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Research article

Effects of technical-tactical skills on enhancing scoring efficiency when competing with opponents using different handedness in table tennis matchups

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ABSTRACT

Technical-tactical skills are key to determining table tennis match performance. Identifying the skills that can increase scoring probability when competing against opponents with different racket handedness is vital. The aim of this study was to investigate the technical-tactical actions that could significantly improve scoring efficiency in SH (same-handedness) matches and OH (opposite-handedness) matches. The statistics of 72 top-level men's singles matches were collected (40 SH matches and 32 OH matches). An independent samples *t-test* was performed to evaluate the differences in the scoring efficiency of the point-winning shot. The results showed that the following maneuvers were crucial technical-tactical skills to increase scoring probability: (1) during the mutual-restriction phase, executing a forehand short push to forehand during service round and a backhand long push to backhand during receiving round against SH opponents ($p < 0.05$, ES: 0.59–0.70), and a backhand short push to middle in receiving round against OH opponents ($p < 0.01$, ES = 0.66); (2) during the initial-attack-and-counterattack phase, performing an initial forehand flip and a loop (drive) to forehand, a counter backhand loop (drive) to backhand during both types of rounds, and a forehand block (lob) to forehand during service round against SH opponents ($p < 0.05$, ES: 0.52–1.18), and an initial forehand loop (drive) to backhand and a counter backhand loop (drive) to forehand during both types of rounds, an initial forehand flip and a loop (drive) to backhand during service round, and an initial backhand flip to middle during receiving round against OH opponents ($p < 0.05$, ES: 0.45–0.99); and (3) during the topspin-exchange phase, hitting a forehand loop (drive) to forehand during service round and a backhand loop (drive) to backhand during both types of rounds against SH opponents ($p < 0.05$, ES: 0.51–1.32), a forehand loop (drive) to backhand during both types of rounds against OH opponents ($p < 0.01$, ES: 0.77–0.91). Professionals are recommended to concentrate on the enhancement of the abovementioned key technical-tactical skills to achieve better match performance.

1. Introduction

Table tennis is a racket sport in which players' competing performances rely heavily on the effects of the application of technical and tactical skills [1–5]. To look at this argument from a microcosmic perspective, the process for reaching a rally outcome is that players alternately employ a stroke technique to hit the ball to a certain placement until the player on one side fails to return the

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opponent's preceding shot during this successive stroke exchanging process [2,4,6].

The dyadically interactive nature of table tennis rally confrontation spontaneously separates the shot sequence of both sides into two rounds, which are the service round and the receive round [5,7]. Furthermore, the exchanging of shots has been chronologically structured into phases according to the technical-tactical abilities required to score in each corresponding stage of a rally [4,8–10] or shot numbers within a rally [3,11]. Regarding the specific technical-tactical elements that can affect the quality of performance, selections of the stroke technique and stroke position [2,6,11–13], applications of the ball placement and ball flight route [1,2,6,7,11] and classifications of the consequent shot outcome [2,3,7,11] are the commonly observable indices that have been analyzed to assess performance. These analytical frameworks and performance indicators enable table tennis practitioners to systematically evaluate players' performances and then provide guidance for training improvements to enhance players' competition level.

Apart from those technical-tactical factors, several contextual variables, such as player quality (world rankings), player racket-hand, match and set durations, game period and score-line dynamics within a match, have also been analyzed to provide insights for understanding match performance from different perspectives [2,13–18]. Within those nonnegligible factors influencing performance, the relationship between competitors' handedness, being a match default, innately determines players' technical-tactical applications throughout the entire match. The reason behind this conclusion is that the relative stroke positions between players are distinct for matchups containing different combinations of competitors' racket-handedness. Furthermore, an identical ball traveling route connects different stroke positions between the rivals (e.g., a crosscourt shot connects the forehand side to the backhand side of players for an opposite-handedness matchup, whereas for a same-handedness matchup, it links either both players' forehand side or backhand side). As a consequence, the method of employing stroke techniques and ball placements during competitions is influenced and manifests as separate features [18]. Although the abovementioned factor has already been taken into consideration by table tennis practitioners (coaches, players, analysts) in training practices and match performance analysis [1,11], to the best of our knowledge, only a handful of studies have been dedicated to investigating this important topic. The existing studies focused on the comparison of the effect of the technical-tactical variables of the first four shots [11,19] or the service round [18] on the outcome of a rally, and so were limited only to certain aspects of players' overall technical-tactical skills.

Therefore, this study aims to discover the technical-tactical skills that are crucial for achieving a more successful performance comprehensively when competing with opponents using different handedness. Previous studies [11,19] analyzed the high occurrence and effective point-scoring technical-tactical employment for matches, including the four possible combinations of players' handedness. However, the study object was the player on one side, including a selection process to designate one player in a matchup to be the target. The design of the present study treats a table tennis competition as a whole and merges matchups with the same interrelationship between players' handedness into one category (a same-handedness match: right-handed vs. right-handed or left-handed vs. left-handed, and an opposite-handedness match: right-handed vs. left-handed or left-handed vs. right-handed). Within the same type of matchup, the relative stroke positions between both sides of players are identical (mirror effect). This approach intends to combine the effects of interaction between players with similar characteristics and seeks out apparent differences in the technical-tactical applications between different types of encounters.

Hence, the objective of the present study is to explore the differences in the scoring efficacy of specific technical-tactical actions between the two match types formed by different combinations of opposing players' handedness. This is achieved by comparing a two-dimensional performance indicator (stroke technique and ball placement) of the point-scoring shot in each of the three interactive phases [4] performed by players on both sides between the two types of matchups. The findings of this study can help coaches and players formulate well-directed training plans and match strategies at the operational level to perform more successfully when competing with opponents using different racket hands. It was hypothesized that there were corresponding technical-tactical skills in all three interactive phases of a rally that would significantly discriminate players' scoring efficiency for the two matchup types.

2. Materials and methods

2.1. Sample

A total of 72 top-level men's singles matches of five major international competitions (2018 and 2019 Table Tennis World Cup, 2018 and 2019 ITTF World Tour Grand Finals and last four rounds of 2019 Table Tennis World Championships) were included in this study. All the matches were played between attacking-style players by a best of seven games system. The matched participants came from four continents: Africa (Nigeria), America (Brazil, the USA), Asia (China, Chinese Taibei, Hong Kong-China, India, Japan, Korea) and Europe (Austria, Belarus, Croatia, Denmark, France, Germany, Sweden). The average (±SD) age, height and weight of the players included were 25.9 (±5.4) years, 177.4 (±7.0) centimeters and 71.8 (±9.3) kilograms, respectively. Among all the sampled matches, 40 matches were played between 28 players (world rankings ranging from 1 to 40) with matching handedness (right-handed vs. right-handed and left-handed vs. left-handed), which were defined as same-handedness (SH) matches. The remaining 32 matches were competed between 23 players (world rankings ranging from 1 to 51) where the competitors had opposite handedness (right-handed vs. left-handed), which were defined as opposite-handedness (OH) matches. The videos of all sampled matches were obtained from public video broadcast websites and watched by playback. The point-by-point data of each match were notated down in an observational sheet constructed in Microsoft Excel (Version 16.0.1, Microsoft Cooperation, USA). The study was approved by the Academic Committee of Sports Coaching College of Beijing Sport University and abided by the Declaration of Helsinki.

2.2. Performance indicator and evaluation index

A two-dimensional performance indicator of the point-winning shot (combination of stroke technique used and ball placement employed) of each individual rally was observed and noted according to Zhang and Zhou [11]. All the shots were categorized into the three interactive phases of a rally based on the study of Yu and Gao [4], which are the mutual restriction phase (first phase), the initial attack and counterattack phase (second phase) and the topspin exchange phase (third phase). The criterion for division of shot phases is based on the tactical intension of certain types of strokes being performed sequentially within a rally. The first phase contains the serve and control strokes. The second phase includes the initial attack stroke of one side and the counterattack or defense stroke of the other side. The third phase covers all the subsequent attacking or defensive strokes. Furthermore, the shots are also divided according to the rounds within a rally, which are the service round shots and the receiving round shots [5].

Scoring efficiency, defined as the proportion of scores produced by a certain technical-tactical action to the total points played in a match, was used as the evaluation index and is adapted from Guo et al. [1] and Tamaki et al. [3], which is calculated by the following equation:

$$\text{Scoring efficiency} = \text{scores produced}/\text{total points in a match} \quad (1)$$

The classifications and operational definitions of the stroke techniques are adapted from Zhang and Zhou [7] and Wang [11] and are displayed in Table 1. The stroke technique of loop and drive, as well as block and lob, are merged for their similar effects on returning a ball.

Typically, the variable of ball placement is classified into nine equal areas [7,11]. However, the longitudinal ball landing location can be self-explanatory according to the stroke technique applied. For example, a loop stroke results in a long ball placement. Therefore, this study adopts the three-area subdivision method used by Guo et al. [1], which is the forehand area, the middle area and the backhand area. Moreover, the forehand and backhand stroke positions of the right-handed player are opposite to those of the left-handed player. The three-area subdivision of ball placement on both sides of the player indicating each match type is shown in Figs. 1 and 2.

2.3. Data collection and reliability

Two experienced analysts were selected to notate the data of the sampled matches. Afterward, four randomly chosen matches of each match type (SH and OH) were used to check the reliability of observational match statistics within the leading observer (intraobserver reliability) and between the two observers (interobserver reliability) (see Supplementary Tables 1–8 for contingency table of the raw data). Cohen's kappa was employed to assess the agreement level [20]. For SH matches, the values for intraobserver reliability for stroke technique and ball placement were 0.97 and 0.92, and the values for interobserver reliability were 0.93 and 0.90. For OH matches, the values for intraobserver reliability for stroke technique and ball placement were 0.96 and 0.91, and the values for interobserver reliability were 0.93 and 0.90. All the test results exhibited very good strength of agreement [21].

2.4. Statistical analysis

First, the descriptive statistics (means and standard deviations) of the scoring efficiency of each two-dimensional performance indicator (stroke technique used and ball placement employed) were computed using Microsoft Excel (Version 16.0.1, Microsoft Cooperation, USA). Afterward, the independent samples *t-test* was performed using SPSS (Version 24.00 SPSS Inc., USA) to make comparisons between the two match types (SH vs. OH), categorized by the round type (service round or receive round) and the phase (mutual controlling phase, initial attack and counterattack phase or topspin exchange phase) in which the point-winning shot occurred. Cohen's *d* (standard mean differences) value was used to measure the effect size of the mean difference. The thresholds for each level of effect size concerning the $|d|$ values are listed as follows: a negligible effect size is reported when the $|d|$ value is less than 0.2, a small effect size is reported when the $|d|$ value is between 0.2 and 0.49, a moderate effect size is reported when the $|d|$ value is between 0.5 and 0.79, and a large effect size is reported when the $|d|$ value is greater than 0.79 [22]. The alpha level of the statistical test was set at 0.05.

Table 1
Classifications and operational definitions of stroke technique.

Stroke technique	Operational definition
Serve	The first stroke in a rally. Player tosses the ball up and hits it during its descent phase. The ball must land on the server's side first before landing on the opponent's side.
Short push	A control technique that produces backspin using an open racket resulting in a short placement on the table
Long push	A control technique that produces backspin using an open racket resulting in a deep placement on the table
Flip	An attack technique that is executed over the table using a short movement. It produces topspin or side-topspin using a closed racket
Loop	An attack technique that produces intensive topspin and fast ball speed using a long explosive movement and a closed racket
Drive	An attack technique that produces weak topspin and fast ball speed using a short explosive movement and a closed racket
Block	A defensive technique that utilizes the rebound force of the oncoming ball to simply ricochet the ball back using a short movement.
Lob	A defensive technique that is executed away from table to produce a high ball arc using a long movement

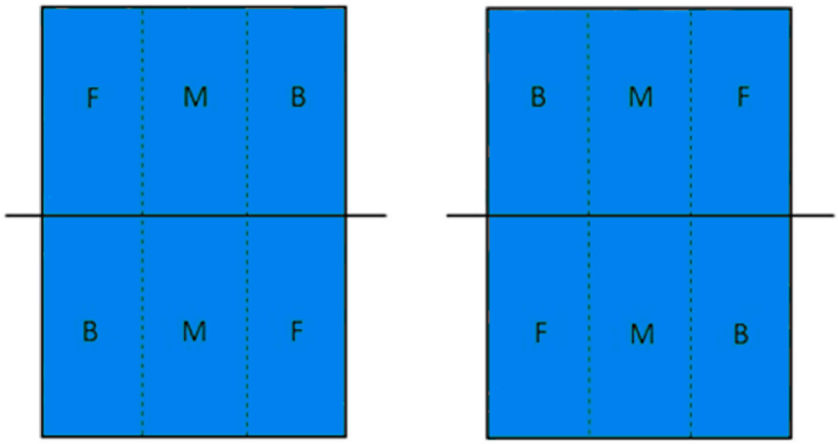

Fig. 1. Three-area subdivision of ball placement for same-handedness (SH) matches. Note: B: backhand area; M: middle area; F: forehand area.

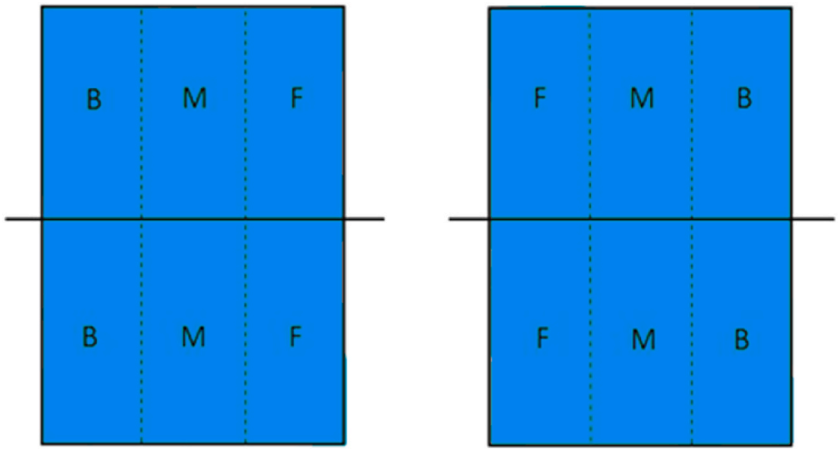

Fig. 2. Three-area subdivision of ball placement for opposite-handedness (OH) matches. Note: B: backhand area; M: middle area; F: forehand area.

3. Results

For rallies ending during the first interactive phase, using a forehand short push to forehand in the service round and a backhand long push to backhand in the receiving round significantly differentiated the scoring efficiency of SH matches from that of OH matches with moderate effect sizes ($p < 0.05$, ES ranging from 0.59 to 0.70). However, employing a backhand short push to middle in the receiving round significantly distinguished the scoring efficiency of OH matches from that of SH matches with a moderate effect size ($p < 0.01$, ES = 0.66) (see Table 2).

For rallies ending during the second interactive phase, employing an initial forehand flip and an initial forehand loop (drive) to forehand and a counter backhand loop (drive) to backhand in both types of rounds, as well as a forehand block (lob) to backhand in the service round, significantly differentiated the scoring efficiency of SH matches from that of OH matches with moderate to large effect sizes ($p < 0.05$, ES ranging from 0.52 to 1.18). However, performing an initial forehand loop (drive) to backhand and a counter backhand loop (drive) to forehand in both types of rounds, an initial forehand flip to backhand and an initial backhand loop (drive) to forehand in the service round, as well as an initial backhand flip to middle in the receiving round, significantly discriminated the scoring efficiency of OH matches from that of SH matches with small to large effect sizes ($p < 0.05$, ES ranging from 0.45 to 0.99) (see Table 3).

For rallies ending during the third interactive phase, executing a backhand loop (drive) to backhand in both types of rounds and a forehand loop (drive) to forehand in the service round significantly discriminated the scoring efficiency of SH matches from that of OH matches with moderate to large effect sizes ($p < 0.05$, ES ranging from 0.51 to 1.32). However, applying a forehand loop (drive) to backhand in both types of rounds significantly differentiated the scoring efficiency of OH matches from SH matches with moderate to large effect sizes ($p < 0.01$, ES ranging from 0.77 to 0.91) (see Table 4).

Table 2
Comparison of scoring efficiency of technical-tactical actions in the first interactive phase of the service round and receiving round.

ST	BP	Service round							Receiving round						
		SH	OH	*t*	95%CI		*p*	*d*	SH	OH	*t*	95%CI		*p*	*d*
	F	0.035 ± 0.024	0.036 ± 0.027	−0.12	−0.013	0.011	0.91	0.04	*	*	*	*	*	*	*
S	M	0.054 ± 0.028	0.052 ± 0.032	0.39	−0.011	0.017	0.70	0.07	*	*	*	*	*	*	*
	B	0.027 ± 0.023	0.026 ± 0.017	0.26	−0.008	0.011	0.80	0.05	*	*	*	*	*	*	*
SR		*	*	*	*	*	*	*	0.010 ± 0.011	0.010 ± 0.011	0.08	−0.005	0.005	0.94	0
	F	0.008 ± 0.011	0.002 ± 0.005	2.81	0.002	0.010	**0.007**	0.70	0.010 ± 0.011	0.012 ± 0.013	−0.71	−0.008	0.004	0.48	0.17
FSP	M	0.012 ± 0.014	0.013 ± 0.011	−0.59	−0.008	0.004	0.55	0.08	0.026 ± 0.019	0.018 ± 0.016	1.81	0.001	0.016	0.08	0.46
	B	0.002 ± 0.004	0.002 ± 0.005	−0.42	−0.003	0.002	0.67	0	0.006 ± 0.012	0.006 ± 0.010	0.12	−0.005	0.006	0.90	0
	F	0.002 ± 0.005	0.001 ± 0.003	1.08	−0.001	0.003	0.28	0.24	0.004 ± 0.007	0.008 ± 0.011	−1.91	−0.008	0.000	0.06	0.43
BSP	M	0.003 ± 0.006	0.001 ± 0.004	0.96	−0.001	0.004	0.34	0.39	0.006 ± 0.009	0.013 ± 0.012	−2.84	−0.012	−0.002	**0.006**	0.66
	B	0.001 ± 0.004	0.000 ± 0.001	1.25	0.000	0.002	0.22	0.34	0.002 ± 0.004	0.002 ± 0.005	−0.16	−0.002	0.002	0.88	0
	F	0.001 ± 0.003	0.000 ± 0.000	1.74	−0.001	0.002	0.09	0.47	0.001 ± 0.003	0.001 ± 0.003	0.73	−0.001	0.002	0.47	0
FLP	M	0.006 ± 0.008	0.004 ± 0.007	1.12	−0.002	0.006	0.27	0.27	0.008 ± 0.009	0.009 ± 0.010	−0.44	−0.005	0.003	0.66	0.11
	B	0.004 ± 0.008	0.003 ± 0.006	0.51	−0.003	0.004	0.61	0.14	0.007 ± 0.010	0.009 ± 0.010	−1.11	−0.007	0.002	0.27	0.20
	F	0.001 ± 0.003	0.000 ± 0.000	1.76	0.000	0.002	0.09	0.47	0.000 ± 0.001	0.001 ± 0.004	−1.42	−0.002	0.000	0.16	0.34
BLP	M	0.001 ± 0.002	0.001 ± 0.004	−0.94	−0.002	0.001	0.35	0	0.001 ± 0.003	0.002 ± 0.004	−0.17	−0.002	0.002	0.87	0.28
	B	0.002 ± 0.005	0.000 ± 0.002	1.83	−0.001	0.003	0.07	0.53	0.004 ± 0.006	0.001 ± 0.004	2.24	0.000	0.005	**0.03**	0.59

Note: ST: stroke technique; BP: ball placement; SH: same-handedness match; OH: opposite-handedness match; S: serve; SR: service error; FSP: forehand short push; BSP: backhand short push; FLP: forehand long push; BLP: backhand long push; F: forehand area; M: middle area; B: backhand area.

Table 3
Comparison of scoring efficiency of technical-tactical actions in the second interactive phase of the service round and receiving round.

ST	BP	Service round							Receiving round						
		SH	OH	*t*	95%CI		*p*	*d*	SH	OH	*t*	95%CI		*p*	*d*
IFF	F	0.010 ± 0.011	0.001 ± 0.004	4.87	0.005	0.013	**<0.001**	1.09	0.011 ± 0.013	0.000 ± 0.002	4.85	0.006	0.015	**<0.001**	1.18
	M	0.003 ± 0.005	0.007 ± 0.011	−1.81	−0.008	0.000	0.08	0.47	0.004 ± 0.007	0.004 ± 0.006	−0.04	−0.003	0.003	0.97	0
	B	0.003 ± 0.005	0.010 ± 0.011	−3.10	−0.011	−0.002	**0.003**	0.82	0.004 ± 0.006	0.008 ± 0.014	−1.37	−0.009	0.002	0.18	0.37
IBF	F	0.004 ± 0.008	0.006 ± 0.007	−0.87	−0.005	0.002	0.39	0.27	0.014 ± 0.014	0.018 ± 0.013	−1.21	−0.010	0.003	0.23	0.30
	M	0.003 ± 0.005	0.003 ± 0.006	−0.47	−0.003	0.002	0.64	0	0.015 ± 0.013	0.022 ± 0.018	−2.02	−0.015	0.000	**0.047**	0.45
	B	0.008 ± 0.009	0.007 ± 0.010	0.05	−0.004	0.005	0.96	0.11	0.033 ± 0.020	0.041 ± 0.031	−1.22	−0.020	0.005	0.23	0.31
IFLD	F	0.026 ± 0.019	0.010 ± 0.012	4.31	0.008	0.023	**<0.001**	1.01	0.018 ± 0.015	0.006 ± 0.007	4.67	0.007	0.018	**<0.001**	1.03
	M	0.013 ± 0.014	0.014 ± 0.017	−0.18	−0.008	0.007	0.86	0.06	0.010 ± 0.013	0.008 ± 0.010	0.83	−0.003	0.008	0.41	0.17
	B	0.016 ± 0.015	0.032 ± 0.020	−3.95	−0.025	−0.008	**<0.001**	0.91	0.011 ± 0.011	0.023 ± 0.017	−3.65	−0.020	−0.006	**0.001**	0.84
IBLD	F	0.005 ± 0.006	0.012 ± 0.012	−2.80	−0.012	−0.002	**0.008**	0.74	0.007 ± 0.008	0.010 ± 0.010	−1.49	−0.007	0.001	0.14	0.33
	M	0.010 ± 0.010	0.008 ± 0.009	1.18	−0.002	0.007	0.24	0.21	0.010 ± 0.013	0.008 ± 0.009	0.39	−0.004	0.007	0.70	0.18
	B	0.014 ± 0.015	0.011 ± 0.009	1.08	−0.003	0.009	0.29	0.24	0.017 ± 0.013	0.015 ± 0.014	0.48	−0.005	0.008	0.64	0.15
CFLD	F	0.026 ± 0.017	0.018 ± 0.014	2.03	0.000	0.015	0.46	0.51	0.012 ± 0.012	0.007 ± 0.007	1.94	0.000	0.010	0.06	0.51
	M	0.014 ± 0.014	0.014 ± 0.015	−0.26	−0.008	0.006	0.80	0	0.006 ± 0.007	0.007 ± 0.009	−0.10	−0.004	0.004	0.92	0.12
	B	0.017 ± 0.017	0.025 ± 0.021	−1.85	−0.017	0.001	0.07	0.42	0.006 ± 0.009	0.008 ± 0.009	−0.76	−0.006	0.003	0.45	0.22
CBLD	F	0.007 ± 0.012	0.021 ± 0.016	−4.30	−0.021	−0.008	**<0.001**	0.99	0.003 ± 0.006	0.009 ± 0.012	−2.55	−0.010	−0.001	**0.014**	0.63
	M	0.014 ± 0.012	0.021 ± 0.017	−1.99	−0.014	0.000	0.051	0.48	0.007 ± 0.010	0.007 ± 0.007	0.13	−0.004	0.004	0.90	0
	B	0.028 ± 0.021	0.017 ± 0.013	2.67	0.003	0.019	**0.009**	0.63	0.010 ± 0.011	0.005 ± 0.008	2.54	0.001	0.010	**0.013**	0.52
FBL	F	0.001 ± 0.004	0.001 ± 0.003	0.71	−0.001	0.002	0.48	0	0.001 ± 0.003	0.001 ± 0.003	−0.43	−0.002	0.001	0.67	0
	M	0.001 ± 0.003	0.000 ± 0.000	1.76	0.000	0.002	0.09	0.47	0.002 ± 0.005	0.001 ± 0.003	1.26	−0.001	0.003	0.21	0.24
	B	0.002 ± 0.004	0.000 ± 0.000	2.55	0.000	0.003	**0.02**	0.71	0.001 ± 0.003	0.000 ± 0.001	1.23	0.000	0.002	0.22	0.45
BBL	F	0.001 ± 0.004	0.001 ± 0.003	0.61	−0.001	0.002	0.54	0	0.001 ± 0.003	0.002 ± 0.006	−0.95	−0.004	0.001	0.35	0.21
	M	0.003 ± 0.005	0.001 ± 0.003	1.34	−0.001	0.003	0.19	0.49	0.003 ± 0.006	0.004 ± 0.005	−0.19	−0.003	0.003	0.85	0.18
	B	0.002 ± 0.004	0.001 ± 0.003	0.86	−0.001	0.003	0.40	0.28	0.001 ± 0.002	0.002 ± 0.004	−1.75	−0.003	0.000	0.09	0.32

Note: ST: stroke technique; BP: ball placement; SH: same-handedness match; OH: opposite-handedness match; IFF: initial forehand flip; IBF: initial backhand flip; IFLD: initial forehand loop or drive; IBLD: initial backhand loop or drive; CFLD: counter forehand loop or drive; CBLD: counter backhand loop or drive; FBL: forehand block or lob; BBL: backhand block or lob; F: forehand area; M: middle area; B: backhand area.

Table 4
Comparison of scoring efficiency of technical-tactical actions in the third interactive phase of the service round and receiving round.

ST	BP	Service round							Receiving round						
		SH	OH	*t*	95%CI		*p*	*d*	SH	OH	*t*	95%CI		*p*	*d*
FLD	F	0.037 ± 0.021	0.027 ± 0.018	2.12	0.001	0.019	**0.04**	0.51	0.030 ± 0.022	0.022 ± 0.017	1.71	−0.001	0.017	0.09	0.41
	M	0.026 ± 0.017	0.030 ± 0.022	−0.93	−0.013	0.005	0.36	0.20	0.029 ± 0.025	0.033 ± 0.018	−0.69	−0.014	0.007	0.49	0.18
	B	0.025 ± 0.018	0.041 ± 0.017	−3.70	−0.024	−0.007	**<0.001**	0.91	0.027 ± 0.026	0.047 ± 0.026	−3.17	−0.032	−0.007	**0.002**	0.77
BLD	F	0.013 ± 0.014	0.018 ± 0.015	−1.22	−0.011	0.003	0.23	0.34	0.013 ± 0.012	0.020 ± 0.017	−1.94	−0.014	0.000	0.06	0.48
	M	0.017 ± 0.018	0.013 ± 0.012	1.14	−0.003	0.011	0.26	0.26	0.019 ± 0.016	0.017 ± 0.013	0.63	−0.005	0.009	0.53	0.14
	B	0.028 ± 0.023	0.013 ± 0.013	3.77	0.008	0.024	**<0.001**	0.80	0.034 ± 0.022	0.011 ± 0.011	5.64	0.015	0.031	**<0.001**	1.32
FBL	F	0.001 ± 0.003	0.000 ± 0.001	0.75	−0.001	0.002	0.46	0.45	0.001 ± 0.005	0.000 ± 0.002	1.27	−0.001	0.003	0.21	0.26
	M	0.001 ± 0.002	0.003 ± 0.006	−1.98	−0.004	0.000	0.054	0.45	0.001 ± 0.003	0.002 ± 0.004	−0.82	−0.003	0.001	0.42	0.28
	B	0.002 ± 0.005	0.001 ± 0.002	1.48	0.000	0.003	0.14	0.26	0.001 ± 0.004	0.001 ± 0.003	−0.05	−0.002	0.002	0.96	0
BBL	F	0.001 ± 0.003	0.000 ± 0.001	1.03	0.000	0.001	0.31	0.45	0.001 ± 0.003	0.002 ± 0.006	−1.41	−0.004	0.001	0.17	0.21
	M	0.004 ± 0.006	0.004 ± 0.009	0.03	−0.004	0.004	0.98	0	0.004 ± 0.007	0.005 ± 0.008	−0.56	−0.005	0.003	0.58	0.13
	B	0.003 ± 0.005	0.002 ± 0.004	0.77	−0.001	0.003	0.45	0.22	0.003 ± 0.005	0.002 ± 0.004	0.98	−0.001	0.003	0.33	0.22

Note: ST: stroke technique; BP: ball placement; SH: same-handedness match; OH: opposite-handedness match; FLD: forehand loop or drive; BLD: backhand loop or drive; FBL: forehand block or lob; BBL: backhand block or lob; F: forehand area; M: middle area; B: backhand area.

4. Discussion

The aim of this study was to discover the technical-tactical skills at the operational level that differentiated the scoring efficiency of two table tennis match types formed by the differences in the interrelationship within the competitors' handedness (SH match: same-handedness match and OH match: opposite-handedness match). A two-dimensional variable (stroke technique and ball placement) of the point-winning shot was employed to make comparisons using Student's *t-test*. The results confirmed the hypothesis that there were technical-tactical actions in both rounds of each of the three interactive phases that would significantly impact the scoring effect when players competed against opponents with different racket handedness.

Typically, the technical-tactical variables used for table tennis performance assessment have been single dimensional and analyzed separately (e.g., stroke technique used, ball placement applied, ball flight route employed) [1,2,7,12,13,19]. However, those technical-tactical elements together have a collective effect on the quality of a stroke and consequently affect the performance outcome. The two-dimensional technical-tactical indicator employed in the present study could provide coaches and players with a further in-depth understanding of elite players' performance to expand their professional knowledge about the detailed patterns of play to gain a positive performance result. Moreover, the evaluation index of scoring efficiency applied in this study enables practitioners to compare the contribution to winning a point of all the technical-tactical actions in each interactive phase of a rally.

The mutual restriction phase is the first section of a rally, in which the major tactical intension of both players is to seek opportunities to launch a powerful initial attack or to decrease the opponent's initial attack quality to secure an effective counterattack [4]. During this phase, the results showed that the point-winning efficacy of serve was the highest among all the methods of technical-tactical employment for the server of both match types, with the ball placement used being in the same order (middle > forehand > backhand). This finding agrees with the conclusions of former studies that serve, being the only nonrestrictive stroke technique, brings the server a certain amount of advantage over the receiver in the early stage of a rally [7,15,18]. Therefore, players should still attach great importance to service training despite the implementation of the rule of nonsheltered service, which has impaired the positive influence of serve on scoring a point.

Executing a forehand short push stroke to the forehand side in the service round, as well as performing a backhand long push stroke to the opponent's backhand in the receiving round, when players competed against a same-handedness opponent, could significantly increase the scoring probability in the first phase compared to playing with an opposite-handedness rival. For preparing for a match against an opposite-handedness rival, a high-quality backhand short push to middle in the receiving round during a control game could apparently enhance the scoring ratio. These findings remind coaches and players to emphasize the training of the corresponding patterns of play to gain an upper hand within the first few shots of a rally before either side seeks to execute an attack according to the opponent's handedness.

The initial attack and counterattack phase has been empirically proven to be the crucial juncture of a rally for singles matches played between elite male table tennis players by Yu and Gao [4], in which a significantly large proportion of rally outcome (63.6%) was produced. Moreover, Fuchs and Lames [23] also confirmed that the first offensive shot was the central phase of a rally for elite men's singles matches, in which the majority of rallies analyzed were terminated by the direct impact of this shot regardless of the technique used.

A previous investigation [19] analyzed the possible stroke techniques that were applied by players using different handedness to return balls on the second and the third shots of rallies. The majority of shot types chosen by elite male players using both handedness to attack were top and flick, which is in line with the present study. Reviewing the data of the study results, it was the phase in which most of the scoring efficiency differences occurred between the specific technical-tactical actions of the two match types. Looking at the information provided by the study results, the capability of hitting both a crosscourt shot of an initial attack using a forehand loop or drive and a counterattack shot using a backhand loop or drive should be highlighted in the training regardless of the rival player's handedness and the rounds that these strokes are going to be performed. However, there were a few specific manners for initiating an attack that should be stressed separately in the formulation of the practice plan and competition strategy.

The ideal way to win a point in this phase in a same-handedness match compared to the other match type (OH) was to apply a forehand flip to carry out an initial attack on the opponent's forehand side of the table in both types of rounds. This phenomenon can be explained by the study result of Malagoli Lanzoni et al. [19], in which the occurrence of flicks in the second and third shots of a rally in a same-handedness matchup is significantly higher than that in an opposite-handedness matchup. Additionally, being able to perform a forehand block or lob to the backhand placement to return an opponent's initial attack in the service round could also result in a significantly positive rally outcome ratio when players competed against a same-handedness rival. For matches played between competitors using different racket handedness, implementing the first attack of a rally using a forehand flip to the opponent's backhand and a backhand loop or drive to the opponent's forehand in the service round, as well as employing a backhand flip to the middle placement in the receiving round, would apparently increase the scoring efficiency.

These findings verify the conclusions of the former studies of Yu and Gao [4] and Fuchs and Lames [23] and once again remind practitioners of the strategic importance of the shot of initial attack in table tennis competitions, as it is a special shot that greatly perturbs the stability of a rally and leads to high probability of rally cessation [4,23]. Furthermore, coaches and players are advised to prioritize the training of technical-tactical abilities for initiating an attack or countering an opponent's first attack and to refer to the results of the current study to refine the crucial skills to increase the likelihood of achieving a winning shot at this stage of a rally when competing against opponents using different handedness.

The typical shot exchange mode for the third phase (namely, the topspin exchange phase or the stalemate phase) of a rally is straightforward, in which players alternatively hit offensive shots back and forth to compel an opponent's stroke error [4,10,18]. Examining the relative results within this study, the distinctions concerning the key point-winning stroke execution manners between

the two match types were noticeable. Executing a forehand loop or drive to the opponent's backhand during the topspin ball exchange in both rounds of a match played between two different-handedness rivals was the pivotal technical ability to strike a winner. However, for the same-handedness match, hitting a backhand loop or driving to the competitor's backhand in both rounds and performing a forehand loop or driving to the opponent's forehand in the service round were the equivalent capacities that athletes ought to grasp to gain advantages over the opponent. These findings were in line with the study of Yu et al. [18], in which a different sample of elite men's singles matches was analyzed. With further confirmation of the current study on the scoring effect of the abovementioned technical-tactical operations in the corresponding match type, coaches should make players better aware of that and highlight their practice in training sessions.

The main contribution of this study is that it obtains the technical-tactical skills on the specific operational level that would affect the point-scoring effectiveness when players encounter opponents using different racket hands. Thus, it provides useful information for professionals to formulate targeted and precise training plans based on the preconditional setting of a table tennis matchup that naturally determines its technical-tactical features. Despite the merits of the current study, there are also some limitations that need to be noted. The findings were limited to training practice and competition strategy for encounters between two male attackers (among contemporary elite male table tennis players, attacking style of player refers to shake-hands grip or pen-hold grip two-wing attacker). Matchups including two defensive styles of players (choppers) or one attacker and one chopper are not suitable for applying the results of the present study. Moreover, as the scoring efficiency of the technical-tactical skills are merged for the same type of matchup according to the handedness between competitors, the findings of the current study are relatively generalized, and specific cases for players on either side using a certain racket-hand may deviate from the study results.

5. Conclusions

In conclusion, the current study compared the point-winning shots during the three interactive phases of a rally of both the service round and the receiving round between two match types (same-handedness match and opposite-handedness match) of elite men's singles matches. The results confirmed the hypothesis that specific technical-tactical skills existed in each type of round for all three interactive phases that would differentiate players' scoring efficiency when competing in matchups with different combinations of competitors' handedness. Table tennis practitioners are suggested to concentrate on enhancing the ability of performing the following technical-tactical strokes: (1) for matchups of players of the same handedness, a forehand short push to forehand during service rounds and a backhand long push to backhand during receiving rounds in the mutual-restriction phase; an initial forehand flip and a loop (drive) to forehand, a counter backhand loop (drive) to backhand in both types of rounds, and a forehand block (lob) to forehand in service rounds during the initial-attack-and-counterattack phase; a forehand loop (drive) to forehand in service rounds and a backhand loop (drive) to backhand in both types of rounds during the topspin-exchange phase. (2) for matchups of competitors with opposite handedness, a backhand short push to middle in receiving rounds during the mutual-restriction phase; an initial forehand loop (drive) to backhand and a counter backhand loop (drive) to forehand in both types of rounds, an initial forehand flip and a loop (drive) to backhand in service rounds, and an initial backhand flip to middle in receiving rounds during the initial-attack-and-counterattack phase; a forehand loop (drive) to backhand in both types of rounds during the topspin-exchange phase. The findings offer precise guidance for coaches and players to formulate targeted training plans and match tactics according to the rival's handedness to achieve more successful performance.

Author contribution statement

Jiangchuan Yu: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data were notated from the public video-broadcast websites by analysts.

Declaration of interest's statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2023.e13307.

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