HUMAN MOVEMENT (ISSN 1899-1955)
2022; 23(2): 128–137

SERVE EFFICIENCY DEVELOPMENT IN WOMEN'S VS. MEN'S PROFESSIONAL TENNIS

original paper
DOI: https://doi.org/10.5114/hm.2022.109071

RALPH GRAMBOW[1], PHILIPP BORN[1], CRAIG O'SHANNESSY[2], JONAS BREUER[1], DOMINIK MEFFERT[1], TOBIAS VOGT[1,3]

[1] Institute of Professional Sport Education and Sport Qualifications, German Sport University Cologne, Cologne, Germany
[2] Brain Game Tennis, Austin, USA
[3] Faculty of Sport Sciences, Waseda University, Tokorozawa, Japan

ABSTRACT

Purpose. The purpose was to identify possible gender-specific differences in long-term serve efficiency development in professional women's and men's tennis.

Methods. The analyses focused on 2 approaches: (1) total tournament comparison and (2) 2nd tournament week vs. 1st tournament week comparison. The data include all single matches at the Wimbledon Championship between 2002 and 2015 (ladies: n = 1771, gentlemen: n = 1772).

Results. The findings showed significant development differences in favour of elite men over elite women in both comparisons. Regarding the total tournament comparison, men's development of 2nd serve points won ($p < 0.001$; $r = 0.86$), 1st serves in ($p < 0.05$; $r = 0.72$), and double fault ($p < 0.001$; $r = 0.85$) percentages improved significantly more. As per the 2nd tournament week vs. 1st tournament week comparison, men's development of 2nd serve points won ($p < 0.05$; $r = 0.68$) and double fault ($p < 0.01$; $r = 0.86$) percentages improved significantly more.

Conclusions. The study revealed serve efficiency development advantages for men over women in both comparisons, especially regarding the quality of the 2nd serve, whereas no development advantages in favour of women over men could be observed in any analysed parameter, indicating possible needs to adapt elite women's coaching.

Key words: elite, coaching, practice, gender, game opening, Wimbledon

Introduction

The importance of the serve in professional women's and men's tennis is well-known [1–4], with an even bigger impact on grass court at Wimbledon compared with the Australian, French and US Open [5–7]. Previous research offers distinguished scientific analyses on elite men's and women's tennis [1, 3–5, 7, 8–14]; however, just over a handful of them took gender-specific differences into account [6, 15–19]. Recently, long-term serve efficiency development has been reported across 14 years (2002–2015) of the Ladies and Gentlemen All England Championships at Wimbledon, stating advantages for players competing in the 2nd tournament week compared with players competing in the 1st tournament week; this is particularly prominent in men's tennis [8, 14]. Directly comparing women's with men's serve efficiency may offer valuable insights not only for players and coaches of both genders, but also for the scientific community. This is by raising the awareness of possible serve efficiency development advantages for women over men or vice versa and if so, players, coaches, and scientist could try to identify differences in the individual training methods. Earlier studies showed that elite men hit significantly more aces and won significantly more points while serving than elite women [17, 20–23]. On this basis, Verlinden et al. [23] speculated about the disparity in physical strength and stature, as well as serve speed as the reason of these gender differences of served aces [24]. Comparing the fastest known serves (Samuel Groth: 263 km/h, 2012; Sabine Lisicki:

Correspondence address: Ralph Grambow, Institute of Professional Sport Education and Sport Qualifications, German Sport University Cologne, Am Sportpark Müngersdorf 6, 50933 Köln, Germany, e-mail: r.grambow@dshs-koeln.de

Received: February 17, 2021
Accepted for publication: May 5, 2021

Citation: Grambow R, Born P, O'Shannessy C, Breuer J, Meffert D, Vogt T. Serve efficiency development in women's vs. men's professional tennis. Hum Mov. 2022;23(2);128–137; doi: https://doi.org/10.5114/hm.2022.109071.

210.8 km/h, 2014) may underline the gender-specific biological disparities between men and women, giving men strategical advantages, since the serve is potentially the most dominant shot in modern tennis [25]. With respect to commonly accepted body constitutional differences [23, 26, 27], it may be considered misleading to interpersonally compare women's with men's serve efficiency. Cumulated by Elliott et al. [26], previous research suggests anthropometric and physiological differences referring to height (i.e., absolute size), muscular strength, flexibility, and power [28, 29], Moreover, and referring to movement learning and motor control, analogous movement patterns have been reported to be functionally improbable [30]. Thus, both physical and motor performance are well-reported to cause a gender-specific impact on serve performance, which has also been based on match-play data [26]. However, with the consideration of intrapersonal comparisons, analysing gender-specific serve efficiency development over time seems reasonable and purposeful, particularly with recently published long-term serve efficiency results of elite men and women [8, 14]. Bearing the above in mind, serve efficiency development in women compared with men competing in the 1st tournament week and 2nd tournament week may help understand gender-specific differences in successfully competing and eventually setting a match strategy as well as preparatory practice patterns.

Therefore, the present study aimed to analyse possible serve efficiency development differences in professional women's and men's tennis within the last 2 decades (Wimbledon 2002–2015; ladies' matches: n = 1771, gentlemen's matches: n = 1772) in order to specify possible gender-specific serve efficiency recommendations to enhance future practices. It was intended to generally identify gender-specific serve efficiency development differences within prominent serve-related parameters based on earlier research (e.g., service game, 1st serve and 2nd serve points won, aces, and double fault percentages) [8, 14]. Further, the awareness of development advantages in women's compared with men's tennis or vice versa may offer purposeful/valuable knowledge for players, coaches, and scientist, allowing to draw conclusions for their own practice patterns (e.g., increased focus on improving 2nd serve quality) or future research (e.g., survey of practice time and focus asking players and coaches of both genders).

Since the modern game of tennis has become less technique-based and increasingly more explosive and dynamic, the serve constitutes a key factor of success and significant tactical changes [25, 31].

Material and methods

Based on the results of 2 earlier studies by Grambow et al. [8, 14] which focused on long-term serve efficiency development in elite women's and men's tennis, as well as possible performance differences within world class tennis players by comparing data of players competing in the 1st tournament week with data of players competing in the 2nd tournament week of the All England Championships between 2002 and 2015, the present study involves 2 main gender-specific comparisons: (1) total tournament comparison and (2) 2nd tournament week vs. 1st tournament week comparison.

Data set

The total tournament data contain all matches played at Wimbledon between 2002 and 2015, specifically 1771 ladies' matches (service games: n = 37,717; serves: n = 248,135) and 1772 gentlemen's matches (service games: n = 63,838; serves: n = 401,527). In turn, 1st tournament week data contain 1562 ladies' matches (service games: n = 33,150; serves: n = 218,028) and 1563 gentlemen's matches (service games: n = 55,989; serves: n = 352,748), and 2nd tournament week data contain 209 ladies' matches (service games: n = 4567; serves: n = 30,107) and 209 gentlemen's matches (service games: n = 7849; serves: n = 48,779). The data were retrieved from the Wimbledon Information System (presented by IBM) in collaboration with Brain Game Tennis and with the approval of the German Sport University Ethics Committee.

Analyses

As explained earlier, body constitutional differences [23, 26, 27] seem to disqualify direct comparisons by absolute numbers; therefore, the gender-specific development over time referring to the individual starting level and improvement percentages should be investigated (i.e., intrapersonal comparison).

For the intrapersonal gender-specific total tournament comparison, yearly women's and men's data were merged in 2-year groups (2002 + 2003, 2004 + 2005, et seq.) for each of the 8 analysed serve parameters to minimize potential statistical peaks. The observed development over the course of the 7 combined tournament year groups (starting with 2002 + 2003 until 2014 + 2015) for both the women's and men's data was compared to identify gender-specific differences, by analysing mean values of the following years, with

the 2002 + 2003 value serving as baseline, and looking for the possible intrapersonal gender-specific differences.

Contrary to this, the intrapersonal gender-specific 2nd tournament week vs. 1st tournament week comparison involved development differences within each 2-year group for the respective world class cohort.

Following the research methodology of Grambow et al. [8, 14], the analysed serve parameters listed below, which are commonly known as valid measures for serve efficiency [32, 33], were applied, with only one parameter added (i.e., 1st serve in):

– the number of 1st and 2nd serve points won by each player (i.e., serve success);

– the number of service games won by each player (i.e., serve success);

– the number of 1st serves in served by each player (i.e., serve performance);

– the number of double faults served by each player (i.e., serve performance);

– the number of aces served by each player (i.e., serve performance);

– the number of serve and volley points played by each player (i.e., serve strategy);

– the number of serve and volley points won by each player (i.e., serve strategy).

The 8 recorded serve efficiency parameters were categorized and divided into 3 groups, again following the methodology of Grambow et al. [8, 14]. The percentages for 2nd serve points won, 1st serve points won, and service games won were assigned to the category *serve success*, since these parameters display how successful men and women were against their opponents while serving. The percentages for valid 1st serves, double faults, and aces were assigned to the category *serve performance*, since these parameters are only influenced by the players' own performance, without their opponents playing any shot. The percentages for serve and volley points played and serve and volley points won were assigned to the third category, *serve strategy*.

Statistical procedures

The statistical procedures were performed by using SPSS Statistics for Macintosh, version 27.0 (IBM Corp., Armonk, NY, USA), as well as Excel 2016 (Microsoft Corp., Redmond, WA, USA).

After *t*-tests application for predefined parameters in both comparisons, effect sizes were calculated by using Pearson's correlation coefficient and interpreted as small ($r \geq 0.1$), medium ($r \geq 0.3$), and large ($r \geq 0.5$) [34], more recently augmented as very large ($r \geq 0.7$) and extremely large ($r \geq 0.9$) [35].

Mean (*M*) and standard deviation (*SD*) are presented as percentages in Tables 1 and 2. The level of significance was set at $p < 0.05$ and, if applicable, further at $p < 0.01$ and $p < 0.001$.

Tables 1 and 2 present the minimum (^{min}) and maximum (^{max}) marks for the relevant percentages, which may be of value for coaches as benchmarks during practice with their athletes.

Ethical approval

The conducted research is not related to either human or animal use.

Results

Serve success

Following the intrapersonal gender-specific total tournament comparison over time, the analyses for 2nd serve points won showed significant development advantages for men's ($M = 1.04$; $SD = 0.01$) compared with women's ($M = 1.01$; $SD = 0.10$) percentages ($p < 0.001$; $r = 0.86$) (Table 1). The analyses for 1st serve points won revealed no significant development differences when comparing men's ($M = 1.02$; $SD = 0.01$) and women's ($M = 1.01$; $SD = 0.01$) percentages ($p = 0.29$), as well as when comparing service games won (men: $M = 1.04$, $SD = 0.01$; women: $M = 1.03$, $SD = 0.15$) percentages ($p = 0.05$) (Table 1).

Following the intrapersonal gender-specific 2nd tournament week vs. 1st tournament week comparison for 2nd serve points won, the analyses showed significant development advantages for men's ($M = 1.04$; $SD = 0.28$) compared with women's ($M = 0.99$; $SD = 0.02$) percentages ($p < 0.05$; $r = 0.68$) (Table 2, Figure 1). The analyses for 1st serve points won revealed no significant development differences when comparing men's ($M = 1.03$; $SD = 0.02$) and women's ($M = 1.03$; $SD = 0.03$) 2nd tournament week and 1st tournament week percentages ($p = 0.86$), as well as when comparing service games won (men: $M = 1.04$, $SD = 0.28$; women: $M = 1.03$, $SD = 0.05$) percentages ($p = 0.61$) (Table 2, Figure 1).

Serve performance

Following the intrapersonal gender-specific total tournament comparison over time, the analyses for 1st serves in showed significant development advantages for men's ($M = 1.05$; $SD = 0.01$) compared with

Table 1. Total tournament parameter percentages including minimum and maximum benchmarks

Total tournament parameters			Tournament years						
			2002 + 2003	2004 + 2005	2006 + 2007	2008 + 2009	2010 + 2011	2012 + 2013	2014 + 2015
Serve success	2nd serve points won (%)	Ladies	45.53	45.45min	46.18	45.95	46.85max	46.33	46.09
		Gentlemen	50.05min	51.62	52.13	52.10	51.70	52.23	52.70max
	1st serve points won (%)	Ladies	64.63	64.70	64.61min	64.97	65.84	64.90	66.18max
		Gentlemen	72.94min	73.53	72.99	74.63	74.39	73.98	74.76max
	Service games won (%)	Ladies	67.18min	67.51	68.55	68.36	70.46max	68.89	69.56
		Gentlemen	79.76min	82.18	82.44	83.09	83.09	83.31	84.40max
Serve performance	1st serve in (%)	Ladies	61.30min	62.91	63.81max	63.05	63.60	63.39	63.17
		Gentlemen	60.18min	62.32	63.50	62.28	63.61	63.89max	63.62
	Double faults (%)	Ladies	5.43min	5.13	4.76	5.02	4.70	4.53max	4.59
		Gentlemen	4.74min	3.96	3.22	3.48	3.26	3.04max	3.41
	Aces (%)	Ladies	3.73min	3.92	4.01	3.93	4.85	4.30	4.94max
		Gentlemen	8.46min	9.05	8.71	9.50	10.30	9.77	10.74max
Serve strategy	Serve and volley points played (%)	Ladies	4.74max	4.20	2.80	2.17	1.61	1.19	1.10min
		Gentlemen	28.66max	20.54	13.26	9.77	6.93min	7.06	9.18
	Serve and volley points won (%)	Ladies	64.39	66.19	65.78	65.65	61.64min	63.64	69.74max
		Gentlemen	67.06min	67.54	67.40	68.17	67.90	67.71	70.59max

Table 2. Second tournament week parameter percentages including minimum and maximum benchmarks

Second tournament week parameters			Tournament years						
			2002 + 2003	2004 + 2005	2006 + 2007	2008 + 2009	2010 + 2011	2012 + 2013	2014 + 2015
Serve success	2nd serve points won (%)	Ladies	45.01	46.45	44.89	47.30max	46.73	43.84min	46.89
		Gentlemen	50.80min	53.00	53.37	54.40	55.74max	52.29	54.23
	1st serve points won (%)	Ladies	66.94	65.36min	66.01	69.39max	67.36	65.98	67.19
		Gentlemen	73.56min	73.87	74.29	77.64	78.28max	74.12	76.95
	Service games won (%)	Ladies	69.19min	71.17	69.26	75.34max	71.96	69.59	72.08
		Gentlemen	80.82min	82.83	83.83	88.10	88.85max	85.13	87.73
Serve performance	1st serve in (%)	Ladies	62.98	64.48	62.20min	62.35	63.56	64.81max	63.45
		Gentlemen	59.81min	60.86	63.43	63.13	64.14	64.42	64.74max
	Double faults (%)	Ladies	4.83	4.62	5.18	4.97	5.27min	4.20max	4.41
		Gentlemen	3.75min	3.32	2.64	2.87	2.81	2.38max	2.64
	Aces (%)	Ladies	4.39min	4.82	4.82	6.45max	5.88	5.58	5.20
		Gentlemen	8.36min	9.24	8.75	11.91	12.57max	9.67	12.34
Serve strategy	Serve and volley points played (%)	Ladies	1.89	3.61	6.00max	1.78	0.31min	1.75	1.01
		Gentlemen	33.44max	18.91	10.30	10.71	8.45	6.76min	9.17
	Serve and volley points won (%)	Ladies	69.19min	71.17	69.26	75.34max	71.96	69.59	72.08
		Gentlemen	67.55	65.21min	68.75	69.89	67.97	70.96	74.15max

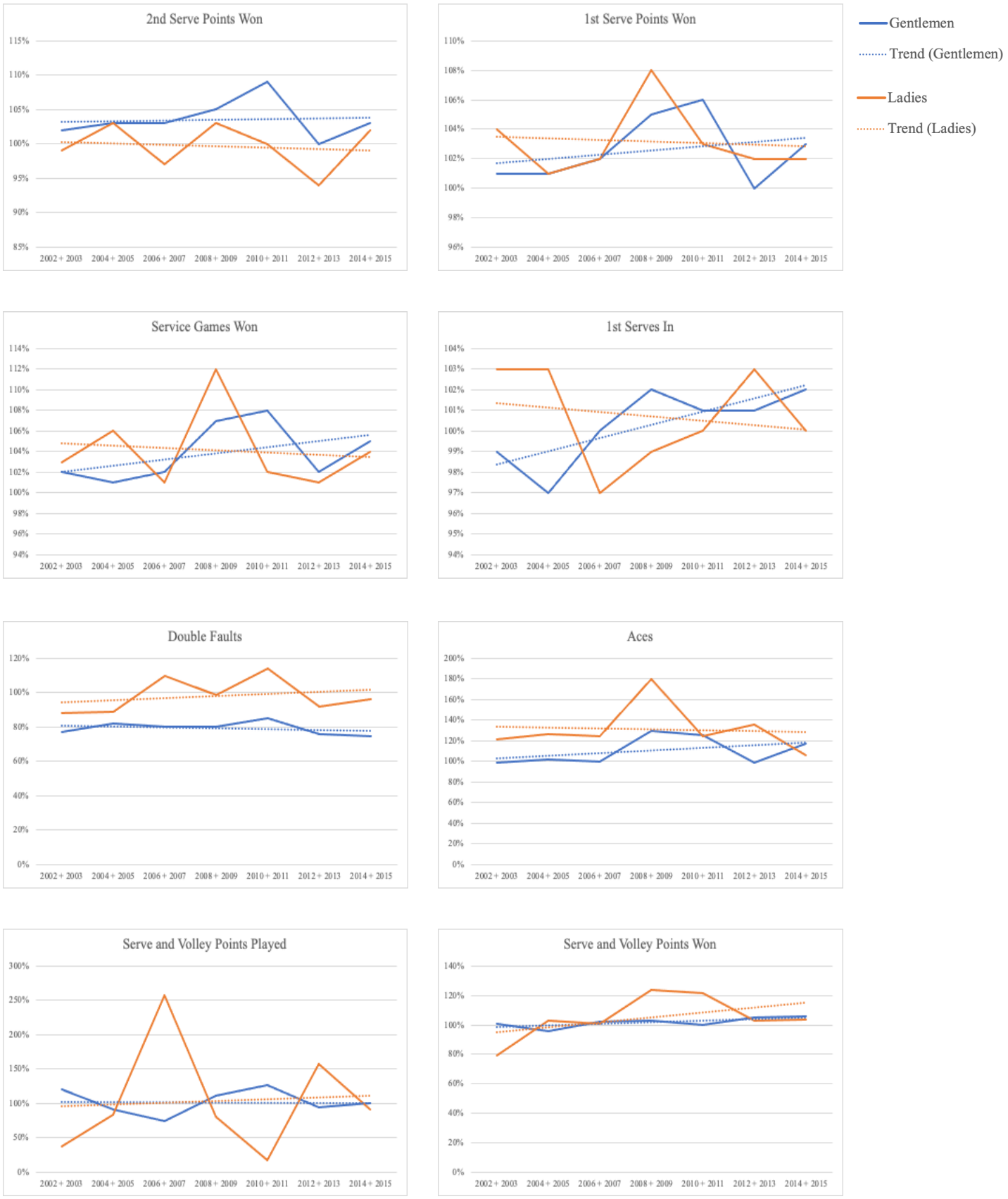

Figure 1. Intrapersonal gender comparisons of the 2nd tournament week vs. 1st tournament week's delta over 2 sequenced years from 2002 + 2003 to eventually 2014 + 2015 in different serve efficiency parameters for men (blue line) and women (orange line), including dotted trend lines, respectively

women's (M = 1.03; SD = 0.01) percentages ($p < 0.05$; r = 0.72) (Table 1). The analyses for double faults revealed significant development advantages for men's (M = 0.72; SD = 0.07) compared with women's (M = 0.88; SD = 0.04) percentages ($p < 0.001$; r = 0.85) (Table 1). The analyses for aces determined no significant development differences when comparing men's (M = 1.14; SD = 0.09) and women's (M = 1.16; SD = 0.12) percentages (p = 0.79) (Table 1).

Following the intrapersonal gender-specific 2nd tournament week vs. 1st tournament week comparison for 1st serves in, the analyses showed no significant development advantages for men's (M = 1.00; SD = 0.02) compared with women's (M = 0.99; SD = 0.24) percentages (p = 0.72) (Table 2, Figure 1). The analyses for double faults revealed significant development advantages for men's (M = 0.79; SD = 0.03) compared with women's (M = 1.02; SD = 0.11) percentages ($p < 0.01$; r = 0.86) when comparing the 2nd tournament week data vs. the 1st tournament week data (Table 2, Figure 1). The analyses for aces determined no significant development differences when comparing men's (M = 1.10; SD = 0.14) and women's (M = 1.24; SD = 0.31) percentages (p = 0.30) (Table 2, Figure 1).

Serve strategy

Following the intrapersonal gender-specific total tournament comparison over time, the analyses for serve and volley points played (p = 0.96) and serve and volley points won (p = 0.58) showed no significant development differences when comparing men's (played: M = 1.02, SD = 0.18; won: M = 0.39, SD = 0.18) and women's (played: M = 1.02, SD = 0.04; won: M = 0.46, SD = 0.25) percentages (Table 1).

Following the intrapersonal gender-specific 2nd tournament week vs. 1st tournament week comparison for serve and volley points played (p = 0.70) and serve and volley points won (p = 0.86), the analyses revealed no significant development differences when comparing men's (played: M = 1.02, SD = 0.03; won: M = 1.03, SD = 0.17) and women's (played: M = 1.04, SD = 0.15; won: M = 1.08, SD = 0.81) percentages (Table 2, Figure 1).

Discussion

Following earlier longitudinal research on women's and men's serve efficiency development at Wimbledon [8, 14], the present study aimed to find gender-specific differences regarding the individual development during the analysed period by using 2 different approaches to be able to directly compare women's and men's development. The findings of the intrapersonal gender-specific total tournament comparison over time showed significant advantages in favour of men's development in serve success (2nd serve points won percentages) and serve performance (1st serve in and double fault percentages) parameters. In the analysis of the intrapersonal gender-specific development differences of the 2nd tournament week vs. 1st tournament week comparison, again the same parameters (i.e. serve success: 2nd serve points won percentages; serve performance: double fault percentages) revealed significant advantages in favour of men's serve efficiency development.

On the basis of the results of earlier studies, increased serve efficiency for elite women's and men's tennis is well accepted [1–4, 6, 8, 9, 13, 14, 36], which ultimately leads to the question if there are differences regarding the elements and extent of the development between women and men.

Development is driven by competition and its impact on winning, which results in an increasingly more dynamic and faster paced while less technique-based modern game of tennis, characterized by strength, speed, and power; this makes the serve a key factor to strategic advantages and, by this, to winning [25, 31]. With the consideration of commonly accepted body constitutional differences [23, 26, 27] and the above indicated role of the serve in tactics and winning in tennis, increased serve efficiency parameters may be of more importance in elite men's tennis compared with elite women's tennis.

Total tournament data for men and women over time depict a general increase, as reported earlier [8, 14], but the intrapersonal gender-specific total tournament comparison shows significant advantages for men over women in 3 out of the 8 analysed serve efficiency parameters (i.e., 1st serve in, 2nd serve points won, and double fault percentages), with no parameters in favour of women over men. Men's development of 1st serve in percentages was significantly more efficient ($p < 0.05$; r = 0.72) compared with women's 1st serve in percentages, reasonably based on the lower starting level (men: 60.18%, women: 61.13%) in the combined Wimbledon tournaments of 2002 + 2003, since both men and women serve at around 63% of their 1st serves in over the following years with very close peak values (e.g. men: 63.89% in 2012 + 2013; women: 63.81% in 2006 + 2007). These percentages in both men and women confirm the previously reported 1st serve in percentages being around 60% [16, 24, 37], but at the same time show an increasing development, with

a significant development advantage in favour of elite men.

Men's development of 2nd serve points won ($p < 0.001$; $r = 0.86$) and double fault ($p < 0.001$; $r = 0.85$) percentages, both being significantly more improved than women's development, seems even more impressive if one considers that men's starting level in both categories was already on a much higher level in the merged 2002 + 2003 Wimbledon percentages (e.g. 2nd serve points won: men: 50.05%, women: 45.53%; double faults: men: 4.74%, women: 5.43%). While men won their points following a 2nd serve at around 52% in the following years (peak value: 52.7% in 2014 + 2015), women increased to around 46% (peak value: 46.85% in 2010 + 2011). The mean value of the 2nd serve points won development difference in elite men's tennis ($M = 1.04$) presents an advantage compared with elite women's tennis ($M = 1.01$). Bearing in mind that all analysed matches were Main Draw Singles matches at Wimbledon, which relates to high performance elite tennis, an increase of 4% appears to be very impressive, even more so when this increase is 4 times as big as the 1% in women's tennis over the same time. Simultaneously, another plausible interpretation of these statistical numbers could be found in the women's return performance. The winning percentages of service points, especially for 2nd serves, are influenced by the return quality of the opponent. With this line of thought, an increased return performance in elite women's tennis (compared with a possibly less increased men's return performance) may cause the differences. Since the following double fault percentages, where again significant differences in favour of elite men were observed, obviously have a direct impact on the 2nd serve points won percentages – because every double fault is a lost point following a 2nd serve – a development advantage in favour of both men's categories seems more reliable. Double fault percentages decreased in both women's and men's tennis, but significantly more in men's tennis. While women served their weakest percentage of 5.43% compared with 4.74% among men (both in the merged 2002 + 2003 events), women managed to decrease to 4.53% (2012 + 2013) and men managed to decrease to 3.04% (2012 + 2013). Men's percentages are between 3.04% and 3.48% over the last 10 years, while women's percentages are between 4.53% and 5.02% in the same time. The difference of development in this area raises questions regarding the importance of practising 2nd serves, underlining earlier findings of 2nd serve winning percentages in elite women's tennis [15]. Previous research has shown that the serve has an even bigger impact in elite men's tennis [20, 38], but if one considers speed differences, not least due to body constitutional differences, and the individual starting level (e.g. men: 4.74%, women: 5.43%), it seems plausible to ask for a similar development possibility over such a long time. Nevertheless, men's (double fault) percentages improved significantly more, which leads to the conclusion that women's tennis may increase the amount of time and/or the way of practising 2nd serves.

The findings regarding development differences in the intrapersonal gender-specific 2nd tournament vs. 1st tournament week comparison showed advantages in the same categories. As in the total tournament comparison, men's development improved significantly more in 2nd serve points won percentages ($p < 0.05$; $r = 0.68$) and in double fault percentages ($p < 0.01$; $r = 0.86$) compared with women's development.

Preventing any misleading interpretation, it should be stated that men and women competing in the 2nd tournament week perform at higher percentages across all analysed categories compared with players competing in the 1st tournament week, as earlier evidence has shown [8, 14]. Men and women improved their 2nd tournament week percentages over time across all categories, but like in the gender-specific total tournament comparison, advantages in the development can be proven statistically in favour of men over women in 2nd serve points won and double fault percentages. Adding to these findings and although only descriptive, Figure 1 illustrates and directly compares men's and women's serve efficiency parameters, showing the percentages and the trend lines for these percentages. Especially noticeable are the differences between men's and women's trend lines, presenting improvement for men's 2nd tournament week data compared with men's 1st tournament week data in all 6 categories of serve success and serve performance; over the same time, the trend for women's 2nd tournament week data compared with 1st tournament week data slightly decreased. This does not mean that women's percentages in the 2nd tournament week are decreasing; the slightly decreasing trend lines rather seem to origin in 1st tournament week improvements. This adds to former research implying that an extended world class cohort in women's tennis [14], and at the same time men competing in the 2nd tournament week, maintained and increased their advantages.

The findings of both intrapersonal gender-specific comparisons revealed no statistically relevant development differences in favour of women over men or vice versa for the two serve strategy parameters (e.g. serve and volley points played percentages and serve and vol-

ley points won percentages). Even if any advantages or disadvantages, especially in the 2nd tournament week vs. 1st tournament week approach, had been observed, they would have to be considered with care, since the serve and volley percentages of women competing in the 2nd tournament week were close to zero.

The findings of both intrapersonal gender-specific comparisons showed no development advantages at all in favour of women over men in any of the analysed parameters. This adds to previous research by Brown and O'Donoghue [20], who analysed similar parameters and reported significantly greater 1st and 2nd serve winning percentages for men over women, who were also serving higher ace and fewer double fault percentages. These percentages relate to matches of all 4 Grand Slam tournaments in 2007. If one considers the long-term approach and the number of categories analysed while comparing the intrapersonal serve efficiency development differences of the respective world class in women's and men's tennis, finding no development advantages at all in favour of women may be seen as a surprise. Previous research comparing elite women's and men's tennis showed mostly advantages on either side [15, 17, 19] or in favour of elite men, but these findings were related to shorter periods of observation [6, 24].

Limitations

In science, prospective trials should be used rather than retrospective analyses, which is not feasible when investigating professional tennis at the highest international levels of competition, especially when analysing long-term data over a period of 14 years.

Using data of pre-set categories (i.e., presented by IBM) may be considered limiting itself, since official category definitions are most reasonable but ultimately non-verifiable pre-set definitions; moreover, they are delivered by a third party. This remains true even if the company is well-established and the data presented are used as official and commonly well-accepted data (e.g. media coverage, coaching).

Big data analyses have tendencies to present significant results because of the large amount of data, which raises the problem of translating these results to the actual practical impact. Effect sizes were calculated to minimize this risk and weigh in the presented significances.

The comparability of the collected findings may be limited in certain areas, since the gender-specific development differences were analysed exclusively for elite men's and women's tennis competition on grass court. This should be taken into consideration when comparing the findings with e.g. hard court or clay court tournaments, lower level competitions, or boys and girls performance.

The data set did not present any biological parameters, such as size/height, weight, or playing hand of the players, so all performed analyses could not account for possible differences in these areas.

Finally, the risk of statistical bias exists, since findings regarding serve success, serve performance, or serve strategy may be influenced by medical issues if the players starting or resuming match-play are not in their best health condition. However, given the enormous number of total matches (e.g. men: 59 injury retirements / 1772 total matches; women: 24 injury retirements / 1771 total matches), the potential data interference may be considered as minor to none.

Conclusions

The aim of the present study was to directly compare long-term serve efficiency development in elite women's and men's professional tennis in order to identify possible advantages for women or men. Therefore, the study based its comparative approach on earlier research, which focused on the Ladies' and, respectively, Gentlemen's Wimbledon Championships held between 2002 and 2015. Furthermore, at some point, most coaches work not only with female or male athletes exclusively, so a better understanding of gender-specific serve efficiency benchmarks (descriptive) may be of general interest, particularly for coaches.

The findings imply significant advantages for elite men's development over elite women's development regarding serve success and serve performance parameters for the intrapersonal gender-specific total tournament comparison over time: in detail, 2nd serve points won percentages, double fault percentages, and 1st serve in percentages. The findings of the intrapersonal gender-specific 2nd tournament week vs. 1st tournament week comparison also depict significant development advantages for elite men over elite women for 2nd serve points won percentages and double fault percentages. The findings for intrapersonal gender-specific 2nd tournament week vs. 1st tournament week comparison additionally suggest an increasing development in all 6 serve success and serve performance parameters in favour of men competing in the 2nd tournament week (last 16 of the world cohort) over men competing in the 1st tournament week (extended world class cohort), whereas the opposite development is suggested for elite women's tennis since the trend lines for all

6 serve success and serve performance parameters are decreasing, which means that the extended world class cohort (women competing in the 1st tournament week) closes the serve efficiency gap to the women competing in the 2nd tournament week (last 16 of the world cohort). For both intrapersonal approaches, the gender-specific total tournament comparison over time and the gender-specific 2nd tournament week vs. 1st tournament week comparison, the serve strategy parameters (i.e. serve and volley points played and won percentages) showed no significant findings.

Conclusively, no development advantages were observed at all in any of the analysed serve efficiency parameters for women over men, while the results for 2nd serve points won, double fault, and 1st serve in percentages prove significant development advantages in favour of men over women. Adding the higher starting level at the 2nd serve points won and double fault percentages in men, it seems plausible to suggest an increase of training time or a change of training style regarding practice patterns of 2nd serves in elite women's professional tennis, and taking up earlier suggestions by Grambow et al. [14] regarding coaching implications in elite women's tennis, particularly the 1st and 2nd serve drill, as well as the serve target zone drill. Percentages shown in Tables 1 and 2 can be used as benchmarks.

Development differences may be driven by the importance of the (analysed) parameters for the strategy and, by this, the success of players, which leads to a conclusion that serve efficiency parameters may have an even bigger impact on strategic advantages and thus on the chances of winning in general in elite men's tennis compared with elite women's tennis.

In this context, future research may focus on scientific surveys directly interviewing professional tennis players and coaches to identify possible gender-specific differences regarding e.g. the actual amount of practice time put into training contents, such as practising 2nd serves, the importance women and men (players and coaches) ascribe to certain training contents, and the possibly different ways of practising serve efficiency related training contents. Future research may also focus on different surfaces, as well as junior tennis to succeed in tomorrow's tennis practice and, eventually, competition.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

References

1. Ma S-M, Liu C-C, Tan Y, Ma S-C. Winning matches in Grand Slam men's singles: an analysis of player performance-related variables from 1991 to 2008. J Sports Sci. 2013;31(11):1147–1155; doi: 10.1080/02640414.2013.775472.
2. Maquirriain J, Baglione R, Cardey M. Male professional tennis players maintain constant serve speed and accuracy over long matches on grass courts. Eur J Sport Sci. 2016;16(7):845–849;doi:10.1080/17461391.2016.1156163.
3. Meffert D, O'Shannessy C, Born P, Grambow R, Vogt T. Tennis serve performances at break points: approaching practice patterns for coaching. Eur J Sport Sci. 2018; 18(8):1151–1157; doi: 10.1080/17461391.2018.1490821.
4. Filipcic A, Zecic M, Reid M, Crespo M, Panjan A, Nejc S. Differences in performance indicators of elite tennis players in the period 1991–2010. J Phys Educ Sport. 2015;15(4):671–677; doi: 10.7752/jpes.2015.04102.
5. Knight G, O'Donoghue P. The probability of winning break points in Grand Slam men's singles tennis. Eur J SportSci.2012;12(6):462–468;doi:10.1080/17461391.2011.577239.
6. O'Donoghue GP, Brown E. The importance of service in Grand Slam singles tennis. Int J Perform Anal Sport. 2008;8(3):70–78; doi: 10.1080/24748668.2008.11868449.
7. Cui Y, Gómez M-Á, Gonçalves B, Sampaio J. Performance profiles of professional female tennis players in Grand Slams. PLoS One. 2018;13(7):e0200591; doi: 10.1371/journal.pone.0200591.
8. Grambow R, O'Shannessy C, Born P, Meffert D, Vogt T. Serve efficiency development at Wimbledon between 2002 and 2015: a longitudinal approach to impact tomorrow's tennis practice. Hum Mov. 2020;21(1):65–72; doi: 10.5114/hm.2020.88155.
9. Takahashi H, Wada T, Maeda A, Kodama M, Nishizono H, Kurata H. Time analysis of three decades of men's singles at Wimbledon. In: Lees A, Cabello D, Torres G (eds.), Science and racket sports IV. London: Routledge; 2008; 239–246.
10. Meffert D, O'Shannessy C, Born P, Grambow R, Vogt T. Tennis at tiebreaks: addressing elite players' performance for tomorrows' coaching. Ger J Exerc Sport Res. 2019;49(3):339–344; doi: 10.1007/s12662-019-00611-3.
11. Pollard G, Cross R, Meyer D. An analysis of ten years of the four Grand Slam men's singles data for lack of independence of set outcomes. J Sports Sci Med. 2006;5(4): 561–566.
12. Kovalchik SA, Bane MK, Reid M. Getting to the top: an analysis of 25 years of career rankings trajectories for professional women's tennis. J Sports Sci. 2017;35(19): 1904–1910; doi: 10.1080/02640414.2016.1241419.

13. O'Donoghue P, Liddle D. A match analysis of elite tennis strategy for ladies' singles on clay and grass surfaces. In: Hughes M, Maynard I, Lees A, Reilly T (eds.), Science and racket sports II. London: Taylor & Francis; 2002; 247–253.
14. Grambow R, O'Shannessy C, Born P, Meffert D, Vogt T. Serve efficiency development indicates an extended women's tennis world class cohort: analysing 14 years of Ladies Wimbledon Championships – implications for coaching. Hum Mov. 2021;22(2):43–52; doi: 10.5114/hm.2021.100011.
15. Carboch J. Comparison of game characteristics of male and female tennis players at grand-slam tournaments in 2016. Trends Sport Sci. 2017;24(4):151–155; doi: 10.23829/TSS.2017.24.4-2.
16. Barnett T, Meyer D, Pollard G. Applying match statistics to increase serving performance. Med Sci Tennis. 2008;13(2):24–27.
17. O'Donoghue P, Ingram B. A notational analysis of elite tennis strategy. J Sports Sci. 2001;19(2):107–115; doi: 10.1080/026404101300036299.
18. O'Donoghue PG. The most important points in Grand Slam singles tennis. Res Q Exerc Sport. 2001;72(2): 125–131; doi: 10.1080/02701367.2001.10608942.
19. Reid M, Morgan S, Whiteside D. Matchplay characteristics of Grand Slam tennis: implications for training and conditioning. J Sports Sci. 2016;34(19):1791–1798; doi: 10.1080/02640414.2016.1139161.
20. Brown E, O'Donoghue P. Gender and surface effect on elite tennis strategy. ITF Coach Sport Sci Rev. 2008; 46(12):9–11; doi: 10.1080/24748668.2008.11868449.
21. Magnus JR, Klaassen FJGM. On the advantage of serving first in a tennis set: four years at Wimbledon. Statistician. 1999;48(2):247–256; doi: 10.1111/1467-9884.00186.
22. O'Donoghue P. Performance models of ladies' and men's singles tennis at the Australian Open. Int J Perform Anal Sport. 2002;2(1):73–84; doi: 10.1080/24748668.2002.11868262.
23. Verlinden M, Van Ruyskensvelde J, Van Gorp B, De Decker S, Goossens R, Clarijs J-P. Effect of gender and tennis court surface properties upon strategy in elite singles. In: Kahn J-F, Lees A, Maynard I (eds.), Science and racket sports III. Abingdon: Routledge; 2004; 163–168.
24. Hizan H, Whipp P, Reid M. Comparison of serve and serve return statistics of high performance male and female tennis players from different age-groups. Int J Perform Anal Sport. 2011;11(2):365–375; doi: 10.1080/24748668.2011.11868556.
25. Fett J, Ulbricht A, Ferrauti A. Impact of physical performance and anthropometric characteristics on serve velocity in elite junior tennis players. J Strength Cond Res. 2020;34(1):192–202; doi: 10.1519/JSC.0000000000002641.
26. Elliott B, Whiteside D, Lay B, Reid M. The female tennis serve: an analagous version of the male serve? 31st Conference of the International Society of Biomechanics in Sport, Taipei 2013.
27. Du Bois C, Heyndels B. It's a different game you go to watch: competitive balance in men's and women's tennis. Eur Sport Manag Q. 2007;7(2):167–185; doi: 10.1080/16184740701353349.
28. Kraemer WJ, Triplett NT, Fry AC, Koziris LP, Bauer JE, Lynch JM, et al. An in-depth sports medicine profile of women college tennis players. J Sport Rehabil. 1995;4(2):79–98; doi: 10.1123/jsr.4.2.79.
29. Roetert EP, Brown SW, Piorkowskil PA, Woods RB. Fitness comparisons among three different levels of elite tennis players. J Strength Cond Res. 1996;10(3):139–143; doi: 10.1249/00005768-199405001-00858.
30. Leversen JSR, Haga M, Sigmundsson H. From children to adults: motor performance across the life-span. PLoS One. 2012;7(6):e38830; doi: 10.1371/journal.pone.0038830.
31. Fernandez-Fernandez J, Ellenbecker T, Sanz-Rivas D, Ulbricht A, Ferrauti A. Effects of a 6-week junior tennis conditioning program on service velocity. J Sports Sci Med. 2013;12(2):232–239.
32. Ferrauti A, Bastiaens K. Short-term effects of light and heavy load interventions on service velocity and precision in elite young tennis players. Br J Sports Med. 2007;41(11):750–753; doi: 10.1136/bjsm.2007.036855.
33. Hernández-Davo H, Urbán T, Sarabia JM, Juan-Recio C, Moreno FJ. Variable training: effects on velocity and accuracy in the tennis serve. J Sports Sci. 2014; 32(14):1383–1388; doi: 10.1080/02640414.2014.891290.
34. Cohen J. A power primer. Psychol Bull. 1992;112(1): 155–159; doi: 10.1037//0033-2909.112.1.155.
35. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc. 2009;41(1):3–13; doi: 10.1249/MSS.0b013e31818cb278.
36. Weber K, Exler T, Marx A, Pley C, Röbbel S, Schäffkes C. Faster serves, shorter rallies and higher time pressure for groundstrokes in world-class tennis [in German]. Leistungssport. 2010;40(5):36–42.
37. Reid M, McMurtrie D, Crespo M. The relationship between match statistics and top 100 ranking in professional men's tennis. Int J Perform Anal Sport. 2010; 10(2):131–138;doi:10.1080/24748668.2010.11868509.
38. Mecheri S, Rioult F, Mantel B, Kauffmann F, Benguigui N. The serve impact in tennis: first large-scale study of big Hawk-Eye data. Stat Anal Data Min. 2016;9(5): 310–325; doi: 10.1002/sam.11316.