

Aus dem Institut für Vermittlungskompetenz in den Sportarten
Abteilung Didaktik und Methodik der Sportarten
der Deutschen Sporthochschule Köln
Institutsleiter: Univ. - Prof. Dr. Tobias Vogt

Vermittlung im Tennis:
Zur Effektivität des Aufschlags im Weltklasse-Tennis
- Analysen und Konsequenzen für das Training -

Von der Deutschen Sporthochschule Köln
zur Erlangung des akademischen Grades

Doktor der Sportwissenschaft
(Dr. Sportwiss.)

angenommene Dissertation

vorgelegt von
Ralph Grambow
aus Bad Oldesloe

Köln, 2023

Erster Gutachter:	Univ. - Prof. Dr. Tobias Vogt
Zweite*r Gutachter*in:	Prof. Dr. Dr. Philipp Zimmer
Vorsitzender des Promotionsausschusses:	Univ. - Prof. Dr. Mario Thevis
Datum der Disputation:	19.12.2022

Eidesstattliche Versicherungen gem. § 7 Abs. 2 Nr. 4 und 5

der Promotionsordnung der Deutschen Sporthochschule Köln, 20. Februar 2013:

Hierdurch versichere ich:

Ich habe diese Arbeit selbstständig und nur unter Benutzung der angegebenen Quellen und technischen Hilfen angefertigt; sie hat noch keiner anderen Stelle zur Prüfung vorgelegen. Wörtlich übernommene Textstellen, auch Einzelsätze oder Teile davon, sind als Zitate kenntlich gemacht worden.

Hierdurch erkläre ich, dass ich die „Leitlinien guter wissenschaftlicher Praxis“ der Deutschen Sporthochschule Köln eingehalten habe.

Köln, Februar 2023

Ralph Grambow

Generelle Anmerkungen

Die vorliegende kumulative Dissertation beinhaltet eine Zusammenstellung von drei wissenschaftlichen Manuskripten, die jeweils in englischer Sprache verfasst und bei internationalen Fachzeitschriften publiziert sind. Gemäß § 3 Absatz 4 der Promotionsordnung der Deutschen Sporthochschule Köln (in der Version vom 30. März 2020) ist der Rahmentext dieser Dissertationsschrift in deutscher Sprache verfasst. Eine Zusammenfassung der Dissertation ist zusätzlich in englischer Sprache beigefügt.

Aus urheberrechtlichen Gründen können gemäß den individuellen Richtlinien und Standards der jeweiligen Fachzeitschrift geringfügige Unterschiede hinsichtlich des Layouts der Manuskripte auftreten. Vereinzelt wurden im Sinne der korrekten Schreibweise und eines einheitlichen Zitationsstandards (APA Style, 7th Edition) und Sprachstils (z. B. Vereinheitlichung auf britisches Englisch) Anpassungen vorgenommen, die von der Originalpublikation abweichen. Zur Vermeidung von Dopplungen bei der Nummerierung von Abbildungen und Tabellen wurden hochgestellte römische Ziffern genutzt, um die entsprechende Abbildung bzw. Tabelle der jeweiligen Studie zuzuordnen zu können.

Im Rahmen dieser vorliegenden Dissertationsschrift wird das Gender-Sternchen (*) genutzt, um geschlechtersensible Sprache zu verwenden und mit seiner Nutzung alle verschiedenen Geschlechteridentitäten anzusprechen, ohne eine dieser Identitäten auszuschließen.

Die dieser vorliegenden Dissertationsschrift zugrunde liegenden Daten der All England Championships von Wimbledon 2002 bis 2015 wurden in Kooperation mit Brain Game Tennis vom Wimbledon Information System bezogen. Dies wurde durch die Ethikkommission der Deutschen Sporthochschule genehmigt.

Publikationen

Nachfolgend werden die der vorliegenden kumulativen Dissertationsschrift zu Grunde liegenden Publikationen aufgelistet. Insgesamt integriert diese Dissertationsschrift drei Originalartikel mit Erstautorenschaft, die bereits in internationalen peer-reviewed Fachzeitschriften publiziert wurden. Im Folgenden erfolgt die Auflistung der Publikationen in chronologischer Reihenfolge.

- [1] **Grambow, R.**, O'Shannessy, C., Born, P., Meffert, D., Vogt, T. (2020). Serve efficiency development at Wimbledon between 2002 and 2015: a longitudinal approach to impact tomorrow's tennis practice. *Human Movement*. 21(1):65-72; <https://doi.org/10.5114/hm.2020.88155>
- [2] **Grambow, R.**, O'Shannessy, C., Born, P., Meffert, D., Vogt, T. (2021). Serve efficiency development indicates an extended women's tennis world class cohort: Analysing 14 years of Ladies Wimbledon Championships – implications for coaching *Human Movement*. 22(2):43-52; <https://doi.org/10.5114/hm.2021.100011>
- [3] **Grambow, R.**, Born, P., O'Shannessy, C., Breuer, J., Meffert, D., Vogt, T. (2022). Serve efficiency development in women's vs. men's professional tennis. *Human Movement*. 23(2):128-137; <https://doi.org/10.5114/hm.2022.109071>

Inhaltsverzeichnis

<i>Generelle Anmerkungen</i>	IV
<i>Publikationen</i>	V
<i>Inhaltsverzeichnis</i>	VI
<i>Abkürzungsverzeichnis</i>	VII
<i>Abbildungsverzeichnis</i>	VIII
<i>Tabellenverzeichnis</i>	IX
<i>Zusammenfassung / Summary</i>	X
1 Einleitung	14
2 Theoretischer Hintergrund und Forschungsstand	16
2.1 Der Aufschlag	16
2.2 Ballwechsellänge im modernen Tennis.....	17
2.3 Wimbledon – Zur Relevanz und Sonderstellung	19
2.4 Hintergründe des Tennistrainings	21
2.5 Forschungslücken und abgeleitete Zielstellungen.....	22
3 Eigene empirische Forschungsarbeiten	27
3.1 Studie I: Serve efficiency development at Wimbledon between 2002 and 2015: A longitudinal approach to impact tomorrow’s tennis practice	27
3.2 Studie II: Serve efficiency development indicates an extended women’s tennis world class cohort: Analysing 14 years of Ladies Wimbledon Championships – implications for coaching	41
3.3 Studie III: Serve efficiency development in women’s vs. men’s professional tennis... ..	58
4 Zentrale Erkenntnisse und Schlussfolgerungen	75
4.1 Hauptergebnisse	75
4.2 Handlungsempfehlungen für den Praxistransfer	78
4.3 Limitationen	80
4.4 Ausblick und weitere Forschungsansätze	81
5 Literaturverzeichnis	83
6 Anhang	89

Abkürzungsverzeichnis

AELTC	All England Lawn Tennis and Croquet Club
ATP	Vereinigung der professionellen männlichen Tennisspieler [Association of Tennis Professionals]
bzw.	beziehungsweise
DTB	Deutscher Tennis Bund
evtl.	eventuell
IBM	Amerikanisches IT- und Beratungsunternehmen [International Business Machines Corporation]
ITF	Tennisweltverband [International Tennis Federation]
min	Minuten
Pkt	Punkten
Tab.	Tabelle [Table]
vs.	versus
WTA	Vereinigung der professionellen weiblichen Tennisspielerinnen [Women's Tennis Association]
z. B.	zum Beispiel

Abbildungsverzeichnis

ABBILDUNG 1: MODELL DER LEISTUNGSFAKTOREN IM TENNIS	21
FIGURE 1^I: CORRELATION OF DIFFERENT TOURNAMENT WEEKS	35
FIGURE 1^{II}: CORRELATION OF DIFFERENT TOURNAMENT WEEKS	50
FIGURE 1^{III}: INTRAPERSONAL GENDER COMPARISONS OF THE 2 ND TOURNAMENT WEEK VS. 1 ST 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	68

Tabellenverzeichnis

TABELLE 1: BALLWECHSELLÄNGE GRAND-SLAM-TURNIER 2016 IM HERRENBEREICH	18
TABELLE 2: KORRELATION GEWINNER DER KATEGORIEN BALLWECHSELLÄNGE UND GEWINN DES MATCHES IM HERRENBEREICH	19
TABELLE 3: KORRELATION GEWINNERIN DER KATEGORIEN BALLWECHSELLÄNGE UND GEWINN DES MATCHES IM DAMENBEREICH.....	19
TABLE 1^I: COMPARISON OF DIFFERENT TOURNAMENT WEEKS	34
TABLE 1^{II}: COMPARISON OF DIFFERENT TOURNAMENT WEEKS	49
TABLE 1^{III}: TOTAL TOURNAMENT PARAMETER PERCENTAGES INCLUDING MINIMUM AND MAXIMUM BENCHMARKS.....	66
TABLE 2^{III}: SECOND TOURNAMENT WEEK PARAMETER PERCENTAGES INCLUDING MINIMUM AND MAXIMUM BENCHMARKS.....	67

Zusammenfassung / Summary

Ganz egal auf welcher sportlichen Ebene man sich im Tennis bewegt: Jedes Spiel und jeder Ballwechsel werden mit einem Aufschlag begonnen. Dies gilt im Jugend- oder Erwachsenentennis, im Damen- oder Herrenbereich, im Breiten- oder Leistungssport. Demnach kommt dem Aufschlag als Eröffnungsschlag per se eine hohe Bedeutung zu. Zudem ist der Aufschlag der einzige Schlag, der ohne Beeinflussung des Gegenübers und aus einer selbst gewählten Position durchgeführt werden kann. Betrachtet man die Länge der Ballwechsel im modernen (Profi-)Tennis, so sind sowohl bei den Damen als auch bei den Herren knapp 70% der Ballwechsel nach 0-4 erfolgreichen Schlägen beendet, wodurch zusehends die Sonderstellung des Aufschlags deutlich wird, weshalb es nur folgerichtig erscheint, dass der Aufschlag im modernen Tennis als wichtigster Schlag gilt.

Die vorliegende kumulative Dissertationsschrift verfolgt das Ziel, sowohl die historische Entwicklung (und vermeintlich gesteigerte Bedeutung) der Aufschlageffektivität innerhalb der Weltklasse im Damen- und Herrentennis festzuhalten und auszuwerten, als auch diese (möglichen) Entwicklungen direkt gegenüberzustellen und daraus resultierende Erkenntnisse für die jeweilige Praxisvermittlung nutzbar zu machen. Zudem wurde erstmals ein Vergleich innerhalb der jeweiligen Weltklasse anhand einer direkten

No matter which level of tennis you play, every game and every rally will start with a serve. This applies to junior or adult tennis, to men's and women's tennis, to amateur and competitive sports. Accordingly, the serve as an opening shot is of great importance per se. In addition, the serve is the only shot that can be executed with no influence by the opponent and from a self-selected (standing) position. If one considers the rally length in modern (professional) tennis, where regardless if in women's and men's tennis 70% of the rallies are finished within 0-4 successful shots, the unique position of the serve becomes increasingly clear, which is why it seems only logical/consequent that the serve is considered the most important shot in modern tennis.

The present cumulative doctoral thesis/dissertation aims to record and analyse the historical development (and their potentially increased importance) of serve efficiency in elite women's and men's tennis, compare the gender-specific developments and transfer potential findings into gender-specific coaching implications. Adding to this, a new approach, which hasn't been used in the existing literature before, was chosen, by directly comparing the 1st and 2nd week match statistics/parameters of the most important

Gegenüberstellung der Kennzahlen/Parameter der ersten und zweiten Turnierwoche des bedeutendsten Tennisturniers der Welt, den All England Championships von Wimbledon, durchgeführt. Die Studien I und II umfassen alle Herren- bzw. Damen Einzelmatches im Hauptfeld von Wimbledon über einen Zeitraum von 14 Jahren (2002 bis 2015), Studie III vergleicht die beobachteten geschlechter-spezifischen Entwicklungsunterschiede innerhalb dieses Zeitraumes.

Die Ergebnisse der ersten Untersuchung zeigen, dass sich die Aufschlageffektivität im Verlauf des Untersuchungszeitraumes signifikant verbessert hat und die Serve & Volley Quote signifikant gesunken ist, wobei die Gewinnquote dieser Taktik gleichbleibend erfolgreich geblieben ist. Beim direkten Vergleich innerhalb der Herren Weltklasse konnten ausschließlich signifikante Vorteile im Bereich der Aufschlageffektivität zugunsten der Spieler der zweiten Turnierwoche festgestellt werden, wodurch eine gesteigerte Bedeutung der Aufschlageffektivität für den Titelgewinn auf dem höchsten Level im professionellen Tennis gefolgert werden kann.

tournament in professional tennis, the All England Championships of Wimbledon.

Studies I and II include all played men's and women's main draw singles matches at Wimbledon over the course of 14 years (between 2002 and 2015), whereas study III compares the gender-specific developments during that time span.

Results of study I show significantly improved serve efficiency over the course of the analysed period of time, while the usage rate of the Serve & Volley strategy significantly decreased, even though the winning percentages remained on the same, successful level. Direct comparison within the men's world class shows one-sided (significant) advantages in favour of the men competing in the 2nd week of the tournament, which relates to increased importance of serve efficiency 'en route' to winning a title at the highest possible stage in men's professional tennis.

Results of study II indicate an extended women's world class cohort. Similar to men's results in study I, findings show significantly increased serve efficiency during the analysed period of time, which all relate to players competing in the 1st tournament week. Results of the third study, show one-sided advantages in favour of men's vs. women's serve efficiency developments, being significant regarding the quality of 2nd serves and the percentage of double faults.

Die Ergebnisse der zweiten Untersuchung deuten auf eine Entwicklung in Richtung einer breiteren Weltspitze im Damentennis hin. Ähnlich wie im Herrenbereich, konnten auch im Damenbereich signifikante Verbesserungen bezüglich der Aufschlageffektivität im Verlauf des Untersuchungszeitraumes festgestellt werden, wobei die Veränderungen innerhalb der ersten Turnierwoche stattgefunden haben. Im Rahmen der dritten Untersuchung sind ausschließlich geschlechterspezifische Entwicklungsunterschiede zugunsten der Herren gegenüber den Damen beobachtet worden. Die Ergebnisse zeigen signifikante Vorteile bezüglich der Qualität der 2. Aufschläge bzw. der Doppelfehleranzahl. In keinem untersuchten Parameter konnte ein Entwicklungsvorteil, signifikant oder nicht, zugunsten der Damen festgehalten werden.

Das Vorhandensein von Zahlen und Statistiken als festem Bestandteil sowohl der Berichterstattung, aber auch der Matchanalyse bzw. der Trainingsvorbereitung im professionellen Tennis, ermöglicht Zuschauer*innen einen tieferen Einblick in die Sportart, Spieler*innen und Trainer*innen eine gezielte Analyse des eigenen Spieles bzw. der eigenen (und folgerichtig auch gegnerischen) Stärken und Schwächen und Wissenschaftler*innen eine gezielte Auseinandersetzung mit Entwicklungen bzw. der Evaluation des Tennissports bzw. des modernen Sportes generell. Mit Blick auf den Transfer der Ergebnisse dieser

All in all, no analysed parameter, significant or not, shows advantages in favour of women's vs. men's professional players.

Match statistics as regular part of media coverage, but also being key elements for match analyses and practice improvements in professional tennis, allow fans/spectators profound insights, players and coaches focused/purposeful analyses of their own (and obviously their opponents) matches, weaknesses and strengths and scientists a selective scientific discussion of the developments in elite modern tennis and in sports in general. With regards to the results of this doctoral thesis, descriptive findings of the long-term analyses and the significant main results of the statistical analyses seem beneficial. Results of study I can be transferred as orientational guideline in competitive and professional men's tennis, whereas results of study II can be transferred directly to competitive and professional women's tennis. Findings of the gender-specific comparison of study III imply a development deficit regarding the quality of 2nd serves in professional women's tennis (compared to men's development over the same period of time), which consequent leads to a potential need of prioritizing or changing the way of training 2nd serves in competitive and professional women's tennis.

Doktorarbeit, erscheinen sowohl die im Rahmen der Langzeituntersuchung beobachteten deskriptiven Prozentwerte der untersuchten Parameter, als auch (prüf-) statistisch signifikanten Hauptkenntnisse als wertvoll. Folgerichtig lassen sich aus den Ergebnissen der Studie I Richtwerte und Orientierungen für die Vermittlung im Leistungs- bzw. Profitennis der Herren ableiten, während sich aus den Ergebnissen der Studie II Richtwerte und Orientierungen für die Vermittlung im Leistungs- bzw. Profitennis der Damen ableiten lassen (vgl. Kapitel 4.2). Der geschlechterspezifische Vergleich im Rahmen von Studie III lässt auf Entwicklungsdefizite im Bereich des 2. Aufschlages im Damenbereich rückschließen, wodurch eine veränderte Trainingsweise oder Schwerpunktsetzung zu hinterfragen ist.

1 Einleitung

Am 7.7.1985 schrieb der damals 17-jährige Boris Becker deutsche Sportgeschichte, indem er als erster ungesetzter Spieler in der 108-jährigen Geschichte Wimbledon das wichtigste Tennisturnier der Welt gewann. Er bezwang im Finale den Südafrikaner Kevin Curren mit 6-3, 6-7, 7-6, 6-4 auf dem „heiligen Rasen“ von Wimbledon (<https://www.wimbledon.com>, Draws Archive). Neben den damals noch weißen Tennisbällen fällt auf, dass beide Kontrahenten nahezu jedem ihrer Aufschläge direkt ans Netz folgten. Im darauffolgenden Jahr wiederholte Boris Becker diesen Erfolg, er hatte zu dieser Zeit scheinbar den Schlüssel zum Erfolg in Wimbledon gefunden: unermüdlich spielte er „Serve & Volley“ und erlangte mit dieser Spielweise sechs Finals in den sieben Jahren von 1985 bis 1991 (drei Titelgewinne 1985, 1986, 1989 und vier zweite Plätze 1988, 1990, 1991, 1995). Dieses Spielsystem deutet auf die hohe Relevanz des Aufschlags („Serve“) hin, da nur mit einem sehr guten Aufschlag die Möglichkeit für den/die Aufschläger*in besteht den Return der Gegnerin bzw. des Gegners am Netz in aussichtsreicher Position zu vollziehen. Ist ein Aufschlag nicht druckvoll und variabel genug, fällt es dem/der Returnspieler*in leicht einen Passierball zu spielen, wenn der/die Aufschläger*in ans Netz läuft (Choppin et al., 2011; Crespo & Miley, 1998; Martin et al., 2012). Martina Navratilova war mit dieser Spielweise sogar noch erfolgreicher, sie gewann zwischen 1982 und 1987 sechsmal in Serie die Damenkonkurrenz in Wimbledon (insgesamt neunmal 1978, 1979, 1982-1987, 1990) (<https://www.wimbledon.com>, Draws Archive).

Seit der Ära Beckers und Kolleg*innen hat sich die Sportart Tennis – wie jede andere Sportart – im professionellen Bereich stark verändert. Beispielsweise hat die Weiterentwicklung des Materials aber auch der gesteigerten Athletik (Antoun, R., 2013; Cross & Pollard, 2009; Schönborn, 2010) im modernen Tennis dazu geführt, dass im Laufe der Jahre die Ballwechsel deutlich kürzer geworden sind (Carboch et al., 2018; Fitzpatrick et al., 2019; Weber et al., 2010) und dadurch folgerichtig die Bedeutung der Spieleröffnung zugenommen hat (Fitzpatrick et al., 2021). Zahlreiche Untersuchungen im Herrenbereich und, in kleinerem Umfang, im Damenbereich, belegen diese Entwicklung, wobei meist Daten aus einzelnen Jahren mit deutlich früheren Zeitpunkten oder mit bereits vorhandener Literatur verglichen wurden (Carboch, 2017; Maquirriain et al., 2016; O’Donoghue & Brown, 2008). Langzeituntersuchungen, die alle Matches der Turniere über einen durchgängigen Zeitraum und anhand gleicher Parameter die Weltspitze der Damen und auch der Herren analysiert haben, sind kaum vorhanden (Ma et al., 2013). Der Teil „Volley“ des Spielsystems Serve & Volley scheint nicht mehr die gleiche Bedeutung zu haben, während der Aufschlag („Serve“) weiterhin der

erfolgsrelevante Faktor für einen Erfolg in Wimbledon zu sein scheint. Dies wird, durch die veränderten Nutzungsspuren des Rasens, für die Zuschauer*innen an den TV-Geräten zuhause leicht ersichtlich, da diese, im Vergleich zu früher, nun deutlich mehr im Grundlinienbereich auftreten und nicht mehr auf dem direkten Weg von der Aufschlagposition ans Netz.

Die vorliegende kumulative Dissertationsschrift hat sich zum Ziel gesetzt, die historische Entwicklung und vermeintlich gesteigerte Bedeutung der Aufschlageffektivität der Weltklasse sowohl im Damen- als auch im Herrenbereich zu analysieren, direkt miteinander vergleichbar zu machen und in der Folge die Erkenntnisse für die Vermittlung zu nutzen und zu übertragen. Servieren die Herren mehr Asse als früher? Hat sich die Doppelfehlerquote bei den Damen verringert? Sind sinkende Gewinnquoten beim Serve & Volley der Grund für die vermeintlich geringere Nutzung dieser Taktik? Haben sich die Damen oder die Herren in gleichen oder unterschiedlichen Bereichen gesteigert? Gibt es Entwicklungsvorteile zu Gunsten eines der Geschlechter? Im Rahmen der vorliegenden, aufeinander aufbauenden Untersuchungen sollen mögliche Unterschiede, aber auch Gemeinsamkeiten herausgearbeitet werden, damit eine eventuell folgerichtige individuelle Vermittlung stattfinden kann.

2 Theoretischer Hintergrund und Forschungsstand

Tennis ist eine sehr vielfältige Sportart, bei der es auf viele verschiedene Arten möglich ist Erfolg zu haben. Spieler*innen können beispielsweise besonders schnell sein, anhand von dominanten Grundschlägen ihre Gegner*innen dominieren, sich durch schnelle und effektive Aufschläge auszeichnen, ihre Gegner*innen auskontern und/oder mental besonders stark sein; die Liste könnte noch weitergeführt werden. Tennis wird generell der Gruppe der Sportspiele zugeordnet, hierbei den Rückschlagspielen (Röthig & Prohl, 2003) und setzt sich bezüglich der Leistungsfaktoren aus einem sehr komplexen Netzwerk an Einflussgrößen zusammen (Ferrauti et al., 2006), bzw. wird die Leistungsstruktur in kaum einer anderen Sportart durch eine ähnliche Vielzahl an Einflussfaktoren geprägt (Ferrauti et al., 2016). Eine Priorisierung erscheint laut Ferrauti et al. (2016) aufgrund der Komplexität der Anforderung nicht möglich. Gleichzeitig unternehmen sie mit ihrem „Modell der Leistungsfaktoren im Tennis“ den Versuch einer grafischen Darstellung dieser komplexen, miteinander verbundenen Zusammenhänge (Ferrauti et al., 2006; Weber & Born, 2012). Laut Born (2017) lässt sich der Tennissport trotz aller Komplexität dennoch auf fünf Situationen reduzieren: den Aufschlag, den Return, das Grundlinienspiel, den Netzangriff und die Passierballsituation. Insbesondere der Aufschlag, oder, in Erweiterung um den Return in der Literatur meist als Spieleröffnung zusammengefasst, ist aufgrund seiner Sonderstellung und vermeintlichen Bedeutung für den Erfolg im Herren-, aber auch im Damenbereich, immer wieder Ziel von Untersuchungen geworden (Crespo & Reid, 2002).

2.1 Der Aufschlag

Der Aufschlag hat, basierend auf dem Regelwerk des Tennissports (siehe <https://www.itftennis.com>, Rules and Regulations, International Tennis Federation (ITF)), in zweifacher Hinsicht eine absolute Sonderstellung im Tennis. Er ist der einzige Schlag, für den die Spieler*innen (1) zwei Versuche haben und zudem der einzige Schlag, der (2) ohne Beeinflussung des Gegenübers stattfindet und somit aus dem Stand, ohne eine vorherige Bewegung zum Ball durchgeführt werden kann. Unterstützt wird diese Sonderstellung durch die Tatsache, dass jeder Punkt in einem Tennismatch zwangsläufig mit einem Aufschlag beginnt, wodurch der Aufschlag eine limitierende Funktion einnimmt. Während im Breitensport oder auch im frühen Jugendalter der Aufschlag aufgrund seiner hohen koordinativen bzw. technischen Anforderungen vermeintlich keine großen Vorteile mit sich bringt, sondern sogar oftmals als Nachteil bzw. Schwierigkeit empfunden wird, nimmt er im professionellen Tennis sowohl im

Damenbereich, aber vor allem im Herrenbereich eine erfolgsbestimmende Rolle ein; so stellen zahlreiche Untersuchungen in der Vergangenheit immer wieder einen Zusammenhang zwischen der Bedeutung des Aufschlags und dem Erfolg im Weltklasse-Tennis her (Filipic et al., 2015; Fitzpatrick et al., 2019; Ma et al., 2013). O'Donoghue and Brown (2008) konnten in ihren Untersuchungen (Grand-Slam-Turniere der Damen- und Herrenkonkurrenzen 2007) zusätzlich die weiterführende Bedeutung des Aufschlags über den direkten Punktgewinn hinaus feststellen. Demnach ergab sich für den fortlaufenden Ballwechsel ein Vorteil für den Aufschläger (im Herrenbereich) durch einen gültigen 1. Aufschlag, da zu 62,4% die Ballwechsel mit drei oder vier Schlägen gewonnen werden konnten, was signifikant mehr war, als die 49,7% bei Ballwechseln mit einer Länge von fünf oder mehr Schlägen. Diesen Unterschied interpretierten die Autoren mit dem aufgehobenen Aufschlag-Vorteil. Der Verlust dieses Aufschlag-Vorteils konnte im Damenbereich bereits nach den ersten beiden Schlägen des Ballwechsels festgestellt werden.

Diese Wichtigkeit des Aufschlags hat aufgrund der dramatischen Veränderungen im Tennissport in den letzten Jahren bezüglich Geschwindigkeit, Aggressivität und Athletik, sicherlich noch zugenommen (vgl. u.a. H.-P. Born, 2014). So liegen beispielsweise die aktuellen Aufschlaggeschwindigkeits-Weltrekorde bei 210,8km/h (Sabine Lisicki, 2014) im Damenbereich und 263km/h (Samuel Groth, 2012) im Herrenbereich. Diese Veränderungen sind zum einen auf das bessere Spielmaterial, aber auch auf neue Trainingsmethoden bzw. Trainingsmöglichkeiten zurückzuführen (Antoun,R., 2013; Cross & Pollard, 2009; Schönborn, 2010). Die Geschwindigkeitsvorteile zugunsten der Herren basieren laut Elliott et al. (2013) und Verlinden et al. (2004) auf den geschlechterspezifischen Unterschieden bezüglich der körperlichen, muskulären Voraussetzungen. Für den Erfolg bei dem wichtigsten Tennisturnier der Welt (Wimbledon), welches die Grundlage der vorliegenden Untersuchung darstellt, aber auch im modernen Weltklasse Tennis sowohl der Damen als auch der Herren generell, erscheint die Rolle des Aufschlags als zentral und dominant, insbesondere in Hinblick und Verbindung zur Entwicklung der Ballwechselstruktur im professionellen Tennis.

2.2 Ballwechsellänge im modernen Tennis

Einhergehend mit den beschriebenen Veränderungen bezüglich der gespielten Geschwindigkeiten, der gesteigerten Aggressivität und der verbesserten Athletik, hat sich die durchschnittliche Ballwechsellänge im Tennis deutlich verkürzt. So berichten Weber et al. (2010) sowohl von einer Abnahme der Ballwechseldauer von 8,3 Sekunden bzw. 7,7 Sekunden

um mehr als 10% auf 6,8 Sekunden, aber auch von der gesunkenen Schlagzahl, wonach über 50% aller Ballwechsel bereits nach vier Schlägen beendet sind. Jüngste Untersuchungen belegen die geschlechterübergreifende Bedeutung kurzer Ballwechsel für den Erfolg im modernen Tennis, wonach sowohl Frauen als auch Männer zu über 90% den Platz als Sieger*in verlassen haben, wenn sie die Kategorie 0-4 Punkte gewonnen haben (Fitzpatrick et al., 2019). Diese Kategorisierung erfolgt aufgrund der (erfolgreich ins Feld) geschlagenen Schläge innerhalb eines Ballwechsels, so dass z. B. jeder Doppelfehler der Ballwechsellänge „0“ zuzuordnen ist. Weiterhin hat sich die durchschnittliche Ballwechsellänge erneut verkürzt, so wurden im Rahmen dieser Analyse der French Open und Wimbledon (2015-2017) nochmals gestiegene Prozentzahlen im Vergleich zu den von Weber beobachteten Werten der Kategorie 0-4 Schläge festgestellt (Damen 66% und Herren 72%) (Fitzpatrick et al., 2019). Analyst Craig O’Shannessy, der im Auftrag der Association of Tennis Professionals (ATP), die auf den Turnieren gesammelten Daten regelmäßig auf der ATP-Homepage unter dem Titel „Beyond the numbers“ interpretiert und veröffentlicht, bestätigt in seinen Untersuchungen die Dominanz der kurzen Ballwechsel und führt zudem an, dass die Prozentzahlen über alle Beläge konstant sind und kaum abweichen, sowohl im Damen- als auch im Herrenbereich. Durchgesetzt hat sich hierbei die Kategorisierung 0-4 Schläge („First Strike“), 5-8 Schläge („Patterns of Play) und 9+ Schläge („Extended Rallies“). Die folgende Tabelle 1 zeigt die von O’Shannessy gesammelten Daten bezüglich der Ballwechsellänge im Herrenbereich bei den Grand-Slam-Turnieren des Jahres 2016, eingeteilt in diese Kategorien.

Tabelle 1: Ballwechsellänge Grand-Slam-Turnier 2016 im Herrenbereich (O’Shannessy, 2016)

RALLY	AUSTRALIAN OPEN	FRENCH OPEN	WIMBLEDON	US OPEN
0-4 shots	69%	67%	71%	68%
5-8 shots	20%	21%	20%	21%
9+ shots	11%	12%	9%	11%

Zusätzlich unterstreicht er in seinen Analysen die Bedeutung der Kategorie 0-4 durch einen von ihm durchgeführten Vergleich Gewinner*in vs. Verlierer*in auf Grand-Slam Ebene (US Open), bei dem zu nahezu 81% bzw. 86% der/die Gewinner*in der Kategorie 0-4 auch das Match für sich entscheiden konnte (siehe Tab.2 und Tab.3, S.19). Dieser Zusammenhang erscheint einerseits als stichhaltig und relevant für die künftige Trainingsplanung, ist aber andererseits auch mathematisch fast folgerichtig, denn durch die Tatsache, dass circa 70% aller gespielten Punkte in genau diese Kategorie fallen, umfasst der Gewinn dieser Kategorie natürlich auch eine deutlich höhere Anzahl an Punkten als beispielsweise die circa 10% aller gespielten

Punkte umfassende 9+ Kategorie. Zusätzlich ist die Auswirkung einzelner Punkte für den Gewinn einer Kategorie (z. B. 0-4: 70 von 100Pkt) mit einer größeren Anzahl an Punkten geringer als in einer Kategorie (z. B. 9+: 10 von 100Pkt) mit weniger gespielten Punkten, wodurch es fast zwangsläufig zu der von O'Shannessy dokumentierten Beobachtung kommen muss. Festzuhalten bleibt aber sicherlich, dass die Kategorie 0-4 den potentiell größten Einfluss auf das Ergebnis eines Matches hat und es diese Tatsache bei der Trainingsplanung zu berücksichtigen gilt.

Table 2: Korrelation Gewinner der Kategorien Ballwechsellänge und Gewinn des Matches im Herrenbereich (O'Shannessy, 2016)

2015 & 2016 US Open Herren			
RALLY	0-4 shots	5-8 shots	9+ shots
WIN %	86%	61%	50%

Table 3: Korrelation Gewinnerin der Kategorien Ballwechsellänge und Gewinn des Matches im Damenbereich (O'Shannessy, 2016)

2015 US Open Damen			
RALLY	0-4 shots	5-8 shots	9+ shots
WIN %	81%	61%	43%

Abschließend begünstigt der in Wimbledon gespielte Rasenbelag laut Literatur den Aufschlag im Quervergleich der vier Grand-Slam-Turniere am meisten. So konnte einerseits festgestellt werden, dass der Rasen in Wimbledon im Vergleich zu Sand- und Hartplätzen der anderen Grand-Slam-Turniere die Wirkung bzw. den Erfolg des Aufschlags bevorzugt (Knight & O'Donoghue, 2012) und andererseits die Bedeutung des Aufschlags für den Erfolg in Wimbledon größer erscheint als in Melbourne, Paris oder New York (Hughes & Clarke, 1995; O'Donoghue & Brown, 2008).

2.3 Wimbledon – Zur Relevanz und Sonderstellung

Die „Lawn Tennis Championships“ von Wimbledon sind das älteste und prestigeträchtigste Tennisturnier der Welt. Sie finden jedes Jahr als drittes der vier Grand-Slam-Turniere nach den Australian und French Open und vor den abschließenden US Open statt. Das besondere an diesen Meisterschaften in Wimbledon ist, dass sie auf Rasen gespielt werden. Zudem ist es das einzige Turnier, welches nicht ausschließlich nach den aktuellen Weltranglistenpositionen die Setzliste bestimmt, sondern auch die Ergebnisse auf Rasen innerhalb der letzten zwei

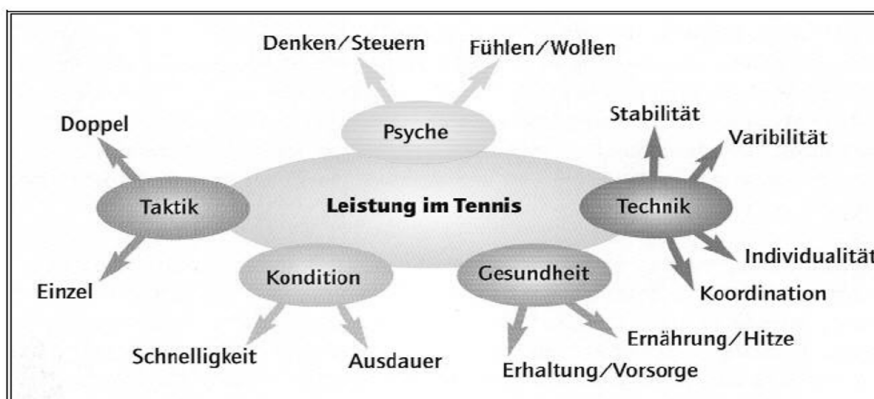
Jahre berücksichtigt. Die Turnierveranstalter, der „All England Lawn Tennis and Croquet Club“ (AELTC), schätzt und bewahrt seine alten Traditionen, so ist Wimbledon beispielsweise das einzige Turnier, bei welchem die Spielkleidung noch zu 90% weiß sein muss. Der Veranstalter (AELTC) selbst ist auch als Besonderheit anzusehen, da es sich um einen eigenständigen Club handelt, während die anderen drei Grand-Slam-Turniere jeweils vom nationalen Tennisverband (Tennis Australia (TA), Federation Francais de Tennis (FFT), United States Tennis Association (USTA)) ausgetragen werden. Im Laufe der letzten Jahre hat bei den Veranstaltern ein Umdenken stattgefunden und einige der Traditionen sind oder werden dem Wandel der Zeit bzw. des Spiels zum Opfer fallen. Um ein paar bedeutendere Beispiele aufzuführen, wird in diesem Jahr (2022) beispielsweise der traditionelle „Middle Sunday“, der spielfreie Sonntag zwischen der 1. und 2. Turnierwoche wegfallen. Dies war bislang nur wetterbedingt und, seit der ersten Auftragung des Turniers 1877, erst in vier Jahren (1991, 1997, 2004 und 2016) geschehen. Eine weitere besondere Änderung war die Einführung des Tiebreaks im entscheidenden fünften Satz beim Spielstand von 12:12 (erstmalig gespielt ab 2019), mit der scheinbar auf die zunehmende Aufschlagdominanz von Seiten der Veranstalter reagiert wurde bzw. werden musste. So brachte das Rekordmatch zwischen John Isner (USA) und Nicolas Mahut (FRA) im Jahre 2010 bereits direkt zu Beginn des Turniers den Zeitplan durcheinander, indem die Erstrundenpartie sich über drei Tage erstreckte und mit 70:68 nach 11:05h im fünften Satz für Isner endete. Dieses Match wurde evtl. als Ausnahme angesehen, aber nachdem das Halbfinale 2018 zwischen Kevin Anderson (RSA) und erneut John Isner (USA) nach 6:36h Spielzeit mit 7:6(6), 6:7(5), 6:7(9), 6:4, 26:24 an den Südafrikaner ging, zweifelten beide Spieler die Sinnhaftigkeit des Modus auf der Pressekonferenz im Anschluss an das Match an. Zudem wurde der Zeitplan erneut durcheinandergebracht und das zweite Halbfinale zwischen Djokovic (SRB) und Nadal (SPA) konnte nicht vor Einbruch der Dunkelheit beendet werden und musste somit vor dem Damenfinale am Samstag fortgesetzt werden (<https://www.wimbledon.com>, AELTC 2021, Draws Archive; alternativ Artikel auf [theguardian.com](https://www.theguardian.com)).

Im Jahr 2001 haben die Veranstalter (AELTC) im Anschluss an das Turnier die Entscheidung für den Neubau aller Plätze getroffen, bei der sich die Zusammensetzung des Rasens veränderte (ab 2002: 100% Perennial Ryegrass, vorher: 70% / 30% Ryegrass / Creeping red fescue, um den Ansprüchen des modernen Tennis besser gerecht werden zu können (<https://www.wimbledon.com>, AELTC 2021)). Diese Veränderung, in Verbindung mit der Einführung neuer Bälle (eingeteilt nach Geschwindigkeit, abhängig zu den Belägen) durch die ITF zu Beginn des Jahres 2002, haben die Auswahl des Untersuchungszeitraumes der vorliegenden Dissertationsschrift beeinflusst, weshalb das Jahr 2002 als Anfangsjahr ausgewählt wurde.

2.4 Hintergründe des Tennistrainings

Die nationale Fachliteratur beschäftigt sich primär mit der Leistungsstruktur im Tennis, also den verschiedenen Komponenten, die Einfluss auf die Leistung im Tennis haben (siehe Abbildung 1, S.21). Übereinstimmend wird von der Technik als dem leistungslimitierenden Faktor gesprochen, wobei Schönborn (2016, S.9) feststellt, dass es in der „tennisspezifischen Weltliteratur... wesentlich mehr Bücher über die Tennistechnik als über das Training derselben“ gibt. Während in diesem Bereich „in der Mehrzahl der Sportarten... bedeutende Entwicklungen zu registrieren“ seien, würde im Tennis das Training sogar im Profibereich noch „viel zu oft demjenigen der Väter der heutigen Spielergeneration gleichen, was in anderen Sportarten kaum noch vorstellbar“ wäre. Laut dem Tennis-Lehrplan des Deutschen Tennis Bundes (1996, S.8) herrscht in der Tennis Praxis noch vielfach die Meinung, dass Trainingsspiele und möglichst viele Wettkämpfe das beste Training seien. „Demgegenüber zeige die Entwicklung der Spitzenleistungen im Tennis und anderen Sportarten, ... dass ein gezieltes und systematisches Training von Technik und Koordination, Taktik, Kondition und Psyche... zu einer wesentlichen Steigerung der allgemeinen und individuellen Leistungsfähigkeit führt.“

Abbildung 1: Modell der Leistungsfaktoren im Tennis (Ferrauti et al., 2006)



Es gibt in der deutschen Fachliteratur zahlreiche Werke, die das Tennistraining unter diesen verschiedenen Gesichtspunkten beschreiben (Schönborn, 2016; Schönborn, 2010, Ferrauti, Maier, & Weber, 2006; Ferrauti, Maier, & Weber, 2016), jedoch sind konkrete Hinweise zur Gewichtung der Schlaganteile, die auf empirischen Untersuchungen der Weltspitze basieren und somit auch der Entwicklung der erfolgsbestimmenden Faktoren der Sportart Rechnung tragen, weit weniger zu finden. Viel mehr wird ein fundierter und breiter Überblick aller möglichen Trainingsinhalte und Trainingsmethoden zu den verschiedenen Leistungsfaktoren gegeben. Dies gilt auch für die beiden vom Deutschen Tennis Bund (DTB) selbst veröffentlichten

Standardwerke DTB Tennis-Lehrplan Band 1 (Technik & Taktik) und DTB Tennis-Lehrplan Band 2 (Unterricht & Training).

2.5 Forschungslücken und abgeleitete Zielstellungen

Unter Berufung auf die immense Bedeutung des Aufschlages für den Erfolg im modernen Tennis (Carboch, 2017; Filipcic et al., 2015; Fitzpatrick et al., 2021; Ma et al., 2013) befasst sich die vorliegende Dissertationsschrift anhand einer Langzeituntersuchung (über 14 Jahre) mit der Bedeutung und der Entwicklung dieser Bedeutung der Aufschlageffektivität im Einzel für den Gewinn des wichtigsten Tennisturniers der Welt sowohl im Damen- als auch Herrenbereich. Aus dieser Analyse werden Rückschlüsse für die Vermittlung des Aufschlages im leistungsbezogenen Tennistraining gezogen. Hieraus abgeleitet lautet die übergeordnete Fragestellung der vorliegenden Dissertationsschrift:

Welche Bedeutung hat die Aufschlageffektivität als solche und in der historischen Entwicklung für den Gewinn der Einzelkonkurrenz bei Weltklasseturnieren?

Als spezifische, operationalisierte Forschungsfragen wird untersucht:

- Verändert sich die Bedeutung der Aufschlageffektivität innerhalb der unterschiedlichen Niveaus der Tennis-Weltklasse (Wochenvergleich: 1. Woche vs. 2. Woche)?
- Gibt es einen Unterschied der Bedeutung der Aufschlageffektivität zwischen der Damen- und Herren-Konkurrenz?
- Gibt es einen Entwicklungsunterschied in Bezug auf die Aufschlageffektivität im Verlauf des Untersuchungszeitraums (von 2002 bis 2015) zwischen Damen und Herren?

Untersuchungsgegenstand der eigenen empirischen Forschungsarbeiten

Alle gespielten Hauptfeldmatches sowohl der Damen- als auch der Herrenkonkurrenz im Einzel zwischen 2002 und 2015 beim bedeutendsten Tennisturnier der Welt, den All England Championships von Wimbledon. Dies bedeutet im Detail die Analyse von 1771 Damen Einzeln und 1772 Herren Einzeln, bei denen die folgenden Parameter untersucht wurden:

- i. Prozentzahlen gewonnener Aufschlagspiele sowie gewonnener Punkte nach 1. Aufschlag und 2. Aufschlag (Kategorie „serve efficiency“)
- ii. Prozentzahlen servierter Asse und Doppelfehler, sowie in Studie III gültiger 1. Aufschläge (Kategorie „serve performance“)

- iii. Prozentzahlen gespielter und gewonnener Punkte der Serve & Volley Taktik (Kategorie „serve strategy“)

Studie I

Hintergrund zur Forschungslücke und Ableitung der Zielstellung¹:

Die Bedeutung des Aufschlags und der Spieleröffnung für den Erfolg im modernen Tennis, speziell im Herrenbereich, sind unbestritten, wobei sich die meisten Studien auf einzelne Jahre oder Turniere beziehen (Fitzpatrick et al., 2021; Maquirriain et al., 2016; O’Donoghue & Brown, 2008). Entwicklungsvergleiche sind zumeist durch die Gegenüberstellung von Ausgangswerten (Vergangenheit) und aktuellen Daten erstellt worden. Langzeitvergleiche unter Einbeziehung durchgehender, kompletter Datensätze inklusive aller Turnierrunden über den kompletten Beobachtungszeitraum hinweg, sind kaum vorzufinden (Ma et al., 2013). Neben der Frage nach einem Langzeitbeleg für eine gesteigerte Aufschlageffektivität im Herrentennis ist es zudem von Interesse, ob die Bedeutung des Aufschlags im weiteren Verlauf eines Grand Slam Turniers zunimmt. Hierfür wählt der zweite Vergleich innerhalb der (Herren-) Weltklasse, durch die Gegenüberstellung der Daten der 1. Woche und der 2. Woche, einen neuartigen Ansatz, der bisher in der Literatur nicht vorzufinden war, oder in alternativer Gruppierung, beispielweise Gewinner vs. Verlierer oder bezogen auf das jeweilige Ranking (Filipic et al., 2015) durchgeführt wurde.

Charakteristik der Stichprobe¹:

In dieser Vollerhebung wurden sämtliche im Hauptfeld gespielten Herren Einzel der All England Championships von Wimbledon zwischen 2002 und 2015 ($n = 1.772$) erfasst. Untersucht wurden 63.838 Aufschlagspiele und insgesamt 401.527 servierte Aufschläge, zu denen 38.173 Asse und 14.420 Doppelfehler zählten.

Untersuchungsschwerpunkte¹:

- i. Langzeitvergleich der Entwicklung / Verbesserung der untersuchten Parameter der Herrenkonkurrenz über die Dauer von 14 Jahren
- ii. Direkter Vergleich der untersuchten Parameter innerhalb der Weltklasse der Herren (1. Woche vs. 2. Woche)

Hypothesen^I:

- (1) Langzeitvergleich belegt signifikant gesteigerte Aufschlageffektivität bezogen auf die Daten des gesamten Turniers, der 1. Woche und der 2. Woche.
- (2) Vergleich innerhalb der Weltklasse unterstreicht die Bedeutung der Aufschlageffektivität für den Gewinn eines Titels bei den Herren in Wimbledon, anhand signifikanter Vorteile zugunsten der Spieler der absoluten Weltklasse (2. Woche) gegenüber den Spielern der erweiterten Weltklasse (1. Woche)

Studie II**Hintergrund zur Forschungslücke und Ableitung der Zielstellung^{II}:**

Die Bedeutung des Aufschlags und der Spieleröffnung für den Erfolg in der Weltspitze des Damentennis sind unbestritten, wenn auch im Vergleich zur Herrenkonkurrenz weniger oft untersucht und in der Literatur sowie Berichterstattung nicht vergleichbar präsent (Carboch, 2017; Cui et al., 2018; O'Donoghue & Brown, 2008; O'Donoghue & Liddle, 2002). Die in Studie I angestrebten und durchgeführten Vergleiche (Langzeit und innerhalb der Weltklasse) eröffnen die Frage nach selbigen Untersuchungen im Damenbereich, beispielsweise bezüglich einer möglichen Bedeutungszunahme des Aufschlags für den Turniergewinn. Die Verwendung identischer Untersuchungsparameter und Anwendung einer einheitlichen Methodik bereitet einen möglichen geschlechterspezifischen Entwicklungsvergleich bereits vor.

Charakteristik der Stichprobe^{II}:

Sämtliche im Hauptfeld gespielten Damen Einzel der All England Championships von Wimbledon zwischen 2002 und 2015 ($n = 1.771$). Untersucht wurden 37.717 Aufschlagsspiele und insgesamt 248.135 servierte Aufschläge, zu denen 10.525 Asse und 12.100 Doppelfehler zählten.

Untersuchungsschwerpunkte^{II}:

- i. Langzeitvergleich der Entwicklung / Verbesserung der untersuchten Parameter der Damenkonkurrenz über die Dauer von 14 Jahren
- ii. Direkter Vergleich der untersuchten Parameter innerhalb der Weltklasse der Damen (1. Woche vs. 2. Woche)

Hypothesen^{II}:

- (1) Langzeitvergleich belegt signifikant gesteigerte Aufschlageffektivität bezogen auf die Daten des gesamten Turniers und der 1. Woche, nicht aber in der 2. Woche.
- (2) Entwicklung der Aufschlageffektivität hat im Damenbereich im Untersuchungszeitraum in der erweiterten Weltklasse (1. Woche) stattgefunden.

Studie III**Hintergrund zur Forschungslücke und Ableitung der Zielstellung^{III}:**

Die in den Studien I und II beobachteten Ergebnisse eröffnen die Frage nach möglichen geschlechterspezifischen Entwicklungsunterschieden zugunsten der Damen- oder der Herren-Weltklasse im beobachteten Untersuchungszeitraum. Ergebnisse früherer Studien belegten signifikante Vorteile zugunsten der Herren in Bezug auf Gewinnquoten beim Aufschlag und die Quote servierter Asse, wobei die Ergebnisse und nicht die Entwicklung im Fokus der jeweiligen Untersuchungen standen (Brown & O'Donoghue, 2008; Carboch, 2017; O'Donoghue, 2002; Reid et al., 2016). Verlinden et al. (2004) setzen diese Unterschiede mit den differierenden biologischen Voraussetzungen in Verbindung und den daraus resultierenden Differenzen bezüglich der Aufschlaggeschwindigkeiten. Entgegen dieser früheren interpersonellen Vergleiche, zielt der angewendete intrapersonelle Vergleich auf das Erkennen möglicher Entwicklungsunterschiede ab und könnte als möglicher Ausgangspunkt für weiterführende Forschung der dafür verantwortlichen Ursachen dienen.

Charakteristik der Stichprobe^{III}:

Sämtliche im Hauptfeld gespielten Damen ($n = 1.771$) und Herren ($n = 1.772$) Einzel der All England Championships von Wimbledon zwischen 2002 und 2015. Untersucht wurden 37.717 Aufschlagspiele der Damen und 63.838 Aufschlagspiele der Herren, mit insgesamt 248.135 servierten Aufschlägen der Damen und 401.527 servierten Aufschlägen der Herren.

Untersuchungsschwerpunkte^{III}:

- i. Langzeitvergleich der geschlechterspezifischen Entwicklungs- / Verbesserungsunterschiede der untersuchten Parameter über die Dauer von 14 Jahren
- ii. Direkter Vergleich geschlechter-spezifischer Entwicklungs- / Leistungsunterschiede innerhalb der jeweiligen Weltklasse (1. Woche vs. 2. Woche)

Hypothesen^{III}:

- (1) Signifikante Entwicklungsvorteile bezüglich der Aufschlageffektivität zugunsten der Herren gegenüber den Damen im Langzeitvergleich
- (2) Signifikante Entwicklungsvorteile bezüglich der Aufschlageffektivität zugunsten der Herren gegenüber den Damen beim direkten Vergleich innerhalb der Weltklasse (1. Woche vs. 2. Woche)
- (3) Keinerlei Entwicklungsvorteile bezüglich der Aufschlageffektivität zugunsten der Damen gegenüber den Herren sowohl im Langzeitvergleich als auch im direkten Vergleich

3 Eigene empirische Forschungsarbeiten

3.1 Studie I: Serve efficiency development at Wimbledon between 2002 and 2015: A longitudinal approach to impact tomorrow's tennis practice

Reference¹

Grambow, R.¹, O'Shannessy, C.², Born, P.¹, Meffert, D.¹, Vogt, T.^{1,3} (2020). Serve efficiency development at Wimbledon between 2002 and 2015: a longitudinal approach to impact tomorrow's tennis practice. *Human Movement*. 21(1):65-72; <https://doi.org/10.5114/hm.2020.88155>

Contributing Institutions¹

¹Institute for Professional Sport Education and Sport Qualifications, German Sport University Cologne, Cologne, Germany

²Brain Game Tennis, Austin, USA

³Faculty of Sport Sciences, Waseda University, Tokorozawa, Saitama, Japan

ABSTRACT¹

Purpose¹. Good serving is crucial to succeed in men's world class tennis; however, both chronological and skill-related service game development remain to be elucidated. The study aimed to systematically analyse the development of serving behaviour and serve efficiency in world class men's tennis over a period of 14 years.

Methods¹. Historical data collected from all matches at the Wimbledon Championship between 2002 and 2015 (matches: $n = 1772$; service games: $n = 63,838$; serves: $n = 401,527$) were included for analyses. The analyses focused on 2 comparisons, serve efficiency development over time and possible differences within the world class, i.e. 1st tournament week results (matches: $n = 1563$; service games: $n = 55,989$; serves: $n = 352,748$) and 2nd tournament week results (matches: $n = 209$; service games: $n = 7849$; serves: $n = 48,779$).

Results¹. An increase was observed of the percentages for service games won ($p < 0.01$), aces served ($p < 0.01$) and 1st and 2nd serve points won ($p < 0.01$), whereas double faults ($p < 0.05$) and serve and volley points played ($p < 0.01$) decreased over time. Direct comparisons of the 1st and 2nd tournament week show advantages in favour for the 2nd tournament week. Players competing in the 2nd tournament week won higher percentages of service games ($p < 0.01$) and points on the 1st ($p < 0.01$) and 2nd serve ($p < 0.05$), and served more aces ($p < 0.05$) but fewer double faults ($p < 0.05$).

Conclusions¹. With a particular impact on the 2nd tournament week, the findings indicate increased serve efficiency in men's world class grass court tennis from 2002 to 2015, which may imply altered practice patterns in tomorrow's training and coaching.

Keywords¹: world class men's tennis, service game, match strategy, training, coaching

Introduction¹

Match statistics are more and more used by the players and coaches to analyse, improve and develop their game. Statistics are applied to analyse matches to eventually implement and transfer gained knowledge from research into practice as well as into match preparation. To feed research that allows for a knowledge transfer and to develop a tennis practice that improves the game and eventually turns losing into winning players, numerous tennis-specific parameters are recorded for public availability by the Association of Tennis Professionals (ATP) and their tournaments. Based on this, several studies have discussed advanced statistics to show and explain a players' success (Gillet et al., 2009; Reid et al., 2010; Takahashi et al., 2008). Herein, the importance of the return, the opening shots and, most of all, the serve and precisely its efficiency are well accepted to impact the outcome of a modern tennis match (Elliott & Saviano, 2001; Ma et al., 2013; Maquirriain et al., 2016; Meffert et al., 2018; O'Donoghue & Brown, 2008).

A longitudinal approach, which not only contains a large number of analysed matches but also compares a large period of time and furthermore separates the world class even more, might identify primary indicators for being very successful and, thus, winning matches.

The most important tennis tournaments, the so-called Grand Slam tournaments (Australian Open, French Open, Wimbledon, US Open), have a special role for several reasons. A total of 128 players compete at a Grand Slam tournament; with this, Grand Slam tournaments comprise the largest draw of all ATP tournaments. In order to win the championship, players need to win seven consecutive rounds. Grand Slams are also played with a best of 5 modus, which means in order to win a match, the player has to win 3 sets (in men's tennis). In no other tournament is it possible to win so many ranking points (e.g. 2000 ATP points) and receive such a great amount of prize money (e.g. £2,250,000 at Wimbledon 2018). Therefore, Grand Slams are most difficult to win, which can be underlined by the small number of different Grand Slam winners over the past years compared with the number of different ATP-tournament winners (e.g. in 2003-2017, Grand Slam: 12, ATP 1000: 27, ATP 500: 63). Following this line of argumentation, a focus of a longitudinal approach on a Grand Slam tournament becomes reasonable. The 4 majors are played on different surfaces: the French Open on clay, the Australian and US Open on hardcourt, and Wimbledon on grass.

The present study focused on one particular tournament which is eventually known as the most famous and traditional tournament in tennis, Wimbledon. Winning this tournament is the highest possible reputation for professional tennis players. Although there are only a few grass court tournaments in the yearly professional tennis calendar, compared with the number

of clay court and hardcourt tournaments, the above stated importance and reputation of the tournament legitimates a longitudinal approach focusing on grass court only.

There are several studies and even more coach's opinions stating the significance of the playing surface with regard to the results of an analytic statistical approach. These opinions may be controversial, as some see the court surface as a main indicator influencing the match outcome and game style (O'Donoghue & Ingram, 2001), whereas others, more recently, recognize no effects of the court surface on the match outcome (Del Corral & Prieto-Rodríguez, 2010) or the rally length, for example (Weber & Born, 2012; Weber et al., 2010).

Wimbledon is the only Grand Slam tournament on grass court, which is known as the fastest surface played at this stage. Considering different opinions about the effects of the play surface, Knight and O'Donoghue (2012) proofed Wimbledon to be serve-beneficial. Hughes and Clarke (1995) and O'Donoghue and Brown (2008) showed serving was more important at Wimbledon than at the Australian Open. With the present study focusing on serve efficiency, analysing Wimbledon results is highly compatible.

The study aimed to prove increased service game efficiency over a period of 14 years (2002-2015) and, furthermore, find differences regarding the service game parameters within the men's tennis world class, by, for the first time, comparing 1st and 2nd tournament week totals of men's Grand Slam tennis, which may serve the understanding of the importance of serve efficiency to win a Grand Slam tournament.

Material and methods¹

Longitudinal data from the Gentlemen's Wimbledon Championship 2002-2015 were collected in collaboration with Brain Game Tennis and in compliance with the German Sport University's Ethic Committee from the Wimbledon Information System, presented by IBM. The data include historical numbers for service parameters, such as aces, double faults, serve percentages, and game patterns, like serve and volley. The examined period contains a total of 1772 matches, 63,838 service games, 401,527 serves, 38,173 aces, and 14,420 double faults, which were considered for analyses.

The data analyses in this study focused on 2 main comparisons. The first one concerned the development and changes of the serve efficiency over time, in this case, from 2002 to 2015.

Choosing 2002 as the starting year for this longitudinal research seemed to be appropriate because Wimbledon organizers decided to rebuild all grass courts following the 2001 championships. The new courts were built out of 100% perennial rye grass, compared with old courts being a split of 70-30 rye grass and creeping red fescue. Furthermore, the International Tennis

Federation introduced new balls in 2002, which would play faster or slower depending on the surface.

For the second focus, the examined world class of tennis players was further separated into 1st and 2nd tournament week, in order to find possible differences within the world class and the even more successful world class (i.e. elite players) over a period of 14 years. Earlier studies analysed a smaller sample size, such as semi-finals to the final or the whole tournament or combined different Grand Slam tournaments (Dindar et al., 2011; Ma et al., 2013; Maquirriain et al., 2016; Nowak & Panfil, 2012; Reid et al., 2016). To the knowledge of the authors, particularly for the second part of the analyses, there are no published data that would cover such a long period.

For the comparison over time, the following details, which are widely accepted as valid measures of serve efficiency (Ferrauti & Bastiaens, 2007; Hernández-Davo et al., 2014), were compiled into spreadsheets for each of the 14 analysed years for all 7 played rounds:

- the number of service games won by all players (i.e., serve success);
- the number of the 1st and 2nd serves won by all players (i.e., serve success);
- the number of aces and double faults served by all players (i.e., serve performance);
- the number of points when serve and volley was played and the number of points when serve and volley was won by all players (i.e., serve strategy).

Serve efficiency parameters were categorized in 3 different groups: serve success, serve performance, and serve strategy. The first category, serve success, contains the parameters of service games won, the 1st serve points won, and the 2nd serve points won, since they show how successful a player was while serving, covering all different types of possibilities of how to win a point as a server (e.g. service winners, multiple shot rallies, etc.). The second category, serve performance, contains all served aces and double faults, being the sole parameters that only include the serve and no other shot by the server or the opponent. The third category, serve strategy, refers to all serve and volley points played and serve and volley points won, focusing on the special strategy of coming to the net directly with the serve.

For the 1st and 2nd tournament week, comparison data were collected separately and divided for rounds 1-3 into the 1st tournament week spreadsheet and rounds 4 to the final into the 2nd tournament week spreadsheet. The 1st tournament week data set examines 1563 matches, 55,989 service games, 352,748 serves, 33,111 aces, and 12,993 double faults, whereas the 2nd tournament week data set contains a total of 209 matches, 7849 service games, 48,779 serves, 5062 aces, and 1427 double faults.

Statistical procedures were performed by using Statistica 7.1 (StatSoft Inc., Tulsa, USA) as well as Excel 2016 (Microsoft Corp., Redmond, USA).

The comparison over time was performed by Spearman's rank correlations analyses, with the correlations interpreted as small at $0.1 < \rho < 0.3$, medium at $0.3 < \rho < 0.5$, and large at $\rho > 0.5$ (Cohen, 1992), more recently augmented as very large for $0.5 < \rho < 0.7$ and extremely large $\rho \geq 0.9$ (Hopkins et al., 2009). A one-way analyses of variance (ANOVA) compared the 1st tournament week totals with the 2nd tournament week totals, with 2nd tournament week totals normed to the size of the general 1st tournament week (i.e. 112 matches), subsequent to Kolmogorov-Smirnov tests. Effect sizes (Cohen, 1992) were calculated and interpreted as small ($f = 0.10$), medium ($f = 0.25$), and large ($f = 0.40$) to support big data analyses.

The level of significance was set to $p < 0.05$. The data in the text and tables are presented as mean percentages.

Ethical approval¹

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

Results¹

Serve Success¹

The analyses of service games won showed significant changes from 2002 to 2015 for the total tournament ($\rho = 0.90$; $p < 0.01$), 1st tournament week ($\rho = 0.79$; $p < 0.01$), and 2nd tournament week ($\rho = 0.77$; $p < 0.01$) (Figure 1¹). A direct comparison revealed significant advantages for the 2nd tournament week totals compared with the 1st tournament week totals ($p < 0.01$; $f = 0.75$) (Table 1¹).

The analyses of points won succeeding 1st serves showed significant changes from 2002 to 2015 for the total tournament ($\rho = 0.66$; $p < 0.01$), 1st tournament week ($\rho = 0.62$; $p < 0.05$), and 2nd tournament week ($\rho = 0.56$; $p < 0.05$) (Figure 1¹). A direct comparison revealed significant advantages for the 2nd tournament week totals compared with 1st tournament week totals ($p < 0.01$; $f = 0.61$) (Table 1¹).

The analyses of points won succeeding 2nd serves showed significant changes from 2002 to 2015 for the total tournament ($\rho = 0.75$; $p < 0.01$) and 1st tournament week ($\rho = 0.63$; $p < 0.05$) (Figure 1¹). A direct comparison revealed significant advantages for the 2nd tournament week totals compared with 1st tournament week totals ($p < 0.05$; $f = 0.44$) (Table 1¹).

Serve Performance¹

The analyses of served aces showed significant changes from 2002 to 2015 for the total tournament ($\rho = 0.84$; $p < 0.01$), 1st tournament week ($\rho = 0.85$; $p < 0.001$), and 2nd tournament week ($\rho = 0.61$; $p < 0.05$), whereas the analyses of served double faults reported significant changes from 2002 to 2015 for the total tournament ($\rho = -0.61$; $p < 0.05$), 1st tournament week ($\rho = -0.61$; $p < 0.05$), and 2nd tournament week ($\rho = -0.71$; $p < 0.01$) (Figure 1¹). A direct comparison revealed significant advantages for the 2nd tournament week totals compared with the 1st tournament week totals, with more served aces ($p < 0.05$; $f = 0.40$) and fewer served double faults ($p < 0.05$; $f = 0.49$) for the 2nd tournament week totals (Table 1¹).

Serve Strategy¹

The analyses of serve and volley points played showed significant changes from 2002 to 2015 for the total tournament ($\rho = -0.80$; $p < 0.01$), 1st tournament week ($\rho = -0.81$; $p < 0.001$), and 2nd tournament week ($\rho = -0.68$; $p < 0.01$), whereas the analyses for serve and volley points won reported only significant changes for the 2nd tournament week ($\rho = 0.59$; $p < 0.05$) (Figure 1¹). A direct comparison of serve and volley points played and serve and volley points won revealed no significant differences when comparing the 2nd tournament week totals with the 1st tournament week totals (Table 1¹).

Table 1¹: Comparison of different tournament weeks

Category			Tournament year													
			2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Serve success	Service games won (%)	Total tournament	79.09	80.46	82.17	82.19	82.19	82.68	83.23	82.95	83.78	82.31	82.94	83.72	84.84	83.96
		1 st week	79.04	80.18	82.03	82.16	82.07	82.41	83.07	81.64	82.73	81.83	82.88	83.26	84.32	83.57
		2 nd week	79.40	82.46	83.24	82.42	83.05	84.69	84.28	91.99	92.12	85.64	83.46	86.69	88.73	86.78
	1 st serve points won (%)	Total tournament	73.42	72.48	73.29	73.78	73.04	72.95	74.27	74.98	75.33	73.37	73.92	74.04	74.43	75.11
		1 st week	73.43	72.29	73.35	73.62	72.85	72.78	74.28	74.09	74.63	73.07	73.99	73.92	74.08	74.86
		2 nd week	73.35	73.78	72.79	75.03	74.32	74.25	74.21	81.18	81.27	75.53	73.35	74.83	77.05	76.85
	2 nd serve points won (%)	Total tournament	49.49	50.68	51.81	51.43	51.73	52.57	52.17	52.02	51.96	51.42	52.37	52.08	52.66	52.75
		1 st week	49.28	50.66	51.50	51.35	51.57	52.38	52.11	51.44	51.15	51.25	52.34	52.10	52.35	52.65
		2 nd week	50.75	50.86	54.14	51.96	52.81	53.98	52.60	56.56	58.85	52.64	52.64	51.96	55.04	53.47
Serve performance	Aces (%)	Total tournament	8.35	8.59	8.89	9.22	8.86	8.56	9.02	9.99	11.27	9.25	9.49	10.07	11.06	10.40
		1 st week	8.50	8.46	8.82	9.24	8.86	8.54	9.01	9.29	10.84	9.10	9.54	10.07	10.69	10.35
		2 nd week	7.36	9.50	9.44	9.04	8.82	8.66	9.04	15.04	14.93	10.33	9.18	10.12	13.88	10.82
	Double faults (%)	Total tournament	5.14	4.32	4.13	3.79	3.47	2.96	3.47	3.49	3.39	3.13	2.95	3.13	3.02	3.81
		1 st week	5.30	4.46	4.25	3.84	3.53	3.07	3.58	3.56	3.44	3.19	3.10	3.15	3.10	3.94
		2 nd week	4.13	3.32	3.27	3.37	3.08	2.16	2.75	3.00	2.95	2.68	1.74	2.96	2.38	2.90
Serve strategy	Serve and volley points played (%)	Total tournament	32.60	24.63	22.44	18.59	14.22	12.29	9.87	9.66	7.51	6.29	6.31	7.86	8.04	10.35
		1 st week	32.39	23.45	22.43	19.03	13.90	13.45	9.55	9.73	7.93	5.48	6.38	7.91	8.01	10.40
		2 nd week	33.91	32.92	22.48	15.32	16.44	3.67	11.94	9.19	4.26	12.09	5.76	7.61	8.28	10.05
	Serve and volley points won (%)	Total tournament	67.47	66.49	66.87	68.36	68.29	66.36	67.58	68.78	68.69	66.86	67.22	68.12	70.60	70.58
		1 st week	67.24	66.59	67.29	68.46	68.27	66.20	67.12	68.64	68.42	67.03	66.44	68.01	69.35	70.70
		2 nd week	68.89	65.99	63.72	67.42	68.37	70.59	69.93	69.84	72.54	66.33	73.94	68.89	79.57	69.71

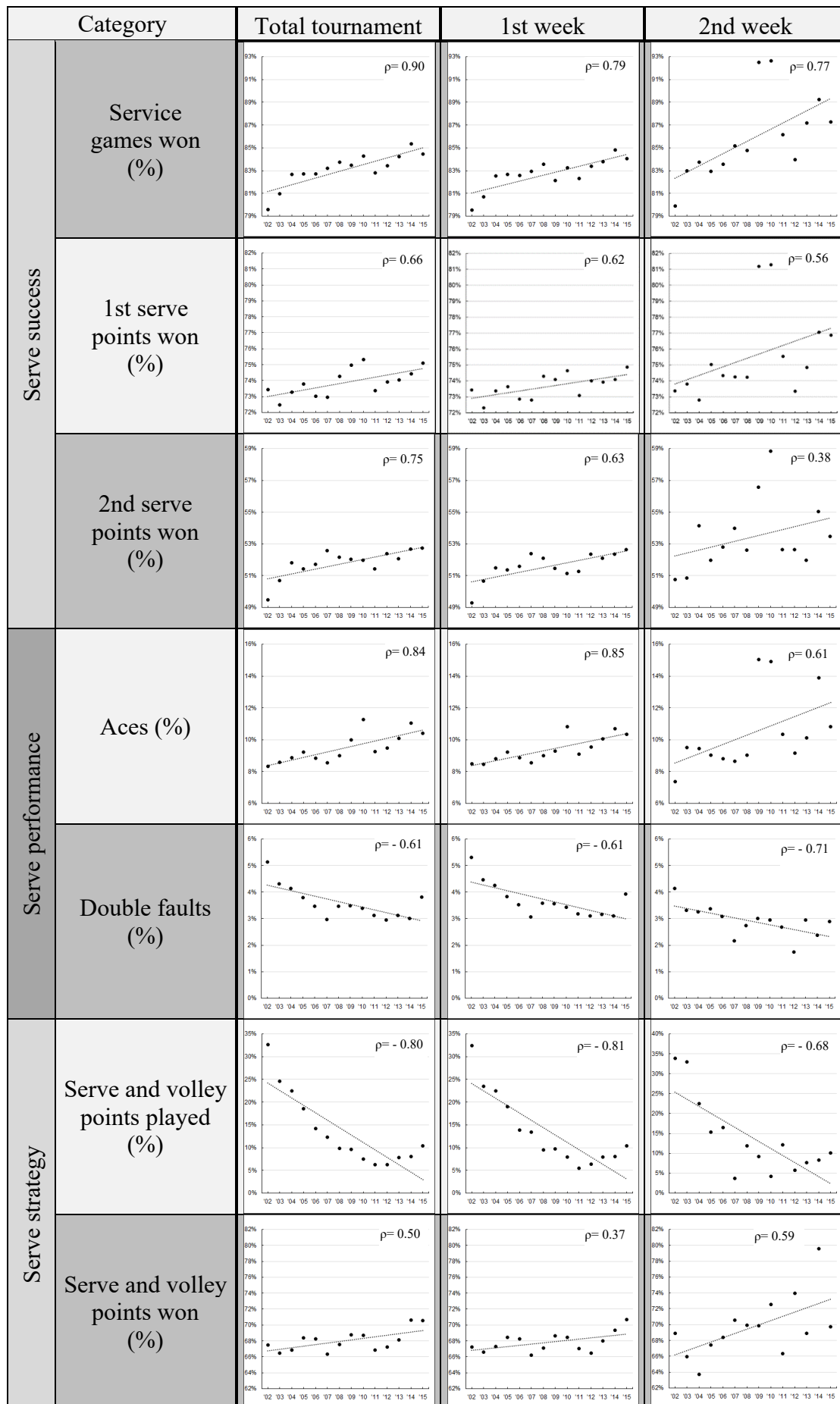


Figure 1!: Correlation of different tournament weeks

Discussion¹

The aim of this study was to systematically analyse the development of serving behaviour and serve efficiency in world class men's tennis over a period of 14 years and to find possible differences within the elite men's tennis by directly comparing 1st and 2nd tournament week totals of men's Grand Slam tennis. With a particular impact on the 2nd tournament week, the present findings indicate the development of increased serve efficiency in men's world class grass court tennis from 2002 to 2015, since total tournament results showed significant changes over the years in 6 out of 7 computed parameters, while the 2nd tournament week totals revealed significant advantages in 5 of the 7 recorded parameters in direct comparison with 1st tournament week totals. These results are in line with previous research, suggesting improved serve and return of serve efficiency in modern professional tennis (Filipic et al., 2015).

The present study findings show significantly increased serve success since the percentages for service games won, and 1st and 2nd serve points won increased over the course of time. Simultaneously, serve performance improved, which was underlined by significantly more served aces and fewer served double faults. However, the serve strategy showed significant changes from 2002 to 2015, including decreased serve and volley points played.

Furthermore, the study results present a one-sided difference regarding a direct comparison between 1st and 2nd tournament week totals, including significant advantages in favour of the 2nd tournament week totals. Not only did the players competing in the 2nd tournament week record a higher serve success by winning their service games and 1st and 2nd serve points at a significantly higher rate; at the same time, their serve performance became better, with serving significantly more aces and significantly fewer double faults. This may be considered surprising because of the higher quality of the competition, meaning the last 16 players in a tournament competing against each other in the 2nd tournament week are supposed not only to serve better but also to return at a higher level. For this reason, the recorded increased serve efficiency by 2nd tournament week totals compared with 1st tournament week totals may be referred to with care.

Since the present findings reveal significantly increased serve success and better serve performance over time, combined with the results of the direct comparison between 1st and 2nd tournament week totals in favour for the players competing in the 2nd tournament week, it seems safe to argue for the importance of serve quality in order to compete for a Grand Slam title like Wimbledon. The study results underline the significance of holding one's own service games in accordance with ongoing competition with better becoming opponents (i.e. closer to the final) and, thus, fewer returning points won. Taking these findings into account, it seems

reasonable that a very high serving quality is needed to compete for or win a Grand Slam title, which may be considered in present and future tennis practice contents. These observations confirm previous research, concerning well accepted importance of serve (Ma et al., 2013; Maquirriain et al., 2016; Meffert et al., 2018) and the serve (efficiency) being even more important to success at Wimbledon compared to other Grand Slam tournaments (Knight & O'Donoghue, 2012; O'Donoghue & Brown, 2008).

Several findings verify improved serve efficiency, one of them being the perfect serve, an ace. The number of aces hit by the players increased over the investigated time. Cross and Pollard (2009) observed increased serve speed in men's singles Grand Slam tennis, a fact that might be a helpful reason for serving aces. Improved serve quality is widely accepted (Barnett et al., 2008; Barnett & Pollard, 2007; Filipcic et al., 2015; Reid et al., 2010), but, most interestingly, while the percentage of hitting aces increased, at the same time the percentage of serving a double fault decreased. Therefore, the line of argumentation may not be that the players are willing to take a greater risk on their serve behaviour in order to hit more aces, since a higher risk most reasonably leads to higher double fault percentages. In turn, the opposite seems to be true, since the double fault percentages decreased from 2002 to 2015. Both an increase in aces and a decrease in double faults once more underline a development of higher serve quality in modern male tennis and are in line with previous research (Barnett et al., 2008; Barnett & Pollard, 2007; Filipcic et al., 2015; Reid et al., 2010).

The present study shows another interesting development concerning serve strategy¹. Over the recorded period, the use of serve and volley as a strategy has dropped (i.e., from 33% in 2002 to 10% in 2015, with even 6% in 2011 and 2012). A change of playing style in modern tennis seems obvious (Schönborn, 2010); however, and in contrast to commonly established successful playing styles in elite tennis (e.g. baseline tennis over serve and volley), it is difficult to believe that the winning percentages over the investigated time may be the reason. The numbers prove a consistent level of winning around the area of 67-68%. A detailed look at the most recent recorded winning percentages shows an increase over the last years (67% in 2002 and 2012; 71% in 2014/2015). The usage rate dropped every year starting from 2002 (33%) until 2011 (6%), before the trend reversed slightly up to 2015 (10%). Even with the slightly reversed trend of usage at the end of the investigated period, it remains questionable if further increasing the usage rate of the serve and volley strategy (10% in 2015) might be successful, since the winning percentage of 71% (2014 and 2015) seems to be very promising. For the last 2 recorded years, the findings revealed the same consistent usage rate percentages for the 1st and 2nd tournament week (8% in 2014; 10% in 2015), while the winning percentages in the 1st tournament

week in 2014 (69%) and 2015 (71%) differ compared to the 2nd tournament week in 2014 (80%) and 2015 (70%). If one considers these numbers, most notably the 80% winning percentage of serve and volley during the 2nd tournament week in the 2014 Wimbledon tournament, it seems advisable to implement this game pattern to the service game more often. While it may be questionable if the winning percentages remain high when serve and volley tactics are implemented more often, an increased use of this strategy and the implementation in current and future practice contents may have a considerable impact on succeeding at highest levels. At this point, an investigation of e.g. Roger Federer's winning campaign in 2017 Wimbledon would be very interesting, particularly with the focus on his usage and winning percentages of the serve and volley strategy.

The indicated long-term increased serve efficiency may also be the reason why Wimbledon organizers were forced to implement rule adjustments by introducing the new final set's tiebreak at 12:12 if no winner has been found before. The recent 2018 Gentlemen's Wimbledon semi-final featured Kevin Anderson (RSA) defeating John Isner (USA) 7:6/6:7/6:7/6:4/26:24 in a 6 h 36 min lasting match, in which both players reached their physical limits owing to their serve performance being so dominant.

Limitations¹

Despite careful considerations, this study is subject to limitations. Ideally prospective, randomized trials are needed, but in the case of elite professional tennis players not feasible. The retrospective nature of the study design was the only possible way to analyse and compare such a great amount of complete match data over a period of 14 years. The risk of statistical bias exists (e.g. injury related serve success, serve performance, serve strategy results, or finally injury dropouts leading to the 59 retirements, as well as the fact that every 2nd tournament week player is also a 1st tournament week player); however, since the study contains every men's match played in Wimbledon between 2002 and 2015 (total matches: $n = 1772$), the risk may be considered as limited. Furthermore, the analysed data presented by IBM pre-set categories like 'aces,' 'points won on 1st serve,' or 'serve and volley points played'. Although the official category definitions are most reasonable, a non-verifiable pre-set definition for officially provided data may be considered as limiting itself.

The collected results are not to every extend transferable. The study only includes men's tennis data; therefore, a transfer to women's or junior's tennis may be insufficient. The same applies partly for a transfer to men's tennis on the 2 main surfaces, clay court and hard court, since the collected data include only grass court matches.

Conclusions¹

The aim of the present study was to investigate men's serve efficiency via a longitudinal approach to all matches played at Wimbledon in years 2002-2015, while not only focusing on a development over time, but also comparing 1st and 2nd tournament week totals in order to examine possible differences within the world class.

The findings provide long-term evidence for increased service game efficiency, suggesting increased serve success and better serve performance. In detail, service games won, 1st and 2nd serve points won, and ace percentages significantly increased; simultaneously, double fault percentages significantly decreased over the time from 2002 to 2015 in men's singles Wimbledon matches. These results are in line with previous research (Barnett et al., 2008; Barnett & Pollard, 2007; Filipcic et al., 2015; Reid et al., 2010). Long-term findings also provide a significant decrease of serve and volley points played, while winning percentages remained stable. A direct comparison of 1st and 2nd tournament week totals recorded differences within elite tennis, showing significant advantages in favour of the 2nd tournament week totals. Serve success (service game, 1st and 2nd serve points winning percentages) and serve performance (ace and double fault percentages) turned out more efficient compared with the 1st tournament week totals.

Long-term findings add on previous research (Barnett et al., 2008; Barnett & Pollard, 2007; Reid et al., 2010) and further prove an increased service game efficiency in elite men's tennis, underlining the importance of transferring these results and, in consequence, implementing the training of these skills into current and future practice contents. The comparison of 1st and 2nd tournament week suggests an even more important role for holding one's own service game on the way to compete and ultimately win a Grand Slam title at Wimbledon.

The present findings might be applicable for all Grand Slam and other ATP tournaments, but need further investigation on the other 3 Grand Slam tournaments, especially because of their different surfaces. All observations may be considered for female tennis; however, since the present study includes exclusively men's tennis, further research is needed on long-term development involving elite female matches.

Acknowledgements¹

The authors would like to express their sincere gratitude to Stefan Laux for his support during data analyses. Also, the authors would like to thank the three unknown reviewers for their valuable comments raised during the revision process.

Disclosure statement¹:

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

Conflict of interest¹:

Authors state no conflict of interest.

3.2 Studie II: Serve efficiency development indicates an extended women's tennis world class cohort: Analysing 14 years of Ladies Wimbledon Championships – implications for coaching

Reference^{II}

Grambow, R.¹, O'Shannessy, C.², Born, P.¹, Meffert, D.¹, Vogt, T.^{1,3} (2021). Serve efficiency development indicates an extended women's tennis world class cohort: Analysing 14 years of Ladies Wimbledon Championships – implications for coaching *Human Movement*. 22(2):43-52; <https://doi.org/10.5114/hm.2021.100011>

Contributing Institutions^{II}

¹Institute for Professional Sport Education and Sport Qualifications, German Sport University Cologne, Cologne, Germany

²Brain Game Tennis, Austin, USA

³Faculty of Sport Sciences, Waseda University, Tokorozawa, Japan

ABSTRACT^{II}

Purpose^{II}. How crucial is good serving to succeed in modern days women's world class tennis? The study aimed to systematically analyse serve efficiency and serving behaviour in elite women's tennis over 14 years to identify possible training patterns.

Methods^{II}. Analyses included historical data collected on all matches at the Ladies Wimbledon Championships of 2002-2015 (matches: $n = 1771$; service games: $n = 37,717$; serves: $n = 248,135$). The study focused on 2 main comparisons, serve efficiency development in 2002-2015 and possible differences within the women's tennis world class, between the 1st (matches: $n = 1562$; service games: $n = 33,150$; serves: $n = 218,028$) and 2nd tournament week results (matches: $n = 209$; service games: $n = 4567$; serves: $n = 30,107$).

Results^{II}. An increase over time was observed for the percentages of service games won ($p < 0.001$), 1st service points won ($p < 0.05$), and aces served ($p < 0.01$), whereas double faults served ($p < 0.05$) and serve and volley points played ($p < 0.001$) decreased significantly. Direct comparisons of the 1st and 2nd tournament week results favour players competing in the 2nd tournament week, showing significant advantages in the percentages of service games won ($p < 0.01$), 1st service points won ($p < 0.05$) and aces served ($p < 0.001$).

Conclusions^{II}. An increased serve efficiency over time was observed, particularly for 1st tournament week results, indicating a more extended women's world class cohort. However, direct comparisons favour players competing in the 2nd tournament week.

Keywords^{II}: world class women's tennis, service game, match strategy, training, practice

Introduction^{II}

Elite tennis is dominated by great players and legends, no matter if we take a look at women's or men's tennis. Whilst in men's tennis only 4 players ranked No. 1 in the world since 2006, 17 different women reached the top during the same time (Association of Tennis Professionals [ATP] and Women's Tennis Association [WTA] homepage, Rankings). Serena Williams is based on her time as No. 1 (319 weeks) and her number of Grand Slam titles (23) the most successful active female tennis player (WTA homepage, Rankings). In order to be so successful and win all these titles, Serena Williams dominates with her powerful baseline game and her even more powerful serve, which is commonly known as the best serve in women's tennis (history), especially under her opponents (e.g. current No. 2, Simona Halep: 'best serve forever', WTA homepage). Her serve seems to separate her from her opponents, which underlines the value of the serve in modern tennis. Whilst in elite men's tennis the importance of the serve, return, and opening shots is well known and analysed (Grambow et al., 2020; Ma et al., 2013; Maquirriain et al., 2016), a longitudinal research focusing on women's serve efficiency might benefit a better understanding of success in elite women's tennis. Elite men win 84% of their service games, 75% of 1st serve points, and 52% of their 2nd serve points, while serving more than 10% of aces (Grambow et al., 2020). Comparable to men's serving, Serena Williams has served the fastest women's serve (122 mph) at the Ladies Wimbledon Championships 2019. However, in general women's serve efficiency remains to be elucidated.

Certainly, tennis players and tennis coaches are most interested in being as successful as possible in reaching the top levels of professional tennis. Therefore, it is most important to understand the characteristics of the sport in order to identify what makes tennis players successful and, thus, what is needed to win titles at the elite level. The International Tennis Federation (ITF) and both the ATP and the WTA deliver several statistics from their matches, serving as information for the commentators and the interested audience but also for the players and coaches in order to improve their own game or prepare for their upcoming opponents. Encouraged by the ITF (Crespo et al., 2003) and the ongoing interest in scientific achievements, scientists also use these statistics to recognize and underline past, current, and possible future elements of the sport.

Whilst elite men's tennis (Grambow et al., 2020; Knight & O'Donoghue, 2012; Ma et al., 2013; Meffert et al., 2018, 2019; Pollard et al., 2006; Takahashi et al., 2008) has regularly been in the focus of scientific analyses and research, only a small number of studies compare gender-specific differences (Barnett et al., 2008; Carboch, 2017; O'Donoghue, 2001; O'Donoghue & Ingram, 2001; O'Donoghue & Brown, 2008; Reid et al., 2016). In fact, elite

women's tennis (Cui et al., 2018; Kovalchik et al., 2017; O'Donoghue & Liddle, 2002) often remains to be elucidated scientifically, especially regarding long-term analyses.

Therefore, the present study focused on the development in serve efficiency over an extended period of time, by analysing all singles matches played at the Ladies Wimbledon Championships between 2002 and 2015, similar to recently reported male long-term analyses (Grambow et al., 2020). The 4 Grand Slam tournaments are the only tournaments in the professional tennis calendar which are played over 2 full weeks. They are held with 128 player draws, giving the players the chance of winning the most world ranking points (e.g. 2000 ATP/WTA points) and the highest prize money (e.g. £2,350,000 for the 2019 Gentlemen's or Ladies' Singles Winner). Wimbledon is the only Grand Slam played on grass court, while the Australian Open and the US Open are played on hardcourt and the French Open is the only one played on clay court. With this, research endeavours regarding the effects of different surfaces on a match outcome suggest different results. Del Corral and Prieto-Rodríguez (2010) revealed no effects of the court surface on a match outcome. Weber and Born (2012); Weber et al. (2010) report no effects on rally length, whereas O'Donoghue and Ingram (2001) suggest the court surface to be the main indicator for a match outcome and game style. Grass court is known as the fastest surface, being serve-beneficial (Knight & O'Donoghue, 2012). The importance of the serve, return, and opening shots in modern tennis is well-documented (Grambow et al., 2020; Ma et al., 2013; Maquirriain et al., 2016; Meffert et al., 2018) and suggested to be even greater on grass court (O'Donoghue & Brown, 2008). With respect to this previous research focused on elite men's tennis, the present study aims to prove increased serve efficiency in elite women's tennis, taking more than a decade of Ladies Wimbledon Championships into account.

The study examines the serve performance, serve success, and serve strategy development over 14 years of Ladies Wimbledon Championships, focusing on world class players, divided into 1st and 2nd tournament week. It is hypothesized that winning percentages of service games, including 1st and 2nd serve points won, increased over the course of 14 years in elite women's tennis, while serve parameters, like aces and double faults, increased and decreased, respectively. It is also hypothesized that comparing findings of the total tournament, the 1st tournament week and the 2nd tournament week results indicate what separates even more successful women (last 16) from successful women (last 128). The findings may serve as indicators of what is needed to succeed at the highest levels on the way to the ultimate goal in tennis, winning a Grand Slam title.

Material and methods^{II}

In collaboration with Brain Game Tennis and with approval of the German Sport University Cologne Ethics Committee, longitudinal data concerning Ladies Wimbledon Championships 2002-2015 were retrieved from Wimbledon Information System (presented by IBM). The collected data included serve percentages for service games, 1st and 2nd serves, service parameters such as aces and double faults, as well as usage and winning percentages for serve and volley points. In total, 1771 matches with 37,717 service games comprising 248,135 serves of which 10,525 were aces and 12,100 were double faults were included for analyses.

Following the research methodology of an earlier study by Grambow et al. (2020), who focused on elite men's tennis, the present study concentrated on 2 main analyses. At first, historical data were analysed for possible developments and changes of elite women's serve behaviour and efficiency (i.e., serve success, serve performance, serve strategy) between 2002 and 2015. Earlier research mostly analysed much smaller sample sizes, focusing on semi-finals to the final or whole tournaments to one year or combined different Grand Slam tournaments (Dindar et al., 2011; Nowak & Panfil, 2012; Reid et al., 2016), but to the knowledge of the authors, there are no published data of elite women's tennis covering such a long period of time, especially not for the second part of the analyses. Taking 2002 as the starting point seemed appropriate owing to the rebuilding of all grass courts after the 2001 championships. Organizers chose to build the new courts out of 100% perennial rye grass, while the old courts were a 70-30 split of rye grass and creeping red fescue. In addition to this, the ITF decided to use new balls in 2002, which would play faster or slower depending on the surface.

The second focus referred to possible differences within the examined women's world class, by further separating the data into 1st tournament week totals and 2nd tournament week totals, in order to analyse what set apart even more successful players (e.g. players competing in the 2nd tournament week, last 16) from successful players (e.g. players competing in the 1st tournament week, last 128). Spreadsheets were compiled for all 7 played rounds in each of the 14 analysed years with the following parameters, which are widely accepted as valid measures for serve efficiency (Ferrauti & Bastiaens, 2007; Hernández-Davo et al., 2014), for the comparison over time:

- the number of 1st and 2nd serves won by all players (i.e., serve success);
- the number of service games won by all players (i.e., serve success);
- the number of aces served by all players (i.e., serve performance);
- the number of double faults served by all players (i.e., serve performance);

- The number of points played by each player when following a serve and volley strategy (i.e., serve strategy);
- the number of points won by each player when following a serve and volley strategy (i.e., serve strategy).

The recorded parameters for serve efficiency were categorized and assigned to 3 different groups: serve success, serve performance, and serve strategy. While the first category, serve success, shows how successful a player was against her opponents (e.g. service winners, multiple shot rallies, etc.) during serving (i.e., percentages of service games won, 1st serve points won, 2nd serve points won), the second category, serve performance, includes only served aces and double faults, since these parameters are defined only by the server and no shots being played by her opponent. The third category, serve strategy, contains all points being played and won while playing serve and volley. Historically, players used this special strategy in Wimbledon, following their serve directly to the net (Barnett & Games, 2010).

Moreover, 1st tournament week totals and 2nd tournament week totals were compared directly. Results of the rounds one, two and three were summarized for 1st tournament week totals (matches: $n = 1562$; service games: $n = 33,150$; serves: $n = 218,028$), whereas results of rounds four, quarter-finals, semi-finals, and final were summarized for 2nd tournament week totals (matches: $n = 209$; service games: $n = 4567$; serves: $n = 30,107$).

Statistical procedures were performed with the use of the SPSS Statistics for Macintosh, version 26.0. (IBM Corp., Armonk, USA), as well as Excel 2016 (Microsoft Corp., Redmond, USA).

A one-way analyses of variance (ANOVA) was applied for a direct comparison of 1st tournament week totals and 2nd tournament week totals, with 2nd tournament week totals normed to the size of a general 1st tournament week (i.e., 112 matches). Effect sizes (Cohen, 1992) were calculated and interpreted as small ($f = 0.10$), medium ($f = 0.25$), and large ($f = 0.40$). Spearman's rank correlations analyses were used for the analyses over time, with $0.1 \leq \rho$ (rho) < 0.3 interpreted as small, $0.3 \leq \rho < 0.5$ as medium, and $\rho \geq 0.5$ as large correlations (Cohen, 1992), more recently augmented with the categories of very large for $0.7 \leq \rho < 0.9$ and extremely large for $\rho \geq 0.9$ (Hopkins et al., 2009).

Data in the text and tables are presented as mean percentages. The significance of the results was set at $p < 0.001$, $p < 0.01$, and $p < 0.05$ for very high significance, high significance, and significance, respectively; trends were accepted for $p < 0.10$.

Ethical approval^{II}

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

Results^{II}

Serve success^{II}

Analyses for service games won (total tournament: minimum 66.69% in 2002, maximum 71.52% in 2010; last 16: minimum 65.05% in 2003, maximum 75.79% in 2009; Table 1^{II}) showed changes from 2002 to 2015 for the total tournament ($p < 0.001$; $\rho = 0.85$) and the 1st tournament week ($p < 0.01$; $\rho = 0.71$), but not for the 2nd tournament week ($p = 0.73$; $\rho = 0.1$; Figure 1^{II}). A direct comparison between the 2 tournament weeks revealed advantages in favour of players competing in the 2nd tournament week ($p < 0.01$; $f = 0.55$; Table 1^{II}).

Analyses for points won following 1st serves (total tournament: minimum 64.10% in 2002, maximum 66.98% in 2015; last 16: minimum 64.42% in 2013, maximum 70.11% in 2009; Table 1^{II}) showed changes from 2002 to 2015 for the total tournament ($p < 0.05$; $\rho = 0.61$) and the 1st tournament week ($p < 0.05$; $\rho = 0.58$), but not for the 2nd tournament week ($p = 0.84$; $\rho = 0.06$; Figure 1^{II}). A direct comparison revealed advantages for the 2nd tournament week totals compared with 1st tournament week totals ($p < 0.05$; $f = 0.43$; Table 1^{II}).

Analyses for points won following 2nd serves (total tournament: minimum 45.00% in 2003, maximum 46.93% in 2010; last 16: minimum 41.78% in 2003, maximum 49.75% in 2009; Table 1^{II}) showed a trend to change from 2002 to 2015 for the total tournament ($p < 0.10$; $\rho = 0.48$), but not for the 1st tournament week ($p = 0.12$; $\rho = 0.43$) and 2nd tournament week ($p = 0.97$; $\rho = -0.01$; Figure 1^{II}). A direct comparison of both tournament weeks revealed no significant differences ($p = 0.64$; $f = 0.09$; Table 1^{II}).

Serve performance^{II}

Analyses for served aces (total tournament: minimum 3.55% in 2002, maximum 5.17% in 2010; last 16: minimum 4.00% in 2003, maximum 7.04% in 2009; Table 1^{II}) showed changes from 2002 to 2015 for the total tournament ($p < 0.01$; $\rho = 0.78$) and the 1st tournament week ($p < 0.01$; $\rho = 0.68$), but not for the 2nd tournament week ($p = 0.20$; $\rho = 0.37$), whereas analyses for served double faults (total tournament: maximum 5.59% in 2002, minimum 4.03% in 2014; last 16: maximum 5.74% in 2009, minimum 4.01% in 2013; Table 1^{II}) showed changes from 2002 to 2015 for the total tournament ($p < 0.05$; $\rho = -0.54$) and a trend to change for the 1st tournament week ($p < 0.10$; $\rho = -0.53$), but not for the 2nd tournament week ($p = 0.23$; $\rho = -0.35$; Figure 1^{II}). A direct comparison revealed advantages for players competing in the 2nd

tournament week by serving more aces ($p < 0.001$; $f = 0.81$), but demonstrated no significant differences by serving more or less double faults ($p = 0.94$; $f = 0.02$; Table 1^{II}).

Serve strategy^{II}

Analyses for serve and volley points played (total tournament: maximum 4.86% in 2002, minimum 0.96% in 2014; last 16: maximum 9.65% in 2006, minimum 0.31% in 2010 and 2011; Table 1^{II}) showed changes from 2002 to 2015 for the total tournament ($p < 0.001$; $\rho = -0.96$) and the 1st tournament week ($p < 0.001$; $\rho = -0.93$); the 2nd tournament week presented a trend to change ($p < 0.10$; $\rho = -0.49$), whereas analyses for serve and volley points won (total tournament: minimum 61.15% in 2011, maximum 70.75% in 2015; last 16: minimum 41.67% in 2003, maximum 84.00% in 2008; Table 1^{II}) showed no significant differences for the total tournament ($p = 0.78$; $\rho = 0.08$) and the 1st tournament week ($p = 0.78$; $\rho = -0.08$), but a trend to change for the 2nd tournament week ($p < 0.10$; $\rho = 0.48$; Figure 1^{II}). A direct comparison of both tournament weeks revealed no differences for serve and volley points played ($p = 0.91$; $f = 0.02$) and serve and volley points won ($p = 0.99$; $f = 0.0$; Table 1^{II}).

Table 1^{II}: Comparison of different tournament weeks

Category			Tournament year													
			2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Serve success	Service games won (%)	Total tournament	66.69	67.67	68.05	67.01	68.20	68.91	68.27	68.45	71.52	69.45	69.40	68.38	69.49	69.63
		1 st week	65.81	68.04	67.73	66.30	68.25	68.64	67.34	67.48	70.99	69.57	69.07	68.50	69.24	69.22
		2 nd week	74.10	65.05	70.25	72.05	67.80	70.59	74.93	75.79	75.40	68.49	71.68	67.54	71.63	72.46
	1 st serve points won (%)	Total tournament	64.10	65.15	64.86	64.54	64.25	64.99	64.68	65.27	66.40	65.31	65.57	64.24	65.41	66.98
		1 st week	63.56	65.09	64.93	64.29	64.13	64.72	64.07	64.69	66.13	65.18	65.26	64.22	65.34	66.82
		2 nd week	68.65	65.56	64.45	66.23	65.23	66.69	68.80	70.11	68.41	66.30	67.63	64.42	66.08	68.11
	2 nd serve points won (%)	Total tournament	46.04	45.00	45.55	45.37	46.20	46.15	46.57	45.30	46.93	46.77	46.24	46.42	46.69	45.51
		1 st week	45.75	45.43	45.52	45.12	46.43	46.31	46.78	44.71	46.64	47.08	46.36	47.00	46.40	45.57
		2 nd week	48.67	41.78	45.74	47.14	44.67	45.11	45.09	49.75	49.11	44.39	45.35	42.45	49.13	45.02
Serve performance	Aces (%)	Total tournament	3.55	3.91	4.22	3.64	3.77	4.25	3.71	4.15	5.17	4.55	4.35	4.25	4.89	4.99
		1 st week	3.40	3.89	4.04	3.56	3.66	4.13	3.39	3.79	5.02	4.43	4.00	4.22	4.96	4.85
		2 nd week	4.86	4.00	5.44	4.23	4.61	5.02	5.96	7.04	6.29	5.47	6.75	4.48	4.27	5.98
	Double faults (%)	Total tournament	5.59	5.27	5.12	5.14	4.68	4.84	4.77	5.27	4.70	4.70	4.84	4.23	4.03	5.16
		1 st week	5.68	5.33	5.22	5.19	4.58	4.82	4.84	5.21	4.66	4.60	4.90	4.26	3.95	5.30
		2 nd week	4.86	4.80	4.45	4.79	5.36	5.02	4.33	5.74	5.01	5.52	4.41	4.01	4.70	4.16
Serve strategy	Serve and volley points played (%)	Total tournament	4.86	4.63	4.44	3.98	3.76	1.78	2.08	2.26	1.69	1.53	1.22	1.17	0.96	1.24
		1 st week	5.03	5.20	4.70	3.91	2.97	1.64	2.22	2.22	1.88	1.69	1.17	1.06	0.93	1.30
		2 nd week	3.44	0.59	2.73	4.45	9.65	2.66	1.10	2.59	0.31	0.31	1.60	1.89	1.23	0.83
	Serve and volley points won (%)	Total tournament	63.32	65.51	66.62	65.76	64.96	67.59	65.68	65.63	62.09	61.15	62.62	64.68	68.45	70.75
		1 st week	64.11	65.90	66.26	65.60	64.14	68.40	64.35	63.88	61.99	60.63	62.79	63.92	67.81	70.62
		2 nd week	53.45	41.67	70.69	66.67	66.84	64.41	84.00	77.55	66.67	83.33	61.76	67.44	72.73	72.22

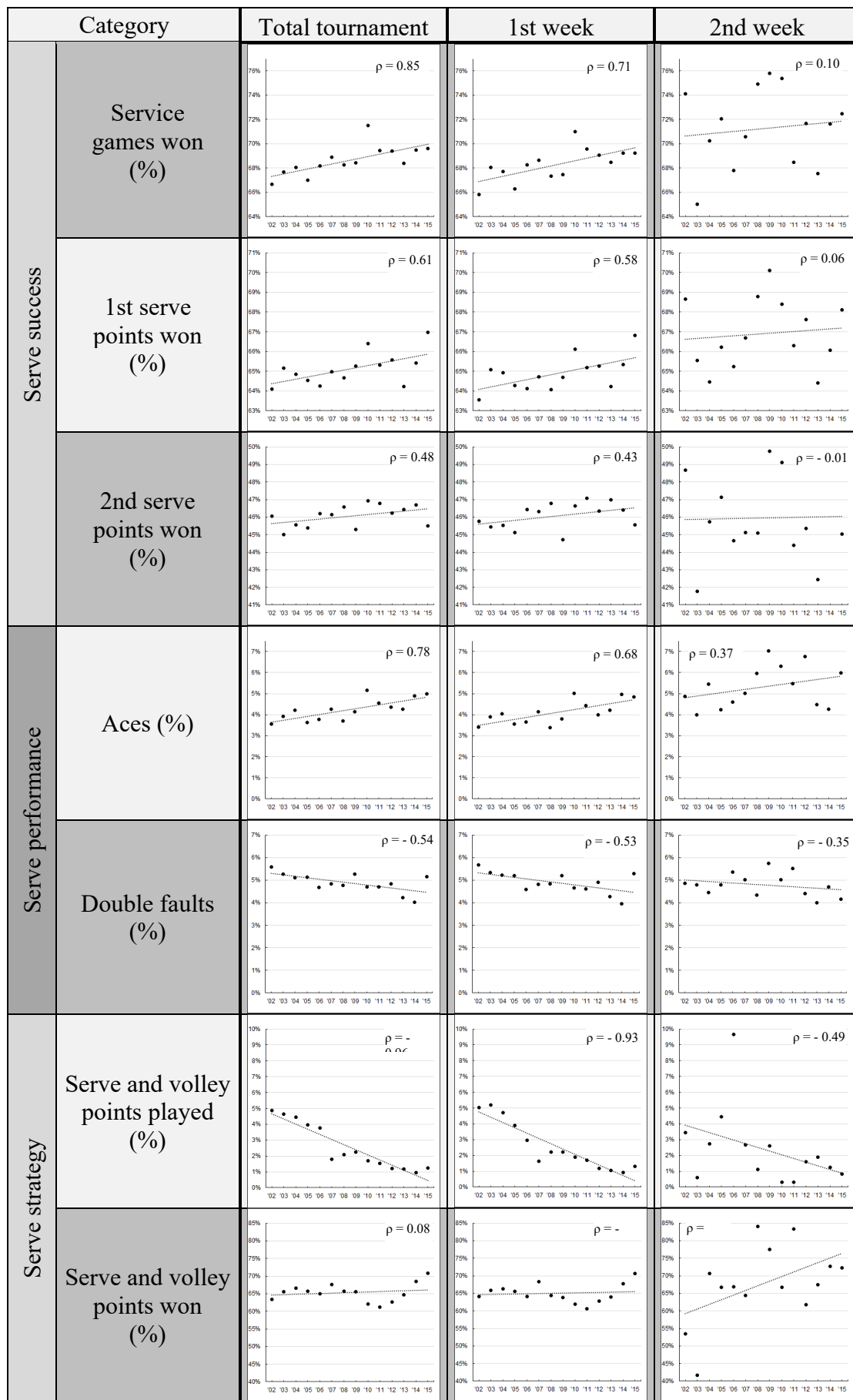


Figure 1^{II}: Correlation of different tournament weeks

Discussion^{II}

The aim of the present study was to find and prove serve efficiency developments in elite women's tennis, by using a longitudinal approach and analysing 14 years of Ladies Wimbledon Championships. The analysed parameters regarding serve success, serve performance, and serve strategy showed significant changes over time for the total tournament in 5 out of 7 categories, for the 1st tournament week totals in 4 out of 7 categories, but none in any category for the 2nd tournament week totals. These findings are in line with earlier results (Filipic et al., 2015). Furthermore, the present study aimed to find possible differences within the women's world class, by directly comparing 1st and 2nd tournament week totals. The findings revealed significant advantages in favour of the players competing in the 2nd tournament week for served aces and success rates of service games won and 1st serve points won. Similar results were observed in elite men's tennis before (Grambow et al., 2020). Comparing minimum and maximum achievements for mean values (total tournament results and 2nd tournament week [last 16] results) regarding serve success and serve performance parameters showed maximum results being closer to today in 9 out of 10 times.

Findings of the comparison over time suggest an increased serve efficiency in elite female tennis at Wimbledon, which may allow an interesting interpretation: tournament totals show an increased number of served aces, as well as increased success rates for the number of service games won and points won after the 1st serve. They also present a decreased number of served double faults. In turn, the findings for 1st tournament week totals show the same significant changes (same categories), only the number of served double faults indicates a statistical trend ($0.05 < p < 0.10$) and findings for 2nd tournament week totals demonstrate no significant changes over time in any of the analysed parameters. The non-existence of any significant increase or decrease in any of the analysed parameters may lead to a conclusion that professional women's tennis has become more competitive and balanced. The observations suggest that the even more successful women (e.g. players competing in the 2nd tournament week at Wimbledon, last 16) were serving at a very high efficiency already more than a decade ago, which separates them from their opponents. Moreover, the present study findings now provide evidence of an increased serve efficiency for tournament totals and 1st tournament week totals, but – as mentioned – not for any parameters of 2nd tournament weeks totals. Thus, the above stated interpretation that developments over the last years have led to a more balanced women's world class appears to be robust. Following this line of thought, it seems reasonable to reflect that any found developments concerning increased serve efficiency in elite female tennis have mainly taken place in the extended world class. This observed development seems to have continued

and even increased, since a very high number of different women reached the top of the world ranking (8 different women between 2016 and 2020) and won a Grand Slam tournament (11 different winners in the last 17 Grand Slam tournaments between 2016 and 2020) in recent years.

Another interpretation, e.g. the non-existence of significant developments for 2nd tournament week totals, may indicate a certain stagnation in the absolute top levels of women's tennis, while the extended world class managed to improve and develop their serve efficiency and by this reduce their performance deficit. But since Serena Williams was the winner of the 2002 Ladies Wimbledon Championships and also the winner of the 2015 Ladies Wimbledon Championships (she won 6 times in the analysed 14 years, 7 times in total, after winning 2016; she also won the Australian Open 2017), it also seems reasonable to question a stagnation with respect to the most successful female tennis player of the open era and, on the contrary, suggest the beforehand discussed more balanced women's world class cohort instead.

In order to find out what is necessary to succeed at the elite level in women's tennis (e.g. winning Wimbledon), dividing the women's world class is of relevance, e.g. when comparing the women's 1st tournament week totals (last 128) to women's 2nd tournament week totals (last 16) for the first time. The present study findings showed advantages in favour of women competing in the 2nd tournament week, more specifically winning their service games and points on 1st serves at significantly higher rates than women competing in the 1st tournament week. These players also serve significantly more aces. No differences were found regarding served double faults, winning points on 2nd serves, or the usage and success rates of playing serve and volley. Second serve points won are the only analysed parameter which actually showed advantages for (last 128) women competing in the 1st tournament week (e.g. in 8 out of 14 analysed years); this could be directly related with a higher return of serve quality by (last 16) women competing in the 2nd tournament week. Consequently, this leads to the assumption that a dominant 1st serve including the capability of hitting aces and a high-quality return of serve (more so returning 2nd serves), but, interestingly, not necessarily a strong 2nd serve including serving only few double faults, increases the chances of playing for the title at Wimbledon. Comparing the absolute numbers over the course of the analysed 14 years showed an interesting ratio of aces vs. double faults in elite women's tennis. While serving 10,525 aces, the players served even more double faults (12,100). This is in contrast to elite men's tennis, where the players served 38,173 aces while hitting 14,420 double faults over the same time span (Grambow et al., 2020). Comparing 1st tournament week absolute numbers (8925 aces vs. 10,662 double faults) with 2nd tournament week absolute numbers (1600 aces vs. 1438 double faults) underlines the above stated

assumption, as women competing in the 2nd tournament week continue to hit double faults but, more importantly, manage to achieve a positive ratio because of their increased number of aces.

The present study reveals improved serve efficiency, which seems to be crucial to succeed at the highest levels of elite tennis, confirming previous research about well-known importance of serve (Ma et al., 2013; Maquirriain et al., 2016; Meffert et al., 2018), even more so on grass court at Wimbledon compared with the other Grand Slam tournaments (Cui et al., 2018; Knight & O'Donoghue, 2012; O'Donoghue & Brown, 2008).

Findings regarding the analysed serve strategies revealed a significant decrease in the use of serve and volley over time. This decrease applies to the total tournament ($p < 0.001$) and to the 1st tournament week totals ($p < 0.001$), but not to the 2nd tournament week totals. These observations are in line with previous results focusing on the 2002-2015 Gentlemen's Wimbledon Championships, with the difference of an additional significant decrease for the 2nd tournament week totals on top to the same decrease in total tournament and 1st tournament week totals (Grambow et al., 2020). The findings showed no significant changes for the serve and volley winning percentages of total tournament and 1st tournament week totals. A change of game style in modern tennis seems obvious (Schönborn, 2010); however, the success rates remained stable at 65% over the analysed 14 years, similar to previously found, with slightly higher winning percentages for the men's success rates (Grambow et al., 2020). Although statistically only indicated by trend ($p = 0.08$), it seems reasonable to discuss the 2nd tournament week totals increase of the serve and volley success rates. Over time, a development from below 60% to more than 75% could be revealed, including a variance in mean values ranging from 42% (in 2003) to 84% (in 2008) or 83% (in 2011). However, these numbers have to be taken with care, since the usage rate percentages of the 2nd tournament week totals are rather low (e.g. mean percentage over the 14 years 2.39%), including great variances (e.g. 2006: 9.65%, 2010 and 2011: 0.31%). Particularly in years 2010 and 2011, when in the completed 2nd tournament week serve and volley was played for only 6 times, the sample size may be considered as too small to allow for any interpretation.

Limitations^{II}

In science, prospective trials should always be preferred over retrospective analyses. Analysing professional tennis competition at the elite level in order to gain knowledge appropriate to possibly impact on future practice contents is only possible with a retrospective study design, particularly in this case with an amount of data covering a period of 14 years.

Findings regarding the serve success, serve performance, or serve strategy may be influenced by a medical issue as the competing players may not be in their best health condition; however, given the enormous number of total matches (e.g. 24 injury retirements out of 1771 analysed matches), a potential data interference may be considered as minor to none.

Every player competing in the 2nd tournament week is part of the 1st tournament week totals, given the structure in which Grand Slam tennis tournaments and professional tennis tournaments in general are played in (e.g. knockout system).

The analysed data presented by IBM pre-set categories like ‘serve and volley points played’, ‘serve and volley points won’, or ‘aces’ may be considered as limiting themselves, since the official category definitions are most reasonable, but ultimately non-verifiable pre-set definitions providing the used official data. Furthermore, pre-set categories like ‘1st serve points won’ present the outcome, but not the content of the game, since the 1st serve itself not necessarily decided the point.

The comparability of the collected findings is limited to certain areas. All analysed matches were played on grass court by elite women, which must be taken under consideration when comparing the present study findings and conclusions with e.g. those for clay court or hard court tournaments or to men’s or junior tennis tournaments.

Conclusion^{II}

The aim of the present study was to analyse elite women’s serve efficiency over an extended period of time and to look for possible keys on the way to succeed at the highest possible stage, in order to be able to suggest present and future practice patterns. Therefore, the present study analysed all played singles matches at the Ladies Wimbledon Championships between 2002 and 2015. In order to examine possible differences within the women’s world class, the data was not only analysed over time but also compared the 1st tournament week totals with the 2nd tournament week totals. The findings provide long-term evidence for an increased serve efficiency development, particularly for an increased serve success and better serve performances. Over time, the rates for service games won, points won on 1st serve, and served aces increased, while, simultaneously, the number of served double faults decreased. These observations are consistent for tournament totals and most pronounced in the 1st tournament week totals, whereas 2nd tournament week totals were unaffected between 2002 to 2015. Thus, a more balanced women’s world class may be suggested with the extended world class having closed in over the analysed 14 years (developments in the 1st tournament week totals; however, not in the 2nd tournament week totals, which may result from better performances in the first place).

Furthermore, it seems important to emphasize that findings for the 1st tournament week totals compared with the 2nd tournament week totals are in favour of women competing in the 2nd tournament week; this concerns served aces and success rates for service games won and 1st serve points won. Interestingly, 2nd serve points won over the analysed period are the only analysed serve success or serve performance parameter which showed no significant improvement over time. Moreover, 2nd serve points won are the only parameter where the 1st tournament week totals showed advantages over the 2nd tournament week totals (e.g. in 8 out of 14 analysed years). This could be related directly to an increased return of serve quality by the (last 16) women competing in the 2nd tournament week.

With this, future research may underpin whether a good 2nd serve leading to higher success rates on the 2nd serves effectively has a smaller impact on the way to succeed at the highest level in elite female tennis (e.g. winning Wimbledon), hinting to the importance of the return of serve, especially returning 2nd serves. Eventually, this may suggest an easy chance for player improvement and, thus, possible separation from competitors; future practice patterns may benefit from the above considerations. In this regard, the long-term analyses of the present study also provide evidence for a gradually diminishing serve and volley strategy, although success rates of serve and volley play remained stable (at around 65%). Future research may also investigate a possible transferability of the findings, e.g. with respect to other surfaces or strategies.

Conclusively, an increased serve efficiency (serve success and serve performance) over time indicates a more extended world class in women's elite grass court tennis and underlines the importance of good serving and the necessity of implementing this in professional practice.

Coaching Implications^{II}

Following the findings of this study, possible guidelines as presented could be implemented in current and future practice. The observed winning percentages on 1st serves (64-70%) and 2nd serves (45-50%) should serve as benchmarks:

- In the 2nd serve drill, the player has to play 20 points and is allowed to serve only 1 serve per point (2nd serve). The player has to win at least 9 points to succeed; every number over 9 points has to be considered very good. If the player fails to reach the 9 points, the drill has to be done again.
- In the 1st serve drill, the player has to play 20 points and is allowed to serve only 1st serves. The point will start only after a successful 1st serve, even if the player needs more attempts. The player has to win at least 13 points; every number over 13 points has to be considered very good. If the player fails to reach the 13 points, the drill has to be done again.
- Both drills playing at least 20 points will take some time, but underline the importance of the serve (and the return of serve for the training partner) and reflect the percentage of how much the serve, return, and opening shots should be implemented in the modern tennis practice. It should also be preferred to outplay the points instead of only serving (which nevertheless should also be done), since the contemplated winning percentages relate not only to the serve alone, but also to the gameplay afterwards.

The findings show elite women serve more double faults than aces, but players competing in the 2nd tournament week (last 16) achieve a slightly positive ratio. Nevertheless, a drill for 2nd serves in order to decrease the number of double faults in elite women's tennis seems beneficial. The presented numbers relate to professional practice:

- Each service box should be split up into 3 zones (wide, body, and centre) in order to have 6 different target zones acting as levels 1-6. The player may choose where to start and serve five 2nd serves aiming for the same target zone. When serving all five 2nd serves successful to the chosen zone, the player reaches the second level (new target zone). With 4 successful serves, the player stays in the current level and serves again 5 serves in order to reach the next level. With 3 successful serves, the player has to go 1 level down and try to pass the previous level successful again. With 2 or less successful 2nd serves, the player has to start from level 1 all over again. The drill finishes with 5 successful serves at level 6. Exercising this drill secures a high number of 2nd serves being served by the player, while getting to know the player's

favourite serving directions (interesting for the player and the coach). In this way, the player may know where to aim in match situations, while being under pressure. In addition, the less favourite target zones may be trained more in the future.

- Alternatively, the drill may be used for psychological practice as well if (1) players compete against a training partner and (2) have to announce deciding serves (e.g. the final (5th) serve after successfully hitting the previous 4 serves to a target zone or hitting the deciding serve for a restart at level 1), in order to be watched serving the final attempt by the coach and the training partner(s).

Acknowledgements^{II}

The authors would like to thank busy bee Stefan Laux for his assistance during data analyses. Also, the authors would like to thank the three unknown reviewers for their valuable comments raised during the revision process.

Disclosure statement^{II}:

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

Conflict of interest^{II}:

The authors state no conflict of interest.

3.3 Studie III: Serve efficiency development in women's vs. men's professional tennis

Reference^{III}

Grambow, R.¹, Born, P.¹, O'Shannessy, C.², Breuer, J.¹, Meffert, D.¹, Vogt, T.^{1,3} (2022). Serve efficiency development in women's vs. men's professional tennis. *Human Movement*. 23(2):128-137; <https://doi.org/10.5114/hm.2022.109071>

Contributing Institutions^{III}

¹Institute for Professional Sport Education and Sport Qualifications, German Sport University Cologne, Cologne, Germany

²Brain Game Tennis, Austin, USA

³Faculty of Sport Sciences, Waseda University, Tokorozawa, Japan

ABSTRACT^{III}

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

Methods^{III}. 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^{III}. 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^{III}. 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^{III}: elite, coaching, practice, gender, game opening, Wimbledon

Introduction^{III}

The importance of the serve in professional women's and men's tennis is well-known (Filipcic et al., 2015; Ma et al., 2013; Maquirriain et al., 2016; Meffert et al., 2018), with an even bigger impact on grass court at Wimbledon compared with the Australian, French and US Open (Cui et al., 2018; Knight & O'Donoghue, 2012; O'Donoghue & Brown, 2008). Previous research offers distinguished scientific analyses on elite men's and women's tennis (Cui et al., 2018; Filipcic et al., 2015; Grambow et al., 2020; Grambow et al., 2021; Knight & O'Donoghue, 2012; Kovalchik et al., 2017; Ma et al., 2013; Meffert et al., 2018, 2019; O'Donoghue & Liddle, 2002; Pollard et al., 2006; Takahashi et al., 2008); however, just over a handful of them took gender-specific differences into account (Barnett et al., 2008; Carboch, 2017; O'Donoghue, 2001; O'Donoghue & Ingram, 2001; O'Donoghue & Brown, 2008; Reid et al., 2016). 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 (Grambow et al., 2020; Grambow et al., 2021). 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 (Brown & O'Donoghue, 2008; Magnus & Klaassen, 1999; O'Donoghue & Ingram, 2001; O'Donoghue, 2002; Verlinden et al., 2004). On this basis, Verlinden et al. (2004) speculated about the disparity in physical strength and stature, as well as serve speed as the reason of these gender differences of served aces (Hizan et al., 2011). Comparing the fastest known serves (Samuel Groth: 263 km/h, 2012; Sabine Lisicki: 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 (Fett et al., 2020). With respect to commonly accepted body constitutional differences (Du Bois & Heyndels, 2007; Elliott et al., 2013; Verlinden et al., 2004), it may be considered misleading to interpersonally compare women's with men's serve efficiency. Cumulated by Elliott et al. (2013), previous research suggests anthropometric and physiological differences referring to height (i.e., absolute size), muscular strength, flexibility, and power (Kraemer et al., 1995; Roetert et al., 1996), Moreover, and referring to movement learning and motor control, analogous movement patterns have been reported to be

functionally improbable (Leversen et al., 2012). 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 (Elliott et al., 2013). 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 (Grambow et al., 2020; Grambow et al., 2021). 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) (Grambow et al., 2020; Grambow et al., 2021). 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 (Fernandez-Fernandez et al., 2013; Fett et al., 2020).

Material and methods^{III}

Based on the results of 2 earlier studies by Grambow et al. (2020; 2021) 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^{III}

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^{III}

As explained earlier, body constitutional differences (Du Bois & Heyndels, 2007; Elliott et al., 2013; Verlinden et al., 2004) 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. (2020; 2021), the analysed serve parameters listed below, which are commonly known as valid measures for serve efficiency (Ferrauti & Bastiaens, 2007; Hernández-Davo et al., 2014), 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. (2020; 2021). 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^{III}

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 ($r \geq 0.5$) (Cohen, 1992), more recently augmented as very large ($r \geq 0.7$) and extremely large ($r \geq 0.9$) (Hopkins et al., 2009).

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^{III}

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

Results^{III}

Serve success^{III}

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^{III}). 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^{III}).

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^{III}, Figure 1^{III}). 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^{III}, Figure 1^{III}).

Serve performance^{III}

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 women's ($M = 1.03$; $SD = 0.01$) percentages ($p < 0.05$; $r = 0.72$) (Table 1^{III}). 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^{III}). 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^{III}).

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^{III}, Figure 1^{III}). 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^{III}, Figure 1^{III}). 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^{III}, Figure 1^{III}).

Serve strategy^{III}

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^{III}).

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^{III}, Figure 1^{III}).

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

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

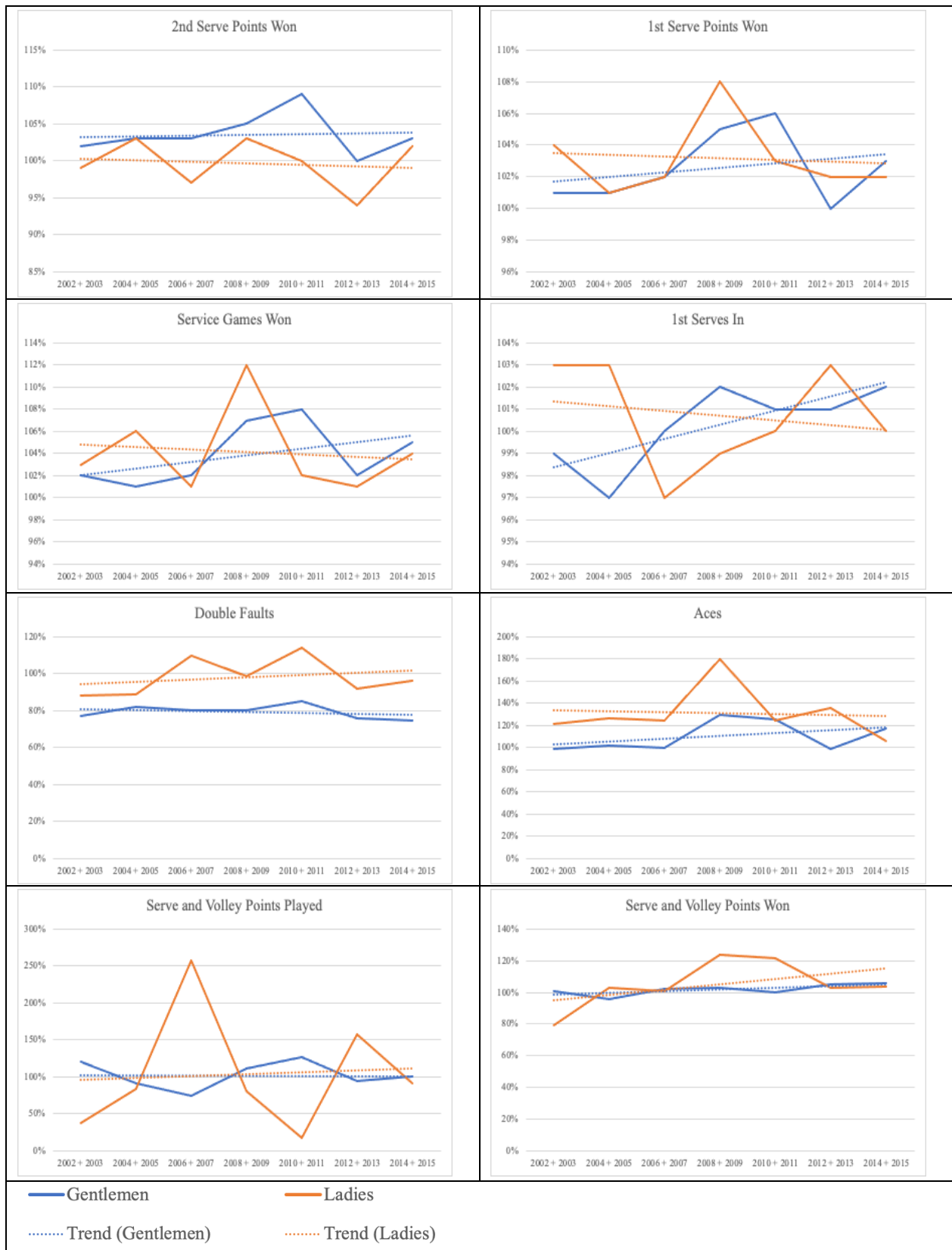


Figure 1^{III}: Intrapersonal gender comparisons of the 2nd tournament week vs. 1st tournament week's delta over 2 sequenced years from 2002 + 2003 to eventually 2014 + 2015 in different serve efficiency parameters for men (blue line) and women (orange line), including dotted trend lines, respectively

Discussion^{III}

Following earlier longitudinal research on women's and men's serve efficiency development at Wimbledon (Grambow et al., 2020; Grambow et al., 2021), 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 analyses 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 (Filipic et al., 2015; Grambow et al., 2020; Grambow et al., 2021; Ma et al., 2013; Maquirriain et al., 2016; Meffert et al., 2018; O'Donoghue & Brown, 2008; O'Donoghue & Liddle, 2002; Takahashi et al., 2008; Weber et al., 2010), 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 (Fernandez-Fernandez et al., 2013; Fett et al., 2020). With the consideration of commonly accepted body constitutional differences (Du Bois & Heyndels, 2007; Elliott et al., 2013; Verlinden et al., 2004) 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 (Grambow et al., 2020; Grambow et al., 2021), 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% (Barnett et al., 2008; Hizan et al., 2011; Reid et al., 2010), 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 (Carboch, 2017). Previous research

has shown that the serve has an even bigger impact in elite men's tennis (Brown & O'Donoghue, 2008; Mecheri et al., 2016), 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 (Grambow et al., 2020; Grambow et al., 2021). 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^{III} 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 originate in 1st tournament week improvements. This adds to former research implying that an extended world class cohort in women's tennis (Grambow et al., 2021), 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 volley 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 (2008), 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 (Carboch, 2017; O'Donoghue & Ingram, 2001; Reid et al., 2016) or in favour of elite men, but these findings were related to shorter periods of observation (Hizan et al., 2011; O'Donoghue & Brown, 2008).

Limitations^{III}

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^{III}

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. (2021) 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^{III} and 2^{III} 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^{III}

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

Conflict of interest^{III}

The authors state no conflict of interest.

4 Zentrale Erkenntnisse und Schlussfolgerungen

4.1 Hauptergebnisse

Aufgrund der bereits erwähnten Entwicklung im modernen Tennis hin zu immer kürzeren Ballwechselln (Carboch et al., 2018; Fitzpatrick et al., 2019; Weber et al., 2010) und der daraus gefolgerten, stark gestiegenen Bedeutung des Aufschlages für den Wettkampferfolg (Carboch, 2017; Fitzpatrick et al., 2021; Ma et al., 2013; O'Donoghue & Brown, 2008), lag der Fokus der vorliegenden kumulativen Dissertationsschrift auf dem Erlangen eines Beleges für die (Langzeit-) Entwicklung der Aufschlageffektivität sowohl im Herren- als auch im Damen-Weltklasse Tennis. Als ergänzende Forschungsfrage ließ sich prüfen, ob mögliche Unterschiede innerhalb der jeweiligen Weltklasse zu finden sind. Die Unterteilung in zwei Turnierphasen (1. Woche vs. 2. Woche) wurde bislang, nach Wissen des Autors, noch nicht wissenschaftlich untersucht. Diese Unterteilung soll einen weiteren Blickwinkel gegenüber bereits vorhandener Literatur eröffnen, bei der die Weltklasse nach Gewinner*innen vs. Verlierer*innen (Meffert et al., 2018) oder aber Turnierlevel Status bzw. Level der Ranglistenposition (Filipic et al., 2015) aufgeteilt wurde. Abschließend wurden sowohl die beobachteten Ergebnisse der Langzeituntersuchung als auch die beobachteten Ergebnisse des Wochenvergleiches auf geschlechterspezifische Entwicklungsunterschiede hin untersucht. Die übergeordnete Motivation bzw. Zielstellung der durchgeführten Untersuchungen (im Rahmen dieser Dissertationsschrift) lag im Transfer der Erkenntnisse und deren Bedeutung für die aktuelle und zukünftige Vermittlung innerhalb der Sportart Tennis, weshalb neben den Ergebnissen der Prüfstatistik im Rahmen aller Studien auch Abbildungen zur Veranschaulichung der deskriptiven Ergebnisse angefertigt wurden. Hierbei handelt es sich um die Prozentwerte der untersuchten Parameter, welche im Trainingsalltag als empirisch belegte Richtwerte durch die Trainer*innen genutzt werden können (siehe Tab.1^I, S.34; Tab.1^{II}, S.49; Tab.1^{III}, S.66; Tab.2^{III}, S.67).

Im Rahmen von Studie I der vorliegenden kumulativen Dissertationsschrift konnten bei der Untersuchung der Herren Weltklasse in sechs der sieben analysierten Parameter signifikante Veränderungen bzw. Verbesserungen im Langzeitvergleich festgestellt werden. Auffällig war hierbei besonders die deutlich gesteigerte Anzahl servierter Asse, während zeitgleich die Anzahl der servierten Doppelfehler signifikant abgenommen hat. Demnach kann die Zunahme der servierten Asse nicht auf eine gesteigerte Risikobereitschaft zurückgeführt werden, die sich in einem Verlust der Sicherheit beim Aufschlag widerspiegelt hätte. Es ist im Gegenteil der Fall, das auch hier eine Verbesserung in Form der gesenkten Doppelfehlerquote festzustellen ist. Zudem wurden ausschließlich verbesserte Gewinnquoten sowohl bei den Aufschlagspielen

insgesamt, aber auch im Detail nach 1. Aufschlägen sowie 2. Aufschlägen beobachtet, während die Nutzung der Serve & Volley Strategie signifikant nachgelassen hat. Beim direkten Vergleich innerhalb der Weltklasse (1. Woche vs. 2. Woche) konnten ausschließlich Vorteile zugunsten der Spieler der 2. Woche beobachtet werden, denn fünf der sieben untersuchten Parameter wiesen hierbei signifikante Unterschiede auf. So servierten die Spieler der 2. Woche im direkten Vergleich der prozentualen Werte mehr Asse, weniger Doppelfehler, gewannen mehr Aufschlagspiele und punkteten sowohl nach 1. und 2. Aufschlägen erfolgreicher. Aus den in diesem Vergleich gesammelten Ergebnissen lässt sich eine nochmals gesteigerte Bedeutung der Aufschlageffektivität für den Gewinn eines Grand Slam Turniers im Herrenbereich schlussfolgern, da eine gesteigerte Returnqualität innerhalb der 2. Woche aufgrund der höher platzierten Konkurrenz durchaus zu erwarten gewesen wäre. Die Gewinnquoten der untersuchten Aufschlagparameter stiegen stattdessen alle innerhalb der 2. Woche an, was somit den Rückschluss der gesteigerten Bedeutung der Aufschlageffektivität für den Gewinn eines Titels der Herrenkonkurrenz in Wimbledon unterstreicht.

Nachdem in Studie I die Weltspitze der Herren analysiert wurde, konnte in Studie II auf die Ergebnisse der Weltspitze im Damentennis zurückgegriffen werden. Analog zu den Ergebnissen der Herren, konnten im Langzeitvergleich der Damenkonkurrenz signifikante Verbesserungen in fünf der sieben untersuchten Parameter festgestellt werden. Besonders auffällig war hierbei die Tatsache, dass die beobachteten Unterschiede ausschließlich bei der Untersuchung der Daten des gesamten Turniers und der 1. Woche des Turniers festgestellt werden konnten, wohingegen bei der Analyse der 2. Woche des Turniers keinerlei signifikante Verbesserungen auftraten. Aufgrund der Anzahl der Matches innerhalb der 1. Woche (112) im Vergleich zur 2. Woche (15) lässt sich erklären, dass auch die Parameter bezüglich des gesamten Turniers signifikante Unterschiede aufgewiesen haben, da die festgestellten Verbesserungen innerhalb der 1. Woche aufgrund der 7,5fach höheren Matchanzahl hauptverantwortlich für die Rückschlüsse auf das gesamte Turnier sind. Beim direkten Vergleich innerhalb der Damenkonkurrenz (1. Woche vs. 2. Woche) konnten (dennoch) Vorteile zugunsten der Spielerinnen der 2. Woche festgestellt werden. Bei drei der sieben untersuchten Parameter, höhere Gewinnquoten der Aufschlagspiele und der gewonnenen Punkte nach 1. Aufschlägen sowie der gesteigerten Anzahl servierter Asse, mit signifikantem Ausmaß. Betrachtet man den direkten Vergleich sowohl der Damen- als auch der Herrenkonkurrenz, so konnte lediglich ein einziger Parameter mit (absoluten, nicht signifikanten) Vorteilen zugunsten der Spieler*innen der 1. Woche festgestellt werden. Die Gewinnquote nach 2. Aufschlägen im Bereich der Damenkonkurrenz nimmt in der 2. Woche gegenüber der 1. Woche ab. Mögliche Interpretationen hierfür sind eine gesteigerte

Returnqualität (und deren Bedeutung) oder (weniger wahrscheinlich) eine geringere Bedeutung des 2. Aufschlags für den Gewinn eines Titels der Damenkonkurrenz in Wimbledon. Aufgrund der Tatsache, dass in der 2. Woche die besten 16 Spielerinnen des Turniers gegeneinander antreten, erscheint die erste Option naheliegender. Die Daten deuten darauf hin, dass Spielerinnen ihre Gegnerinnen beim Return des 2. Aufschlags in der 2. Woche erfolgreicher unter Druck setzen können und dies von Bedeutung für den Gewinn des Turniers zu sein scheint. Bei der Interpretation der signifikanten Erkenntnisse beider Untersuchungen fällt auf, dass im Rahmen der Langzeituntersuchung alle signifikanten Veränderungen bzw. Verbesserungen innerhalb der 1. Woche der Turniere stattgefunden haben. Gleichzeitig konnten durch den direkten Vergleich Vorteile zugunsten der Aufschlageffektivität der Spielerinnen der 2. Woche nachgewiesen werden, was die Schlussfolgerung nahelegt, dass die erweiterte Weltklasse (Spielerinnen innerhalb der 1. Woche) im Laufe des Untersuchungszeitraumes den Rückstand bezüglich ihres Leistungsniveaus deutlich verkürzt hat. Diese beobachtete Erweiterung der Weltklasse im Damenbereich untermauert die Zahlen der letzten fünf Jahre, denn im Zeitraum von 2017-2021 führten acht verschiedene Damen die Weltrangliste an und bei 19 Grand Slam Turnieren gab es 14 verschiedene Siegerinnen (<https://wtatennis.com>, Rankings und Tournaments).

Die Erkenntnisse der ersten beiden Studien bezogen sich ausschließlich auf die Entwicklungen innerhalb der Herren- bzw. Damenweltklasse bei einer isolierten Betrachtung. Das angewendete, identische Untersuchungsdesign wurde im Vorfeld bewusst gewählt, um anschließend die Möglichkeit eines geschlechterspezifischen Vergleichs im Rahmen der Studie III zu ermöglichen. Sowohl im Rahmen des Langzeitvergleichs als auch beim direkten Vergleich konnten ausschließlich Vorteile zugunsten der Entwicklung im Herrenbereich festgestellt werden. Während sich drei der untersuchten acht Parameter beim Langzeitvergleich signifikant veränderten bzw. verbesserten, waren es zwei Parameter beim direkten Vergleich: In beiden Fällen konnten Entwicklungsvorteile bezüglich erhöhter Gewinnquoten nach den 2. Aufschlägen (Herren $50,05^{\min}$ und $52,70^{\max}$, Damen $45,45^{\min}$ und $46,85^{\max}$, siehe Tab.1^{III}, S.66) und in verbesserten Doppelfehlerquoten (Herren $4,74^{\min}$ und $3,04^{\max}$, Damen $5,43^{\min}$ und $4,53^{\max}$, siehe Tab.1^{III}, S.66) festgestellt werden. Zudem konnten beim Langzeitvergleich Vorteile der Herren bei der gesteigerten Prozentzahl gültiger 1. Aufschläge festgehalten werden (Herren $60,18\%^{\min}$ und $63,89\%^{\max}$, Damen $61,30^{\min}$ und $63,81^{\max}$, siehe Tab.1^{III}, S.66). Unter Einbeziehung der Tatsache, dass bei keinem der Parameter beider Untersuchungen eine größere Verbesserung zugunsten der Damen beobachtet werden konnte, lassen sich ausschließlich Entwicklungsvorteile zugunsten der Herren insbesondere bezüglich der Qualität des 2. Aufschlags konstatieren.

Während Studie I die Bedeutung der Aufschlageffektivität, insbesondere während der 2. Woche des Grand Slam Turniers in Wimbledon, über den Verlauf des Untersuchungszeitraumes von 2002 bis 2014 innerhalb der Herren Weltklasse unterstreicht, deuten die Ergebnisse der Studie II ebenfalls eine verbesserte Aufschlageffektivität im Damenbereich an. Jedoch sind hier die Beobachtungen primär in der erweiterten Weltspitze (1. Woche) festzustellen. Studie III belegt eindeutige Entwicklungsvorteile zugunsten der Herren, bei denen trotz höherer Ausgangswerte prozentual größere Entwicklungen im Untersuchungszeitraum stattgefunden haben.

4.2 Handlungsempfehlungen für den Praxistransfer

„Im Zentrum einer jeden Planung und Durchführung von Sport-, Spiel- und Bewegungsangeboten stehen die Vermittlungsziele. Abhängig von der jeweiligen Zielgruppe (...) werden geeignete Inhalte ausgewählt (...) zum Erreichen der gesetzten Ziele“ (Vogt & Klein, 2020, S.29). Sowohl die Ergebnisse aus Studie I (Herren) als auch die Ergebnisse aus Studie II (Damen) unterstreichen die Bedeutung des Aufschlags bzw. der Aufschlageffektivität für den Erfolg auf höchstem Level im modernen Tennis. Daher lässt sich schlussfolgern, dass eine erfolgsorientierte Vermittlung diese Erkenntnisse für die Wettkampfvorbereitung berücksichtigen sollte. Die im Rahmen der Langzeituntersuchung beobachteten Prozentwerte der untersuchten Parameter können ebenso als Richtwert bei der Vermittlung im Leistungs- bzw. Profiteennis dienen, wie auch die (statistisch signifikanten) Haupterkennnisse. Folglich lassen sich aus Studie I Richtwerte für die Praxisvermittlung im Herrenbereich ableiten und aus Studie II Richtwerte für Praxisvermittlung im Damenbereich, für welche an dieser Stelle jeweils ein möglicher Transfer exemplarisch aufgezeigt werden soll. Studie III belegt zudem Entwicklungsvorteile zugunsten der Herren insbesondere bezüglich des 2. Aufschlags (Gewinnquote 2. Aufschlag und Doppelfehlerquote). Während im Herrenbereich die Prozentzahlen servierter Asse den Anteil an servierten Doppelfehlern um ein Vielfaches übersteigen (Studie I), servieren die Damen mehr Doppelfehler als Asse (Studie II) und weisen in diesem Bereich Entwicklungsdefizite gegenüber den Herren auf (Studie III).

Folgerichtig erscheint es sinnvoll, speziell im Damenbereich, bei der Vermittlung eine gesteigerte Sicherheit, aber auch eine erhöhte Genauigkeit beim 2. Aufschlag anzustreben, sowie eine umfangreiche Anzahl 2. Aufschläge im Training zu servieren. Dazu sollen die im Nachfolgenden aufgeführten Trainingsübungen mögliche Ansätze bieten. Wie oben beschrieben ist der Aufschlag der einzige Schlag im Tennis, bei dem der/die Gegner*in keinerlei Auswirkungen auf das Gelingen hat. Die folgende (erste) Trainingsform, die hier exemplarisch für

eine Spielerin konzipiert wurde, hat den Vorteil, dass die Spielerin als auch der/die Trainer*in die bevorzugten Aufschlagrichtungen erkennen und somit diese im Match priorisiert anspielen können. Vor dem Hintergrund der Leistungsverbesserung der Spielerin erscheint es zweckmäßig die fehleranfälligeren Richtungen bei der künftigen Vermittlung im Training zu priorisieren. Die Richtwerte orientieren sich an den Forschungsergebnissen dieser Arbeit und beziehen sich auf das Training im weiblichen Profibereich (Grambow et al., 2021). Beide Aufschlagfelder werden in jeweils drei Zonen (Mitte, Körper, Außen) eingeteilt, so dass es sechs verschiedene Zielzonen gibt, die als Level 1-6 definiert werden (zur besseren Übersicht, siehe grafische Darstellung S.89 in Kapitel 6, Anhang). Die Spielerin sucht sich eine Zone als erstes Ziel aus und serviert unter Berücksichtigung der persönlichen Aufschlagrituale fünf 2. Aufschläge in Richtung dieser Zone. Sollten alle fünf Aufschläge erfolgreich in die Zielzone serviert werden, steigt die Spielerin in das jeweils nächste „Level“ auf. Für die folgenden Level gilt, bei vier von fünf erfolgreichen Versuchen verbleibt die Spielerin in diesem Level, bei drei von fünf Versuchen steigt die Spielerin um ein Level ab, bei zwei oder weniger Treffern muss die Spielerin wieder in Level 1 neu starten. Die Übungsform gilt als geschafft sobald in Level 6 fünf erfolgreiche Aufschläge in einem Durchgang serviert werden. Dieses Training kann sehr langfristig, über mehrere Monate angesetzt werden. Sollte der Fokus im Training hingegen auf der Verbesserung des 1. Aufschlags liegen, lässt sich diese Übung leicht adaptieren, indem je nach Spielniveau die Grenzen um einen Versuch erleichtert werden. Entsprechend bedeuten in diesem Fall drei erfolgreiche 1. Aufschläge den Verbleib in einem Level, vier oder fünf erfolgreiche Versuche den Aufstieg. Bei lediglich zwei gültigen Aufschlägen erfolgt der Abstieg um ein Level, bei einem oder keinem gültigen Versuch muss in Level 1 neu gestartet werden. Im Jugendbereich ist eine Herabsetzung der Aufschlagversuche auf drei oder vier Aufschlagversuche (mit angepassten Quoten) oder eine veränderte Aufteilung der Zielfelder (vier statt sechs) denkbar. Basierend auf den Erkenntnissen der vorliegenden Studien ist die Bedeutung erfolgreicher Punkte bei eigenem Aufschlag (Prozentzahlen 1. Aufschlag, 2. Aufschlag, Aufschlagsspiele) entscheidend für den Erfolg auf der höchsten Ebene im professionellen Tennis. Auch beim Erlernen neuer Techniken empfiehlt es sich in manchen Übungen die Erfolge und Misserfolge zu dokumentieren und dadurch den Lernzuwachs zu fördern (für einen Überblick zum „errorless learning“ siehe bspw. Buszard et al. (2013)).

Folgerichtig sollten neben Übungsformen zur Verbesserung der Aufschlagtechnik, Aufschlagsicherheit und Aufschlaggenauigkeit (wie gerade vorgestellt), auch Spielformen mit 1. und 2. Aufschlägen einen zeitlich hohen Anteil bei der Vermittlung der Sportart Tennis, nicht nur im Profibereich, einnehmen. Hierbei sollten die erhobenen Ergebnisse oder bereits

vorhandene und zukünftig erhobene Daten als Richtwerte dienen, indem beispielsweise 20 Punkte nach erfolgreichem, gültigem 1. Aufschlag ausgespielt werden und der servierende Spieler mindestens 14, besser 15 Punkte für das erfolgreiche Abschließen der Spielform gewinnen muss. Diese Zahlen sind aus den beobachteten Gewinnquoten beim 1. Aufschlag aus Studie I (zwischen 72,48-75,33%, siehe Tab.1¹, S.34) abgeleitet und beziehen sich somit auf den Herrenbereich. Entsprechend wäre die Spielform bei 2. Aufschlägen mit erneut 20 Punkten, bei denen der Spieler pro Punkt nur einen Aufschlag machen darf, mit mindestens 10 Punktgewinnen erfolgreich absolviert (beobachtete Gewinnquoten beim 2. Aufschlag laut Studie I zwischen 49,49-58,85%, siehe Tab.1¹, S.34). Gelingt es dem Spieler nicht die angestrebte Gewinnquote zu erzielen, so kann nach einer kurzen Pause ein zweiter Versuch gestartet oder die Rolle mit dem Trainingspartner (Returnspieler) getauscht werden. Die gewählten Serienumfänge sind bewusst zeitintensiv, da der Anteil der Spieleröffnung und der ersten Folgeschläge unter Berücksichtigung der eigenen Ergebnisse, aber auch bereits vorhandener Daten (siehe Tabelle 1, Ballwechsellänge bei Grand-Slams 2016, O'Shannessy, S.18) mindestens 50% betragen sollte. Neben dieser bewussten Gewichtung sollte auch der Zeitpunkt solcher Trainingsformen überdacht werden. Es erscheint sinnvoll diese Trainingsinhalte nicht, wie im Trainingsalltag häufig praktiziert, nur am Ende einer Trainingseinheit durchzuführen, sondern vielmehr auch bereits im ausgeruhten, voll konzentrierten Zustand zu Beginn einer Trainingseinheit, bei der lediglich die körperliche Erwärmung und ein kurzes Einschlagen (vergleichsweise zu den 5min im Wettkampf) vorangeschaltet ist.

4.3 Limitationen

Die Ergebnisse der vorliegenden Dissertationsschrift basieren auf den Daten aller gespielten Einzelmatches sowohl in der Damen- als auch der Herrenkonkurrenz des bedeutendsten Tennisturniers der Welt, den All England Championships von Wimbledon im Zeitraum von 2002 bis 2014. Somit umfasst der untersuchte Datensatz eine sehr große Stichprobe, die mögliche verletzungsbedingt verfälschte Daten ausgleichen sollte. Zwar ist nicht auszuschließen, dass einige Spieler*innen sich während ihrer Wettkämpfe verletzt haben oder diese bereits verletzt angetreten haben, jedoch sollten sich keine systematischen Verzerrungen finden. Durch die hohe Fallzahl (1771 Einzelspiele bei den Herren bzw. 1772 bei den Damen) und dadurch, dass es sich um eine Vollerhebung handelt, dürften einzelne Verletzungen nicht so sehr ins Gewicht fallen.

Aufgrund der Tatsache, dass ausschließlich Matches des in Wimbledon gespielten Bodenbelags Rasen untersucht wurden, sind die Ergebnisse nur bedingt übertragbar für die alternativen Bodenbeläge Sand- und Hartplatz. Die Analyse basiert auf Grundlage der Daten des Wimbledon Information Systems, welche von der Firma IBM erhoben und kategorisiert werden. Diese Kategorisierung birgt ein gewisses Fehlerpotenzial, wobei im Rahmen dieser Dissertationsschrift bewusst Parameter ausgesucht wurden, die eine mögliche subjektiv individuell unterschiedliche Einteilung nahezu ausschließen. Im Detail unterliegen die ausgewählten Kategorien wie z. B. Asse, Doppelfehler, Gewinnquoten nach Aufschlägen bzw. bei Aufschlagspielen oder auch Serve & Volley Quoten keinerlei subjektiver Wertung, wohingegen mögliche Parameter, wie beispielsweise unerzwungene oder erzwungene Fehler, subjektiven Spielraum bieten und daher auf deren Einbeziehung im Rahmen dieses Dissertationsprojektes verzichtet wurde.

Aus statistischer Sicht muss berücksichtigt werden, dass Datensätze mit entsprechend großen Umfängen (wie in der vorliegenden Arbeit) eine Tendenz haben sehr schnell Signifikanzen anzuzeigen, wodurch im Rahmen der vorliegenden Untersuchungen Effektstärken zur weiteren Bestimmung bzw. genaueren Gewichtung der jeweiligen Ergebnisse berechnet wurden. Im Rahmen des geschlechterspezifischen Vergleichs der Studie III, aber auch bei den jeweiligen individuellen Untersuchungen der Studien I und II waren keinerlei biologische Parameter der Spieler*innen bekannt, folglich können keine Rückschlüsse in diesem Bereich getätigt werden. Abschließend sind in der Wissenschaft vorbestimmte Untersuchungsmuster immer zu bevorzugen, jedoch ist dies im Falle des Profiteennis nicht oder nur schwer möglich. Hier bleibt nur die Möglichkeit der retrospektiven Untersuchung bereits gespielter Turniere.

4.4 Ausblick und weitere Forschungsansätze

Die Bedeutung des Aufschlags für den Erfolg im professionellen Tennis erscheint unumstritten (Carboch, 2017; Filipcic et al., 2015; Fitzpatrick et al., 2021; Ma et al., 2013; O'Donoghue & Brown, 2008) und auch die verbesserte Aufschlageffektivität, sowohl im Herren- als auch im Damenbereich, konnte anhand der vorliegenden kumulativen Dissertationsschrift im Langzeitvergleich nachgewiesen werden (Grambow et al., 2022; Grambow et al., 2021; Grambow et al., 2020). Entwicklungsunterschiede zugunsten der Herren wurden im geschlechterspezifischen Vergleich gleichsam beobachtet. Für ein breiteres Bild gilt es zu prüfen, ob diese Beobachtungen auch für die beiden, am häufigsten auf der ATP-Tour bespielten, Bodenbeläge Sand- und Hartplatz gelten. Hierfür empfiehlt es sich die weiteren Grand Slam

Turniere in Melbourne, Paris und New York nach dem gleichen Muster zu analysieren. Die parallel stattfindenden Junior*innen Wettbewerbe bei den vier Grand-Slam-Turnieren bieten eine weitere Möglichkeit der Analyse, um die Ergebnisse der Damen und Herren auf den Nachwuchsbereich auszuweiten.

Vor dem Hintergrund des Transfers der gewonnenen Erkenntnisse auf andere Sportarten, ist eine Übertragung der Methodik bezüglich des direkten Vergleichs innerhalb der jeweiligen Weltklasse denkbar, beispielsweise im Golfsport, bei dem nahezu alle großen Events inklusive der vier Majors, die analog zu den Grand-Slams im Tennis zu verstehen sind, im 4-Tages-Format durchgeführt werden. Hier ließe sich die entwickelte Analysemethodik übertragen, indem ein Vergleich der Leistungen der ersten beiden Tage (vor dem Cut) mit den Leistungen der Tage drei und vier, an denen nur noch die bessere Hälfte (gemessen an der Positionierung nach den ersten beiden Tagen) des Teilnehmerfeldes teilnehmen darf, verglichen werden.

Die Ergebnisse der geschlechterspezifischen Analyse weisen Vorteile zugunsten der Herren gegenüber den Damen auf, wodurch eine Untersuchung möglicher Ursachen einen weiteren Forschungsansatz darstellt. Hierfür gilt es herauszufinden, ob unterschiedliche Trainingsinhalte bzw. Trainingsschwerpunkte ein möglicher Grund für diese Unterschiede sind. Dies könnte mit Hilfe gezielter Fragebögen an Spieler*innen und Trainer*innen geschehen, die sowohl nach den generellen Trainingsinhalten und -umfängen, aber auch nach saisonalen bzw. Bodenbelag abhängigen Unterschieden fragen. Zudem wären weitere Befunde dazu hilfreich, ob die Spieler*innen und Trainer*innen die Bedeutung der Trainingsinhalte und Trainingsschwerpunkte bezüglich des Aufschlags unterschiedlich bewerten. Nicht zuletzt vor dem Hintergrund des direkten Vergleichs innerhalb der jeweiligen Weltklasse bedarf es hier weiterer Forschung zu den Ergebnissen solcher Umfragen, beispielsweise gestaffelt nach den jeweiligen Ranglistenpositionen.

5 Literaturverzeichnis

- Antoun, R. (2013). *Winning Tennis. Das Strategie- und Taktik-Buch*. München: Copress Verlag.
- Barnett, T., & Games, S. (2010). How the court surface is affecting the serve-and-volley. *Journal of Medicine and Science in Tennis*, 15(3), 26-28.
- Barnett, T., Meyer, D., & Pollard, G. (2008). Applying match statistics to increase serving performance. *Journal of Medicine and Science in Tennis*, 13(2), 24-27.
- Barnett, T., & Pollard, G. (2007). How the tennis court surface affects player performance and injuries. *Medicine and Science in Tennis*, 12(1), 34-37.
- Born, H.-P. (2014). Aufschlag, Return und Spieleröffnung. *Deutsche Tennis Zeitung*, 67 (6), 30-31.
- Born, P. (2017). *Systematische Analyse der erweiterten Spieleröffnung des Aufschlägers im Herrentennis der Weltspitze inklusive Ableitung anwendungsorientierter Trainingsformen (Dissertation, Sportwissenschaft)*. Zentralbibliothek Deutsche Sporthochschule Köln.
- Brown, E., & O'Donoghue, P. (2008). Gender and Surface Effect on Elite Tennis Strategy. *ITF coaching and sport science review*, 15(46), 9-11.
- Buszard, T., Reid, M., Farrow, D., & Masters, R. (2013). Implicit motor learning: Designing practice for performance. *ITF coaching and sport science review*, 60, 3-5.
- Carboch, J. (2017). Comparison of game characteristics of male and female tennis players at grand-slam tournaments in 2016. *Trends in Sport Sciences*, 4(24), 151-155. <https://doi.org/10.23829/TSS.2017.24.4-2>
- Carboch, J., Placha, K., & Sklenarik, M. (2018). Rally pace and match characteristics of male and female tennis matches at the Australian Open 2017. *Journal of Human Sport and Exercise*. 13(4), 743-751. <https://doi.org/10.14198/jhse.2018.134.03>
- Choppin, S., Goodwill, S., & Haake, S. (2011). Impact characteristics of the ball and racket during play at the Wimbledon qualifying tournament. *Sports engineering*, 13(4), 163-170. <https://doi.org/10.1007/s12283-011-0062-7>
- Cohen, J. (1992). A power primer. *Psychological bulletin*, 112(1), 155-159. <https://doi.org/10.1037/0033-2909.112.1.155>
- Crespo, M., & Miley, D. (1998). *Advanced Coaches Manual*. London: The International Tennis Federation, ITF Ltd.
- Crespo, M., & Reid, M. (2002). Modern tactics: an introduction. *ITF Coaching and Sport Science Review*, 27(2).

- Crespo, M., Reid, M., & Miley, D. (Eds.) (2003). *Applied sport science for high performance tennis*. London: The International Tennis Federation, ITF Ltd.
- Cross, R., & Pollard, G. (2009). Grand Slam men's singles tennis 1991-2009 serve speeds and other related data. *ITF Coaching and Sport Science Review*, 49, 8-10.
- Cui, Y., Gómez, M.-Á., Gonçalves, B., & Sampaio, J. (2018). Performance profiles of professional female tennis players in grand slams. *PLOS ONE*, 13(7), e0200591. <https://doi.org/10.1371/journal.pone.0200591>
- Del Corral, J., & Prieto-Rodríguez, J. (2010). Are differences in ranks good predictors for Grand Slam tennis matches? *International Journal of Forecasting*, 26(3), 551-563. <https://doi.org/10.1016/j.ijforecast.2009.12.006>
- Deutscher Tennis Bund. (1996). *Tennis-Lehrplan Band 2 – Unterricht & Training*. München: BLV.
- Dindar, M. D., Toksöz, I. I., Taşkın, C. n., & Uluçam, E. (2011). Analysis of the serves in the men's semi-final and final competitions of wimbledon tennis tournament. *Sport Sciences*, 6(3), 185-192. <https://dergipark.org.tr/en/pub/nwsaspor/issue/20136/213788>
- Du Bois, C., & Heyndels, B. (2007). It's a Different Game You Go to Watch: Competitive Balance in Men's and Women's Tennis. *European Sport Management Quarterly*, 7(2), 167-185. <https://doi.org/10.1080/16184740701353349>
- Elliott, B., & Saviano, N. (2001). Serves and returns. World-class tennis technique. *Human Kinetics*, 207-222.
- Elliott, B., Whiteside, D., Lay, B., & Reid, M. (2013). The Female Tennis Serve: An Analogous Version of the Male Serve? In *ISBS-Conference Proceedings Archive*.
- Fernandez-Fernandez, J., Ellenbecker, T., Sanz-Rivas, D., Ulbricht, A., & Ferrauti, A. (2013). Effects of a 6-Week Junior Tennis Conditioning Program on Service Velocity. *Journal of Sports Science and Medicine*, 12(2), 232-239. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3761833/>
- Ferrauti, A., & Bastiaens, K. (2007). Short-term effects of light and heavy load interventions on service velocity and precision in elite young tennis players. *British journal of sports medicine*, 41(11), 750-753. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2465289/>
- Ferrauti, A., Maier, P., & Weber, K. (2006). *Tennistraining*. Aachen: Meyer und Meyer Verlag.
- Ferrauti, A., Maier, P., & Weber, K. (2016). *Handbuch für Tennistraining: Leistung-Athletik-Gesundheit*. Aachen: Meyer & Meyer Verlag.
- Fett, J., Ulbricht, A., & Ferrauti, A. (2020). Impact of Physical Performance and Anthropometric Characteristics on Serve Velocity in Elite Junior Tennis Players. *Journal of Strength and Conditioning Research*, 34(1), 192-202. <https://doi.org/10.1519/JSC.0000000000002641>

- Filipic, A., Zecic, M., Reid, M., Crespo, M., Panjan, A., & Nejc, S. (2015). Differences in performance indicators of elite tennis players in the period 1991-2010. *Journal of Physical Education and Sport*, 15(4), 671-677. <https://doi.org/10.7752/JPES.2015.04102>
- Fitzpatrick, A., Stone, J. A., Choppin, S., & Kelley, J. (2019). Important performance characteristics in elite clay and grass court tennis match-play. *International Journal of Performance Analysis in Sport*, 19(6), 942-952. <https://doi.org/10.1080/24748668.2019.1685804>
- Fitzpatrick, A., Stone, J. A., Choppin, S., & Kelley, J. (2021). Investigating the most important aspect of elite grass court tennis: Short points. *International Journal of Sports Science & Coaching*, 16(5), 1178-1186. <https://doi.org/10.1177/1747954121999593>
- Gillet, E., Leroy, D., Thouvarecq, R., & Stein, J. F. (2009, Mar). A notational analysis of elite tennis serve and serve-return strategies on slow surface. *J Strength Cond Res*, 23(2), 532-539. <https://doi.org/10.1519/JSC.0b013e3181818efe29>
- Grambow, R., Born, P., O'Shannessy, C., Breuer, J., Meffert, D., & Vogt, T. (2022). Serve Efficiency Development In Women's vs. Men's Professional Tennis. *Human Movement*, 23(2), 128-137. <https://doi.org/10.5114/hm.2022.109071>
- Grambow, R., O'Shannessy, C., Born, P., Meffert, D., & Vogt, T. (2020). Serve Efficiency Development At Wimbledon Between 2002 And 2015: A Longitudinal Approach To Impact Tomorrow's Tennis Practice. *Human Movement*, 21(1), 65-72. <https://doi.org/10.5114/hm.2020.88155>
- Grambow, R., O'Shannessy, C., Born, P., Meffert, D., & Vogt, T. (2021). Serve Efficiency Development Indicates An Extended Women's Tennis World Class Cohort: Analysing 14 Years Of Ladies Wimbledon Championships – Implications For Coaching [journal article]. *Human Movement*, 22(2), 43-52. <https://doi.org/10.5114/hm.2021.100011>
- Hernández-Davo, H., Urbán, T., Sarabia, J. M., Juan-Recio, C., & Javier Moreno, F. (2014, 2014/08/27). Variable training: effects on velocity and accuracy in the tennis serve. *Journal of Sports Sciences*, 32(14), 1383-1388. <https://doi.org/10.1080/02640414.2014.891290>
- Hizan, H., Whipp, P., & Reid, M. (2011, 2011/08/01). Comparison of serve and serve return statistics of high performance male and female tennis players from different age-groups. *International Journal of Performance Analysis in Sport*, 11(2), 365-375. <https://doi.org/10.1080/24748668.2011.11868556>
- Hopkins, W., Marshall, S., Batterham, A., & Hanin, J. (2009). Progressive Statistics for Studies in Sports Medicine and Exercise Science. *Medicine & Science in Sports & Exercise*, 41(1), 3-12. <https://doi.org/10.1249/MSS.0b013e3181818cb278>
- Hughes, M., & Clarke, S. (1995). Surface effect on elite tennis strategy. *Science and racket sports*, 3, 272-277.

- Knight, G., & O'Donoghue, P. (2012, 2012/11/01). The probability of winning break points in Grand Slam men's singles tennis. *European journal of sport science*, 12(6), 462-468. <https://doi.org/10.1080/17461391.2011.577239>
- Kovalchik, S. A., Bane, M. K., & Reid, M. (2017, 2017/10/02). Getting to the top: an analysis of 25 years of career rankings trajectories for professional women's tennis. *Journal of Sports Sciences*, 35(19), 1904-1910. <https://doi.org/10.1080/02640414.2016.1241419>
- Kraemer, W. J., Triplett, N. T., Fry, A. C., Koziris, L. P., Bauer, J. E., Lynch, J. M., McConnell, T., Newton, R. U., Gordon, S. E., Nelson, R. C., & Knuttgen, H. G. (1995). An in-depth sports medicine profile of women college tennis players. *Journal of Sport Rehabilitation*, 4(2), 79-98. <https://doi.org/10.1123/jsr.4.2.79>
- Leveresen, J. S. R., Haga, M., & Sigmundsson, H. (2012). From children to adults: motor performance across the life-span. *PloS one*, 7(6), e38830. <https://doi.org/10.1371/journal.pone.0038830>
- Ma, S. M., Liu, C. C., Tan, Y., & Ma, S. C. (2013). Winning matches in Grand Slam men's singles: An analysis of player performance-related variables from 1991 to 2008. *Journal of Sports Sciences*, 31(11), 1147-1155. <https://doi.org/10.1080/02640414.2013.775472>
- Magnus, J. R., & Klaassen, F. J. G. M. (1999). On the advantage of serving first in a tennis set: four years at Wimbledon. *Journal of the Royal Statistical Society (Series D): The Statistician*, 48(2), 247-256. <https://doi.org/10.1111/1467-9884.00186>
- Maquirriain, J., Baglione, R., & Cardey, M. (2016). Male professional tennis players maintain constant serve speed and accuracy over long matches on grass courts. *European journal of sport science*, 16(7), 845-849. <https://doi.org/10.1080/17461391.2016.1156163>
- Martin, C., Bideau, B., Nicolas, G., Delamarche, P., & Kulpa, R. (2012). How does the tennis serve technique influence the serve-and-volley? *Journal of Sports Sciences*, 30(11), 1149-1156. <https://doi.org/10.1080/02640414.2012.695079>
- Mecheri, S., Rioult, F., Mantel, B., Kauffmann, F., & Benguigui, N. (2016). The serve impact in tennis: First large-scale study of big Hawk-Eye data. *Statistical Analysis and Data Mining: The ASA Data Science Journal*, 9(5), 310-325. <https://doi.org/10.1002/sam.11316>
- Meffert, D., O'Shannessy, C., Born, P., Grambow, R., & Vogt, T. (2018). Tennis serve performances at break points: Approaching practice patterns for coaching. *European journal of sport science*, 18(8), 1151-1157. <https://doi.org/10.1080/17461391.2018.1490821>
- Meffert, D., O'Shannessy, C., Born, P., Grambow, R., & Vogt, T. (2019). Tennis at tiebreaks: addressing elite players' performance for tomorrows' coaching. *German Journal of Exercise and Sport Research*, 49(24), 339-344. <https://doi.org/10.1007/s12662-019-00611-3>
- Nowak, M., & Panfil, R. (2012). Scoring abilities in the game of tennis—a pragmatic study of unique cases. *Human Movement*, 13(4), 313-322. <https://doi.org/10.2478/v10038-012-0036-z>

- O'Donoghue, P. (2001, Jun). The Most Important Points in Grand Slam Singles Tennis. *Research Quarterly for Exercise and Sport*, 72(2), 125-131. <https://doi.org/10.1080/02701367.2001.10608942>
- O'Donoghue, P., & Ingram, B. (2001, 2001/01/01). A notational analysis of elite tennis strategy. *Journal of Sports Sciences*, 19(2), 107-115. <https://doi.org/10.1080/026404101300036299>
- O'Donoghue, G. P., & Brown, E. (2008, 2008/11/10). The Importance of Service in Grand Slam Singles Tennis. *International Journal of Performance Analysis in Sport*, 8(3), 70-78. <https://doi.org/10.1080/24748668.2008.11868449>
- O'Donoghue, P. (2002, 2002/08/15). Performance models of ladies' and men's singles tennis at the Australian Open. *International Journal of Performance Analysis in Sport*, 2(1), 73-84. <https://doi.org/10.1080/24748668.2002.11868262>
- O'Donoghue, P., & Liddle, D. (2002). A match analysis of elite tennis strategy for ladies' singles on clay and grass surfaces. *Science and racket sports II*, 247.
- O'Shannessy, C. (2016, 10. November). *The first 4 shots*. Tennis Symposium, German Sports University, Köln. (auch unter <https://braingametennis.com> oder ATP beyond the numbers, ATP homepage)
- Pollard, G., Cross, R., & Meyer, D. (2006). An Analysis Of Ten Years Of The Four Grand Slam Men's Singles Data For Lack Of Independence Of Set Outcomes. *Journal of Sports Science and Medicine*, 5(4), 561-566. <https://www.ncbi.nlm.nih.gov/pubmed/24357950>
- Reid, M., McMurtrie, D., & Crespo, M. (2010). The relationship between match statistics and top 100 ranking in professional men's tennis. *International Journal of Performance Analysis in Sport*, 10(2), 131-138. <https://doi.org/10.1080/24748668.2010.11868509>
- Reid, M., Morgan, S., & Whiteside, D. (2016). Matchplay characteristics of Grand Slam tennis: implications for training and conditioning. *Journal of Sports Sciences*, 34(19), 1791-1798. <https://doi.org/10.1080/02640414.2016.1139161>
- Roetert, E. P., Brown, S. W., Piorkowskil, P. A., & Woods, R. B. (1996). Fitness Comparisons Among Three Different Levels of Elite Tennis Players. *Journal of Strength and Conditioning Research*, 10(3), 139-143.
- Röthig, P., & Prohl, R. (2003). *Sportwissenschaftliches Lexikon*. Schorndorf: Hofmann.
- Schönborn, R. (2010). *Optimales Tennistraining: der Weg zum erfolgreichen Tennis vom Anfänger bis zur Weltspitze*. Balingen: Spitta Verlag.
- Schönborn, R. (2016). *Tennis Techniktraining*. Aachen: Meyer & Meyer Verlag.
- Takahashi, W.H., Wada, T., Maeda, A., Kodama, M., Nishizono, H., & Kurata, H. (2008). Time analysis of three decades of men's singles at Wimbledon. In *Science and racket sports IV*, 261-268. Routledge.

- Verlinden, M., Van Ruyskensvelde, J., Van Gorp, B., De Decker, S., Goossens, R., & Clarijs, J.-P. (2004). Effect of gender and tennis court surface properties upon strategy in elite singles. *Science and racket sports III*, 163-168.
- Vogt, T., & Klein, D. (2020). Zielgruppenspezifische Vermittlung: Inhalte, Methoden und Modelle. In T. Vogt (Hrsg.), *Vermittlungskompetenz in Sport, Spiel und Bewegung. Sportartspezifische Perspektiven* (S. 29-49). Aachen: Meyer & Meyer Verlag.
- Weber, K., & Born, P. (2012). Die besondere Bedeutung der erweiterten Spieleröffnung im Leistungstennis. *Leistungssport*, 42(6), 26-32.
- Weber, K., Exler, T., Marx, A., Pley, C., Röbbel, S., & Schäffkes, C. (2010). Schnellere Aufschläge, kürzere Ballwechsel und höherer Zeitdruck für Grundschläge in der Tennis-Weltspitze. *Leistungssport*, 40(5), 36-42.

6 Anhang

Grafische Darstellung der möglichen Zoneneinteilung der in Kapitel 4.2 vorgestellten Aufschlag Trainingsform. Die Levelnummern bzw. die zu absolvierende Levelreihenfolge ist frei wählbar.

