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Research article

Technical and Tactical Actions of the World's Leading Male Table Tennis Players Between 1970 and 2021

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Abstract
This research aimed to determine the quantitative and qualitative structure of winning systems of the world's leading male table tennis players between 1970 and 2021. The study used the Wu game analysis method, modified by the authors, which consists of observing the game from playback, identifying the winning actions of a given player, and sorting and counting the actions, depending on the accuracy of the observation. The project identified all World Championships and Olympic Games medallists, resulting in 244 men's matches being analyzed. Three time periods were considered based on the ball used, including the 38 mm celluloid ball, 40 mm celluloid ball, and 40 mm plastic ball. Differences in the level structure, depending on the observation period, were assessed using the chi-squared test of independence. The Pearson contingency coefficient was calculated, and multiple comparisons were made. The research showed that the use of combinations changed slightly with changes in ball size and material. The first three strokes were very important in all periods. However, the importance of serves as direct scoring strokes decreased. These findings may be related to changes in the size and material used for ball production. The most winning serves in the game of the top men were side-spin forehand serves, which were also used most often during 3rd-ball-attack winning combinations. The number of actions won directly with a return, and in the return-counterattack combination, accounted for, and still constitute, about 30%, with an increasing number of backhand flicks. The research also showed an increase in the use of backhand strokes compared to forehand strokes. These findings should be considered when creating basic goals in table tennis training plans.

Key words: Table tennis, game analysis, technical and tactical actions.

Introduction

Table tennis is one of the world's most popular sports and is practiced by around 300 million people (Gu et al., 2019). It has been shown to be the best sport for brain development, a sport for everyone, and for life (Amen, 2010). Various aspects of table tennis are the subject of numerous studies. For example, some research concerns game theory (Chen and Su, 2015), anthropometry (Djokic et al., 2017; Pradas et al., 2021), exercise physiology (Kondric et al., 2008; 2013), the type of load during the game (Zagatto et al., 2010), sports medicine (Kondric et al., 2010), regeneration (Videmšek et al., 2007), motor skills, and physical training (Malik, 2004).

Table tennis is a sport in which technique plays an important role (Wu, 2017; Faber, 2016). It is one of the fastest ball games in the world, where the player requires technical, tactical, mental, and physical skills (Faber, 2016). Requirements for motor, mental, technical, and tactical fitness, among others, have undoubtedly changed over the past decades. The evolution of equipment (more and more advanced technologies) and changes in the regulations, such as the size and weight of the ball, restrictions on rubbers, the length of a set (up to 11 before 2001 to 21), restrictions on gluing, and preparing rubbers, were developed. These changes likely had an impact on the course of the game and the solutions used by the players. Therefore, finding answers to questions on which specific tactical and technical activities were most effective and how the game has evolved over the period mentioned above in terms of elite table tennis performance is paramount.

Observing and analyzing player behaviors and actions is a critical aspect of training optimization in table tennis. Numerous studies draw attention to various technical and tactical aspects of the game, such as the length of the action, the importance of service actions, return actions, and errors (Malagoli Lanzoni et al., 2014). The literature on table tennis game analysis unanimously states that its structure comprises three phases, including (1) serve-and-counterattack, (2) return-and-counterattack, and (3) counterattack (long actions and stalemate), which are mostly based on the Wu game analysis method (Liu and Tang, 2015; Zhou and Zhang, 2022). This approach uses a player's last stroke in each rally as an observation unit.

Based on the method described above, a more in-depth analysis of the strokes used by the players, especially their combinations, shows, however, that particular technical and tactical actions can be distinguished, defined as technical-tactical combinations (combinations for score and game pieces). These technical-tactical actions include serve-and-counterattack, return-and-counterattack, attack-and-counterattack, defense-and-counterattack, push-and-counterattack, and chop-and-counter, and can build an overall game (Grycan, 2007). Game elements defined in this way (defined as Level 1) can be further analyzed in more detail as specific actions, such as stroke and counterattack (e.g., side-back-spin forehand-serve and counterattack, Level 2), and even more precisely as combinations of strokes that involve two specific consecutive strokes (e.g., side-back-spin-forehand-serve and forehand-topspin, Level 3). Such detailing allows for a very accurate and reliable analysis of a table tennis player's game (Grycan et al., 2022).

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It is challenging to find studies in the literature on game analysis that provide a detailed description of the strokes and combinations of strokes used by the world's leading players to win a point, such as specific serves or returns or combinations of service and attack. Therefore, performing further quantitative research is of particular interest as it can provide coaches and players with information on the most common combinations of strokes and technical and tactical actions used by the best players in the world. Indeed, they indicate current and new trends and the most effective solutions for full or partial implementation of player training plans.

Table tennis has evolved and changed over more than a century. In the "small celluloid ball period" to 2000, Li (2009) lists eras of defense (1920 - 40), penhold grip forehand topspin (1950s), and fast attack (1960s - 70s), and the development of double-sided topspin attack during the 80's and 90's. In the 1970s, all major play types/styles appeared related to the development of smooth rubbers, short pimples, anti-spin, and long pimples (Zhang, 2008). Between 1970 and 2000, the International Table Tennis Federation (ITTF) introduced several rule changes to simplify the game, such as a ban on serving from behind the back and a black and red rubber introduction. A critical event in this period was the addition of table tennis to the program of the Olympic Games in 1988. During the "big celluloid ball period" from 2001 to 2015, some significant changes were introduced, including a 40 mm celluloid ball, behind-the-elbow-serving, a ban on fresh rubber glue, an 11-point set play, and the use of water glue. Li (2009) discussed the series of structural changes to the game, which he called "irrational aggressiveness." Such an aggressive play strategy should include, but not be limited to: aggressive and relentless serve-and-three-ball-attack, return-and-counter-attack aimed at taking the initiative, more variety, and counterattack; in attack-and-counterattack, attack first with greater force and change direction first; in defense-and-counterattack, aggressively press the opponent and look for every opportunity to counterattack while maintaining stroke confidence.

In any play style, you should make the most of your strengths. In 2008, the backhand game was developed based on the premise of "irrational aggressiveness." According to Persson (2018), backhand play became the key to success, and playing to 11 points leads to more offensive tactics. Outstanding research on the world's leading players shows that in games between Zhang Jike and Ma Long, the quality of the first three strokes was decisive (Lei et al., 2015). Fang Bo's analysis demonstrated, among other things, the need to improve the quality of serve-and-counterattack and backhand defense (Zhang and Tang, 2015). Fuchs and Lames (2015) examined the games of top players and found that the average rally length was shorter for men than for women.

In the big plastic ball period between 2016 and 2021, many changes took place in the game, such as the ball having less spin, increased stroke variability, and emphasis on the importance of fast play and physical preparation (Persson, 2018). According to Shen (2019), the proportions of strokes used changed slightly, with a reduction in topspin from 45% to 42%, an increase in the use of push from 9% to 14%, a decrease in long returns from 18% to 9%, and an increase in the half-long return from 47% to 54%. Shen (2019) also stated that game complexity had increased. At the same time, the share of long serves in the game had increased. Moreover, Japanese researchers (Inaba et al., 2017) found that technique and tactics have not changed much, but the quality of game technique has significantly decreased, with Lee et al. (2019) drawing similar conclusions.

Zhou's research (2019) confirmed that the first three strokes are decisive when playing with a plastic ball. During the "plastic ball period," Ma Long emerged to be the most dominant player. At the same time, it seems that the strokes of the best players were quite diverse, notably among the Chinese, especially Fan Zhendong and Xu Xin. Examination of Ovtcharov's games against the top four Chinese players found that the latter had a clear advantage. Concurrently, he discovered that perfecting the first four strokes (serve-and-counter and return-and-counter) led to a relatively high chance of playing successfully against Zhang Jike and other Chinese players (Straub, 2016). Numerous studies by Djokic (2002; 2017) and Djokic et al. (2017; 2020) on the serve-and-counterattack and return-and-counterattack of the top European players confirmed the importance of the first three strokes.

Answering the question of which technical-tactical actions ensure points coring in table tennis appears critical and is of particular practical importance for the training of high-class players and coaches, especially at the initial training stage (Grycan, 2017; 2019). Elements of play, strokes, and stroke combinations (i.e., technical-tactical actions) are the most critical building blocks of any training program for players and coaches. As such, knowledge about what was most important in the game of the greatest table tennis champions in the world seems to be particularly attractive to anyone looking for their optimal path to mastery.

Through conducting constant observation and analysis of the gameplay of players at the highest level and studying the existing literature, this work assumed that the structure of winning systems had changed slightly in all parts of the game over the last 50 years, and the differentiating factor could be the changes to the ball and equipment used. Every part of the game (every tactical combination) has its role in every period, but the most important periods are probably the first shots: serve-and-return and the subsequent attack. Another change assumed to be crucial relates to the use of the serve, with numerous rule changes evolving from unreadable to more and more readable, and the expectation that winning directly from a serve became increasingly difficult.

In order to test the above hypotheses, the present research aimed to determine the winning technical and tactical actions of the world's leading table tennis players between 1970 and 2021 and assess changes in the quantitative and qualitative structure of these actions over time depending on the type of ball used in the game.

Methods

Study design and procedures

The study used the Wu game analysis method, modified by the authors, which is described in a previous study (Grycan et al., 2022). The method consists of observing the game from playback (video, YouTube, and others), counting the winning actions of a given player, and sorting and identifying the actions, depending on the accuracy of the observation. The analyzed technical-tactical actions were the last winning stroke (in the case of a service or a return) or a combination of the two last strokes and included three levels of observation. Observation and counting at Level 1 involved identifying ten winning combinations, such as service, return, return-and-counterattack, and attack-and-counterattack (Table 2). At Level 2, the first stroke type from the combination and their number within the identified combinations were then determined and included 61 types, such as stroke-and-counterattack, topspin, forehand-and-counterattack, and push and forehand-and-counterattack (Table 3). The last and most detailed level, Level 3, determined and counted the final hits in the combination, which included over 400 possible combinations, such as push forehand-and-topspin forehand, and fast attack forehand-and-topspin forehand (Table 4).

We considered an attack as all fast attacking or topspin attacking strokes, including attacking short balls and flicks. However, to be more specific, we also separated fast attacking strokes from topspin attacking strokes. Fast attacking strokes (shortly: fast attack) are strokes with speed and no to medium spin that are a close-to-the-table attack, off-the-table attack, smash, smashing-backspin-ball, killing the lob, and flicks. Topspin attacking strokes (shortly: topspin) are strokes with high topspin and medium to high speed that are a high-spin-loop, smashing-loop, side-spin-loop, reverse-side-spin-loop, or a fake-spin-loop. For blocking strokes, we consider all close-to-the-table defending strokes as fast-block, punch-block, side-spin-block, backspin-block, cushion-block, or topspin-block. We also considered an off-the-table-defending-strokes block as fishing and lobbing. Pushing strokes are considered strokes played close to the table against backspin balls with backspin and include slow push, fast push, drop-shot push, or side-spin push. Meanwhile, chopping strokes are all defending strokes with backspin rotation, like quick chop, slow chop, side-spin chop, chop against topspin, or chop against smash.

As a counterattack in various combinations, such as serve-and-counterattack, return-and-counter-attack, and attack-and-counterattack, we considered all possible rally-winning strokes. For example, the most winning serve-and-counterattack is serve-forehand-sidespin-counterattack. We also considered three types of rotation: topspin (forward rotation), backspin (backward rotation), and side-spin (sideward rotation). Method reliability (measured with Cronbach's alpha) was established at levels 0.7 - 0.99, depending on the observation level (Grycan et al., 2022).

Observations were carried out by the same person, one of the authors of this manuscript, who has over 40 years of table tennis coaching experience at the international level. A slow-motion function was used to identify the type of stroke, combination, rotation, etc. The data were collected and sorted manually.

Participants

The project identified all World Championships and Olympic Games medallists between 1970 and 2021. The finals and medal matches of the Olympic Games and World Championships individual and team events that were available on the internet were selected. In addition, in the absence of games by the best players, select games from other world events (World Cup, Asian Games, Continental Championships, and in a few cases other international and national competitions) were analyzed. Also, the best matches of representatives of each play type/style were searched for in each competition cycle and selected (Grycan, 2019). For example, we chose the best representatives (medallists of major events) of the shakehand grip and penhold grip, the topspin attack and fast attack, the chop defense, and the so-called combi-attack, in a given competition cycle. In total, 244 men's matches were analyzed. The period between 1970 and 2001 included 27 old-format 'best of 5' and 37' best of 3' completed matches, with 114 matches partially incomplete. Between 2002 and 2015, only two analyzed matches were incomplete, while all analyzed matches were completed from 2016 to 2021. In total, 128 matches of world competition medallists representing 22 countries were analyzed. In addition, some of the greatest matches of the best Polish representatives were selected. The detailed characteristics and number of players are presented in Table 1.

All material obtained was sorted into three subgroups based on the time division in accordance with changes in ball regulations. The following time periods were considered: (1) 1970 - 2000 (38 mm celluloid ball), (2) 2001 - 2015 (40 mm celluloid ball), and (3) 2016 - 2021 (40 mm plastic ball) (Inaba et al., 2017; Lee et al., 2019). There were 9300 recorded combinations in period one, 5410 in period two, and 4984 in period three (Table 2).

Statistical analysis

For individual game elements, on each level over three observation periods, the percentage frequencies of technical-tactical actions won were calculated. Differences in the level structure, depending on the observation period, were assessed with the chi-squared (χ^2) test of independence at a significance level of $\alpha = 0.05$. If the expected number was too small (< 5), the frequency of combinations was aggregated or not included in the analyses. In order to assess the relationship between the structure and the period of observation, the Pearson contingency coefficient was calculated with a correction for the size of the contingency table. For confirmed changes in the structure of game elements, multiple comparisons were made using the test for two proportions, with Bonferroni's correction used for the significance level. Therefore, the differences in the rate of wins of the analyzed combination between the observation periods were considered statistically significant at $p < 0.017$. The magnitude of the effect of the difference was assessed by Cohen's h after the arc transformation of the proportion, assuming for $0.20 \leq |h| < 0.50$: small effect size, for $0.50 \leq |h| < 0.80$: medium effect size, and for $|h| \geq 0.80$: large

effect size. Values of h < 0 meant a decreased frequency, and h > 0 meant an increased frequency of winning actions over time. In summary, the following data and variables were ana-lyzed: (1) percentage frequencies of winning technical-tactical actions, (2) χ^2 - to determine the difference in the structure of these actions between periods, (3) corrected contingency coefficient (Ccorr) - to establish the relationship between the structure and the period of observation, and (4) Cohen's h – to assess the effect size.

Table 1. Characteristics of analysed players.

The style of the play	The best Champions (Total Number of analysed matches)	Number of analysed players/ Number of left handed players	Number of analysed players/Number of Olympic Champions in singles/Number of World Champions in singles			
			CHINA	ASIA (without China)	EUROPE	OTHER
Fast attack shakehand	Teng (5), Falk (7)	7/1	3/0/0	4/0/0	1/0/0	1/0/0
Fast attack penhold	Kohno (5), Jiang (12), Liu (12)	13/3	9/1/5	2/0/1	1/0/0	0
Topspin attack both sides shakehand	Jonyer (5), Kong (11), Zhang (11)	46/16	6/2/2	9/0/0	29/0/3	2/0/0
Topspin fh+Attack bh shakehand	Waldner (26), Persson (16), Wang LQ (10),Ma Long (33)	27/4	8/2/7	3/0/1	16/1/4	0
Topspin+Attack penhold	Yoo (4), Ryu (5), Ma Lin (15), Wang Hao (11)	20/7	8/1/4	9/2/3	2/0/0	1/0/0
Combi Attack	Cai (4), Lo (3)	5/2	1/0/0	1/0/0	2/0/0	1/0/0
Chop defence	Chen (4), Ding (7), Joo 10)	16/0	7/0/0	5/0/0	4/0/0	0

Table 2. Differences between win rates for Level 1 game elements observed over three periods.

Level 1	1970-2000 (1)	2001-2015 (2)	2016-2021 (3)	(1) vs. (2)		(1) vs. (3)		(2) vs. (3)		χ^2	P<	C_{corr}
	n=9300	n=5410	n=4984	h-Cohen	p*	h-Cohen	p*	h-Cohen	p*			
1. Serve	12.52%	9.63%	8.27%	-.092	<.001	-.140	<.001	-.048	.015			
2. Serve+Counterattack	19.88%	21.16%	20.47%	.032	.062	.015	.407	-.017	.381			
3. Return	16.20%	14.36%	15.13%	-.051	.003	-.030	.093	.022	.271			
4. Return+Counterattack	12.06%	14.71%	14.39%	.078	<.001	.069	<.001	-.009	.636			
5. Attack+Counterattack	17.14%	17.01%	16.35%	-.004	.835	-.021	.231	-.018	.372			
6. Block+Counterattack	9.87%	7.43%	7.54%	-.087	<.001	-.083	<.001	.004	.826	372.9	.001	.154
7. Push+Counterattack	3.20%	4.64%	8.55%	.074	<.001	.133	<.001	.159	<.001			
8.Attack-against-chop+Counterattack	2.92%	4.71%	4.01%	.094	<.001	.060	.001	-.034	.081			
9. Chop+Counterattack	2.26%	3.18%	2.25%	.057	.001	-.001	.967	-.058	.004			
10. Other	3.94%	3.16%	3.05%	-.042	.016	-.048	.007	-.006	.744			

h-Cohen – the value of h Cohen indicator (effect size), p* - statistical significance at p<0.017, χ^2 – the value of chi-square test, p – the significance of χ^2 test, C_{corr} - corrected contingency coefficient.

Table 3. Differences between the frequencies of won actions with different types of plays (Level 2) of game fragments (Level 1) observed in three periods.

Level 1 Level 2	1970-2000 (1)	2001-2015 (2)	2016-2021 (3)	(1) vs. (2)		(1) vs. (3)		(2) vs. (3)		χ^2	P<	C_{corr}
				h-Cohen	p*	h-Cohen	p*	h-Cohen	p*			
1. Serve	**n=1164**	**n=521**	**n=412**									
1.1. Serve fh sidespin	23.45%	46.64%	65.05%	.492	<.001	.865	<.001	.373	<.001			
1.2. Serve fh backspin-no-spin	60.14%	21.50%	14.32%	-.811	<.001	-.999	<.001	-.188	.005			
1.3. Serve bh sidespin	8.51%	3.84%	9.71%	-.197	.001	.042	.459	.239	<.001	513.0	.001	.518
1.4. Serve fh reverse	2.58%	15.16%	6.55%	.477	<.001	.195	<.001	-.282	<.001			
1.5. -1.10 other	5.33%	12.86%	4.37%	0268	<.001	-.045	.447	-.312	<.001			
2.Serve+Counterattack-attack	**n=1849**	**n=1145**	**n=1020**									
2.1. Serve fh sidespin+Counter-attack	21.90%	43.41%	60.20%	.464	<.001	.802	<.001	.338	<.001			
2.2.Serve fh backspin-no-spin+Counterattack	60.36%	25.59%	18.92%	-.719	<.001	-.879	<.001	-.161	<.001			
2.3. Serve bh sidespin+Counter-attack	7.36%	6.11%	7.75%	-.050	.192	.015	.705	.064	.135	782.7	.001	.472
2.4. Serve fh reverse+Counterat-tack	2.16%	12.31%	7.45%	.422	<.001	.258	<.001	-.164	<.001			
2.5 - 2.10. other	8.22%	12.58%	5.69%	.143	<.001	-.100	.013	-.243	<.001			

h-Cohen – the value of h Cohen indicator (effect size), p* - statistical significance at p<0.017, $\chi 2$ – the value of chi-square test, p – the significance of $\chi 2$ test, C_{corr} - corrected contingency coefficient

Table 3. Continue…

Level 1 Level 2	1970-2000 (1)	2001-2015 (2)	2016-2021 (3)	(1) vs. (2) h-Cohen	 p*	(1) vs. (3) h-Cohen	 p*	(2) vs. (3) h-Cohen	 p*	χ^2	P<	C_{corr}
3. Return	**n=1507**	**n=777**	**n=754**									
3.1. Push fh	28.14%	30.76%	24.54%	.058	.191	-.082	.069	-.139	.007			
3.2. Topspin and Fast attack fh	29.66%	21.11%	13.13%	-.197	<.001	-.410	<.001	-.213	<.001			
3.3. Push bh	15.99%	12.61%	15.92%	-.097	.031	-.002	.962	.095	.065			
3.4. Flick bh	3.85%	16.22%	24.54%	.434	<.001	.642	<.001	.208	<.001	352.3	.001	.369
3.5. Flick fh	12.61%	11.58%	4.38%	-.031	.479	-.304	<.001	-.273	<.001			
3.6. Topspin and Fast attack bh	4.71%	5.92%	11.94%	.054	.215	.268	<.001	.214	<.001			
3.7. - 3.10 other	5.04%	1.80%	5.57%	-.184	<.001	.024	.595	.207	<.001			
4. Return+Counterattack	**n=1122**	**n=796**	**n=717**									
4.1.Push fh+Counterattack	38.15%	48.74%	38.49%	.214	<.001	.007	.881	-.207	<.001			
4.2. Push bh+Counterattack	22.55%	21.86%	29.29%	-.017	.721	.154	.001	.171	.001			
4.3. Topspin-fh+Counterattack	14.97%	8.79%	3.91%	-.193	<.001	-.397	<.001	-.204	<.001			
4.4. Flick-fh+Counterattack	11.59%	5.90%	3.07%	-.204	<.001	-.343	<.001	-.139	.008	247.2	.001	.322
4.5. Flick bh+Counterattack	2.85%	8.04%	14.23%	.236	<.001	.434	<.001	.198	<.001			
4.6. Topspin-bh+Counterattack	2.67%	3.39%	5.44%	.042	.362	.142	.002	.100	.052			
4.7. Chop-bh+Counterattack	1.96%	.88%	2.51%	-.093	.056	.037	.431	.130	.013			
4.8.Fast attack-bh+Counterattack	1.69%	.88%	2.65%	-.073	.129	.066	.160	.139	.008			
4.9-4.12 other	3.57%	1.51%	0.42%	-.134	.006	-.250	<.001	-.117	.033			
5. Attack+Counterattack	**n=1594**	**n=920**	**n=815**									
5.1. Topspin-fh+Counterattack	48.37%	61.30%	47.85%	.261	<.001	-.010	.810	-.271	<.001			
5.2.Fast attack-bh+Counterattack	15.75%	8.26%	22.58%	-.233	<.001	.174	<.001	.407	<.001			
5.3.Fast attack-fh+Counterattack	18.19%	5.98%	9.45%	-.387	<.001	-.256	<.001	.131	.007	187.9	.001	.267
5.4. Topspin-bh+Counterattack	13.36%	18.26%	14.48%	.135	.001	.032	.452	-.102	.034			
5.5. Flick-Fh+Counterattack	3.64%	3.59%	2.82%	-.003	.947	-.046	.293	-.044	.368			
5.6. Flick-bh+Counterattack	.69%	2.61%	2.82%	.158	<.001	.171	<.001	.013	.785			
6. Block+Counterattack	**n=918**	**n=402**	**n=376**									
6.1. Block-bh+Counterattack	66.78%	67.41%	66.49%	.014	.821	-.006	.921	-.020	.784			
6.2. Block-fh+Counterattack	15.25%	15.92%	13.56%	.018	.757	-.048	.438	-.067	.355			
6.3. „Fishing"-bh+Counterattack	11.44%	7.46%	6.65%	-.137	.028	-.168	.009	-.032	.658	29.3	.001	.142
6.4. „Fishing"-fh+Counterattack	5.34%	7.46%	12.50%	.087	.134	.256	<.001	.169	.019			
6.x. Lob+Counterattack	1.20%	1.74%	.80%	.045	.434	-.040	.527	-.086	.243			
7. Push+Counterattack	**n=298**	**n=251**	**n=426**									
7.1. Push-bh+Counterattack	44.63%	49.00%	38.26%	0.088	0.307	-0.129	0.087	-0.217	.784	7.9	.019	.118
7.2. Push-fh+Counterattack	55.37%	51.00%	61.74%	-0.088	0.307	0.129	0.087	0.217	.355			
8.Attack-against-chop+Counterattack	**n=298**	**n=251**	**n=426**									
8.1. Aac-Topspin-fh+Counterattack	83.82%	89.41%	90.00%	0.165	0.061	0.184	0.053	0.019	.784			
8.2. Aac-Topspin-bh+Counterattack	4.41%	8.24%	6.50%	0.159	0.071	0.092	0.317	-0.067	.355	25.8	.001	.227
8.3. -8.4 other	11.76%	2.35%	3.50%	-0.392	<0.001	-0.324	0.001	0.068	.355			
9.Chop+Counterattack	**n=210**	**n=172**	**n=112**									
9.1. Chop-bh+Counterattack	69.05%	81.98%	85.71%	0.303	0.004	0.405	0.001	0.102	0.408	14.8	.001	0.223
9.2. Chop-fh+Counterattack	30.95%	18.02%	14.29%	-0.303	0.004	-0.405	0.001	-0.102	0.408			
10. Other	**n=366**	**n=171**	**n=152**									
10.1. 'Net' or 'edge'	57.10%	76.02%	76.32%	0.405	<0.001	0.412	<0.001	0.007	0.951			
10.2. Opponent's serve fault	40.71%	23.39%	21.71%	-0.374	<0.001	-0.415	<0.001	-0.040	0.719	28.7	.001	.245
10.3. -10.5 other	2.19%	0.58%	1.97%	-0.144	0.179	-0.015	0.879	0.129	0.261			

h-Cohen – the value of h Cohen indicator (effect size), p* - statistical significance at p<0.017, $\chi 2$ – the value of chi-square test, p – the significance of $\chi 2$ test, C_{corr} - corrected contingency coefficient

Table 4. **Differences between the frequencies of winning actions with combinations (Level 3) of plays (Level 2) observed in three periods.**

Level 1 Level 2 Level 3	1970-2000 (1)	2001-2015 (2)	2016-2021 (3)	(1) vs. (2)		(1) vs. (3)		(2) vs. (3)		χ^2	P<	C_{corr}
				h-Cohen	p*	h-Cohen	p*	h-Cohen	p*			
1. Serve												
1.1.Serve fh sidespin	**n = 273**	**n = 243**	**n = 268**									
Long-backspin	10.26%	6.58%	13.43%	-.133	.137	.099	.253	.232	0.011			
Long-topspin	10.26%	9.88%	11.19%	-.013	.886	.030	.725	.043	0.629			
Short-backspin	34.07%	47.33%	31.72%	.271	.002	-.050	.561	-.321	<0.001	20.4	.009	.186
Short-topspin	25.27%	19.34%	27.24%	-.143	.108	.045	.604	.187	0.036			
Rapid	20.15%	16.87%	16.42%	-.084	.341	-.097	.263	-.012	0.890			
1.2.Serve fh backspin-nospin	**n = 700**	**n = 112**	**n = 59**									
Long-backspin	17.00%	11.61%	16.95%									
Long-nospin	16.43%	9.82%	15.25%									
Short-backspin	32.43%	43.75%	42.37%							12.9	.117	.141
Short-nospin	17.43%	21.43%	16.95%									
Rapid	16.71%	13.39%	8.47%									
1.3.Serve bh sidespin	**n = 99**	**n = 20**	**n = 40**									
Long-backspin	7.07%	25.00%	10.00%	.509	.017	.105	.563	-.404	.130			
Long-topspin	8.08%	15.00%	22.50%	.219	.332	.412	.020	.193	.496			
Short-backspin	28.28%	20.00%	40.00%	-.194	.448	.248	.181	.442	.127	13.8	.032	.358
Short-topspin	39.39%	20.00%	27.50%	-.430	.102	-.253	.188	.177	.529			
Rapid	17.17%	20.00%	0.00%									
1.4. Serve fh reverse	**n = 99**	**n = 20**	**n = 40**									
Long-backspin	23.33%	13.92%	14.81%									
Long-topspin	16.67%	7.59%	14.81%									
Short-backspin	30.00%	41.77%	33.33%							9.8	.279	.303
Short-topspin	13.33%	30.38%	22.22%									
Rapid	16.67%	6.33%	14.81%									
2. Serve+Counterattack												
2.1.Serve-fh-sidespin+Counterattack	**n = 405**	**n = 497**	**n = 614**									
2.1.1.Serve-fh-sidespin+Topspin-fh	48.64%	50.91%	47.23%	.045	.499	-.028	.659	-.074	.223			
2.1.2. Serve-fh-sidespin+Attack-bh	5.68%	6.64%	17.10%	.040	.552	.371	<.001	.331	<.001			
2.1.3.Serve-fh-sidespin+Topspin-bh	10.37%	10.06%	7.33%	-.010	.878	-.107	.089	-.097	.106			
2.1.4.Serve-fh-sidespin+Push-fh	2.22%	8.65%	9.28%	.298	<.001	.320	<.001	.022	.715			
2.1.5. Serve-fh-sidespin+Block-bh	9.38%	7.04%	5.21%	-.085	.200	-.162	.010	-.077	.203	174.0	<.001	.364
2.1.6. Serve-fh-sidespin+Attack-fh	15.31%	3.82%	1.95%	-.410	<.001	-.523	<.001	-.113	.060			
2.1.7. Serve-fh-sidespin+Flick-fh	2.96%	3.42%	6.51%	.026	.698	.170	.012	.144	.020			
2.1.8.Serw-fh-sidespin+Push-bh	3.70%	5.43%	1.47%	.083	.221	-.145	.021	-.228	<.001			
2.1.9. - 2.1.11 other	1.73%	4.02%	3.91%	.140	.044	.134	.048	-.006	.922			
2.2. Serve fh backspin+Counterattack	**n = 1116**	**n = 293**	**n = 193**									
2.2.1.Serve-fh-backspin+Topspin-fh	50.63%	52.56%	36.79%	.039	.556	-.280	<.001	-.319	.001			
2.2.2. Serve-fh-backspin+Attack-bh	9.05%	8.19%	15.03%	-.031	.645	.185	.010	.216	.018			
2.2.3.Serve-fh-backspin+Topspin-bh	9.23%	7.17%	6.22%	-.075	.268	-.113	.173	-.038	.684			
2.2.4.Serve-fh-backspin+Push-fh	5.20%	8.53%	10.36%	.133	.031	.196	.005	.063	.496			
2.2.5. Serve-fh-backspin+Block-bh	6.54%	6.48%	4.15%	-0.002	0.972	-0.107	0.202	-0.105	0.271	66.1	<.001	.226
2.2.6. Serve-fh-backspin+Attack-fh	6.63%	2.05%	4.66%	-0.234	0.003	-0.086	0.301	0.148	0.103			
2.2.7. Serve-fh-backspin+Flick-fh	4.93%	6.14%	4.66%	.053	.404	-.012	.875	-0.066	0.486			
2.2.8.Serve-fh-backspin+Push-bh	3.85%	4.10%	4.66%	.012	.849	.040	.595	0.028	0.763			
2.2.9. - 2.2.11 other	3.94%	4.78%	13.47%	.041	.522	0352	<.001	0.311	0.001			
2.3. Serve bh sidespin+Counterattack	**n = 136**	**n = 70**	**n = 79**									
2.2.1.Serve-fh-backspin+Topspin-fh	40.44%	57.14%	46.84%	.336	.024	.129	.362	-0.207	0.211			
2.2.2. Serve-fh-backspin+Attack-bh	7.35%	18.57%	13.92%	.342	.016	.216	.119	-0.126	0.442	34.3	<.001	.389
2.2.3.Serve-fh-backspin+Topspin-bh	7.35%	10.00%	20.25%	.094	.514	.384	.006	0.290	0.086			
2.2.4.Serve-fh-backspin+Push-fh	44.85%	14.29%	18.99%	-.692	<.001	-.566	<.001	0.127	0.445			
2.4. Serve fh reverse+Counterattack	**n = 40**	**n = 141**	**n = 76**									
2.2.1.Serve-fh-backspin+Topspin-fh	45.00%	43.26%	32.89%									
2.2.2. Serve-fh-backspin+Attack-bh	35.00%	21.99%	21.05%							9.2	.057	.227
2.2.3.Serve-fh-backspin+Topspin-bh	20.00%	34.75%	46.05%									

h-Cohen – the value of h Cohen indicator (effect size), p* - statistical significance at p<0.017, $\chi 2$ – the value of chi-square test, p – the significance of $\chi 2$ test, Ccorr - corrected contingency coefficient.

Table 4. Continue…

Level 1 Level 2 Level 3	1970-2000 (1)	2001-2015 (2)	2016-2021 (3)	(1) vs. (2)		(1) vs. (3)		(2) vs. (3)		χ^2	P<	C_{corr}
				h-Cohen	p*	h-Cohen	p*	h-Cohen	p*			
4.Return+Counterattack												
4.1.Push fh+Counterattack	**n = 428**	**n = 388**	**n = 276**									
4.1.1. Push-fh+Topspin-fh	32.48%	43.56%	39.49%	.229	.001	.146	.057	-.082	.296			
4.1.2. Push-fh+Block-bh	22.90%	19.33%	13.77%	-.087	.213	-.238	.003	-.150	.061			
4.1.3. Push-fh+Topspin-bh	6.07%	10.57%	10.51%	.164	.020	.162	.033	-.002	.980			
4.1.4. Push-fh+Block-fh	12.85%	6.19%	2.90%	-.231	.001	-.391	<.001	-.161	.052			
4.1.5. Push-fh+Fast attack-bh	5.37%	1.80%	9.78%	-.198	.007	.168	.027	.367	<.001	102.7	<.001	.331
4.1.6. Push-fh+Fast attack-fh	5.37%	1.55%	4.71%	-.219	.003	-.030	.696	.188	.016			
4.1.7. Push-fh+Push-fh	1.87%	2.58%	7.97%	.048	.492	.298	<.001	.250	.001			
4.1.8. Push-fh+Push-bh	3.74%	3.61%	2.54%	-.007	.921	-.069	.381	-.062	.437			
4.1.9. Push-fh+Flick-bh	1.64%	2.58%	4.71%	.066	.347	.181	.017	.115	.139			
4.1.10. - 4.1.13 other	7.71%	8.25%	3.62%	.020	.777	-.180	.027	-.200	.016			
4.2. Push bh+Counterattack	**n = 428**	**n = 388**	**n = 276**									
4.2.1. Push-bh+Topspin-fh	26.09%	41.95%	39.52%	.337	.001	.288	.002	-.049	.630			
4.2.2. Push-bh+Block-bh	24.51%	17.82%	6.67%	-.164	.101	-.513	<.001	-.349	.001			
4.2.3. Push-bh+Topspin-bh	10.28%	9.77%	10.00%	-.017	.864	-.009	.922	.008	.940			
4.2.4. Push-bh+Block-fh	9.09%	9.20%	1.90%	.004	.971	-.336	.001	-.339	.001			
4.2.5.Push-bh+Push-bh	5.53%	5.17%	9.52%	-.016	.871	.153	.102	.169	.109			
4.2.6. Push-bh+Fast attack-bh	3.16%	1.72%	8.10%	-.094	.357	.219	.020	.314	.005	83.4	<.001	.385
4.2.7. Push-bh+Fast attack-fh	5.53%	2.87%	2.86%	-.134	.191	-.135	.159	-.001	.992			
4.2.8.Push-bh+Push-fh	1.19%	1.72%	9.05%	.045	.643	.393	<.001	.348	.002			
4.2.9.Push-bh+Push-bh	3.56%	4.02%	4.29%	.024	.804	.038	.687	.013	.898			
4.1.10. - 4.1.13 other	11.07%	5.75%	8.10%	-.194	.058	-.101	.283	.093	.371			
4.3.Topspin-fh+Counterattack	**n = 168**	**n = 70**	**n = 28**									
4.3.1. Topspin-fh+Topspin-fh	45.83%	58.57%	60.71%									
4.3.2. Topspin-fh+Fast attack-bh	23.21%	11.43%	14.29%							6.4	.168	.188
4.3.3. -4.3.5 other	30.95%	30.00%	25.00%									
4.4. Flick-fh+Counterattack	**n = 130**	**n = 47**	**n = 22**									
4.4.1. Flick-fh+Block-bh	30.77%	25.53%	9.09%	-.117	.500	-.563	.037	-.447	.118			
4.4.2. Flick-fh+Fast attack-fh	22.31%	27.66%	22.73%	.124	.461	.010	.965	-.114	.665	19.0	.004	.351
4.4.3. Flick-fh+Fast attack-bh	13.85%	25.53%	50.00%	.297	.069	.808	<.001	.511	.048			
4.4.4. - 4.4.5.6 other	33.08%	21.28%	18.18%	-.267	.132	-.344	.164	-.078	.767			
4.5.Flick bh+Counterattack	**n=32**	**n=64**	**n=102**									
4.5.1. Flick-bh+Topspin-fh	34.38%	29.69%	28.43%									
4.5.2. Flick-bh+Fast attack-bh	28.13%	20.31%	33.33%									
4.5.3. Flick-bh+Block-bh	15.63%	20.31%	21.57%							6.1	.407	.206
4.5.4. -4.6.6 other	21.88%	29.69%	16.67%									
4.6. Topspin-Attack bh+Counterat-tack	**n = 30**	**n = 27**	**n = 39**									
4.6.1. Topspin-bh+Topspin-fh	43.33%	59.26%	30.77%									
4.6.2. Topspin-bh+Topspin-bh	40.00%	14.81%	41.03%							7.9	.095	.338
4.6.3. Topspin-bh+other	16.67%	25.93%	28.21%									
4.7.Chop-bh+Counterattack	**n=22**	**n=7**	**n=18**									
4.7.1.Chop-bh+Chop-bh	50.00%	57.14%	38.89%							.84	.656	.174
4.7.x. Chop-bh+other	50.00%	42.86%	61.11%									
4.8.Attack-bh+Counterattack	**n = 19**	**n = 7**	**n = 19**									
4.8.1.Attack-bh+Fast Attack-bh	63.16%	71.43%	68.42%							.20	.903	.088
4.8.2.Attack-bh+Fast attack fh	36.84%	28.57%	31.58%									
5. Attack+Counterattack												
5.1.Topspin-fh+Counterattack	**n = 771**	**n = 564**	**n = 390**									
5.1.1.Topspin-fh+Topspin-fh	57.85%	75.00%	62.31%	.366	<.001	.091	.144	-.275	<.001			
5.1.2.Topspin-fh+Attack-bh	10.38%	4.79%	10.51%	-.215	<.001	.004	.943	.219	.001			
5.1.3.Topspin-fh+Attack-fh	10.38%	3.19%	6.92%	-.297	<.001	-.123	.055	.173	.008			
5.1.4.Topspin-fh+Topspin-bh	5.71%	6.74%	5.90%	.043	.439	.008	.895	-.035	.602			
5.1.5.Topspin-fh+Block-bh	6.87%	2.84%	5.64%	-.192	.001	-.051	.420	.141	.030			
5.1.6.Topspin-fh+Block-fh	3.76%	2.84%	3.33%	-.052	.355	-.023	.712	.029	.661	81.1	<.001	.239
5.1.7.Topspin-fh+ Fishing'-bh	1.95%	1.06%	.26%	-.073	.201	-.179	.020	-.105	.151			
5.1.8.Topspin-fh+Push-fh	.65%	1.60%	1.54%	.092	.094	.087	.140	-.005	.944			
5.1.9.Topspin-fh+Chop-bh	1.04%	1.06%	1.54%	.003	.963	.045	.460	.042	.518			
5.1.10.Topspin-fh+Push-bh	.65%	.71%	1.79%	.007	.894	.108	.068	.100	.123			
5.1.x.Topspin-fh+other	.78%	.18%	.26%	-.092	.133	-.075	.278	.017	.793			

h-Cohen – the value of h Cohen indicator (effect size), p* - statistical significance at p<0.017, $\chi 2$ – the value of chi-square test, p – the significance of $\chi 2$ test, Ccorr - corrected contingency coefficient.

Table 4. Continue…

Level 1 / Level 2 / Level 3	1970-2000 (1)	2001-2015 (2)	2016-2021 (3)	(1) vs. (2) h-Cohen	(1) vs. (2) p*	(1) vs. (3) h-Cohen	(1) vs. (3) p*	(2) vs. (3) h-Cohen	(2) vs. (3) p*	χ2	p	Ccorr
5.2.Attack-bh+Counterattack	**n = 251**	**n = 76**	**n = 184**									
5.2.1.Attack-bh+Attack-bh	34.66%	38.16%	56.52%	.073	.577	.443	<.001	.370	.008			
5.2.2. Fast attack-bh+Fast attack-fh	23.11%	10.53%	21.74%	-.342	.017	-0.033	.736	.309	.035	35.5	<.001	.303
5.2.3.Fast attack-bh+Topspin-fh	37.45%	47.37%	19.02%	.201	.123	-0.414	<.001	-.616	<.001			
5.2.x.Fast attack-bh+Others	4.78%	3.95%	2.72%	-.041	.761	-0.110	.273	-.069	.602			
5.3.Fast attack-fh+Counterattack	**n = 290**	**n = 55**	**n = 77**									
5.3.1. Fast attack-fh+ Fast attack-fh	83.10%	81.82%	67.53%	-.034	.817	-0.365	.003	-.332	.069			
5.3.2. Fast attack-fh+ Fast attack-bh	4.48%	7.27%	16.88%	.119	.381	0.420	<.001	.301	.107	16.5	.011	.230
5.3.3. Fast attack-fh+Block-bh	6.90%	5.45%	6.49%	-.060	.695	-0.016	.901	.044	.806			
5.3.x. Fast attack-fh+other	5.52%	5.45%	9.09%	-.003	.985	0.138	.251	.141	.438			
5.4.Topspin-bh+Counterattack	**n = 213**	**n = 168**	**n = 118**									
5.4.1. Topspin-bh+Topspin-fh	49.77%	48.81%	46.61%	-.019	.853	-0.063	.583	-.044	.714			
5.4.2. Topspin-bh+Topspin-bh	37.09%	38.10%	18.64%	.021	.841	-0.417	.001	-.437	<.001			
5.4.3. Topspin-bh+Attack-bh	4.23%	4.17%	22.03%	-.003	.977	0.563	<.001	.566	<.001	51.5	<.001	.357
5.4.4. Topspin-bh+Block-bh	2.35%	4.76%	8.47%	.132	.198	0.283	.011	.151	.204			
5.4.x. Topspin-bh+other	6.57%	4.17%	4.24%	-.107	.308	-0.104	.382	.004	.977			
5.5.Flick-Fh+Counterattack	**n = 58**	**n = 33**	**n = 23**									
5.5.1. Flick-fh+Topspin-fh	36.21%	48.48%	4.35%	.249	.255	-0.871	.005	-1.120	.001			
5.5.2. Flick-fh+Block-bh	22.41%	21.21%	17.39%	-.029	.894	-0.126	.618	-.097	.725	16.2	.013	.419
5.5.3. Flick-fh+Fast attack-bh	17.24%	9.09%	26.09%	-.244	.288	0.216	.370	.460	.094			
5.5.x. Flick-fh+other	24.14%	21.21%	52.17%	-.070	.751	0.587	.017	.657	.019			
5.6.Flick-bh+Counterattack	**n = 11**	**n = 24**	**n = 23**									
5.6.1. Flick-bh+Topspin-fh	36.36%	29.17%	34.78%									
5.6.2. Flip-bh+Fast attack-bh	27.27%	20.83%	43.48%							4.8	.313	.337
5.6.x. Flick-bh+other	36.36%	50.00%	21.74%									
6. Block+Counterattack												
6.1.Block-bh+Counterattack	**n = 613**	**n = 271**	**n = 250**									
6.1.1. Block-bh+Block-bh	39.31%	35.42%	26.40%	-.080	.272	-0.276	<.001	-.196	0.027			
6.1.2. Block-bh+Topspin-fh	24.63%	35.06%	32.40%	.229	.001	0.172	.020	-.056	.522			
6.1.3. Block-bh+Attack-fh	17.13%	6.64%	7.60%	-.332	<.001	-0.295	<.001	.037	.671			
6.1.4. Block-bh+Block-fh	6.85%	11.44%	10.80%	.160	.023	0.140	.053	-.020	.817	86.6	<.001	.303
6.1.5. Block-bh+Fast attack-bh	5.87%	7.75%	19.20%	.075	.295	0.418	<.001	.343	<.001			
6.1.6. Block-bh+'Fishing;-bh	2.61%	0.74%	1.20%	-.153	.070	-0.105	.201	.048	.589			
6.1.7. Block-bh+Topspin-bh	1.96%	1.11%	1.60%	-.070	.367	-0.027	.724	.043	.626			
6.1.x. Block-bh+other	1.63%	1.85%	0.80%	.016	.821	-0.077	.344	-.093	.301			
6.2.Block-fh+Counterattack	**n = 140**	**n = 64**	**n = 51**									
6.2.1. Block-fh+Block-bh	25.00%	23.44%	21.57%	-.036	.810	-0.081	.624	-.045	.812			
6.2.2. Block-fh+Topspin-fh	23.57%	50.00%	43.14%	.557	<.001	0.419	.009	-.138	.465			
6.2.3. Block-fh+Attack-fh	14.29%	10.94%	9.80%	-.101	.513	-0.138	.418	-.037	.844	18.9	.016	.307
6.2.4. Block-fh+Block-fh	12.14%	6.25%	7.84%	-.207	.200	-0.144	.402	.062	.739			
6.2.5. -6.2.x other	25.00%	9.38%	17.65%	-.425	.010	-0.180	.287	.245	.193			
6.3.'Fishing'-bh+Counterattack	**n = 105**	**n = 30**	**n = 25**									
6.3.1. 'Fishing'-bh+Topspin-fh	32.38%	40.00%	52.00%	.159	.439	0.400	.069	.241	.377			
6.3.2.'Fishing'-bh+ Fishing'-bh	39.05%	10.00%	8.00%	-.706	.003	-0.776	.004	-.070	.798			
6.3.3. 'Fishing'-bh+Topspin-bh	13.33%	13.33%	8.00%	<.001	1.00	-0.174	.467	-.174	.530	31.6	<.001	.474
6.3.4. 'Fishing'-bh+Fast attack-bh	3.81%	13.33%	28.00%	.355	.053	0.722	<.001	.368	.181			
6.3.x. 'Fishing'-bh+other	11.43%	23.33%	4.00%	0.319	0.101	-0.287	0.268	-0.606	0.048			
6.4.'Fishing'-fh+Counterattack	**n = 49**	**n = 30**	**n = 47**									
6.4.1. 'Fishing'-fh+Topspin-fh	14.29%	50.00%	55.32%	0.796	0.001	0.902	<0.001	0.107	0.650			
6.4.2.'Fishing'-fh+Chop-bh	18.37%	16.67%	27.66%	-0.045	0.848	0.222	0.282	0.267	0.270	29.0	<.001	.529
6.4.3. -6.4.x other	67.35%	33.33%	17.02%	-0.694	0.004	-1.075	<0.001	-0.380	0.103			
7.Push+Counterattack												
7.1.Push-bh+Counterattack	**n = 133**	**n = 123**	**n = 163**									
7.1.1. Push-bh+Topspin-fh	27.82%	47.15%	42.33%	0.403	0.002	0.306	0.010	-0.097	0.417			
7.1.2. Push-bh+Block-bh	21.05%	9.76%	7.98%	-0.318	0.014	-0.381	0.001	-0.063	0.598	36.2	<.001	.323
7.1.3.Push-bh+Push-bh	9.02%	6.50%	12.27%	-0.094	0.454	0.106	0.372	0.200	0.105			
7.1.4. Push-bh+Topspin-bh	7.52%	8.94%	4.91%	0.052	0.679	-0.109	0.351	-0.161	0.176			
7.1.5. Push-bh+Fast attack-fh	9.02%	4.88%	1.84%	-0.165	0.196	-0.338	0.005	-0.173	0.146			
7.1.6.Push-bh+Push-fh	6.77%	5.69%	3.07%	-0.045	0.723	-0.174	0.137	-0.130	0.274			
7.1.7-7.1.11 other	18.80%	17.07%	27.61%	-0.045	0.720	0.210	0.077	0.255	0.037			

h-Cohen – the value of h Cohen indicator (effect size), p* - statistical significance at p<0.017, χ2 – the value of chi-square test, p – the significance of χ2 test, Ccorr - corrected contingency coefficient.

Table 4. Continue…

Level 1 Level 2 Level 3	1970-2000 (1)	2001-2015 (2)	2016-2021 (3)	(1) vs. (2)		(1) vs. (3)		(2) vs. (3)		χ2	p	Ccorr
				h-Cohen	p*	h-Cohen	p*	h-Cohen	p*			
7.2.Push-fh+Counterattack	**n = 165**	**n = 128**	**n = 263**									
7.2.1. Push-fh+Topspin-fh	31.52%	43.75%	45.63%									
7.2.2. Push-fh+Block-bh	20.61%	17.19%	14.07%									
7.2.3. Push-fh+Topspin-bh	9.09%	9.38%	8.37%							18.1	.054	.205
7.2.4. Push-fh+Block-fh	9.09%	9.38%	6.46%									
7.2.5. Push-fh+Fast attack-bh	5.45%	3.13%	9.13%									
7.2.6. -7.2.12 other	24.24%	17.19%	16.35%	-.175	.144	-.197	.045	-.022	.835			
8.Attack-against-chop+Counterattack												
8.1.Aac-Topspin-fh+Counterattack	**n = 228**	**n = 228**	**n = 180**									
8.1.1.Aac-Topspin-fh+Topspin-fh	64.47%	87.72%	80.56%	.561	<.001	.364	<.001	-.197	.047			
8.1.2. Aac-Topspin-fh+Fast attack-fh	25.00%	7.02%	13.33%	-.511	<.001	-.300	.004	.211	.034	49.5	<.001	.319
8.1.3.Aac-Topspin-fh+Push-fh	7.46%	0.44%	3.33%	-.421	<.001	-.186	.074	.235	.026			
8.1.x. Aac-Topspin-fh+other	3.07%	4.82%	2.78%	.091	.337	-.017	.862	-.108	.291			
8.2.Aac-Topspin-bh+Counterattack	**n = 10**	**n = 17**	**n = 13**									
8.2.1.Aac-Topspin-bh+Topspin-fh	60.00%	88.24%	69.23%							3.0	.221	.347
8.2.2. Aac-Topspin-bh+Fast attack-fh	40.00%	11.76%	30.77%									
9. Chop+Counterattack												
9.1.Chop-bh+Counterattack	**n = 145**	**n = 141**	**n = 96**									
9.1.1.Chop-bh+Chop-bh	28.28%	49.65%	41.67%	.442	<.001	.282	.032	-.160	.228			
9.1.2. Chop-bh+Fast attack-fh	24.14%	21.99%	17.71%	-.051	.666	-.158	.236	-.107	.422			
9.1.3.Chop-bh+Chop-fh	19.31%	13.48%	5.21%	-.158	.184	-.449	.002	-.291	.039	39.8	<.001	.355
9.1.4. Chop-bh+Fast attack-bh	4.14%	6.38%	14.58%	.101	.395	.374	.004	.273	.037			
9.1.5.Chop-bh+'Fishing'-fh	5.52%	2.84%	8.33%	-.136	.259	.111	.391	.247	.059			
9.1.6. - 9.1.8 other	18.62%	5.67%	12.50%	-.411	.001	-.170	.208	.242	.065			
9.2.Chop-fh+Counterattack	**n = 65**	**n = 31**	**n = 16**									
9.2.1.Chop-fh+Chop-bh	33.85%	38.71%	12.50%	.101	.642	-.519	.098	-.620	.069			
9.2.2. Chop-fh+Fast attack-fh	10.77%	35.48%	12.50%	.608	.005	.054	.844	-.553	.102	21.5	.002	.476
9.2.3.Chop-fh+Chop-fh	20.00%	12.90%	6.25%	-.192	.396	-.422	.196	-.229	.487			
9.2.4. -9.2.6 other	35.38%	12.90%	68.75%	-.539	.024	.681	.018	1.220	<.001			

h-Cohen – the value of h Cohen indicator (effect size), p* - statistical significance at p<0.017, χ2 – the value of chi-square test, p – the significance of χ2 test, Ccorr - corrected contingency coefficient.

Results

The current research assessed the use of particular point-scoring technical-tactical actions in three periods. The results of the levels analyzed are presented in Table 2, Table 3, and Table 4. The tables contain the ten technical-tactical actions (Level 1), the 40 most scoring strokes and combinations (Level 2), and the 79 most scoring stroke combinations (Level 3).

Level 1

The frequencies of winning technical-tactical actions by players at Level 1 were significantly different between the three observation periods (Table 2), although the relationship in changes in the structure of such winning actions was very weak (Ccorr < 0.20). The tendency to decrease the frequency of winning actions in the following three periods was observed for serve (Table 2). An increased frequency was found for push-and-counterattack between the first and second periods and the first and third periods. Compared to the years 1970 to 2000 (1), the frequency of winning was higher between 2001 and 2015 (2) and 2016 to 2021 (3) for return-and-counterattack and push-and-counterattack, while it was only higher for attack-against-chop-and-counterattack and chop-and-counterattack for period 2. Meanwhile, the frequencies were lower for serve, block-and-counterattack, and return only for period 2. Compared to 2001-2015, there was a lower frequency of winning serves and a higher frequency of chop-and-counterattack and push-and-counterattack winners between 2016 and 2021. The effect size for all differences was insignificant and below the cut-off point for a small effect size.

Levels 2 and 3

All Level 1 game elements had a significantly different structure of the frequency of winning actions, with particular strokes at Level 2 depending on the observation period (Table 3). For block-and-counterattack and push-and-counterattack, the relationship between the structure and the observation period was very weak (Ccorr < 0.20), though the relationship was stronger for the remaining strokes. In subsequent periods of observation, the frequency of winning actions increased for sidespin-forehand-serves, sidespin-forehand-serves-and-counterattack, flick-backhand, and flick-backhand-and-counterattack. Meanwhile, the frequency of winning actions decreased for backspin-nospin-forehand-serves, backspin-nospin-forehand-serves-and-counterattack, topspin-attack-forehand, topspin-forehand-and-counterattack, and flick-forehand-and-counterattack. However, no clear trends were seen for the other strokes.

The frequency of winning actions with individual combinations varied by observation period for most strokes (Table 3 and Table 4). This frequency was not diversified in the case of backspin-nospin-forehand-serves, backhand-sidespin-serves, reverse-forehand-serves, reverse-fore

hand-serves-and-counterattack, topspin-forehand-and-counterattack, flick-backhand-and-counterattack, topspin-attack-backhand-and-counterattack, chop-backhand-and-counterattack, attack-backhand-and-counterattack, flick-backhand-and-counterattack, push-forehand-and-counter-attack, or attack-topspin-backhand-and-counterattack.

There were no regular changes in the frequency of winning actions in subsequent observation periods for any combination. Between the years 2016 and 2021, the frequency increased for side-backspin-long-forehand-serve and decreased for short-side-backspin-serve compared to the previous observation period. For serve-and-counterattack, the frequency increased for sidespin-forehand-serve-and-attack-backhand, and the frequency decreased for forehand-sidespin-serve-and-push-backhand.

Analysis of particular technical-tactical actions

1. Serve

The structure of the serve differed in particular periods ($\chi 2$ test results - moderately strong – Ccorr = 0.56 - significant relationship, $p < 0.001$) between the win frequencies for com- binations (1.1 - 1.7) and the observation period. The frequency of winning actions increased over time for sidespin-forehand-serves and decreased for backspin-no-spin-forehand-serves (Table 3). The effect size of differences between periods one and two, and periods one and three for sidespin-forehand-serves and backspin-nospin-forehand-serves, was moderate and strong but was weakest between periods two and three. Statistical analysis showed that, in the following periods, the share of winning serves in particular periods decreased significantly (Table 2). The serves with the highest frequency of winning actions were sidespin-forehand-serves (Table 3), and their number increased among the counted share wins.

The backspin and no-spin forehand serves had very high use during the small ball period (in the first work assessed). In subsequent periods, the use of these serves for direct scoring decreased (Table 2 and Table 3). It is noteworthy that side-spin backhand serve use increased during the plastic ball period. Short backspin serves have the highest frequency of use among wins (Table 3 and Table 4).

2. Serve and counterattack

The numerical structure of the serve-counterattack differed in particular periods ($\chi 2$ test results - moderately strong – Ccorr = 0.47, $p < 0.001$) between the frequencies of wins in individual combinations (from sidespin-forehand-serve-and-attack-backhand to others) and the observation period (Table 2). The frequency of winning actions increased with time for sidespin-forehand-serve-and-attack-backhand and decreased for backspin-nospin-forehand-serves. The frequency for sidespin-backhand-serve and counterattack was similar in the three observation periods. For aggregated combinations, despite the significant differences in the frequency of winning actions between the periods, Cohen's h indicates no effect ($h < 0.20$).

The analysis showed that serve-and-counterattack was the most scoring and most frequently used part of the game (Table 2). The dominant combinations of serve-and-counterattack were sidespin-forehand-serves and counter-attacks (topspin-forehand-fast -attack-backhand, topspin-backhand, push-forehand, etc., Table 3 and Table 4). The number of these combinations increased significantly (e.g., side service-forehand-attack-backhand) with time through individual periods. Combinations of other serves were most effective when combined with topspin-forehand (Table 4). This applies to serve-forehand-backspin, serve-backhand-sidespin, and serve-forehand-reverse.

3. Return

Returns constituted 16.20%, 14.36%, and 15.13% of all winning actions in particular periods (Table 2). The most scoring returns were forehand-push, topspin-attack-forehand, and backhand-push (Table 3). In the return attack of the short ball, the number of flick-forehand attacks decreased with time, while the number of flick-backhand attacks increased (statistically significantly). In the first period, a high frequency of flick-forehand was found, while a higher frequency of flick-backhand than forehand was found in the second period, and the flick-backhand had by far the greatest use in the third period. In individual periods, an increase in the use of the flick return was found, while the importance of the topspin-attack returns decreased. The frequency of using backhand strokes as a return generally increased with time (Table 3 and Table 4). In the third period, for example, a clear increase in the use of topspin return backhand was observed.

4. Return and counterattack

Return-and-counterattack accounted for 12.06%, 14.71%, and 14.39% in individual periods (Table 2). The most used return-and-counterattack was push-forehand-and-counter-attack, with a trend of increased then decreased use observed (Table 3). Other frequently used stroke combinations were push-backhand-and-counterattack and push-forehand-and-counterattack, which accounted for 65% (Table 4). At the same time, there was a higher utilization over time of push-backhand-and-counterattack and flick-backhand-counterattack combinations.

The most frequently scoring counter-stroke in return-and-counterattack actions (highest frequency) was topspin-forehand (Table 4). All return-and-topspin shares yielded 911 shares, which is 35% of the return-and-counterattack shares won. In particular periods, there was a clear decrease in the use of topspin-and-counterattack and a clear increase in the use of flick-and-counterattack. A clear trend was observed: from dominant forehand to double-sided play in this combination. The frequency of using the forehand in subsequent periods was 69%, 65%, and 44%, respectively, and backhand use was 31%, 35%, and 56%.

5. Attack and counterattack

All winning shares of attack-and-counterattack accounted for 17.14%, 17.01%, and 14.39% in subsequent periods (Table 2). The work stated that attack combinations were won by topspin-and-counterattack, fast attack-and-counterattack, and flick-and-counterattack (Table 3). The most common counterattack was topspin-forehand (Table 4). The most common combination found was topspin-forehand-and-topspin-forehand (Table 4). Similar to return-and-counterattack, the attack-and-counterattack game

element showed an obvious decrease in flick-forehand-and-counterattack use and a significant increase in flick-backhand-and-counterattack use. A slight tendency to increase the use of the backhand side (i.e., from the dominant forehand to the so-called double-sided game) was also noted. In all three periods, an advantage of a topspin attack over a fast attack was observed. However, the structure of this combination has changed over time, with the use of topspin and fast-attack.

After the introduction of the plastic ball, an increase in the use of the fast attack-and-counterattack combination was observed. Particular changes included backhand-counterattack from 8.26% to 22.58% and forehand-counterattack from 5.98% to 9.45% (Table 3). At the same time, a decrease in the use of the topspin-forehand-and-counterattack share was observed in the third period (after increasing from 48.37% in the first to 61.30% in the second) to 47.85% (Table 3). Concurrently, it was observed that the most frequent counterattacks after topspin-forehand were fast-attack-forehand-fast-attack-forehand and fast-attack-backhand-fast-attack, followed by topspin-backhand-topspin-forehand (Table 4).

6. Block and counterattack

In the periods of small celluloid ball, large celluloid, and large plastic ball, the block-counterattack combination accounted for 9.87%, 7.43%, and 7.54%. (Table 2). Among the so-called defensive strokes, a greater use of backhand strokes was indicated. Defense close to the table (block) was also used more often than defens-at-half-distance (fishing, Table 3). The highest scoring combinations involved a block-backhand-and-counterattack (block-backhand-and-block-backhand, block-backhand-topspin-forehadn, block-backhand-and-attack-forehand, etc.).

7. Push and counterattack

Statistical analysis shows that the share of push-and-counterattack winning actions increased significantly in subsequent analysis periods (Table2). At Level 2, 57% of combinations used push-forehand-and-counterattack and 43% of the winning actions used push-backhand-and-counterattack. The most commonly used counterattack in these combinations was topspin-forehand (Table 4).

8. Attack-against-chop-and-counterattack

The most common combination of attack-against-chop-and-counterattack found at Level 2 was topspin-forehand-and-counterattack (Table 3), while the most frequently used combination was topspin-forehand-and-topspin-forehand (Table 3, Table 4). This combination alone accounted for 68% of all action wins against the chop. The second and complementary action was the combination of topspin-forehand and smash-forehand, which gave a 14% winning action.

9. Chop and counterattack

Matches of 16 different defensive players were analyzed, and they performed 494 defense-chop-and-counterattack rallies. However, 26 rallies of this type were also performed by eight different attackers. Among all examined shares, chop-and-counterattack accounted for 2.26%, 3.18%, and 2.25% of wins in subsequent periods (Table 2). The most common combination found at Level 2 was chop-backhand-and-counterattack, while the most commonly used combinations of chop-backhand-and-counterattack were chop-backhand-and-chop-backhand, chop-backhand-and-attack-forehand, and chop-backhand-and-chop-forehand (Table 3, Table 4).

10. Other

Among all tested actions, other actions, such as nets and edges, serve errors by the opponent, and illegal serves, accounted for 3% of winning actions (Table 2). There were no differences between the number of these actions over the three periods.

Discussion

This research aimed to determine the quantitative structure of the winning actions of the world's leading table tennis players and assess changes in their structure over time based on the type of ball used in the game. Each element of the game (each tactical combination) has an important role in each analyzed period (differentiated by changing the type of ball). The research shows that individual combinations used changed slightly with the development of table tennis and changes in ball regulations. Indeed, this can be seen quite clearly, for example, in the number of directly won serves since their percentage as directly winning strokes decreased from period to period. Therefore, the importance of serving as a direct scoring stroke decreased, which is consistent with the predictions of some authors (Djokic, 2002; Djokic et al., 2019). This may be related to the greater readability of serves (changes in the way of serving) but also to smaller rotations caused by changes in the size and material used for ball production (Inaba et al., 2017; Lee et al., 2019). The observed trend, however, does not change the fact that the importance of service use is still very high. Together with the combinations of serves-and-counterattacks, they give almost 29% of points won in the last period studied in the work. Similar observations were made by Djokic et al. (2020), who estimated that serves accounted for 11.6% of direct winning actions and 22.4% of those serving a point immediately after (3rd ball attack).

Gaining an advantage in serving actions (3rd ball attack - serve-and-counterattack) can be the primary goal in table tennis player training plans. Indeed, backspin-nospin-forehand serves had very high use during the small ball period (in the first scoring period) when the serving rules were not restrictive (in the first scoring period, players could hide the ball behind their body and under their elbow). However, its importance has decreased with plastic balls and new regulations. The most frequently scoring serves (the highest frequency of winning actions among the serves in the research conducted in this paper) in the game of the top men are forehand side serves. These serves turn out to be the most scoring during the plastic ball period, during which the serve seems to be much more readable than in previous periods. Furthermore, they are used most often during 3rd-ball-attack and serve-and-counterattack winning combinations.

Another important observation made in the current work is the type of returns used in the game. The number of actions won directly with a return and a return-and-counterattack combination (the 4th ball attack) accounted for, and still constitute, about 30% of the winning actions. As such, it seems to be another part of the game (after the serve and the serve-and-counterattack) that must have a special place in the training plan. The first three-four strokes are very important in all periods (serve, return, serve-and-counterattack, and return-and-counterattack). These findings are consistent with the literature (Zhang et al., 2013).

Among all the used side serves, short side-backspin serves were most used, typically in the right combination with short side-top serves and long and fast serves with different rotations, different places of fall, and different tossing and serving places. This is due to the tactical principles used by the best players - the need for changeability and illegibility of the game (Grycan 2007).

Among the returns used, a significant increase in the number of flip-backhands was noticeable. This may be related to the lower speed and rotation of the game, which allows for easier positioning for the backhand, even on the forehand side (Fuchs and Lames, 2021), although it may also have related to greater opportunities to use various backhand flick techniques to maintain high variety. Furthermore, and despite the tendency described above, the fore-hand push was still the most common return, which is probably related to the short serve often performed by opponents to the forehand side of the table.

The research paper showed an increase in the use of backhand strokes compared to forehand strokes in particular periods. This applied not only to the return described above but also to attack-and-counterattack and push-and-counterattack. So we can talk about a change in the game, from the dominant forehand, which was noticeable during the small ball period, to a double-sided game, with a balance of using shots from both sides. In block-and-counter-attack actions, you can see a much greater use of the block backhand than the block forehand. This is most likely due to, in addition to the reasons described above, the fact of increasing the offensiveness of the forehand side and replacing the block forehand with topspin or fast attack. block-forehand-and-counterattack rallies were fewer than block-backhand-and-counterattack. As such, there was greater use of forehand-attack-counterattack than block-forehand-and-counterattack. This proportion was constant and has not changed in particular periods.

Among the offensive strokes used by the players, there was a greater share of topspin strokes than fast attacks. An interesting trend was also observed in the attack-and-counterattack combinations, with a fast-attack-and-counterattack decrease in the third period and an increase in topspin-and-counterattack. Perhaps this is due to the specificity of playing with a large plastic ball, resulting in different rotations of the ball, a different flight trajectory, and a greater possibility, or even necessity, of using a fast attack (Inaba et al., 2017; Lee et al., 2019). At the same time, it was observed that in attack-and-counterattack actions, the last stroke (counterattack) was usually the same type of stroke as the preceding attack. The exception was a topspin backhand, which was usually followed by a topspin forehand.

Among the used combinations related to scoring a point, the increase in the use of the push-and-counterattack combination in the third of the analyzed periods, in relation to the first two, is noteworthy. This is probably due to the slightly higher amount of short serves with a bottom (back) spin and the number of drop shots played in the first two strokes of the serve and the return.

Limitations

A certain conspicuous limitation of this work is the fact that the researched material consisted only of men, so the results of the analysis should only be related to men's table tennis. In the near future, however, we planned to evaluate the most used strokes and combinations used by females.

The type of ball determined the specification of the periods, but it must be remembered there were also changes in the rules of glue use, set length, and serving. Perhaps these were factors that could significantly affect the type of combinations ending in a point.

The observation and analysis used in this work may seem simplified because it concerns one, or a combination of, the last two strokes in action and does not cover all strokes performed by the players in the match. Perhaps evaluating the entire course of the game would change the picture of the analysis to some extent.

It is worth noting that a different number of matches per player was analyzed, and handedness and style of play were excluded from the assessment.

Another challenge should be an even more in-depth quantitative and qualitative analysis of the most scoring actions and the use of its results to improve training programs for young athletes and trainers of initial and basic table tennis training.

It should also be considered a work limitation that there was only one observer of the matches in the study.

Conclusion

The current research shows that using individual combinations changed slightly with the development of table tennis and changes in ball regulations. However, the scoring of the first three strokes (serve, return, serve-and-counterattack, and return-and-counterattack) percentage was higher in periods of other actions. It can also be concluded that the importance of serves as direct scoring strokes is decreasing. This may be related to the increased readability of the serves, which was caused by changes in the size and material of the balls.

The most winning serves in the game of the top men were side-spin-forehand serves, which turned out to be the most scoring during the plastic ball period. They are also most often used during winning combinations, including the 3rd-ball-attack and serve-and-counterattack. The number of actions won directly with a return and the return-and-counterattack combination accounted for, and still constitute about 30% of the winning actions, with a significant increase in the number of flip-backhands. The research also showed an increase in the use of backhand strokes compared to forehand strokes in particular periods.

In the attack-and-counterattack combinations during the plastic ball period, an increase in the share of fast-attack was observed, with a decrease in topspin. Perhaps this is due to the specificity of playing a large plastic ball. Among the combinations used for point scoring, the increase in the use of the push-and-counterattack combination in the third of the analyzed periods, in relation to the first two, is noteworthy. The above findings should be taken into account when creating basic goals in table tennis training planning.

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Key points

- The project identified and analyzed 244 matches of medalists of the World Championships and the Olympic Games in the years 1970-2021
- The most scoring technical and tactical actions in table tennis were identified
- The first three strokes in all periods are very important, however the importance of serves as direct scoring strokes is decreasing. The number of actions won directly with a return and in the Return-Counterattack combination accounted for and still constitute about 30%
- The research showed an increase in the use of backhand strokes compared to forehand strokes in particular periods.
- The findings should be taken into account when creating basic goals in the training plan of table tennis.

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