different distribution was observed for TR phases and half court actions.

RSA has been considered a crucial element in team sport performance and analyses of RSE during official games has been conducted in soccer (9), rugby (17), and field hockey (37). In elite men's basketball players (12), only one game has been analyzed, thus limiting the generalizability of results, especially to women's basketball. In the present study, during a game each player performed more RSEs with respect to those registered in field hockey and rugby (17,37). Furthermore within each RSE, the occurrence of sprints resulted similar to that of men's field hockey (37) and higher than that of youth male soccer (9). These findings highlight the relevance of women's basketball training focused on RSA.

The type of recovery between sprint bouts could affect overall sprint performance (36), with passive recovery determining lower sprint time and lower fatigue index while performing a basketball-specific RSA test (10). Similarly to men's field hockey (37), women's basketball players tended to recover from RSE primary standing or walking (passive recovery). When an activity was performed between sprints, HM and JUMP occurred separately or in sequence. Jumping or other high intensity movements performed between sprint bouts have been shown to increase the physiological load of RSA (8). These findings could be useful for future research focusing on the development of a new specific basketball RSA test that includes HM and JUMP activities between sprint bouts.

This study provides coaches with relevant information regarding the typology of sprint activity in women's basketball, which could be used for improving the specificity of their training plan. Players of this study sprinted more frequently (every 33 s of LT) compared to young male (39 s) (3,5) and collegiate female players (37.6 s) (25), but less frequently than reported for elite male Australian players (20.9 s) (26), argues the necessity for basketball training plans to consider the players' gender, age and level of competition. This consideration is reinforced by the higher occurrence of changes of activity (around 2.6 s) observed in the elite women's basketball players with respect to collegiate counterparts (2.8 s) (25), although lower than that reported for male elite players (2.2 s) (5).

The analysis of sprint distances yielded interesting information. Around 57% of the sprints were performed over 1-5 m with an additional 30% over 6-10 m. These distances were shorter with respect to those recorded during rugby male elite games (18), likely due to the reduced dimension of the basketball court. However, the basketball sprint and RSA tests reported in the literature

(24,16,12,10,38,13) mainly require players to sprint over longer distances and do not correspond well to the game requirements. Therefore, future studies should consider the development of sprint tests < 10 m for evaluating women's basketball players. In addition, due to the high frequency of short sprints in basketball, it could be speculated that conducting a time-motion analysis based on sprint speed categories would not be meaningful.

Although players tended to perform linear sprints, curved sprint and sprints with change of direction were 52% of the total sprints. In considering that CODSs represent 1/5 of total sprints, these results substantiate the prevalent role of agility in women's basketball game (13), especially performed without the ball. However, it has to be noted that 17.1% of the total sprint activity was carried out bouncing the ball, highlighting the contribution of sprinting while dribbling to the overall activity demands of female basketball game-play.

This study did not support the hypothesis that HIA would decrease throughout the game, a result in line with the findings relative to University level women's basketball (25). Conversely, youth elite male basketball players showed a significant decrease in total HIA in the last quarter of the game (5). The most likely explanation for this contrasting data is that our players averaged at least 20 min of LT per game, which may not be sufficient to induce fatigue by the end of the game. Comparatively, athletes in BenAbdelkrim et al. study (5) averaged of almost 35 min of LT per game. Furthermore, it is necessary to consider that also tactical factors can heavily influence the pace of a game, particularly towards the end of a quarter or of a game (3,5). Therefore, future research is needed to investigate the role of different tactical aspects and game strategies on the movement patterns of players.

We found no differences between LT and ST for all games analyzed suggesting that the observed game phases and team patterns reported could be used to establishing a performance model of elite women's basketball. Moreover, a significant difference inside the occurrence of LT and ST phases with a duration of up to 1 min and a work to rest ratio never above 1.69 (1^{st} quarter) were shown. Interesting to note, these results are in line with the literature on youth male basketball (22), indicating a mean playing time and break period of ~ 1.5 and 1 min, in seasonal and tournament elite junior male basketball competition, respectively. These data could provide basketball coaches with detailed information that can be used to design their training sessions in term of drill duration and workload. The different distribution between games for half court actions and TR phases underlines the heterogeneity and variability of basketball games in this specific area. In particular, the higher number of actions played on total court, mostly including 1 or 2 TR phases, suggests that coaches should train their players using a limited number of TRs. This novel information calls for further analysis of half and full court actions to help coaches optimizing their basketball training sessions with particular reference to basketball drills and scrimmages.

PRACTICAL APPLICATION

The present findings highlight the relevance of repeated-sprint activity in women's basketball and call for the future development of basketball RSA tests specifically related to the actual demand of the game. Specifically, training should focus on RSA drills with at least 4 sprint repetitions and a recovery time between bouts of around 15 s. Basketball coaches should consider using both passive and active recovery with the latter including high intensity specific movements and jumps between sprint bouts. In addition to linear sprints, coaches should also train CSs and CODSs at distances of 10m or less. This approach could be useful to improve the players' capability to accelerate over short distances, which could be a discriminant factor of basketball performance. Furthermore, CS performed bouncing the ball should be widely trained, especially in considering the high occurrence of these technical aspects during a game. Work to rest ratio between 1:1 and 2:1 should be considered for basketball drills and small-sided games which proved to be effective in training players (2,11). However, to meet the game requirements drill bouts duration should last approximately 1 min. In considering that almost 1/3 of the actions were performed on half court, coaches of women basketball should also focus on small-sided games played on only half court. Finally to improve training specificity, drills played on full court should include mainly two TR phases.

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FIGURE LEGENDS

Table 1. Means ± *SD* and (ranges) of activity classes (Standing/Walking=SW, Low intensity specific movement=LM, Jogging=JOG, Medium intensity specific movement=MM, Running=RUN, High intensity specific movement=HM, Sprinting=SPRINT, Jumping=JUMP) of players for each game in relation to their occurrence (n and %), proportion of live time (%), and duration (s).

Table 2. Means ± *SD* of frequency of occurrence (%) of high intensity actions (HIA) (Sprinting=SPRINT, High intensity specific movement=HM, and Jumping=JUMP) in relation to their execution with or without the ball.

Table 3. Means ± *SD* of frequency of occurrence (%) of sprinting typology (Linear=LS, Curved=CS, and Change of Direction=CODS) in relation to their execution with or without the ball.

Table 4. Means ± *SD* of frequency of occurrence (%) of time categories (1-20s, 21-40s, 41-60s, 61-80s, >80s) for live time (LT) and stoppage time (ST).

Figure 1. Means and *SD* of frequency of occurrence (%) of sprint activity in relation to 5 classes of distances (1-5m; 6-10m; 11-15m; 16-20m; >20m).

Figure 2. Frequency of occurrence (%) of transfer phases (TR) in relation to one (1TR), two (2TR), three (3TR), four (4TR) and more than four TR (>4TR) categories. *=P<0.05.

Classes of activity	Frequency of occurrence (n)	Frequency of occurrence (%)	Live time (%)	Duration (s)
SW	205 ± 42 (121–280)	35.4 ± 2.0	50.2 ± 5.5	7.42 ± 10.58
LM	91 ± 23 (55–137)	15.5 ± 2.0	10.0 ± 2.7	1.69 ± 1.17
JOG	73 ± 20 (40–121)	12.8 ± 3.0	11.7 ± 2.9	2.66 ± 2.21
MM	56 ± 20 (20–104)	9.6 ± 2.5	6.5 ± 2.4	1.77 ± 0.95
RUN	63 ± 16 (36–105)	11.0 ± 1.8	13.1 ± 2.4	3.13 ± 1.58
HM	25 ± 10 (13–56)	4.5 ± 1.5	2.7 ± 1.4	1.62 ± 0.92
SPRINT	44 ± 15 (18–72)	7.8 ± 2.2	5.2 ± 1.8	1.77 ± 0.80
JUMP	19 ± 10 (5–44)	3.4 ± 1.5	0.6 ± 0.3	0.46 ± 0.13

Table 1. Means ± *SD* and (ranges) of activity classes (Standing/Walking=SW, Low intensity specific movement=LM, Jogging=JOG, Medium intensity specific movement=MM, Running=RUN, High intensity specific movement=HM, Sprinting=SPRINT, Jumping=JUMP) of players for each game in relation to their occurrence (n and %), proportion of live time (%), and duration (s).

HIA	High intensity with ball (%)	High intensity without ball (%)
SPRINT	38.6 ± 6.3	52.7 ± 3.2
HM	17.3 ± 2.3	31.5 ± 3.2
JUMP	44.1 ± 5.9	15.8 ± 1.3

Table 2. Means ± *SD* of frequency of occurrence (%) of high intensity actions (HIA) (Sprinting=SPRINT, High intensity specific movement=HM, and Jumping=JUMP) in relation to their execution with or without the ball.

Sprint activity	Total sprint (%)	Sprint with the ball (%)	Sprint without the ball (%)
LS	48.3 ± 2.9	14.5 ± 5.8	55.2 ± 3.5
CS	31.0 ± 3.9	59.1 ± 2.0	25.2 ± 4.1
CODS	20.7 ± 1.5	26.4 ± 5.9	19.6 ± 1.1

Table 3. Means ± *SD* of frequency of occurrence (%) of sprinting typology (Linear=LS, Curved=CS, and Change of Direction=CODS) in relation to their execution with or without the ball.

Time Category	**LT (%)**	**ST (%)**
1-20s	43.4 ± 7.8	51.1 ± 8.4
21-40s	29.0 ± 4.2	29.1 ± 5.4
41-60s	13.5 ± 1.5	7.0 ± 3.6
61-80s	6.5 ± 2.4	4.3 ± 2.7
>80s	7.6 ± 5.5	8.6 ± 3.4

Table 4. Means ± *SD* of frequency of occurrence (%) of time categories (1-20s, 21-40s, 41-60s, 61-80s, >80s) for live time (LT) and stoppage time (ST).

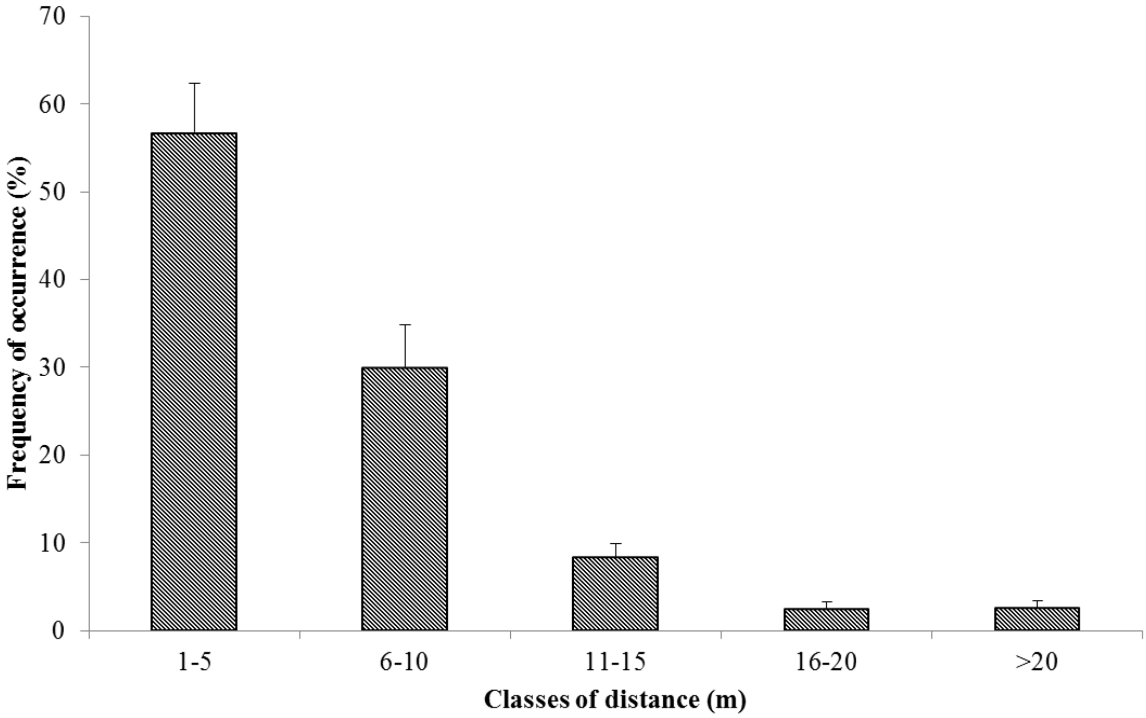
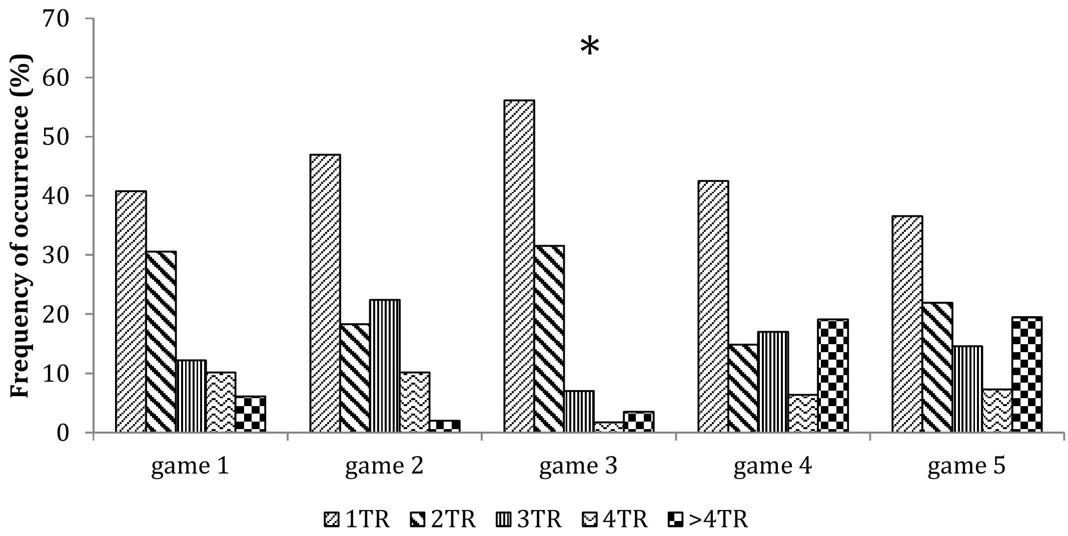


Figure 1. Means and *SD* of frequency of occurrence (%) of sprint activity in relation to 5 classes of distances (1-5m; 6-10m; 11-15m; 16-20m; >20m).



483

484 **Figure 2.** Frequency of occurrence (%) of transfer phases (TR) in relation to one (1TR), two

485 (2TR), three (3TR), four (4TR) and more than four TR (>4TR) categories. *=p<0.05.