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Notational singles match analysis of male badminton players who participated in the African Badminton Championships

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ABSTRACT

Purposes of this study were firstly, to determine the notational singles match analysis results of male badminton players and secondly, to determine relationships between notational singles match analysis determined strokes and foot movements in male badminton players, who participated in the African Badminton Championships. Twenty male singles matches from the team and individual events of the 2014 All Africa Badminton Championships were recorded live via video cameras and analysed using the Dartfish video analysis software package. Average match duration (1470.4 s), real time (432.9 s) and percentage of real time played (29.8%), number of rallies per match (68.4) and shots per rally (6.5) were calculated. Average shots per rally were found to be 6.5 and the work density, .4. Average stroke frequency per match was: drive – 122.1, clear – 118, smash – 56.2, net strokes – 54.3, drop-shot – 24.2 and the round-the-head stroke – 1.2. Foot movements delivered the following average results per match: chasse-step – 174.6, shuffle – 161.7, split-step – 61.6, half-lunge – 52.20, forward-lunge – 46.1 and scissors kick – 38.3. Significant Spearman Rank Correlation Coefficients existed between various foot movements and strokes. The study confirmed the applicability of computerised notational analyses in determining singles badminton match characteristics.

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Badminton; foot movements; notational analysis; strokes

1. Introduction

Badminton is one of the major racket sports (Lees, 2003), characterised by high-speed movements and shot executions which demands high tactical, technical and psychological abilities as well as a high level of physical conditioning (Omosegaard, 1996). However, researchers and sport practitioners are only able to determine the exact demands of badminton matches, if they precisely analyse the different match movements and movement patterns (Hughes, 2008). In this regard, computerised notational analysis is one of the analysis methods that can be applied to determine the match characteristics of badminton (Hughes, Hughes, & Behan, 2007). In computerised notational analysis researchers record different badminton matches via a digital video camera (Hughes et al., 2007; Ming, Keong,

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& Ghosh, 2008). Thereafter, they use a video analysis software package such as Dartfish to analyse the video footage in detail, and to display the match analysis results in digital format (Hughes & Franks, 2004; O'Donoghue, 2014; Wilson, 2008). Despite the benefits of this analysis method, only a hand-full of researchers have thus far used this method to analyse badminton matches (Abian-Vicen, Castanedo, Abian, & Sampedro, 2013; Ming et al., 2008). Furthermore, no researchers have analysed the match characteristics of African badminton players. The need for more up-to-date research in this area has also been accentuated by the change in the badminton scoring system during 2006 from the traditional 3 sets, 15-points system to the new 3 sets, 21-points system (Ming et al., 2008).

Several studies have made use of notational analysis to investigate the characteristics of badminton match play. For example, temporal structure analyses of 14 matches played during a 1999 Spanish International Tournament revealed the following characteristics: the average game duration was 1689.3 ± 313 s, with 6.06 ± 1.08 shots performed per rally time; the real time played was 548.7 ± 98.6 s, while the performance time was 6.4 ± 1.3 s; the work density was found to be .5 ± .1; the total rallies played was 83.3 ± 11.0, with total shots averaging 510.7 ± 109.8 (Cabello-Manrique & Gonzalez-Badillo, 2003). In another study, Abian-Vicen et al. (2013) assessed the temporal and notational structures of matches played during the 2008 Beijing Olympic Games and found the following average results for the first and second games of the men singles matches, respectively: the duration of games was 1128 ± 256.5 and 1121.0 ± 214.0 s; the real time played was 310.5 ± 40.7 and 303.3 ± 52.3 s. Players only spend 28.1 ± 3.4 and 27.3 ± 2.4% of the total time on match play activities; rally time was found to be 9.0 ± .9 and 9.1 ± 1.4 s; shots per rally were 9.7 ± .8 and 9.9 ± 1.4; rest time was 24.1 ± 3.8 and 25.2 ± 4.6 s; work density was .38 ± .06 and .36 ± .04; and shot frequencies per rally were 1.08 ± .04 and 1.09 ± .03. Cabello, Padial, Lees, and Rivas (2004) analysed a large sample (n = 79) of national, international and world class Spanish, male badminton players and revealed an average total playing time of 2090 ± 921 s, an average total work time (total time when the shuttle was in play) of 707 ± 261 s, an average work time of 7.3 ± 1.3 s, an average rest time of 14.2 ± 3.4 s, an average work rest ratio of .53 ± .12 as well as an average number of rallies' value of 98 ± 32.

In a different study, Ming et al. (2008) used notational and time motion analyses to investigate differences in simulated badminton match characteristics, when state-level male Malaysian badminton players made use of the new (21 points) and old scoring systems (15 points), respectively. They reported 17.3 ± 2.7 vs. 24.1 ± 2.4 min for match durations; 8.6 ± 1.3 vs. 12.0 ± 1.2 min for average game duration; 4.6 ± .9 s vs. 4.6 ± .5 s for rally time; 9.7 ± 1.3 s vs. 10.3 ± 1.4 s for rest time; .5 ± .1 vs. .46 ± .07 for work density; 331.3 ± 44.7 vs. 463.5 ± 21.4 for number of shots per match; 70.3 ± 1.3 vs. 97 ± 6.7 for the number of rallies per match and 4.7 ± .8 vs. 4.8 ± .5 for the average shots per rally when last-mentioned scoring systems, respectively were used. Although last-mentioned notational analysis results do provide sport practitioners in the badminton fraternity with information regarding the singles match characteristics of male players, it is unclear whether African badminton players will display the same match characteristic profile as their international counterparts. Over the last two decades, studies have only focused on badminton players from Spain (Cabello et al., 2004), Malaysia (Ming et al., 2008), and the top international players, who participated in the 1996 Hong Kong Badminton Open (Tong & Hong, 2000) and 2008 Beijing Olympic Games (Abian-Vicen et al., 2013).

Another aspect that researchers do not give attention to is the possible relationships between specific notational singles match analysis results. Relationships between match analysis components such as strokes and foot movements may provide researchers and practitioners with important information regarding the influence of different strokes on players' foot movements or *vice versa*. Researchers and practitioners will then be able to focus their attention directly on the most important and influencing components that need to be addressed during physical and skills training.

Since notational analysis enables players, coaches, sport scientists and other sport related professionals to assess the physiological and psychological demands of badminton in such a way that measurable and subjective outcomes that are specific and unprejudiced can be obtained (Hughes & Bartlet, 2008), it is important to apply this method to analyse African badminton player matches. This analysis method can also be used to furnish coaches with data and clues about performance weaknesses in distinct areas (Carling, Reilly, & Williams, 2009; James, 2008; Liebermann & Franks, 2007). At the end, a better understanding of players' weaknesses as well as the physiological and psychological demands of badminton may enable sport scientists to compile conditioning programmes specifically according to the demands of match play. Conditioning programmes that are tailored in this way will improve match play performances and overall success.

It is against this background that the purposes of this study were firstly, to determine the notational singles match analysis results of male badminton players, who participated in the African Badminton Championships and secondly, to determine relationships between notational singles match analysis determined strokes and foot movements in male badminton players, who participated in the African Badminton Championships.

2. Methods

2.1. Design

The design of the study was a selected group, observational, descriptive and *ex post facto* design. Ethical approval for the study was obtained from the Ethics Committee of the institution, where the research was conducted (NWU-00199-14-A1). In addition, permission to conduct the research was also obtained from the managers of participating African teams, coaches of the participating players, the Badminton World Federation (BWF), the Badminton Confederation of Africa (BCA), Badminton South Africa (BSA) and the Botswana Badminton Association (BBA).

2.2. Participants

Twelve male, single players (age: 24.4 ± 4.6 years), who participated in the team and individual events of the All Africa Senior Badminton Championships of 2014, which was held in Lobatse, Botswana, willingly volunteered to participate in this study. The players represented the following African countries during participation: Botswana, Cameroon, Egypt, Mauritius, Nigeria, Seychelles, South Africa, Zambia and Zimbabwe. Only in cases where the manager and coach of a certain player as well as the player himself provided voluntary written consent to participate in the study, that player was allowed to participate. Furthermore, only badminton players who were actively involved and competing as members of their

respective national badminton federations in the above-mentioned tournament as well as those who were totally injury-free at the time of testing were eligible to participate in the study. All participants were considered to be the best players of their respective African countries during the time of the tournament.

The competitive badminton playing experience of these players varied between 4 and 12 years, with an average of 9.3 ± 2.7 years. They trained for 4.3 ± 1.2 days a week on average, with training that consisted of court and resistance training sessions.

2.3. Procedures

Three months before the start of the tournament permission to conduct the research was requested via email from the BWF, the BCA, BSA and the BBA. A day before the tournament started, the managers' meeting was attended by the researchers and detailed information with regard to the study design, purpose, procedures and possible risks of participation was provided to the managers of each of the participating teams. This opportunity was also used to inform the head referee of the relevant tournament of the study and to obtain permission from him to conduct the research during the tournament. On the first day of the tournament, informed consent was obtained from the participating players and permission was also obtained from each of the coaches, who were involved with players. During this time, players also completed a general information questionnaire regarding their exercising habits, injury incidence and competing level.

Before the start of each match, a Sony Handycam with full HD (Sony HDR-PJ790VE Handycam, Sony Corporation, Tokyo, Japan) was stationed on a tripod stand behind each of the courts on a gallery that was on the first floor of the hall, in which all the matches were played. The warm-up period was then used to adjust the cameras, and to check if the video footage was recorded accurately. Video recordings of each match were downloaded onto a laptop computer and analysed by means of the Dartfish Team Pro video analysis software package (version 5.5, Rte de la Fonderie 6, CP 53 – 1705, Fribourg 5, Switzerland). The same qualified sport scientist, who has been participating in badminton at an international level, performed all analyses. A month before the analyses were performed, the sport scientist, received training from an analyst, who has been doing match analysis for a variety of sports and who is currently training university students to use Dartfish. Twenty-five per cent of the matches were randomly selected and re-analysed a month later by the same sport-scientist in order to prevent interpersonal variability in the different observations and interpretations of activities and to verify the accuracy of the original analyses.

2.4. Measures

2.4.1. Computerised notational analysis

Video footage was recorded for twenty men's singles matches from the team and individual events of the All Africa Senior Badminton Championships. All matches were recorded live. The video recordings of each match were downloaded onto a laptop computer and analysed by means of the Dartfish Team Pro analysis software package (version 5.5, Rte de la Fonderie 6, CP 53 – 1705, Fribourg 5, Switzerland). Dartfish was used to do the analyses due to the wide range of features that can be used. These features include the capacity to track and break down movements and badminton strokes for analyses as well as the capacity

to record the duration of different movements and phases of the match. The video footage was therefore coded and the frequency and duration of all movements, strokes and match periods were analysed.

The following match-related variables were analysed:

2.4.1.1. Badminton strokes. Clear: a shot that took the shuttle over the head of the opponent with a flat or rising trajectory towards the baseline of the rival court (Abian-Vicen et al., 2013; Brahms, 2014).

Drive: a hard shot that was executed while the racket head was at the mid part of the body and took the shuttle to the middle of the court with a flat trajectory (Abian-Vicen et al., 2013; Brahms, 2014).

Drop: a smooth shot executed in such a way that the shuttle followed a downward trajectory towards the front of the court (Abian-Vicen et al., 2013; Brahms, 2014).

Net: a precise shot from near the net, which also included the push, kill and brush (Abian-Vicen et al., 2013; Brahms, 2014).

Smash: an aggressive overhead shot that moved the shuttle in a downward trajectory (Abian-Vicen et al., 2013; Brahms, 2014).

Round-the-head: a forehand overhead stroke on the overhead backhand side, that was used instead of attempting a backhand overhead shot (Brahms, 2014; Grice, 1996).

Serve: the act of starting the game or putting the shuttle into play. The server hit the shuttle beneath waist height in such a way that it landed in the receiver's service court (Blomqvist, Luhtanen, & Laakso, 2000; Brahms, 2014).

2.4.1.2. Foot movements. Chasse-step: This movement usually occurred, when a player stepped on one foot to the side, followed closely by the other foot. One foot led the movement, while the other foot came in behind the leading foot as the position changed (Grice, 1996).

Scissors-kick: This was often used as the last movement when hitting overhead forehands, in which the legs swapped positions while in the air (Brahms, 2014).

Shuffle-step: This type of step was often used, when moving forward or backward towards the backhand side. For example, when a player wanted to reach a shuttle at the net on the forehand side, the non-dominant leg would move forward and across to the forehand side with the body facing the corner of the court (Grice, 1996).

Split-step: This was a very low jump, in which the feet came off the ground and spread a little apart, while the player was bending forward before he pushed off towards the target (Leitch, 2013).

Lunging is an essential foot movement of competitive badminton players (Cronin, McNair, & Marshall, 2003; Kuntze, Mansfield, & Sellers, 2010). A lunge is defined as a position where one leg is positioned forward, while the knee is bent and the foot placed flat on the ground whereas the other leg is positioned at the back. Due to multifarious lunging movements in badminton, lunges were classified into the following categories: lunge-to-left (to reach a shuttle on the left-hand side); lunge-to-right (to reach a shuttle on the right-hand side); lunge-forward (to reach a shuttle to the front of the body); lunge-backward (to reach a shuttle behind the player) and half-lunges (this was when a player made an incomplete lunge to get to the shuttle).

2.4.1.3. Time related variables. Match duration: the time that elapsed from the first service until the shuttle touched the ground during the last point, which also included: rest periods between points and games (Abian-Vicen et al., 2013).

Percentage real time played: real time played multiplied by 100 divided by the match duration (Abian-Vicen et al., 2013).

Rally durations: the periods realised for the length of each rally. A rally was defined as the time that started when the service took place until the shuttle touched the ground (Abian-Vicen et al., 2013).

Real time played: the time that the shuttle was in play from the first to the last point of the match (Abian-Vicen et al., 2013).

Rest time: the time that elapsed from when the shuttle touched the ground until the next service was performed; that is periods during which the shuttle was not in play (Abian-Vicen et al., 2013).

Shots per rally time: number of shots divided by real time played (Abian-Vicen et al., 2013).

Work density: total rally time divided by total rest time observed during the game (Abian-Vicen et al., 2013; Cabello et al., 2004; Ming et al., 2008).

Each match was analysed according to the different rallies and sets that were played as well as the time periods of the match. The clock function of the Dartfish Team Pro video analysis software package was used to determine all the time-related variables.

2.5. Statistical analysis

After the match analyses were completed, the raw data for each of the variables were entered into Microsoft Excel (Microsoft Office Professional Plus, 2013). Firstly, all variables were corrected for match duration by dividing the specific variable by match duration in seconds. The Statistical Data Processing package (StatSoft Inc., 2015) was used for the rest of the analyses. Descriptive statistics (averages, standard deviations, minimum and maximum values) for each of the relevant variables were calculated. Cronbach's Alpha and Intraclass Correlation analyses were used to determine the reliability of match analysis results between data of the original analysis and 25% of the randomly selected matches. The 95% confidence intervals (CI) for the Intraclass Correlation analyses were also determined. Spearman Rank Correlation Coefficient, rho was used to determine relationships between values of different shots and foot movements. Lastly, a Fisher r to z transformation was calculated to determine the 90% confidence intervals (CI) from the correlation coefficients (r). The level of significance was set at $p \leq .05$. The strength of correlations was categorised based on the following criteria: <.1 (trivial), <.3 (small), <.5 (moderate), <.7 (large), <.9 (very large) and <1 (nearly perfect) (Hopkins, Marshall, Batterham, & Hanin, 2009).

3. Results

3.1. Reliability of notational analysis

A total of 5 randomly selected matches (25% of the total matches that were previously analysed) were re-analysed for both shots played (strokes), foot movements and time-related variables (match duration, rally duration, work density and rest time). The average Cronbach's Alpha values were .97 for strokes played, .99 for foot movements and .99 for

Table 1. Descriptive statistics of all foot movement-related variables that were performed during single matches of male, African badminton players.

Variables	Mean	Minimum	Maximum	SD
Values not corrected for match duration				
Chasse steps per match	174.6	55.0	297.0	73.6
Scissors kicks per match	38.3	12.0	70.0	15.7
Shuffle steps per match	161.7	36.0	306.0	66.1
Split steps per match	61.6	28.0	104.0	23.9
Half lunges per match	52.2	22.0	82.0	18.4
Lunges forward per match	46.1	10.0	76.0	18.3
Lunges backward per match	12.2	.0	53.0	12.8
Lunges to left per match	21.8	7.0	48.0	13.8
Lunges to right per match	15.5	5.0	30.0	8.5
Values corrected for match duration (s)				
Chasse steps/s during match	.12	.06	.18	.04
Scissors kicks/s during match	.03	.01	.04	.01
Shuffle steps/s during match	.11	.03	.15	.04
Split steps/s during match	.04	.02	.07	.02
Half lunges/s during match	.04	.02	.05	.01
Lunges forward/s during match	.03	.01	.06	.01
Lunges backward/s during match	.01	.00	.03	.01
Lunges to left/s during match	.01	.01	.03	.01
Lunges to right/s during match	.01	.00	.02	.00

Note: SD = Standard deviation.

time-related variables. On the other hand Intraclass Correlation analyses revealed values of .95 (95% CI: .69–.99) for strokes played, .97 (95% CI: .44–.95) for foot movements and .99 (95% CI: .89–1.00) for time-related variables.

3.2. Foot movement-related variables

Table 1 contains the descriptive statistics of all foot movement-related variables that were identified through the match analyses of the male, singles African badminton players.

From Table 1, it is clear that the chasse-step (174.6 ± 73.6; .12 ± .04) and shuffle foot movements (161.7 ± 66.1; .11 ± .04) were performed much more during match play than any other foot movements. The split-step (61.6 ± 23.9; .04 ± .02), half-lunge (52.20 ± 18.44; .04 ± .01), forward-lunge (46.1 ± 18.3; .03 ± .01) and scissors kick (38.3 ± 15.7; .03 ± .01) were the next most executed foot movements.

3.3. Stroke-related variables

Results with regard to the different badminton stroke-related variables that were executed during 20 single matches are presented in Table 2.

The drive (122.1 ± 27.4: .08 ± .02) and clear (118.0 ± 32.4: .08 ± .02), followed by the serve (68.5 ± 12.8: .05 ± .01), smash (56.2 ± 23.1: .04 ± .01) and net strokes (54.3 ± 19.7; .04 ± .01) were identified as the most frequently performed strokes during badminton singles, match play. The drop shot was only performed 24.2 ± 13.6 (.02 ± .01) times on average during a match, whereas the round-the-head strokes were rarely (1.2 ± 1.3; .00 ± .00) executed during match play. Similarly, results revealed that a total of 444.3 ± 101.1 shots were executed during each match, which led to shots per rally and shots frequency values of 6.5 ± 1.3 and 1.03 ± .06, respectively.

Table 2. Descriptive statistics of all stroke-related variables that were performed during single matches of male, African badminton players.

Variables	Mean	Minimum	Maximum	SD
Values not corrected for match duration				
Number of shots per match	444.3	264.0	633.0	101.1
Shots per rally	6.5	4.8	8.9	1.3
Clears per match	118.0	63.0	199.0	32.4
Drives per match	122.1	66.0	183.0	27.4
Drops per match	24.2	2.0	47.0	13.6
Net shots per match	54.3	17.0	92.0	19.7
Round-the-head shots per match	1.2	.0	4.0	1.3
Serves per match	68.5	55.0	111.0	12.8
Smashes per match	56.2	25.0	113.0	23.1
Values corrected for match duration (s)				
Shots/s during match	1.03	.89	1.13	.06
Clears/s during match	.08	.05	.13	.02
Drives/s during match	.08	.05	.12	.02
Drops/s during match	.02	.00	.03	.01
Net shots/s during match	.04	.02	.06	.01
Round-the-head shots/s during match	.00	.00	.00	.00
Serves/s during match	.05	.04	.06	.01
Smashes/s during match	.04	.02	.06	.01

Note: SD = Standard deviation.

Table 3. Descriptive statistics of all time-related variables that were identified through the badminton match analyses of male, African badminton players.

Variables	Mean	Minimum	Maximum	SD
Rally frequency	68.4	55.0	111.0	12.8
Rally duration (s)	5.6	1.6	20.9	5.8
Real time played (s)	432.9	261.1	602.3	91.6
Match duration (s)	1470.4	966.0	2263.0	341.9
Percentage of real time played	29.8	23.1	42.3	4.5
Rest time in-between rallies (s)	17.3	10.5	28.2	4.6
Work density	.4	.3	.7	.1

3.4. Time-related variables

Time-related variables' results that were obtained from the single matches are presented in Table 3.

According to the tabulated results, the average match duration for African male badminton players was 1470.4 ± 341.9 s, and the real time and percentage of real time played were 432.9 ± 91.6 s and 29.8 ± 4.5%, respectively. The average for rallies was 5.6 ± 5.8 s, players performed an average of 6.5 ± 1.3 shots per rally during each match and work density was determined to be .4 ± .1 on average during matches. Lastly, on average players rested for 17.3 ± 4.6 s in-between rallies during each match.

3.5. Relationships between shots and foot movements

Results with regard to the Spearman Rank Correlation Coefficients and 90% confidence intervals between the different badminton shot- and foot movement-related variables that were corrected for match duration are presented in Table 4.

Table 4. Results of the Spearman Rank Correlation Coefficients and 90% confidence intervals (in brackets) between the different badminton shot- and foot movement-related variables (corrected for match duration) that were identified during match play.

	Clear	Drive	Drop	Net	Round-the-head	Serve	Smash
Chasse steps	.44*M	.44	.05	.39	−.16	−.30	.71*VL
	(.08–.70)	(.07–.70)	(−.33 to .42)	(.01–.67)	(−.51 to .23)	(−.61 to .09)	(.45–.86)
Scissors kicks	.01	−.20	−.18	−.42	.02	−.24	.50*L
	(−.37 to .40)	(−.54 to .20)	(−.52 to .21)	(−.69 to −.05)	(−.36 to .39)	(−.57 to .15)	(.15–.74)
Shuffle steps	.54*L	.23	−.36	−.01	−.17	.12	.12
	(.20–.76)	(−.16 to .56)	(−.65 to .02)	(−.39 to .37)	(−.51 to .23)	(−.27 to .48)	(−.27 to .48)
Split steps	.63*L	.47*M	−.51*T	−.32	−.42	.06	.20
	(.33–.82)	(.11–.72)	(−.74 to −.16)	(−.62 to .07)	(−.69 to −.04)	(−.32 to .43)	(−.20 to .54)
Half lunges	.10	−.01	.09	.15	.10	−.11	.18
	(−.29 to .46)	(−.38 to .37)	(−.30 to .45)	(−.24 to .50)	(−.29 to .46)	(−.47 to .28)	(−.21 to .52)
Forward lunges	.17	.36	.18	.55*L	−.05	−.11	.42
	(−.22 to .52)	(−.02 to .65)	(−.22 to .52)	(.22–.77)	(−.42 to .34)	(−.47 to .28)	(.04–.69)
Backward lunges	.15	.24	.20	.71*VL	.25	−.27	.53*L
	(−.2 to .50)	(−.15 to .57)	(−.19 to .54)	(.45–.86)	(−.15 to .57)	(−.59 to .12)	(.19–.76)
Lunges to left	.04	.20	.30	.50*L	−.04	−.10	.42
	(−.35 to .41)	(−.20 to .54)	(−.09 to .61)	(.15–.74)	(−.41 to .35)	(−.46 to .29)	(.04–.69)
Lunges to right	.17	.25	.30	.58*L	.07	−.17	.48*M
	(−.22 to .52)	(−.14 to .58)	(−.09 to .61)	(.25–.78)	(−.31 to .44)	(−.52 to .22)	(.12–.73)

*$p \leq .05$; <.1 (trivial), <.3 (small), <.5 (moderate), <.7 (large), <.9 (very large) and <1 (nearly perfect); where T = trivial, S = small, M = moderate, L = large, VL = very large and NP = nearly perfect.

Spearman Rank Correlation Coefficients (Table 4) indicate moderate significant relationships between players' chasse steps and clearing shots ($r = .44$, $p = .05$), split steps and drive ($r = .47$, $p < .05$) and lunges-to-the-right direction and smash shots ($r = .48$, $p < .05$). Very large significant relationships are observed between the chasse-step foot movements and smash shots ($r = .71$, $p < .05$) and between backward lunges and net shots ($r = .71$, $p < .05$). Large significant relationships exist between scissors kick foot movements and smash shots ($r = .50$, $p < .05$), shuffle-steps and clear shots ($r = .54$, $p < .05$) and split-steps and clear shots ($r = .63$, $p < .05$). Similarly, large significant relationships are observed between forward lunges and net shots ($r = .55$, $p < .05$), lunges-to-the-left direction and net shots ($r = .50$, $p < .05$), backward lunges and smash shots ($r = .53$, $p < .05$) and between lunges-to-the-right direction and net shots ($r = .58$, $p < .05$). Lastly, a trivial significant relationship is detected between split steps and drop shots ($r = -.51$, $p < .05$).

4. Discussion

Overall, the study showed that computerised notational analysis is a reliable method to determine the singles match characteristics of male badminton players, who participated in the African Badminton Championships. Results with regard to the singles match characteristics that are related to time revealed that the average match duration was 1470.4 s, of which 17.3 s was spent resting in-between rallies. The average real time and percentage of real time played were calculated to be 432.9 s and 29.8%, respectively. The average work density was .4. Overall players performed 68.4 rallies per match and 6.5 shots per rally time, with an average rally duration of 5.6 s per match. Analyses with regard to different strokes played during matches revealed that the drive (122.1 times) and clear (118.0 times), followed by the serve (68.5 times), smash (56.2 times) and net strokes (54.3 times) were most often performed. However, the drop shot was only performed 24.2 times on average during matches, whereas the round-the-head strokes were rarely (1.2 ± 1.3) performed. On average 444.3 shots were played per match with a shot frequency of 1.03 shots per second. A further analysis showed that chasse-steps (174.6 times), followed by shuffles (161.7 times) were the foot movements that were performed the most, compared to split-steps (61.6 times), half-lunges (52.2 times), forward-lunges (46.1 times) and scissors-kicks (38.3 times) that were performed fewer times. Lunges to the right (15.5) and lunges backward (12.2) were rarely performed.

Compared to other studies, the average match duration for this study was lower (1470.4 s) than the reported values of previous studies that varied between 2378 s (Abian-Vicen et al., 2013), 2090 s (Cabello et al., 2004) and 1689.3 s (Manrique & Gonzalez-Badillo, 2003). However, a study by Ming et al. (2008) reported a lower value of 1047 s for the matches that they analysed. Differences in match duration results between studies may be attributed to differences in players' level of play and the methodology used to analyse match duration. For example, most elite badminton players have developed great anticipation skills together with fast reaction and movement times which enable them to accurately predict and respond to almost any shot that an opponent performs (De França Bahia Loureiro & De Freitas, 2012). In addition, players learn to adapt to opponents style of playing when playing against them more regularly (Blomqvist, 2001). All of these factors will lead to longer rallies, which would lead to higher match durations. With regard to differences in study methodology,

Ming et al. (2008) for example made use of simulated matches, instead of actual matches, which may have negatively influenced the average match duration value that was reported.

A more or less similar average percentage for real time played was reported by Abian-Vicen et al. (2013) for players, who participated in the 2008 Beijing Olympic Games (29.8% vs. 26.0%). However, the absolute real time played average for this study was considerably lower (432.9 s) than values reported by other researchers: 613.7 s (Abian-Vicen et al., 2013), 548.8 s (Manrique & Gonzalez-Badillo, 2003) and 707 s (Cabello et al., 2004). Therefore, players in this study spent much less time being active during matches, compared to players of other studies. One of the main factors that determine the percentage of real time played is the average rest time per match. Players in this study rested on average for 17.3 s in-between rallies, compared to Olympic players, who rested on average for 24.1 and 25.2 s in-between rallies during the first and second games of men's single matches (Abian-Vicen et al., 2013). In contrast, Cabello-Manrique, Padial, Lees, and Rivas (2004) analysed a large sample ($n = 79$) of top national male badminton players and revealed an average rest time for periods in-between rallies of 14.2 s. An average value of 12.9 s was reported for international players (Cabello-Manrique and Gonzalez-Badillo (2003), 9.7 s for young national players (Ming et al., 2008) and 11.4 s for international players (Faude et al., 2007). These studies concluded that more experienced players such as Olympians rested more in-between rallies than top-national and young national players. These findings suggest that more experienced players have to ability to slow down match momentum and to optimally use the rest periods that are available in order to recover more effectively between rallies.

Players on average performed 68.4 rallies per match at a frequency of 6.5 shots per rally that led to an average work density of .4 with 5.6 s as an average for rally duration. However, other researchers observed higher average work density values for badminton players: .5 (Cabello et al., 2004; Faude et al., 2007; Manrique & Gonzalez-Badillo, 2003). In contrast, Abian-Vicen et al. (2013) presented a lower average work density value for players in their study (.4). These results suggest that players who compete at a higher level obtain higher work density values during match play than those who compete at a lower level. Work density increases relative to work time increases and also as the level of competitions increases (Cabello et al., 2004). Cabello et al. (2004) also noted that rest periods increased as match durations become longer. Therefore, the lower average work density value for players in this study may partly be explained by the lower average rallies per match (68.4) that were performed, compared to players of other studies (83.3) (Cabello et al., 2004). Moreover, players only spent 5.6 s on average per rally, which would negatively influence the work density. Although Faude et al. (2007) reported a similar value of 5.5 s for average rally time, they made use of simulated, instead of actual competition matches. Another factor that may also influence work density is the average number of shots played per rally as it also affects average rally time. Comparatively, players in this study played a much lower average number of shots per rally (6.5) than more elite players, who participated in the 2008 Olympic Games (1st set = 9.7 and 2nd set = 9.9) (Abian-Vicen et al., 2013). On the other hand, various researchers reported lower average values for number of shots played per rally than what we observed: 6.1 for younger international badminton players (aged 21.8 ± 3.3) from France, Italy, Portugal and Spain (Manrique & Gonzalez-Badillo, 2003); 4.7 and 4.8 for young men (age: 14–17 years) when analysing simulated badminton singles matches played according to the 21 and 15 point system, respectively (Ming et al., 2008).

Consequently, factors that determine work density differences between studies include the use of different scoring systems (old 15-point vs. the new 21-point system) during match play, the level of play, differences in playing level between opponents and inter-relationships between different time-related variables. In this regard, research showed that the new 21-point system led to a higher average work density value than the old 15-point system (.48 vs. .46) (Ming et al., 2008). In addition, above-mentioned results suggest that higher levels of play deliver higher average work density values than lower levels of play. Manrique and Gonzalez-Badillo (2003) also indicated that longer rally times and a greater quantity of rallies, which will give raise to higher average work density values, are observed when players of similar playing levels compete against each other, compared to when opponents' playing levels differ. Significant inter-relationships ($r = .42$, $p < .01$) between average rest time and number of rallies played as well as between average work and rest time during badminton matches ($r = .67$; $p < .01$) (Cabello et al., 2004), would also lead to changes in work density between matches and different studies. Different time-related variables may also influence results of different match analysis' characteristics. For instance, Cabello et al. (2004) showed that an increase in the number of rallies played, forced players to rest longer during matches. In our study, an increase in work time also led to an increase in rest time which would suggest that the last-mentioned assumption is correct.

Results with regard to strokes, which were executed during each of the matches, revealed that players performed the drive (122.1 times) and clear strokes (188.0 times) the most. Other strokes were performed at much lower frequencies, with values ranging between 68.5 times (serve) and 1.2 times (round-the-head) per match. Therefore, the round-the-head stroke was the least performed stroke with many players who did not perform it even once during matches. The drive can either be used as an offensive stroke in situations where a player, for example, wants to pass his opponent, or as a defensive shot in situations, where a player, for example, wants to return a smash. In some situations, the drive can also be used to surprise the opponent by driving the shuttle down the side line. On the other hand, clear shots are used to drive the shuttle to the opponent's baseline by making use of either a rising or flat trajectory. What is interesting to note, is that an attacking shot such as the smash was only performed 56.2 times on average during matches. This may be due to the fact that the smash is categorised as an energy tapping shot which may lead to higher fatigue levels if performed continuously over a long time.

Foot movement data showed that the chasse-step (174.6) and the shuffle-step (161.7) were the most frequently used foot movements during match play. This was followed by the split-step (61.6), the half (52.2) and the forward-lunge (46.1). The chasse- and shuffle-steps are simple foot movements which allow players to move to the shuttle in an effective and time-efficient way. These foot movements also enable players to recover fast and keep their stable positions so that they can move to the mid-court in the shortest possible time in order to receive the next shot. Kuntze et al. (2010) made use of a video-based experimental study to show that the lunge is the most frequently used foot movement in badminton. They showed that almost 15% of all foot movements during competitive singles matches were lunges (Kuntze et al., 2010). In our study, lunging-related foot movements contributed 25.3% to the total amount of foot movements during matches with half-lunges performed the most (8.9%), and backward-lunges performed the least amount of times (2.1%). A full lunge to either side of the court may be energy tapping if performed frequently and extensively, therefore, players utilise half-lunges more as it is a more energy efficient movement

and enable players to respond to the next anticipated shot faster. Backward-lunges are performed the least number of times during a match as most shuttles that travel to the backward part of the court would be intercepted before players would have to move backwards. The backward-lunge leads to a weight transfer to the back leg which would place a player in a dangerous position and vulnerable to especially drop shots because of the fact that it would take him longer to transfer his weight back to the front foot and accelerate to the front to intercept a front court shot.

In this study researchers also determined relationships between different badminton shot- and foot movement-related variables. No other studies have established relationships between last-mentioned variables, which make it difficult to directly compare results of this study to similar studies. Results revealed that split steps were significantly correlated to three badminton shots, namely the clear, drive and drop shots whereas chasse steps (clear and smash), backward lunges (net and smash) and lunges to the right (net and smash) were all significantly correlated to two shots. All other foot movement-related variables, except for half lunges, were significantly correlated with one badminton shot. The round-the-head and serve shots did not deliver any significant correlations with foot movement-related variables.

Results indicate that split steps have the biggest influence on especially attacking badminton strokes such as clears, drives and drops. Split steps are characterised by a very low jumping movement, in which the feet come off the ground and spread a little apart which allow players to move swiftly on the court. It is obvious that in badminton, taller players have some advantages. They can produce a more effective smash from the baseline due to the height of the contact point. They can also deliver perfect low serves easily in comparison with shorter players. Players rarely smash a shuttle during a split step, as it is easier to perform a drop, clear, or drive stroke from this position. Three other foot movements namely chasse steps, backward lunges and lunges to the right were also significantly related to the smash shot. The chasse step occurs when a player steps on one foot to the side, followed closely by the other foot. One foot leads the movement, while the other foot comes in behind the leading foot. It is obvious that smashing is an explosive and aggressive attacking stroke, in which the performer needs to accelerate before execution. Chasse step, lunges backward and lunges to the right (racket arm) are all movements that allow players to accelerate so that they can propel their bodies in order to smash the shuttle more effectively. On the other hand, both backward lunges and lunges to the right were also significantly related to the net shot. In a lot of cases lunging movements will be used to deceive players in thinking that a smash shot is going to be played, but instead players play a net shot such as a drop.

5. Conclusion

In conclusion, computerised notational analysis revealed that male badminton players, who participated in the African Badminton Championships were active for 29.8% of the total match time which relates to 1470.4 s and spent 17.3 s on average during a match on rest in-between rallies; they performed 68.4 rallies per match at an average duration of 5.6 s, during which a stroke was performed every 1.03 s; the real time played was 432.9 s, which relates to a work density of .43; they executed the drive (122.1) and clear strokes (118.0) the most times during a match and performed the shuffle (161.7) and chasse-step (174.6) the most frequently during match play. The study also revealed moderate significant relationships between players' chasse steps and clearing shots, split steps and drive, and also lunges

to the right direction and smash shots. Very large relationships were observed between the chasse step foot movements and smash shots, and between backward lunges and net shots. A large significant relationship also existed between scissors kick foot movements and smash shots, shuffle-steps and clear shots, and between split-steps and clear shots. Similarly, large significant relationships were observed between forward lunges and net shots, lunges to the left direction and net shots, backward lunges and smash shots and between lunges to the right direction and net shots. Lastly, a trivial significant relationship was detected between split steps and drop shots.

This is the first study to provide sport practitioners (sport scientist and coaches) with information concerning the badminton singles match characteristics of African players. However, the study does not provide information with regard to the internal demands of match play. Future studies will, therefore, need to also consider parameters such as heart rate together with notational analysis results to more precisely describe the demands of badminton singles match play. Furthermore, this study only focussed on badminton players, who participated in the All Africa Senior Badminton Championship of 2014. Therefore, future studies should include bigger samples of African badminton players to verify the notational analysis results. In the meantime, African badminton players should be provided with opportunities to develop and exploit their performance potential, especially in view of findings that values of several singles match analysis characteristics differed from those of international players.

6. Practical applications

Overall, results suggest that a typical conditioning programme for badminton players should develop drills and activities that take place for durations of 5.57 s at a time at a work to rest ratio of 1:3 – a rally duration time of 5.57 s divided by the average rest in-between rallies of 17.3 s. Drills and activities should continue for a total duration of 3–5 min after which a break of 2 min must be allowed before continuing with another set of 3–5 min. This will simulate the real time played, which ranges between 7 and 10 min with a 2-min break which is the rest period that players receive between sets during match play. The intensity of activities must be quite high and incorporate especially chasse-steps, shuffle-steps, split-steps, half- and forward lunges. Conditioning drills should also include the drive, clear, serve, smash and net strokes as these strokes are the most often performed during match play.

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