Title: Performance structure analysis of the men´s and women´s badminton doubles matches in the Olympic Games from 2008 to 2016.

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FINAL REPORT

INTRODUCTION:

Badminton is one of the most practised sports in the world (Laffaye et al., 2015). In official competition there are 5 events (men's singles, women's singles, men's doubles, women's doubles and mixed doubles) with different temporal and notational characteristics among them (Gawin et al., 2015; Liddle et al., 1996). Only a few researchers have compared singles and doubles disciplines with conflicting results (Alcock & Cable, 2009; Gawin et al., 2015; Liddle et al., 1996). One aspect to be considered that could help to justify some of these discrepancies is the change in the badminton scoring system that occurred in 2006. Currently, in the 5 events, a match consists of the best of three games of 21 points with a difference of two points up to a maximum of 30 points, with the rally point scoring condition. Alcock and Cable (2009) found no differences in rally or match length or in total number of shots comparing men's singles and men's doubles matches with the old scoring system (the best of three games of 15 points with a player/team only scoring when in charge of the service) in twelve competitive matches (6 singles and 6 doubles). On the other hand, these authors found that men's doubles events recorded higher values than men's singles in the variables related to the intensity of the rally (shots per rally and shots per second). Gawin et al. (2015) comparing the five events with the rally point scoring system did not find differences between events in total match duration or rest time between rallies but found that the rallies were shorter in the doubles events than in the singles events with the exception of the women's doubles.

Several studies have analysed the timing factors and the notational badminton structure comparing the old scoring system with the new rally point scoring system (Chen & Chen, 2008; Chen, Wu, & Chen, 2011; Ming, Chen Chee Keong, & Ghosh, 2008) but we have only found two studies that analysed the evolution of badminton during the last few years with the new rally point scoring system (Abián et al., 2014; Laffaye et al., 2015). It is noteworthy that all studies that have analysed the evolution of badminton through the temporal structure and with a notational approach have been conducted on the men's singles event, and the evolution of the other badminton events (i.e. doubles) is unknown. Laffaye et al. (2015) performed a longitudinal study analysing the men's singles finals in all Olympics from the Barcelona Games in 1992 to the London Games in 2012 and found a change in the temporal structure of the badminton game with an important increase in shot frequency (~34%) and a decrease in effective playing time (~34%), with an inflexion point between the 2004 and 2008 Olympics when the rally point scoring system was introduced by the Badminton World Federation. Abián et al. (2014) comparing men's singles matches from Beijing 2008 and London 2012 found that total game duration, real time, rest time at point 11, rally time, shots per rally and shots per game were greater in 2012 than in 2008. Since 2006, with the rally point scoring system, badminton has evolved towards longer rallies with greater rest intervals pushing the limits of the badminton regulations (Abián et al., 2014; Laffaye et al., 2015).

Many of the badminton studies that incorporate physiological measurements together with the analysis of temporal factors are based on simulated competitions and not on matches that took place in real top-level tournaments (Abian-Vicen et al., 2014; Alcock & Cable, 2009; Cabello & Gonzalez, 2003; Fernandez-Fernandez, de la Aleja Tellez, Moya-Ramon, Cabello-Manrique, & Mendez-Villanueva, 2013; Liddle et al., 1996). A match with players who are not of the highest level or under training conditions generates a different time structure from a match in a real tournament (Leong & Krasilshchikov, 2016) because badminton involves a high level of perceptual-motor performance (Munzert, Zentgraf, Stark, & Vaitl, 2008), as well as a tactical component (Hastie, Sinelnikov, & Guarino, 2009) and a psychological burden in real competition (Faude et al., 2007). From a physiological point of view, elite players need to perform at their maximum limits of speed, agility, flexibility, endurance and strength (Ghosh, 2008; Ooi et al., 2009; Phomsoupha & Laffaye, 2015). Badminton is characterised by a combination of moderate to high intensity rallies (~10 s) caused by short repetitive actions, with short periods of low intensity or rest (~25 s) (Cabello & Gonzalez, 2003; Docherty, 1982; Majumdar et al., 1997). Singles events are more demanding than doubles, with greater distance covered, higher heart rate and similar resting times during the match (Liddle et al., 1996). Studies that compare men and women players have focused on singles events, with the men's singles event showing significantly higher rally duration, strokes per rally and resting time between rallies (Abian-Vicen et al., 2013; Fernandez-Fernandez et al., 2013), however women's single events showed a higher work density and percentage of time played (Abian-Vicen et al., 2013). Fernandez-Fernandez et al. (2013) found no differences in physiological and perceptual responses (heart rate, lactate concentration and rate of perceived exertion) between female and male youth elite badminton players (age = ~ 16 years old) during a simulated badminton match. Faude et al. (2007) found no differences between male and female elite badminton players during simulated badminton matches in heart rate or lactate concentration but found higher values in oxygen uptake, minute ventilation and energy expenditure in the male group.

Temporal and Notational badminton studies performed to date have focused on the singles events (Abian-Vicen et al., 2013; Abián et al., 2014; Laffaye et al., 2015). There is a lack of information concerning the badminton match structure in doubles events, and we have not found any study that analyses the evolution of men's and women's doubles badminton events in temporal and notational structure with the current "rally-point scoring" system introduced by the Badminton World Federation in 2006. The purpose of this study was to compare the timing factors and notational structure of top world level badminton in men's and women's doubles matches among the Olympic Games in Beijing, London and Rio to observe the evolution of this sport between 2008 and 2016.

METHODS:

Sample

All the matches from the quarterfinals to the final of the men's doubles and women's doubles events from the 2008 Beijing Olympic Games, 2012 London Olympic Games and 2016 Rio Olympic Games were analysed (n = 48 matches, 114 games and 4119 rallies). All of them were retrieved from the Olympic Multimedia Library supplied by the International Olympic Committee Studies Centre. Matches were played with the current "rally point scoring" system, where the team that wins the best of 3 games of 21 points is the winner. Given the category of the tournament, all the participants were among the best pairs in the world at that time.

Materials

Official videos recorded by the International Olympic Committee in the Beijing 2008 Olympic Games, London 2012 Olympic Games and Rio 2016 Olympic Games were used to carry out the analysis of the matches. Reproduction was carried out using VCL Media Player software and the timing structure was measured with a digital stopwatch (Casio, Tokyo, Japan). It is worth mentioning that all measurements and observations were made by the same investigator who had had extensive training in the methods and procedure used in this study. The analyst was instructed to watch the videos of the badminton matches and record his observations directly using a table.

Parameters

The independent variables were the place where the games were played (Beijing 2008 Olympic Games, London 2012 Olympic Games and Rio 2016 Olympic Games) and the event (men's doubles and women's doubles). The dependent variables were the temporal values: match duration (the time that elapsed from the first service until the shuttlecock touched the ground on the last point, including rest time periods between points and games); real time played (the time in which the shuttlecock was in play from the first to the last point of the match); percentage of real time played (real time played multiplied by 100 divided by the match duration); rally time (the time from the service until the shuttlecock touched the ground on each point); rest time (the time that elapsed from when the shuttlecock touched the ground until the next service was performed); time point 11 (when any player scored the 11^{th} point for the first time in the game, the time that elapsed from when the shuttlecock touched the ground until the next serve); work density (rally time divided by rest time) and notational details: total points played (total number of points played by both players); shots per rally (total number of times the shuttle was hit by both players from the serve until it hit the ground); and shot frequency (number of shots divided by real time played).

The percentages obtained for each type of the last shot of the rally were also analysed: (1) Smash: an aggressive overhead shot with a downward trajectory, 2) Drop: a smooth shot from above the head with a downward trajectory towards the front of the court, 3) Net: a precise shot from near the net (including net drop, push, kill and brush), 5) Drive: a hard shot made at middle body height and in the middle of the court with a flat trajectory, 6) defence: a precise defensive shot in response to an attack from the opposing players, and 7) unforced error: an error by a player during the rally in a situation where it was not expected: i.e. there was no excessive pressure from the opponent and there were possibilities to make effective shots to place the shuttlecock in the other court.

It should be noted that the variables listed above are generally recognised to comprise an effective evaluation index for analysing the timing factors and notational structure of badminton matches (Cabello & Gonzalez, 2003; Faude et al., 2007). The reliability coefficient was calculated in order to ensure that the observation results of the analyst were consistent. In this study, the reliability coefficient for all variables was ≥0.96.

Statistical Analysis

The following software programs were used: *Microsoft Excel spreadsheet* (Microsoft, Spain) to store the results and *SPSS v. 17.0* (SPSS Inc., USA) to perform the statistical calculations using descriptive and inferential statistical tests and to calculate means, standard deviations and ranges. Initially, normality was tested in all variables with the Kolmogorov-Smirnov test. All the variables showed a normal distribution, therefore a two way ANOVA 2 x 3 was used to establish the differences in the variables between the two modalities (men's doubles and women's doubles) and among the three Olympics analysed (Beijing, London and Rio) and subsequently post hoc Bonferroni tests were used for two-group comparisons. The 95% confidence interval was calculated in all pairwise comparisons. The criterion for statistical significance was set at $P < 0.05$. All the data are presented as mean ± standard deviation.

RESULTS:

A comparison of the absolute timing factors of matches played in Beijing, London and Rio Olympics in men's doubles and women's doubles modalities is presented in Table 1. Higher values in match duration were found in the matches played in Rio compared to the matches played in Beijing (difference (diff) = 1196.7 s, 95% Confidence Interval (CI): 124.4 to 2269.0 s; $P = 0.024$) and London (diff = 1477.9 s, 95% CI: 405.6 to 2550.2 s; $P = 0.004$) in women's doubles and compared to the matches played in Beijing (diff = 1243.4 s, 95% CI: 171.1 to 2315.7 s; $P = 0.018$) in men's doubles (Figure 1). No differences were found in match duration between modalities. The real time played was higher in Rio compared to London (diff = 305.0 s, 95% CI: 63.3 to 546.6 s; $P = 0.009$) in the women's doubles modality and this modality showed higher real time played in Beijing (diff = 289.4 s, 95% CI: 93.9 to 485.0 s; $P = 0.005$) and Rio (diff = 297.3 s; 95% CI: 101.7 to 492.8 s; $P = 0.004$) than the men's doubles modality (Figure 1). The percentage of time played was higher in the women's doubles modality than the men's doubles modality in the three Olympics analysed (Beijing: diff = 8.7 %, 95% CI: 5.5 to 11.8 %; $P < 0.001$, London: diff = 3.9 %, 95% CI: 0.7 to 7.0 %; $P = 0.016$, Rio: diff = 7.1 %, 95% CI: 4.0 to 10.2 %; $P < 0.001$) and in the men's doubles modality the percentage of time played was higher in London than in Rio (diff = 4.2 %; 95% CI: 0.3 to 8.0 %; $P = 0.031$). The total shots per match in the women's doubles modality in the Rio Olympics were higher than in the women's doubles in London (diff = 431.1 shots per match; 95% CI: 122.2 to 740.0 shots per match; $P = 0.004$) and men's doubles in Rio (diff = 267.4 shots per match; 95% CI: 17.4 to 517.5 shots per match; $P = 0.037$).

Table 1: *Mean ± Standard deviation obtained in absolute match timing factors.*

	Beijing	London	Rio	*P* value [b]	*P* value [c]
Match duration (s)					
Men's doubles	2657.0 ± 755.7	2903.8 ± 859.7	3900.4 ± 899.2 #	< 0.001	0.015
Women's doubles	2840.6 ± 652.7	2559.5 ± 884.3	4037.4 ± 1053.9 # ‡		0.003
***P* value [a]**		0.975			
Real time played (s)					
Men's doubles	478.3 ± 153.8	569.9 ± 135.2	616.3 ± 146.9	0.033	0.359
Women's doubles	767.7 ± 242.2 *	608.5 ± 213.2	913.5 ± 240.5 * ‡		0.012
***P* value [a]**		0.001			
% time played					
Men's doubles	18.1 ± 3.2	20.0 ± 3.5	15.8 ± 2.1 ‡	0.019	0.035
Women's doubles	26.7 ± 3.5 *	23.9 ± 2.1 *	22.9 ± 3.8 *		0.050
***P* value [a]**		< 0.001			
Total played points					
Men's doubles	88.4 ± 18.9	79.4 ± 16.2	98.5 ± 20.0	0.015	0.150
Women's doubles	74.5 ± 15.1	77.4 ± 19.7	96.7 ± 24.0		0.052
***P* value [a]**		0.296			
Total shots per match					
Men's doubles	732.4 ± 223.8	840.4 ± 184.1	946.2 ± 214.3	0.007	0.237
Women's doubles	963.2 ± 265.8	782.5 ± 276.0	1213.6 ± 302.6 * ‡		0.005
***P* value [a]**		0.046			
Rest time between games (s)					
Men's doubles	135.4 ± 8.3	132.9 ± 8.8	147.4 ± 17.6	0.022	0.075
Women's doubles	148.3 ± 19.2	135.1 ± 10.5	147.6 ± 10.7		0.095
***P* value [a]**		0.191			

[a] *P* value between Men's doubles and Women's doubles; [b] *P* value between Olympic games; [c] *P* value between Olympic games within each event; # Significant difference from Beijing (*P*<0.05); ‡ Significant differences from London (*P*<0.05); * Significant differences from Men's doubles (*P*<0.05)

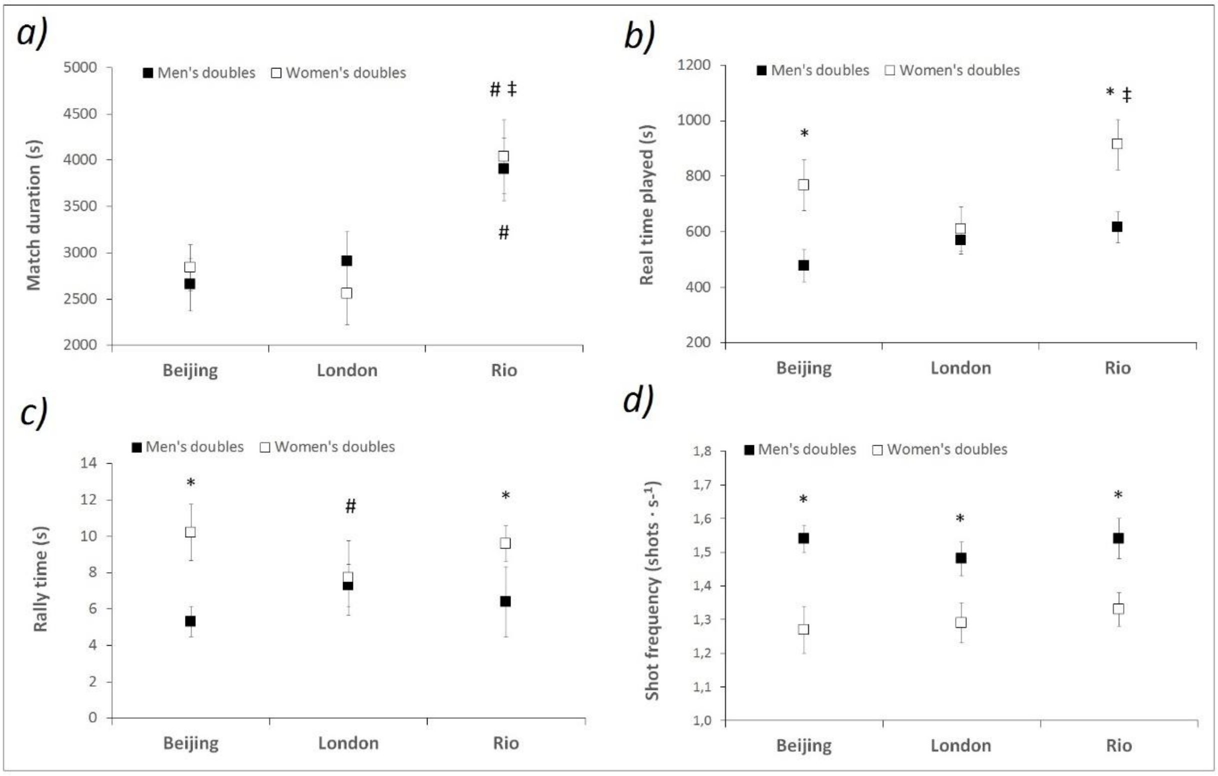

Figure 1: *Comparison between modalities and Olympics in match duration, real time played, rally time and shot frequency. (# Significant difference from Beijing (P<0.05); ‡ Significant differences from London (P<0.05); * Significant differences from Men's doubles (P<0.05))*

A comparison of the relative timing factors is presented in Table 2. Shots per rally were higher in women's doubles than men's doubles in Beijing (diff = 4.7 shots per rally; 95% CI: 2.7 to 6.6 shots per rally; *P* < 0.001) and Rio (diff = 3.0 shots per rally; 95% CI: 1.1 to 5.0 shots per rally; *P* = 0.003). In the women's doubles group shots per rally in London were lower than in Beijing (diff = 3.0 shots per rally; 95% CI: 0.6 to 5.4 shots per rally; *P* = 0.010) and Rio (diff = 2.9 shots per rally; 95% CI: 0.5 to 5.3 shots per rally; *P* = 0.013) and in the men's doubles group shots per rally were higher in London than in Beijing (diff = 2.5 shots per rally; 95% CI: 0.1 to 4.9 shots per rally; *P* = 0.039). Rally times were higher in women's doubles than in men's doubles in Beijing (diff = 4.9 s; 95% CI: 3.2 to 6.5 s; *P* < 0.001) and Rio (diff = 3.2 s; 95% CI: 1.6 to 4.9 s; *P* < 0.001). In the women's doubles group the rally time was lower in London than in Beijing (diff = 2.5 s; 95% CI: 0.5 to 4.6 s; *P* = 0.010) (Figure 1). Rest time between rallies was higher in Rio than in Beijing (diff = 6.1 s; 95% CI: 2.6 to 9.6 s; *P* < 0.001) and London (diff = 5.2 s; 95% CI: 1.7 to 8.7 s; *P* = 0.002). Work density was higher (P<0.001) and shot frequency was lower (P<0.001) in women's doubles than men's doubles in all the Olympics analysed (Figure 1). Finally in the men's doubles group the rest time at point 11 was higher in Rio than in Beijing (diff = 23.1 s; 95% CI: 8.8 to 37.5 s; *P* = 0.001) and London (diff = 19.0 s; 95% CI: 4.7 to 33.4 s; *P* = 0.006).

Table 2: *Mean ± Standard deviation obtained in relative timing factor.*

	Beijing	London	Rio	*P* value (b)	*P* value (c)
Shots per rally					
Men's doubles	8.2 ± 1.5	10.7 ± 1.6 #	9.7 ± 2.1	0.341	0.041
Women's doubles	12.9 ± 2.1 *	9.8 ± 1.9 #	12.7 ± 2.2 * ‡		0.004
P value (a)		< 0.001			
Rally time (s)					
Men's doubles	5.3 ± 1.0	7.3 ± 1.4	6.4 ± 1.6	0.680	0.072
Women's doubles	10.2 ± 7.7 *	7.7 ± 1.6 #	9.6 ± 1.9*		0.009
P value (a)		< 0.001			
Rest time (S)					
Men's doubles	21.4 ± 2.2	26.5 ± 3.1 #	30.0 ± 5.1 #	< 0.001	< 0.001
Women's doubles	25.0 ± 4.1	21.7 ± 5.4*	28.6 ± 2.6 ‡		0.005
P value (a)		0.440			
Work density					
Men's doubles	0.25 ± 0.06	0.28 ± 0.06	0.21 ± 0.03	0.029	0.111
Women's doubles	0.41 ± 0.07 *	0.36 ± 0.06 *	0.34 ± 0.07 *		0.062
P value (a)		< 0.001			
shot frequency (shots · s^{-1})					
Men's doubles	1.54 ± 0.04	1.48 ± 0.05	1.54 ± 0.06	0.043	0.078
Women's doubles	1.27 ± 0.07 *	1.29 ± 0.06 *	1.33 ± 0.05 *		0.086
P value (a)		< 0.001			
Rest time at point 11 (s)					
Men's doubles	68.2 ± 6.6	72.3 ± 17.7	91.3 ± 14.5 # ‡	< 0.001	< 0.001
Women's doubles	73.6 ± 9.6	74.0 ± 10.0	87.3 ± 5.8		0.034
P value (a)		0.756			

(a) *P* value between Men's doubles and Women's doubles; (b) *P* value between Olympic games; (c) *P* value between Olympic games within each event; # Significant difference from Beijing (*P*<0.05); ‡ Significant differences from London (*P*<0.05); * Significant differences from Men's doubles (*P*<0.05)

Time intervals in the duration of the rallies and the breaks between rallies are shown in Figure 2. The most frequently occurring rallies in all the matches were between 0 and 6 s accounting for 56.4 % of the rallies. Men's doubles recorded higher values in the shortest intervals (0-3 and 3-6 s) and women's doubles higher values in the longest intervals (from 9 s). However, for the rest intervals, 72.6 % of the breaks were between 12 and 30 s. As can be seen in Figure 1 the intervals in both modalities (men's and women's doubles) increased from 2008 to 2016 in the analysed Olympics.

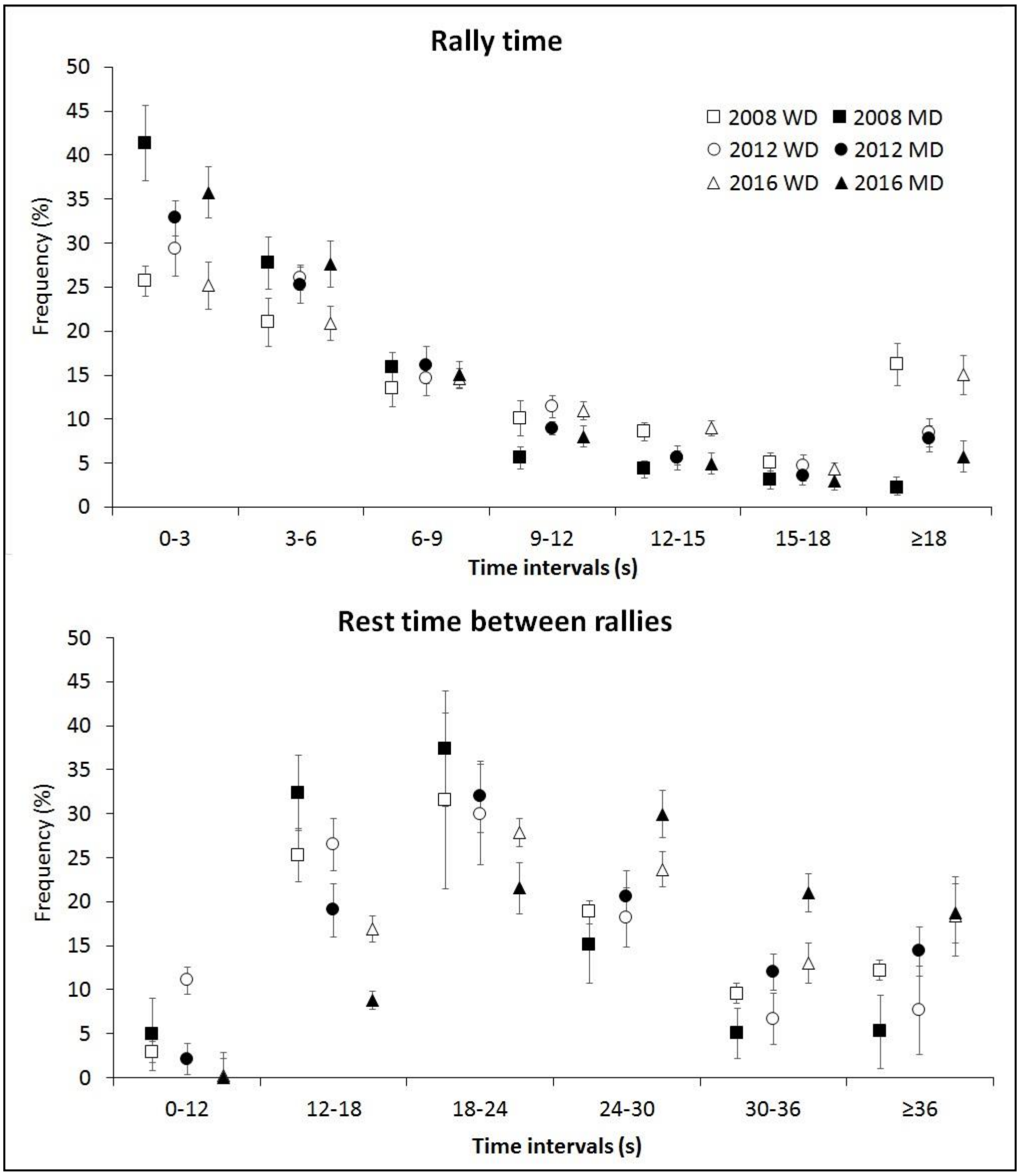

Figure 2: *Mean percentage of playing intervals (performance time) and recovery (rest time) in all the matches.*

The frequency distribution of the last shot of each rally during the matches is shown in Table 3. The unforced error (52.9 ± 4.9 %) and the smash (21.3 ± 4.8 %) were the most frequent last shots of the rally. The net shot was used more frequently in the men's doubles than the women's doubles in Beijing (diff = 6.1 %; 95% CI: 3.1 to 9.0 %; $P < 0.001$), and in the women's doubles than the men's doubles in London (diff = 3.3 %; 95% CI: 0.4 to 6.3 %; $P = 0.028$). Moreover the net shot was used more frequently by the men's group in Beijing than in London (diff = 8.3 %; 95% CI: 4.7 to 12.0 %; $P < 0.001$) or Rio (diff = 7.4 %; 95% CI: 3.8 to 11.1 %; $P < 0.001$). Finally the defence shot was used more frequently as the last shot of the rally by the women's group in London than in Beijing (diff = 1.8 %; 95% CI: 0.4 to 3.3 %; $P = 0.009$) or Rio (diff = 1.5 %; 95% CI: 0.1 to 3.0 %; $P = 0.039$).

Table 3: *Mean ± Standard deviation obtained in the last shot of each rally during the match.*

	Beijing	London	Rio	*P* value [(b)]	*P* value [(c)]
Unforced error					
Men's doubles	50.8 ± 2.5	54.9 ± 4.3	49.5 ± 5.5	0.215	0.059
Women's doubles	55.0 ± 4.1	54.1 ± 4.6	53.7 ± 5.9		0.832
***P* value [(a)]**		0.062			
Smash					
Men's doubles	20.5 ± 1.8	20.8 ± 4.6	24.2 ± 3.0	p = 0.096	0.210
Women's doubles	22.8 ± 3.8	17.8 ± 6.0	21.4 ± 6.4		0.085
***P* value [(a)]**		0.382			
Drop					
Men's doubles	1.0 ± 0.8	2.0 ± 1.9	2.5 ± 2.1	p = 0.051	0.189
Women's doubles	1.6 ± 1.4	0.9 ± 1.5	2.8 ± 1.9		0.088
***P* value [(a)]**		0.895			
Net					
Men's doubles	17.3 ± 2.6	9.0 ± 2.1 #	9.9 ± 3.2 #	0.001	< 0.001
Women's doubles	11.3 ± 2.1 *	12.3 ± 4.5 *	11.3 ± 2.4		0.710
***P* value [(a)]**		0.587			
Drive					
Men's doubles	9.3 ± 2.4	12.0 ± 3.8	13.0 ± 5.6	0.062	0.163
Women's doubles	8.6 ± 4.5	12.5 ± 3.7	9.9 ± 3.2		0.158
***P* value [(a)]**		0.339			
Defense					
Men's doubles	1.1 ± 0.9	1.3 ± 1.1	0.9 ± 1.1	0.028	0.751
Women's doubles	0.6 ± 0.7	2.5 ± 1.9 #	1.0 ± 0.9 ‡		0.007
***P* value [(a)]**		0.464			

[(a)] *P* value between Men's doubles and Women's doubles; [(b)] *P* value between Olympic games; [(c)] *P* value between Olympic games within each event; # Significant difference from Beijing (*P* <0.05); ‡ Significant differences from London (*P* <0.05); * Significant differences from Men's doubles (P<0.05).

Table 4 gives the comparison between sets in the main timing factors. The percentage of time played, shots per rally, rally time and work density were higher ($P < 0.05$) in set 1 than set 2 or set 3. Rest time was lower ($P < 0.05$) in set 1 than sets 2 and 3. The rest time at point 11 was higher ($P < 0.05$) in set 3 than set 1 and finally shot frequency was higher ($P < 0.05$) in set 3 than sets 1 and 2.

Table 4: *Mean ± Standard deviation obtained in the timing factors in each set of the match.*

	Set 1 (n=48)	**Set 2 (n = 48)**	**Set 3 (n = 18)**
game duration (s)	1211.8 ± 337.3	1248.3 ± 328.2	1320.2 ± 305.2
Real time played (s)	291.9 ± 96.2	273.9 ± 102.7	248.8 ± 82.7
% time played	24.4 ± 5.2	21.9 ± 5.4 #	19.2 ± 5.4 #
Total played points	35.9 ± 4.8	35.9 ± 4.6	37.2 ± 4.4
Total shots per match	399.9 ± 108.9	377.6 ± 121.7	361.5 ± 93.6
Shots per rally	11.1 ± 2.5	10.4 ± 2.9 #	9.8 ± 2.7 #
Rally time (s)	8.1 ± 2.4	7.6 ± 2.6 #	6.8 ± 2.5 #
Rest time (S)	24.4 ± 5.5	26.1 ± 5.2 #	27.8 ± 5.3 #
Rest time at point 11 (s)	75.9 ± 11.3	78.9 ± 19.5	89.6 ± 14.3 #
Work density	0.34 ± 0.09	0.29 ± 0.09 #	0.25 ± 0.09 #
shot frequency (shots · s^{-1})	1.40 ± 0.13	1.41 ± 0.13	1.48 ± 0.13 # ‡

Significant difference from Set 1 (P<0.05); ‡ Significant differences from Set 2 (P<0.05)

DISCUSSION:

Badminton matches in the doubles modalities became longer from 2008 to 2016. In Rio 2016 the matches of both men's doubles and women's doubles exceeded, on average, one hour duration (~ 1 hour and 6 minutes), an increase in the duration of the matches of ~ 44.4 % with respect to Beijing 2008. The increase in the duration of the matches was due to the increase in real time played but mainly to the increase in rest time between points. The duration of the matches was much higher than that recorded by other authors in the singles modalities with both the old scoring system (Cabello & Gonzalez, 2003; Chen & Chen, 2008) and the new scoring system (Abian-Vicen et al., 2013; Abián et al., 2014). The increase in match length was the main cause for changing the scoring system in 2006, and initially the change achieved its objective and the matches became shorter (Chen & Chen, 2008; Chen et al., 2011; Ming et al., 2008); but badminton has evolved over time in the last few years and currently we find matches are longer than with the old scoring system. Thus the Badminton World Federation is again considering a change in the scoring system to the best of 5 sets of 11 points which will undoubtedly also condition the characteristics of players' training.

The main cause of the increase in the duration of the doubles matches in recent years is that the rest between points and at point 11 of each game is getting longer. The values for the rest periods between points recorded in Rio 2016 were higher than those listed by other authors in the doubles modalities with the current scoring system (Gawin et al., 2015) and were also higher than those recorded in the singles modalities with the old scoring system (Cabello & Gonzalez, 2003; Cabello, Padial, Lees, & Rivas, 2004; Faude et al., 2007) and with the current scoring system (Abian-Vicen et al., 2013; Abián et al., 2014), although we must take into account that the most current study of the referenced analysed matches was from 2012. The breaks in badminton are covered by the Badminton rules, which indicate that the game must be continuous. Possibly the increase in the intensity of the points means that the players try to rest as much as possible between points; however, it is the referee's job to see that the regulated rest times are respected by the players. Another aspect that has also conditioned the rest between points is the inclusion of Hawk-Eye in the Olympic Games of Rio 2016, which can be requested by the players when they do not agree with the referee's decision (in each game the players can request all the Hawk-Eye reviews that they deem appropriate until they make two mistakes). Actually, Hawk-Eye causes longer waiting times until the final decision appears on the screens, and the Badminton World Federation should try to optimise the Hawk-Eye technology to reduce the waiting time as much as possible. It should be noted that in Rio 2016, the rest at point 11 lasted an average of 91.3 ± 14.5 s in the men's doubles and 87.3 ± 5.8 s in the women's doubles, these values are above the 60 s stipulated in the regulations.

From Beijing 2008 to Rio 2016 the men's and women's doubles have evolved in a similar manner, however, it is worth highlighting the values found in the women's doubles in the London Olympic Games where practically all the analysed variables showed values that broke the trends found during the three Olympics Games analysed (2008, 2012 and 2016) in both modalities (Tables 1 and 2). These results are conditioned by the fact that in the London Olympics there were eight women players (four women's doubles pairs) who were disqualified for lack of competitiveness in the group stage (two pairs from South Korea, one from China and one from Indonesia). The disqualification allowed four lower-level pairs to progress to the quarter-finals of the women's doubles and resulted in more unequal matches with a decrease in match duration, total shots per match, rally time and all the variables that reflect the intensity of the matches.

The temporal structure of the women's doubles matches was different from that of the men's doubles. The women's doubles showed matches with higher real time played, percentage of time played, rally time and work density; however the rest times did not differ from the men's doubles. Possibly this is because the ability of the female players to defend against the opponent's attacks is equal to that of their male counterparts, but the velocity of their offensive strokes is lower. Women badminton players have shown in previous studies 17.2 % less power in the push-off phase of a jump and 37.1 % less hand grip strength than their men badminton counterparts (Abian-Vicen, Del Coso, Gonzalez-Millan, Salinero, & Abian, 2012). Significant correlations have been found between playing ability and certain factors such as speed ($r = 0.67$) explosive strength ($r = 0.55$) shoulder strength ($r = 0.69$), muscular endurance ($r = 0.75$) and agility ($r = 0.83$) (Nandalal, Ranjit, & Kumar, 2011; Tiwari, Rai, & Srinet, 2011) and specific badminton training has not modified the gender differences presented in physically active subjects who have not had specific training, which would condition the power of the shots in order to win the points (Abian-Vicen et al., 2012; Abian, Alegre, Lara, Rubio, & Aguado, 2008; Demura et al., 2003; Wood, Grant, du Toit, & Fletcher, 2017). This would indicate that men can perform more powerful smashes and drives than women to win the points or to generate defective returns that allow them to win the point in fewer shots. Gender differences in physical characteristics would also justify the higher shot frequency found in the men's doubles modality.

The most frequently occurring rallies in the distribution of the playing intervals recorded a duration of 0 to 6 s (Figure 2) this contrasts with the results presented in other studies in the singles modality where the matches showed a predominance of 3 to 9 s intervals (Abian-Vicen et al., 2013; Abián et al., 2014; Cabello & Gonzalez, 2003; Laffaye et al., 2015). The shortening of the serve reception area in the doubles modalities versus singles modalities could justify these differences in the playing intervals since it gives a certain advantage to the pair that receives the serve to gain the initiative and win the point with fewer shots. The highest frequency in the distribution of breaks between points by time intervals in both doubles modalities was between 18 and 24 s. These values are higher than those found in the singles modalities where the highest frequencies were found between 9 and 18 s with the current scoring system (Abian-Vicen et al., 2013; Abián et al., 2014) and between 6 and 12 s with the old scoring system (Cabello & Gonzalez, 2003; Laffaye et al., 2015). Similarly, shot frequency in the doubles modalities in the present study (Table 2) is higher than those previously recorded in the singles modalities (~ 1 shots · s^{-1}) (Abian-Vicen et al., 2013; Abián et al., 2014; Alcock & Cable, 2009). In the singles modality the surface of the court that each player must cover is 34.7 m^2, whereas in the doubles modality this surface is reduced to 20.4 m^2 since in spite of the court being bigger in this modality there are two players to cover the court, allowing doubles players to hit the shuttlecock earlier and thus increase shot frequency. The recorded values for shot frequency in the present study were also higher than those recorded in other studies in doubles modalities (Alcock & Cable, 2009). This may be because in our study the data were taken from matches at the Olympic Games, ensuring the highest level of the players in the world in a competition that only occurs every 4 years which means game intensity is always maximum and even somewhat higher than that registered in other competitions that have a higher than average frequency.

In the comparison between sets, we can see that the first game presented higher values than the other two in the timing factors related to the intensity of play (% time played, shots per rally, rally time and work density) which may be because the players are experiencing fatigue and reduce the intensity of the game. This fatigue possible also causes an increase in the rest time between points and at point 11 as the match progresses. These results contrast with those observed in other studies analysing singles matches. Chen and Chen (2008) analysing Thai badminton players found an increase in set duration, rest time and average duration of points in the second and third set compared to the first, on the other hand Chen et al. (2011) and Abian-Vicen et al. (2013) did not find differences between sets analysing men's singles matches.

PRACTICAL APLICATIONS

Knowledge of the timing structure in the doubles modalities is critical for coaches in elite badminton to plan the duration of the exercises and the training and to establish the speed and the frequency they need in hitting the shuttlecock. The present results suggest that coaches need to apply a differentiated approach in training men and women elite doubles badminton players. The evolution that badminton is experiencing makes these studies necessary to be able to adapt training to the real characteristics of the competition. The information about the rest time between points and at point 11 of each game can help the Badminton World Federation to modify the regulation of breaks or encourage the referees to apply the rules more strictly.

CONCLUSION:

In conclusion, the results of this study showed that badminton in the men's and women's doubles modalities evolved from the 2008 Beijing Olympics to the 2016 Rio Olympics towards longer matches with greater rest intervals between points pushing the limits of the badminton regulations. The evolution that badminton experienced from 2008 to 2016 was similar in the men's and women's doubles, however the timing structure of the women's doubles was different from the men's doubles. The women's doubles showed longer point duration which generated greater real time in the matches and percentage of time played while the men's doubles showed greater intensity in the points that was reflected in higher shot frequency.

Rally time intervals between 0 and 6 s and rest times between rallies of 18 to 24 s were the most frequent in all Olympics and modalities. The significant differences observed in the timing factor of the doubles badminton matches between Olympics and modalities may help players, coaches and federations to manage types of workouts or competition schedules more specifically to adapt to the current characteristics of badminton.

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