EFFECTS OF MATCH FORMS AND OUTCOMES ON THE PHASE-BASED ELITE MALE TABLE TENNIS MATCH PERFORMANCE

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Abstract:

The aim of the study was to explore the service round technical-tactical performance indicators of three phases discriminating the match result and the two match forms. The statistics of 72 professional men's singles matches of the 2018 international competitions were collected. A chi-square test was used to assess the relationship between match form, match outcome and service round result. Afterwards, a two-way ANOVA was performed to evaluate the effect of match form (SHM: match between players of the same handedness and OHM: match between players of the opposite handedness) and match result on three evaluation indices of thirteen technical-tactical indicators. The results displayed that: (1) there was a weak relationship between the service round outcome and match form for both the winning and losing players ($p<0.001$, ES=0.12); (2) the winners outperformed the defeated players by a higher technical effectiveness in all three phases with small to moderate effects ($p<0.05$, ES:0.50-1.00) at both match forms; (3) the usage rate of performance indicators of the first four strokes phase and six strokes above phase distinguished the SHM matches from the OHM matches by small to large effects ($p<0.05$, ES:0.50-1.26). This study offers insights for practitioners to comprehend the technical-tactical aspects that are deciding for performance when competing against different types of opponents and to make effective training plans and match strategies.

Key words: *notational analysis, performance evaluation, technical-tactical analysis, dominant hand, racquet sports*

Introduction

Table tennis is a dynamical interactive racquet sport, which requires a high quality of open skills of players (Fuchs, et al., 2018). Amongst all the aspects attributed to a successful performance, the application and outcome of technical-tactical actions are decisive for players to outperform their opponents within the dyadic interactions (Guo, Liang, Xiao, & Hao, 2020; Malagoli Lanzoni, Di Michele, & Merni, 2014; Tamaki, Yoshida, & Yamada, 2017). Therefore, notational analysis of the key technical-tactical performance indicators that are linked to a positive result can provide practitioners with useful references to how to make corresponding training and match strategy adjustments and to enhance player's competing level (Hughes & Bartlett, 2002).

In table tennis competition the rule of scoring is applied, and the course of a table tennis match follows an obvious time sequence property (Xiao, Zhou, Liu, Qin, & Yu, 2018). The unit for scoring a point is a rally, which is a successive strokes exchange process beginning by a serve and ending with the either side's stroke error or winner (Guo, et al., 2020; Wang, 2019). In the meantime, both players alternately execute serve until one of them gains the designated points to win a set.

Different analytical methods have been applied so far to assess table tennis technical-tactical performance. Some studies considered individual stroke as the subject and investigated the effectiveness of each stroke number within a rally (Tamaki, et al., 2017; Zhou & Zhang, 2019), the technique used

(Loh & Krasilshchikov, 2015; Malagoli Lanzoni, et al., 2014), the ball placement and flight path applied (Guo, et al., 2020; Wang, 2019). The results were informative for professionals to interpret performance at a detailed operational level. However, the relationship between the successive strokes in a rally is isolated from each other, which is considered deficient since the relationship among strokes and their interdependence seem to be more important aspects attributed to the quality of performance (Tang, Cao, & Deng, 2010; Wu, Liu, & Zheng, 2016). Other research treated a rally competing process as a whole and focused on the positive and negative streak of rally outcomes based on the score-line to investigate the fluctuations of player's performance (Chen & Tian 2014; Liu, Shi, & Ren, 2017). This type of study offered evidence for match analysis in combination with the situational factors, which helped the professionals to look into the stability of their performance. Nonetheless, the specific actions that caused the exhibited advantage and disadvantage periods of performance were not included, which is considered to be fundamental for deciding performance outcome.

Phase-based analysis approaches, known as the three-phase evaluation method, has assisted the predominance of China in the competitive field of table tennis (Xiao, et al., 2018; Zhang, Xiao, Zhou, & Fang, 2018). It divides a rally competing process into three ordinal phases (serve and attack phase, receive and attack phase, stalemate phase) according to the stroke number to evaluate the corresponding technical-tactical abilities to score at different stages of a rally (Fuchs, et al., 2018; Zhang, Zhou, & Yang, 2018). This analytical framework enables effective description of the competing features of a rally and assesses players' technical-tactical performance systematically and holistically, which has been largely adopted by analysts at the practical level (Xiao et al., 2018; Zhang, Liu, Hu & Liu, 2013; Zhang, et al., 2018).

Meanwhile, other variables related to contextual and temporal factors affecting technical-tactical performance in table tennis should also be examined (Gómez, García-de-Alcaráz, & Furley, 2017; Leite, Barbieri, Miyagi, Malta, & Zagatto, 2017). Amongst them, the relative quality of the opposition and the handedness of both players are preconditional important factors being fixed during the matches. The former one has been commonly considered as the difference in rankings between the rivals and is used to measure the comparative strength (Gómez, et al., 2017; Malagoli Lanzoni, et al., 2014; Zhang et al., 2013). However, at the elite level, especially for players reaching the later tournament rounds, it is rather the actual tactics adopted in the match than any gap in rankings that influence performance. The impact of handedness of the oppositions on performance, however, has been underrated in the previous research to the best of our knowledge. A recent study (Lanzoni, Di Michele, Bartolomei & Semprini, 2019) analysed the occurrence of stroke type and ball bouncing area of the initial three strokes within a rally considering players' handedness and found that the left-handed players exhibited a higher level of offensiveness and a greater capacity in adjusting their serves. Such findings provide clues for further investigation, as well as the relationship between the handedness of rivals determines how players behave technically and tactically throughout the entire rallying process, and consequently separate the winning mechanisms in two match forms – the one in matches between players of the same handedness (same handedness match – SHM) from the one in matches between players of the opposite handedness (opposite handedness match – OHM).

Therefore, in order to achieve a more complex understanding of interacting performance factors in table tennis match-play (Hughes & Franks, 2004; O'Donoghue, 2009), the study tried to investigate the critical technical-tactical patterns discriminating the elite male table tennis players' performance in two match forms. This is done by observing three-phase performance indicators in service round to make comparisons between the winning and losing players competing in different match forms (SHM vs. OHM). It was hypothesised that the winning players in both match forms would outperform the losing players in efficiency and frequency of technical-tactical patterns within each of the three phases.

Methods

Sample

Adopting an observational study design, the study selected a total of 72 men's singles matches of 2018 international top-level competitions played by 31 elite male players (worlding rankings ranging from 1 to 142) and collected the detailed point-by-point data of each match. The sampled match data are comprised of the last three rounds of each ITTF World Tour Platinum (Qatar Open, German Open, China Open, Korea Open, Australian Open, Austrian Open), 14 matches of the 2018 ITTF World Tour Grand Finals (one match was excluded due to player's withdrawal) and 16 matches of the 2018 Men's World Cup. The handedness of players was established according to which hand was used to hold the racket (Peters & Murphy, 1992). These 19 right-handed and 12 left-handed players were from Belarus, Brazil, China, Denmark, France, Germany, Hongkong (China), Japan, Korea, Sweden, the UK, and the USA. All players were 25.9±5.5 years of age, 178±7cm in height and 72±5.5kg in weight. Thirty matches were contested between players of the same handedness (right-handed players won

23 matches and left-handed players won seven matches), while 42 matches involved two players of the opposite handedness (right-handed players won 25 matches and left-handed players won 17 matches). All the sampled matches were played between offensive style players according to the definition of McAfee (2009). The study protocol was approved and followed the guidelines stated by the Academic Committee of Sports Coaching College from Beijing Sport University and conformed to the recommendations of the Declaration of Helsinki.

Data collection and reliability

Two experienced analysts (four years of notating and analysing table tennis statistics) participated in the data collection. Prior to the formal procedure, a training session was held to get a common ground on the operational definition of the performance indicators and data collection process. After the data collection, two randomly chosen matches of each match form (SHM match and OHM match) were observed again by two analysts to test the intra- and inter-observer reliability (see Supplementary Table 1-4 for contingency table of the raw data of the two matches). The Cohen's kappa was used to evaluate the level of agreement (O'Donoghue, 2010). The values of intra-observer reliability for the SHM match and OHM match were 0.96 and 0.95, respectively, and the ones of inter-observer reliability for SHM match and OHM match were 0.93 and 0.93, respectively, displaying very good strength of agreement (Altman, 1991).

Performance indicators and evaluation indices

Table 1 outlines thirteen performance indicators of service round categorized into the initial four strokes, the fifth stroke and the six strokes above, based on the three-phase structure proposed by Wu et al. (1988). As service round switches into a one-point format after both sides have scored 10 points and takes place less frequently, all points after tiebreak (10:10) were excluded from the study. The operational definitions of the performance indicators are adapted from the previous studies of Malagoli Lanzoni et al. (2014), McAfee (2009), Pfeiffer, Zhang and Hohmann (2010), and Wang (2019).

The three commonly used evaluation indices, namely, the scoring rate (ranging from 0 to 1), the usage rate (ranging from 0 to 1) and the technical effectiveness (ranging from 0 to 1) were employed

Table 1. Classification and operational definition of service round performance indicators

Category	Indicator (Abbreviation)	Definition
Initial four shots phase	Serve (S)	Serve error or receive error
	Serve and attack non-topspin (SANT)	Winner or error of using attack technique (flip, loop, drive) on the third stroke
	Serve and attack topspin (SAT)	Winner or error of using counterattack technique (loop, drive, smash) on the third shot
	Serve and control (SC)	Winner or error of using control technique (push, chop) on the third shot
	Serve and defence (SD)	Winner or error of using defence technique (block, lob) on the third shot
Fifth shot phase	Fifth shot after serve and attack non-topspin (FSANT)	Winner or error on the fifth shot after using attack technique (flip, loop, drive) on the third shot
	Fifth shot after serve and attack topspin (FSAT)	Winner or error on the fifth shot after using counterattack technique (loop, drive, smash) on the third shot
	Fifth shot after serve and control (FSC)	Winner or error on the fifth shot after using control technique (push, chop) on the third shot
	Fifth shot after serve and defence (FSD)	Winner or error on the fifth shot after using defence technique (block, lob) on the third shot
Six shots above phase	Forehand against forehand (FAF)	Winner of hitting a forehand stroke to opponent's forehand or error of hitting a forehand stroke to against an opponent's forehand return
	Forehand against backhand (FAB)	Winner of hitting a forehand stroke to opponent's backhand or error of hitting a backhand stroke to against an opponent's forehand return
	Backhand against forehand (BAF)	Winner of hitting a backhand stroke to opponent's forehand or error of hitting a forehand stroke to against an opponent's backhand return
	Backhand against backhand (BAB)	Winner of hitting a backhand stroke to opponent's backhand or error of hitting a backhand stroke to against an opponent's backhand return

to evaluate the outcome of each individual performance indicator. The formulas were based on the study of Zhang et al. (2013) and listed as follows:

$$\text{Scoring rate (SR)}=\text{winners} / (\text{winners}+\text{errors}) \quad (1)$$

$$\text{Usage rate (UR)}=(\text{winners}+\text{errors}) / (\text{all points of a match}) \quad (2)$$

The technical effectiveness (TE) value of a performance indicator is a function of its scoring rate and usage rate, and is computed using the following formula:

$$TE = -\left(1+\frac{\sqrt{2}}{2}\right)+\left(1.5+\sqrt{2}\right) * TE_0 - \frac{\sqrt{2}}{2} * TE_0^{\,2} \quad (3)$$

where TE_0 is calculated as:

$$(TE_0) = (1 + UR)^{SR-0.5} \quad (4)$$

Statistical analysis

Descriptive statistics of service round results and the three evaluation indices of performance indicators were computed as frequencies and means with standard deviations (SD). Later, inferential analysis was conducted, using (a) Pearson's chi-square test to detect the relationship between match forms (SHM and OHM), match outcome (winning and losing players) and service round result (winning two points, winning one point and losing two points). Cramer's V coefficient (V) was calculated to quantify the effect sizes. The criteria of values were described as small (V=0.10), medium (V=0.30) or large (V≥0.50) (Gravetter & Wallnau, 2007); (b) two-way ANOVA, treating match form and match result as two factors and test the effect of each individual factor, as well as the interaction of these two factors on the value of three evaluation indices of each performance indicator. Partial eta squared (η_p^2) was calculated as the effect size estimate, with its strength being interpreted as the following: <0.06 as small, <0.14 as moderate, and ≥0.14 as large (Cohen, 2013). The *post-hoc* pairwise independent *t*-test was used to assess the difference between the level of factor which had significant effect. Standardized mean differences (Cohen's *d*) was computed to quantify the effect size of mean difference with thresholds being 0.2, trivial; 0.6, small; 1.2, moderate; 2.0, large; and>2.0, very large (Hopkins, Marshall, Batterham, & Hanin, 2009). The analyses were done using SPSS (Armonk, NY: IBM Corp.) and the alpha level of statistical test was set at .05.

Results

There was a significant small association between the match forms, match outcome and the service round result (χ^2=87.998, p<0.001, ES=0.115). The winning player of both match forms was able to win relatively more consecutive two points (SHM: 34.3%, OHM: 35.2%) in their serves than losing two points (SHM: 17.6%, OHM: 16.8%).

Table 2 and Figure 1 show the descriptive statistics, results of two-way ANOVA and *post-hoc* pairwise test for technical effectiveness, scoring rate and usage rate values of SHM and OHM during three phases (detailed *post-hoc* pairwise results and effect sizes are shown in Supplementary Table 5). The interaction of the match form and match result had significantly small effects on the technical effectiveness of FSANT and BAB (p<0.05, ES: 0.028-0.039), the scoring rate of FSAT (p<0.05, ES=0.031) and the usage rate of FSAT (p<0.01, ES=0.039).

The effectiveness of FSAT for the losing player during SHM matches was significantly higher than that of the respective side of OHM matches with a moderate effect (p<0.001, ES=1.00). Furthermore, the scoring rate of BAB for the winning players of SHM matches were significantly higher than that of the respective side of OHM matches with a moderate effect (p<0.01, ES=0.63). The usage rate of SANT and FAB for the losing player of SHM matches was significantly lower than that of the respective side of OHM matches with small to moderate effects (p<0.01, ES: 0.57-0.77). However, the usage rate of SC and BAB for both the winning and losing player of SHM matches was significantly higher than that of the respective sides of OHM matches with small to large effects (p<0.05, ES: 0.50-1.26).

For SHM matches, the effectiveness of S, FSC and FAF of the winning players were significantly higher than that of the losing players with small to moderate effects (p<0.05, ES: 0.67-0.75). For OHM matches, the effectiveness of S, SANT, SAT, FSC, FSAT and FAB of the winning players were significantly higher than that of the losing one with small to moderate effects (p<0.05, ES: 0.50-1.00). Meanwhile, the scoring rate of S, SANT, SAT, FSANT, FSAT and FAB of the winning players were significantly higher than that of the losing with small to moderate effects (p<0.05, ES: 0.45-0.83).

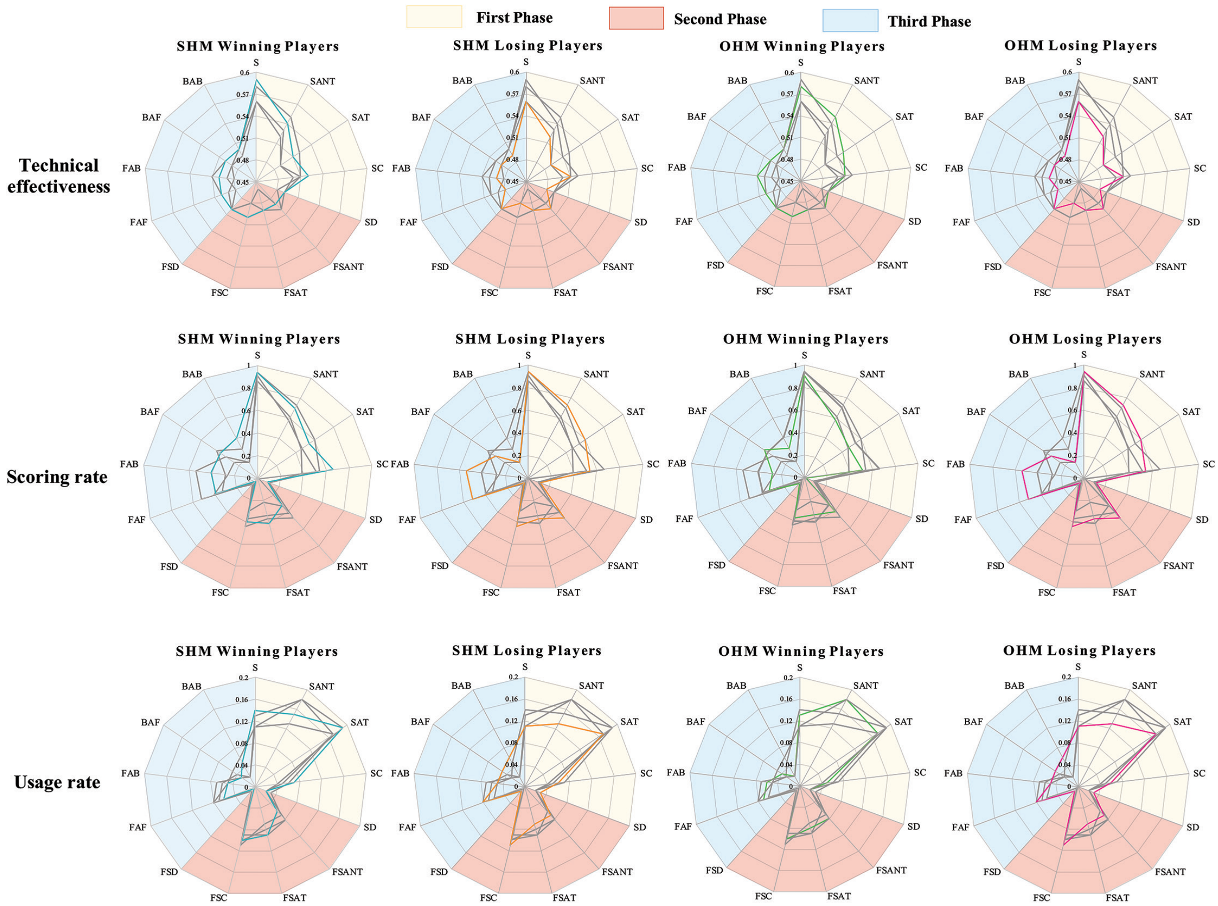
Discussion and conclusion

The aim of this study was to understand how elite table tennis players performed within different match forms defined by the dominant hands. With the scoring system changing from 21 points to 11 points, and the rotation of service round turning from 5 points into 2 points, the tempo and intensity of the switch of serve and receive game are elevated. The main results of the study reflected that the winning side in both match forms was able to maintain a positive momentum in their service round by effective technical and tactical execution. Moreover, it was found that the serve and the fifth shot after serve and control were the key indicators that differentiated between the winning and losing

Table 2. Descriptive statistics and two-way ANOVA results for technical effectiveness, scoring rate and usage rate of service round performance

		Winning Player			Losing Player			Interaction								
		Mean±SD			Mean±SD			TE			SR			UR		
		TE	SR	UR	TE	SR	UR	F	Sig.	η_p^2	F	Sig.	η_p^2	F	Sig.	η_p^2
S	SHM	0.59±.04	0.94±.10	0.14±.06	0.56±.04	0.91±.16	0.11±.06	.221	.639	.002	.606	.437	.004	.703	.403	.005
	OHM	0.58±.04	0.94±.12	0.13±.06	0.56±.04	0.86±.20	0.11±.06									
SANT	SHM	0.54±.04	0.70±.22	0.15±.07	0.52±.04	0.58±.29	0.13±.06	.022	.882	.000	.003	.958	.000	.299	.585	.002
	OHM	0.55±.04	0.73±.16	0.18±.08	0.53±.04	0.61±.20	0.18±.07									
SAT	SHM	0.51±.04	0.54±.18	0.19±.08	0.49±.04	0.47±.18	0.17±.08	1.166	.282	.008	1.198	.276	.008	1.552	.215	.011
	OHM	0.52±.05	0.60±.24	0.17±.09	0.49±.04	0.46±.19	0.19±.09									
SC	SHM	0.52±.03	0.66±.33	0.07±.04	0.51±.03	0.51±.40	0.06±.04	.330	.566	.002	.000	.999	.000	.273	.602	.002
	OHM	0.51±.03	0.54±.39	0.05±.04	0.50±.02	0.39±.42	0.04±.04									
SD	SHM	0.49±.02	0.09±.28	0.02±.02	0.48±.02	0.01±.06	0.03±.03	2.739	.100	.019	.734	.393	.005	1.335	.250	.009
	OHM	0.49±.02	0.11±.28	0.02±.03	0.49±.02	0.10±.28	0.02±.03									
FSANT	SHM	0.49±.03	0.32±.31	0.06±.05	0.50±.03	0.41±.33	0.07±.05	4.000	.047	.028	4.507	.036	.031	.931	.336	.007
	OHM	0.50±.04	0.47±.35	0.08±.04	0.49±.03	0.33±.27	0.08±.04									
FSAT	SHM	0.49±.04	0.41±.32	0.09±.04	0.49±.03	0.34±.32	0.07±.04	3.645	.058	.025	.573	.450	.004	5.632	.019	.039
	OHM	0.49±.03	0.37±.33	0.08±.04	0.46±.03	0.22±.26	0.09±.05									
FSC	SHM	0.50±.03	0.40±.29	0.10±.06	0.48±.03	0.37±.25	0.11±.07	.225	.636	.002	1.176	.280	.008	1.728	.191	.012
	OHM	0.50±.03	0.44±.30	0.10±.05	0.48±.03	0.30±.30	0.09±.05									
FSD	SHM	0.50±.01	0.03±.18	0.004±.01	0.50±.01	0.07±.22	0.01±.02	.155	.694	.001	.222	.639	.002	1.806	.181	.013
	OHM	0.50±.01	0.05±.22	0.01±.01	0.50±.01	0.05±.22	0.01±.01									
FAF	SHM	0.50±.03	0.39±.30	0.06±.03	0.48±.03	0.33±.32	0.08±.04	.044	.835	.000	.300	.585	.002	.528	.469	.004
	OHM	0.50±.02	0.52±.32	0.07±.04	0.49±.03	0.40±.33	0.08±.04									
FAB	SHM	0.50±.02	0.41±.34	0.05±.03	0.49±.02	0.28±.32	0.05±.03	3.253	.073	.023	1.801	.182	.013	.279	.598	.002
	OHM	0.51±.03	0.54±.38	0.06±.04	0.48±.03	0.26±.29	0.07±.04									
BAF	SHM	0.50±.03	0.39±.45	0.03±.03	0.49±.03	0.43±.41	0.05±.03	1.853	.176	.013	.858	.356	.006	2.358	.127	.017
	OHM	0.50±.02	0.34±.38	0.04±.03	0.49±.02	0.25±.35	0.03±.03									
BAB	SHM	0.50±.03	0.40±.42	0.05±.04	0.49±.03	0.29±.31	0.06±.04	5.687	.018	.039	.673	.413	.005	2.916	.090	.020
	OHM	0.50±.02	0.16±.34	0.02±.03	0.50±.01	0.16±.32	0.02±.02									

Note. S: serve; SANT: serve and attack non-topspin; SAT: serve and attack topspin; SC: serve and control; SD: serve and defence; FSANT: the fifth shot after serve and attack non-topspin; FSAT: the fifth shot after serve and attack topspin; FSC: the fifth shot after serve and control; FSD: the fifth shot after serve and defence; FAF: forehand against forehand; FAB: forehand against backhand; BAF: backhand against forehand; BAB: backhand against backhand; SHM: match between players of the same handedness; OHM: match between players of the opposite handedness; TE: technical effectiveness; SR: scoring rate; UR: usage rate.



Note: First Phase: the initial four strokes phase; Second Phase: the fifth stroke phase; Third Phase: the six above strokes phase; S: serve; SANT: serve and attack non-topspin; SAT: serve and attack topspin; SC: serve and control; SD: serve and defence; FSANT: the fifth stroke after serve and attack non-topspin; FSAT: the fifth stroke after serve and attack topspin; FSC: the fifth stroke after serve and control; FSD: the fifth stroke after serve and defence; FAF: forehand against forehand; FAB: forehand against backhand; BAF: backhand against forehand; BAB: backhand against backhand; SHM: match between players of the same-handedness; OHM: match between players of the opposite handedness.

Figure 1. Technical effectiveness, scoring rate and usage rate of service round performance.

performance within both match forms. Serve and control, forehand against backhand and backhand against backhand were the key indicators that separated the same handedness matches (SHM) matches from the opposite handedness matches players (OHM) matches. The findings offer empirical evidence concerning the vital performance indicators deciding performance outcome and separating two match forms of elite men's singles match.

Initial four shots phase

Although the implementation of non-shelter service rule, the increase in the ball diameter (from 38 mm to 40 mm+) and change of ball material (from celluloid to plastic) hinder the power of serve technique that provides players unique advantages among all types of techniques (Zheng, Oh, Kim, Dickson, & De Bosscher, 2018), serve was the only performance indicator in which the winning players outperformed the losing ones within both match forms. The comparatively higher scoring rate and usage rate of winning players resulted in the difference in the serve effectiveness for SHM, while the significantly larger scoring rate mostly led to the gap of serve efficiency in OHM. The evidence suggests that players should still attach great importance to the training of serve and master a set of effective serve combinations when playing against opponents with opposite handedness, as a direct serve winner could help preserve player's physical capacity without any further body movement.

Among the remaining four indicators, serve and attack is the main technical-tactical pattern employed by players with attacking style, with the intention of maximizing service advantage to score directly or to dominate the later rally competing phase (Gómez, et al., 2017; Tamaki, et al., 2017; Wang, 2019). The current study provides empirical evidence that the usage rate of serve and attack topspin was the highest among all the indicators (0.17-0.19 per rally), which can be explained by the previous findings that there was a significant increase in receivers' application of flip into the return of short serve to take initiative on attack

(Wang, 2019; Zhang, et al., 2018). However, the results further showed an apparent difference in the efficiency of both the attack non-topspin and topspin after serve on the third stroke for winning and losing players in OHM, whereas for SHM such a gap was inconspicuous. Understanding this phenomenon could then help player to refine the serve and attack strategies when encountering opponents with the contralateral dominant hand.

The occurrence of serve and control in SHM was significantly higher than that in OHM, which is in line with the result of Lanzoni et al. (2019). On the contrary, serve and attack non-topspin appeared notably with a higher frequency in OHM. These two patterns of play are used to deal with a control reception (push or chop) on the third stroke. The instinctive reaction of the attacking-style players during an ordinary non-topspin return is to actively launch an attack to gain the upper hand in the rest of a rally. Due to the difference in stroke positions between the rivals under two match forms, the difficulty is increased in OHM when players attempt to execute a high-quality control reception to restrict the server's subsequent attack. Therefore, the first four strokes phase is the pivotal section of a rally for OHM as it determines the following rally performance to a large extent. In comparison, as long as a rally continues with a successful reception, the third and the fourth strokes during SHM could not discriminate winning and losing players, considering technical effectiveness, scoring rate and usage rate.

Fifth shot phase

The fifth stroke usually becomes the turning point of a rally, in which the rally competing process transforms from the serve and attack or the receive and attack to the stalemate phase (Zhang, et al., 2018). During this course, the shot exchange pattern between oppositions is commonly converted from the game of control and counter-control with varied spins (such as sidespin, backspin, side-topspin, etc.), or initiating attack and counterattack, to the simple and direct technical-tactical employment, namely, attacking each other with topspin strokes (Jiang & Yao, 2015; Zhang, et al., 2018). The current study showed that the fifth stroke after serve and control was the only indicator leading to an obvious performance difference between the winning and losing players within both match forms. This pattern of play could produce more variations of the subsequent playing patterns than others, as there are more types of ball spin than the most appeared topspin at the fifth shot. Therefore, executing an effective control stroke after serve to lower the quality of receiver's fourth stroke return, and terminating the rally with a powerful fifth shot should be a well-practiced stroke combination for players during training.

The fifth shot after serve and attack topspin was another key shot exchange pattern that affected the match performance of two players using opposite dominant hands. The losing side exhibited a significantly high usage rate and low scoring rate, compared to the winning side and its counterpart in SHM matches. Such phenomenon may be due to the ineffective serve, which enables opponents to employ an aggressive attack on reception. Consequently, a weak counterattack is inevitable on the third stroke, and thus the probability of committing a stroke error on the fifth shot increases for the servers.

Meanwhile, it is worth mentioning that although the performance of the fifth shot after serve and attack non-topspin was found to be less important, it was the only pattern of play where the losing players outperformed the winning ones in SHM in all the three evaluation indices. This could be possible due to the fact that the winning players tended to use flip or loop when returning, so as to change the rally into topspin exchange, which might result in a decrease in the quality of control reception (Xiao, et al., 2018; Zhang, et al., 2018). Such finding implies that when losing against rivals with same handedness, serving players should adopt a strong backspin or side-backspin serve in order to force the opponent to employ a control reception, which would help them initiate an attack on the third shot to seek winning-stroke opportunities on the fifth shot.

Six shots above phase

The influence of serve and following attack on the rally outcome gradually diminish with the number of strokes increasing (Gómez, et al., 2017; Tamaki, et al., 2017). At this stage, the rally mainly consisted of topspin strokes and the technical selection is limited, so that the decisive manner to score is to hit an offensive forehand or backhand stroke to force opponent's error or to obtain a winner. The forehand-to-forehand drive or loop skill significantly differentiated the winning from the losing performance within the stalemate phase of SHM, whereas the efficiency of using forehand attack to force an opponent's backhand error in service round was crucial for OHM. This finding implies that the key technical choice that distinguishes match performance at this stage of rally is the use of forehand attack to score. Given the fact, players with attacking style should be tactically aware of employing forehand offence during this phase whenever possible, regardless of the opponent types as the aggressiveness of forehand is enhanced by greater time and space to hit than that of backhand (McAfee, 2009).

Moreover, the forehand-against-backhand ball exchange produced a significantly larger proportion of points in OHM, while, in SHM, the ratio of rally outcome decided by backhand-against-backhand was outstanding. This is due to the difference in relative stance between the rivals, and an identical ball flight path connects different stroke positions within different match forms. The success rate of a crosscourt stroke is theoretically higher than that of a down-the-line shot for a longer ball flight distance travelled. The results indicate that in the fast topspin strokes exchange, the primary tactical choice of elite male players is to ensure the accuracy of stroke rather than taking risks of precipitating the attack.

This study provides novel findings for comprehending the phase-based technical-tactical performance of service round that discriminates the match outcome and two forms of match in elite male table tennis. However, there are still some limitations needed to be acknowledged. First, only the performance of male players was analysed and the generalization of the findings to female players is limited. Second, the specific technical-tactical variables, such as the exact technique (loop, push, lob, etc.) and the ball placement were not included. Furthermore, the service round performance for points after tiebreak (10:10) could be investigated separately to further compare the technical-tactical performance characteristics between the regular points and the key points.

As for practical suggestions, it is advised that coaches and players deliberately focus on the following technical-tactical aspects during training and match preparation: (i) the serve and reception in the first four strokes phase, the ability to deal with all possibilities on the fifth shot after using control techniques on the third shot, and the forehand against forehand skill in the topspin exchange when competing against opponents with same handedness; (ii) all the first to five shots, and the ability to transform topspin stalemate phase into using forehand's attacking opponent's backhand when against players with opposite handedness. Future research could use the phase-based performance indicators to analyse players game style when encountering different types of opponents. Meanwhile, the contextual variables, such as different match and game periods (losing, leading, tiebreak, etc.) should be considered to evaluate player's performance along with psychological and physical aspects.

The present study was designed to assess the phase-based service round performance indicators differentiating between the two forms of elite men's singles match and within each match form defined by the handedness of players. The results revealed corresponding patterns of play in each three phases of a rally that separated the winning player from the losing one and the match played between rivals using the same dominant hand from those using opposite dominant hands. The findings provide insights for the practitioners to understand the technical-tactical aspects leading to a successful performance when competing against different types of opponents. For practical application, coaches are recommended to formulate training plans emphasizing the crucial playing manners of each match form to enhance players' competing level effectively.

References

Altman, D.G. (1991). *Practical statistics for medical research.* CRC Press.

Chen, L., & Tian, M.J. (2014). Characteristics of periodic "fluctuate" phenomenon of event-group performance in match. *Journal of Beijing Sport University, 37*(11), 117-123. http://doi.org/10.19582/j.cnki.11-3785/g8.2014.11.020

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences.* Academic Press.

Fuchs, M., Liu, R., Malagoli Lanzoni, I., Munivrana, G., Straub, G., Tamaki, S., Yoshida, K., Zhang, H., & Lames, M. (2018). Table tennis match analysis: A review. *Journal of Sports Sciences, 36*(23), 2653-2662. http://doi.org/10.1080/02640414.2018.1450073

Gómez, M.Á., García-de-Alcaráz, A., & Furley, P. (2017). Analysis of contextual-related variables on serve and receiving performances in elite men's and women's table tennis players. *International Journal of Performance Analysis in Sport, 17*(6), 919-933. http://doi.org/10.1080/24748668.2017.1407208

Gravetter, F.J., & Wallnau, L.B. (2007). *Statistics for the behavioural sciences* (7th ed.). Wadsworth.

Guo, W.X., Liang, M.F., Xiao, D.D., & Hao, W.Y. (2020). A systematic and comparative study on the line-changing strategies in top-level table tennis players. *International Journal of Performance Analysis in Sport, 20*(6), 1018-1034. http://doi.org/10.1080/24748668.2020.1823162

Hopkins, W., Marshall, S., Batterham, A., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise, 41*(1), 3-12. http://doi.org/10.1249/MSS.0b013e31818cb278

Hughes, M.D., & Bartlett, R.M. (2002). The use of performance indicators in performance analysis. *Journal of Sports Sciences, 20*(10), 739-754. http://doi.org/10.1080/026404102320675602

Hughes, M. & Franks, I. (Eds.) (2004). *Notational analysis of sport: Systems for better coaching and performance in sport*. Psychology Press.

Jiang, J.J., & Yao, J.X. (2015). Evaluation on tactical skills in table tennis single match and reconstruction and applications of its diagnostic. *Journal of Tianjin University of Sport, 30*(5), 432-437. http://doi.org/10.13297/j.cnki.issn1005-0000.2015.05.011

Lanzoni, I. M., Di Michele, R., Bartolomei, S., & Semprini, G. (2019). Do left-handed players have a strategic advantage in table tennis?. *International Journal of Racket Sports Science*, *1*(1), 61-69.

Leite, J.V.D.M., Barbieri, F.A., Miyagi, W., Malta, E.D.S., & Zagatto, A. M. (2017). Influence of game evolution and the phase of competition on temporal game structure in high-level table tennis tournaments. *Journal of Human Kinetics*, *55*(1), 55-63. http://doi:10.1515/hukin-2016-0048

Loh, T.C., & Krasilshchikov, O. (2015). Stroke type and shot outcome analysis in world elite and U-21 international men singles table tennis players. *International Journal of Health, Physical Education and Computer Science in Sports, 19*(1), 108-113.

Liu, R.Z., Shi, Z.H., & Ren, J. (2017). Competition momentum analysis model of table tennis based on double moving average. *Journal of Shanghai University of Sport, 41*(03), 79-82. http://doi.org/10.16099/j.sus.2017.03.012

McAfee, R. (2009). *Table tennis: Steps to success*. Human Kinetics.

Malagoli Lanzoni, I., Di Michele, R., & Merni, F. (2014). A notational analysis of shot characteristics in top-level table tennis players. *European Journal of Sport Science, 14*(4), 309-317. http://doi.org/10.1080/17461391.2013.819382

O'Donoghue P. (2009). Interacting performances theory. *International Journal of Performance Analysis in Sport, 9*(1), 26-46. http://doi.org/10.1080/24748668.2009.11868462

O'Donoghue, P. (2010). *Research methods for sports performance analysis.* Routledge.

Peters, M., & Murphy, K. (1992). Cluster analysis reveals at least three, and possibly five distinct handedness groups. Neuropsychologia, 30(4), 373-380.

Pfeiffer, M., Zhang, H., & Hohmann, A. (2010). A Markov chain model of elite table tennis competition. *International Journal of Sports Science and Coaching, 5*(2), 205-222. http://doi.org/10.1260/1747-9841.5.2.205

Tamaki, S., Yoshida, K., & Yamada, K. (2017). A shot number based approach to performance analysis in table tennis. *Journal of Human Kinetics, 55*(1), 7-18. http://doi.org/10.1515/hukin-2017-0002

Tang, J.J., Cao, H.B., & Deng, Y.X. (2010). The formation and application of tactic combination model in the table tennis competition. *Journal of Beijing Sport University, 33*(11), 108-110. http://doi.org/10.19582/j.cnki.11-3785/g8.2010.11.031

Wang, J. (2019). Comparison of table tennis serve and return characteristics in the London and the Rio Olympics. *International Journal of Performance Analysis in Sport, 19*(5), 683-697. http://doi.org/10.1080/24748668.2019.1647732

Wu, F., Liu T.L., & Zheng, X.Y. (2016). The application of Logistic Regression Model in table tennis technique analysis: Based on the matches between Wang Hao and Zhang Jike. *Journal of Beijing Sport University, 39*(5), 96-102. http://doi.org/10.19582/j.cnki.11-3785/g8.2016.05.017

Wu, H., Wu, H.O., Cai, X., Sun, Q., Wang, S., & Chen, M. (1988). Strength evaluation and technique analysis on Chinese players in table tennis matches of the 1988 Olympic Games. *China Sport Science and Technology, 24*(8), 21-29.

Xiao, D.D., Zhou, X.D., Liu, H., Qin, Z.J., & Yu, Y. (2018). The construction and application of Double Three-phase Method on table tennis technique and tactics. *China Sport Science and Technology, 54*(5), 112-116. http://doi.org/10.16470/j.csst.201805017

Zhang, H., Liu, W., Hu, J.J., & Liu, R.Z. (2013). Evaluation of elite table tennis players' technique effectiveness. *Journal of Sports Sciences, 31*(14), 1526-1534. http://doi.org/10.1080/02640414.2013.792948

Zhang, X.D., Xiao, D.D., Zhou, X.D., & Fang, W.Y. (2018). The construction and application of dynamic Three-phase Method on Table Tennis Technique and Tactics. *China Sport Science and Technology, 54*(1), 80-83. http://doi.org/10.16470/j.csst.201801011

Zhang, H., Zhou, Z., & Yang, Q. (2018). Match analyses of table tennis in China: A systematic review. *Journal of Sports Sciences, 36*(23), 2663-2674. http://doi.org/10.1080/02540414.2018.1460050

Zheng, J., Oh, T., Kim, S., Dickson, G., & De Bosscher, V. (2018). Competitive balance trends in elite table tennis: The Olympic Games and World Championships 1988–2016. *Journal of Sports Sciences, 36*(23), 2675-2683. http://doi.org/10.1080/02640414.2017.1375174

Zhou, X.D., & Zhang, Y.Q. (2019). Exploration about the competitive performance and countermeasures of table tennis based on board characteristics in the context of the new ball era. *Journal of Tianjin University of Sport, 34*(2), 78-84. http://doi.org/10.13297/j.cnki.issn1005-0000.2019.02.012

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