Success Factors in Soccer Defense
–
Match Analysis in Soccer based on Positional Tracking Data

Zur Erlangung des akademischen Grades eines
DOKTORS DER PHILOSOPHIE (Dr. phil.)

von der KIT-Fakultät für Geistes- und Sozialwissenschaften des
Karlsruher Instituts für Technologie (KIT)
angenommene

DISSERTATION

Von

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Tag der mündlichen Prüfung: 19.07.2024

2023

Success Factors in Soccer Defense

Dissertation Leander Forcher

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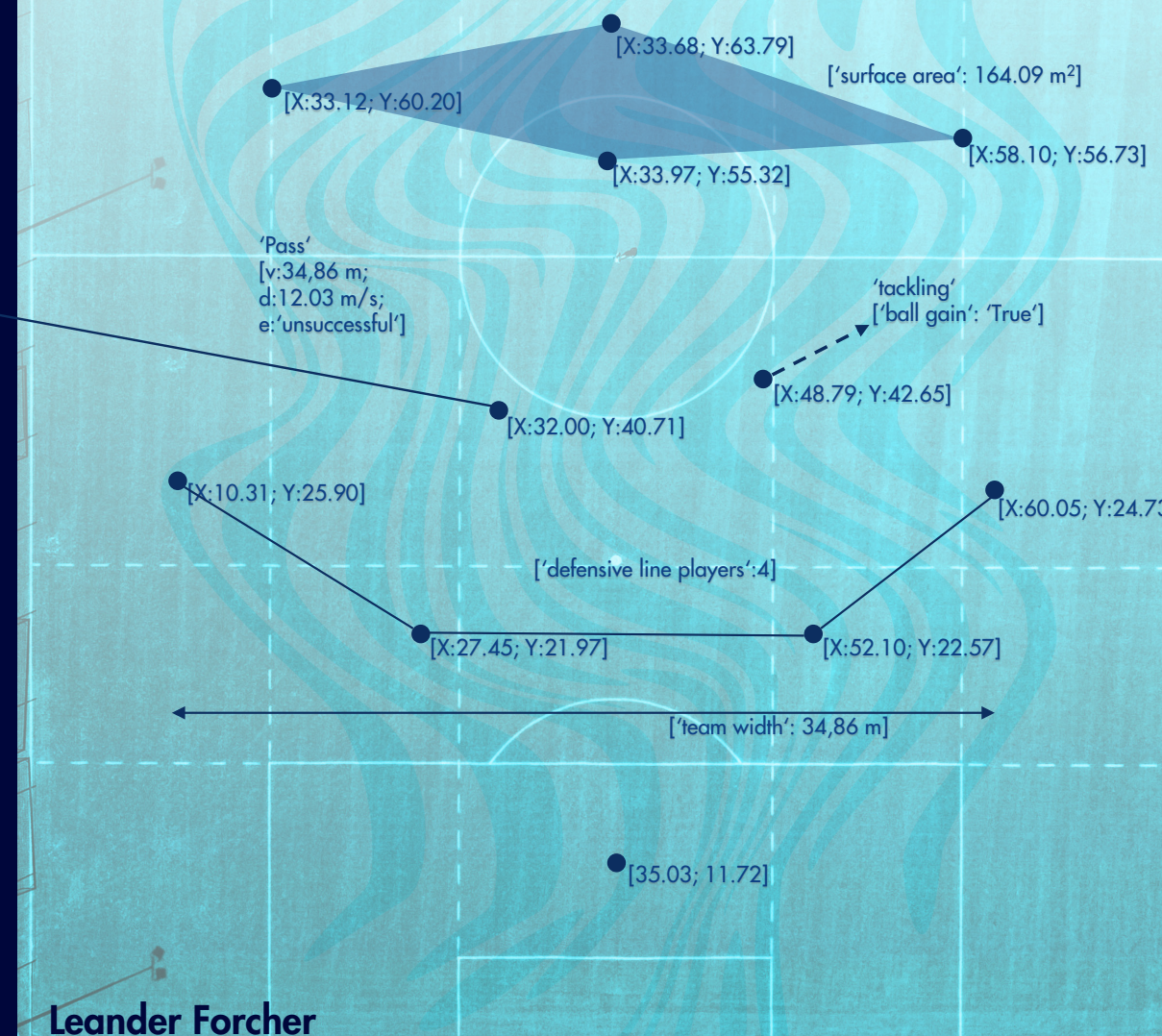

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Acknowledgments

This work was elaborated in my role as research associate at the Institute of Sports and Sports Science (IfSS) at the Karlsruhe Institute of Technology (KIT). I would therefore like to thank Prof. Dr. Alexander Woll for offering me the opportunity and the trust to conduct scientific research about match analysis in soccer at this level. Only this gave me the opportunity to develop personally and contentwise in the subject to which I dedicated myself so intensively in the last years.

I would also like to show gratitude to my supervisors, without whose support this work would not have been possible.
I would like to thank Prof. Dr. Darko Jekauc, who was always there with a helping hand and supported me, especially concerning qualitative research, scientific writing, and statistical methods. Without the support of Dr. Matthias Kempe, I could not have embarked on this journey. The opportunity to learn coding to meet my passion of match analysis on a statistical level, to always bring out the best in me, and push me to the next statistical level, has enriched this work immensely.
Last but not least, special thanks go to Dr. Stefan Altmann who I cannot thank enough for his encouragement in every working topic and especially the personal support beyond the collaboration. Your support has helped me to develop not only regarding content, but also personally.

Most importantly, none of this work would have been possible without my family. I am forever grateful for the unlimited support through the whole PhD journey. It would be impossible to mention all the countless things you have helped me with. You gave me confidence and perseverance. Especially without my brother Leon the work could have not been the same. I want to thank you for the exceptional opportunity to accompany each other so closely in a phase of life, the daily exchange, and the inspiration for a drive for more. Moreover, thank you Mara, from the bottom of my heart, for your patience, support and love throughout the years.

Thank you to everyone who supported me and made this journey a memorable one.

Summary

Soccer is one of the most famous sports of the world. One reason for its popularity is the unpredictability of events and match results. With 22 individual players behaving with almost infinite degrees of freedom while interacting with each other, no playing sequence looks like a previous one. With the increasing availability of highly accurate tracking data insights into this complex gameplay can be gained. This data comprises an almost continuous measure of the positions of all players and the ball. By evaluating this tracking data, particularly the tactical match performance of soccer players can be analyzed. Especially, it becomes possible to investigate the off-ball behavior of players which is neglected in the majority of research in this context. Moreover, most studies analyzing tactical behavior using tracking data focused on offensive actions such as passing or shooting. However, soccer is a defensive emphasized team sport (e.g. low scoreboard) and defense is at least as important to success as offense. Therefore, this thesis aims to analyze the tactical match performance during the defensive playing phases (i.e. defensive play & defensive transition) at the individual level, group level, and team level. Thereby, the possibilities of tracking data analysis are exploited to identify the factors of successful tactical behavior of players in defense.

In the theoretical background, this thesis provides a basis for the conducted studies and their comprehensive discussion. First, epistemological and scientific-philosophical considerations are made to reflected on how the findings of this thesis are obtained and how the conclusions are drawn. Further, this thesis is subsumed in the subject field of sports science to place this work in the broader context of sports science. Subsequently, the individual complex match performance in soccer, which is the main subject of interest in this thesis, is theoretically elaborated. In detail, the main facets of the complex match performance (physical, technical, tactical, psychological) and their influencing factors (internal and external factors) are outlined. Building on this theoretical framework, the appearance of a collaborative team performance consisting of 11 individuals is presented. After presenting the match performance of soccer players, the main approaches to analyze this performance are described. This includes the subjective video analysis, the notational analysis, and the spatio-temporal analysis of tracking data. This overview of different types of match analysis provides a theoretical foundation of the methods used in this study since two types were used as main method to assess the tactical match performance in defense.

Based on the theoretical background, the individual papers of this thesis are presented which comprise a review and three original studies.

First, the review paper comprehensively summarized the current state of research on spatio-temporal analysis of defensive play using tracking data. Thereby, highly heterogenous approaches to analyze defensive play in soccer using tracking data were identified.

Second, the first original study of this thesis focused on the defensive pressure characteristics in the playing phase of defensive play. The analysis of tracking data showed that defensive pressure was higher in successful defensive plays compared to unsuccessful defensive plays. Furthermore, defensive pressure on the ball-leading player and on attackers in ball proximity was higher compared to defensive pressure on all attacking players.

Third, the second original study analyzed rest defense (≙ particular group tactic) in the playing phase of defensive transition. Through the evaluation of the expert interviews, the group tactic of rest defense was defined. The data analysis indicated that the time to regain possession after a ball loss is the most important success criterion in defensive transition. Furthermore, the numerical superiority of rest defending players and their space control in deep spaces behind the defensive-line were identified as important success factors in rest defense.

Fourth, the last original paper analyzed the compact organization of the defending team in the playing phase of defensive play. Thereby, successful defensive plays revealed a higher compactness of defenders close to the ball and a higher contraction of compactness of the whole defending team compared to unsuccessful defensive plays.

With the presented findings the relevant success factors of the defensive playing phases can be derived. Concluding, for successful defensive play it is most important to press the ball-leading player at the individual level. At the group level, it is also crucial to cover close pass options by pressurizing the attackers close to the ball and increasing the compactness of defenders in ball proximity. At the team level, the contraction of compactness is important for successful defensive play. In contrast to the playing phase of defensive play, it is decisive for rest defense in the playing phase of defensive transition, to control deep spaces and possible dangerous counterattackers to be successful and stop opposing counterattacks.

Based on those findings, principles of play were formulated which comprise superordinate beneficial tactical behavior patterns in the respective playing phases. For instance, press the ball-leading player and cover close pass options in defensive play, or create numerical superiority in rest defense in defensive transition. Those principles of play enable an effective practical application of the results of this thesis. This includes, for example, the objective evaluation of tactical match performances to eventually enhance future match performances to drive success in defense.

In summary, this thesis presented enhanced match analyses using positional tracking data to identify success factors in defense and uncode the game of soccer.

Zusammenfassung

Fußball ist eine der bekanntesten Sportarten der Welt. Ein Grund für seine Beliebtheit ist die Unvorhersehbarkeit von Spielereignissen und -ergebnissen. Durch die Anzahl von 22 Spielern auf dem Feld, die miteinander interagieren und dabei fast unendlich viele Freiheitsgrade nutzen können, ähnelt keine Spielszene der anderen. Mit der zunehmenden Verfügbarkeit von hochpräzisen Positionsdaten lassen sich Einblicke in dieses komplexe Spielgeschehen gewinnen. Diese Positionsdaten beinhalten die nahezu kontinuierliche Positionen aller Spieler und des Balls während des gesamten Spiels. Mit ihrer Auswertung kann insbesondere das taktische Verhalten der Fußballspieler analysiert werden. Gleichzeitig ermöglichen diese Daten die Untersuchung des Verhaltens der Spieler, die nicht in direktem Ballbesitz sind (ballfern). Dies wird in der Mehrzahl der Untersuchungen zur taktischen Spielleistung vernachlässigt. Darüber hinaus konzentrieren sich die meisten Studien, die das taktische Verhalten anhand von Trackingdaten analysieren, auf offensive Aktionen wie Pässe oder Torschüsse. Jedoch ist Fußball eine eher defensiv betonte Mannschaftssportart (z.B. wenige Tore), in der die Defensive für den Erfolg einer Mannschaft mindestens genauso entscheidend ist wie die Offensive. Deshalb untersucht diese Thesis die taktische Spielleistung während der defensiven Spielphasen (d.h. kontrollierte Defensive & defensives Umschalten) auf den unterschiedlichen Ebenen der taktischen Spielleistung von Individual-, Gruppen- und Mannschaftsebene. Dabei werden die Möglichkeiten der Positionsdatenanalyse genutzt, um die Faktoren für ein erfolgreiches taktisches Verhalten der Spieler in der Defensive zu identifizieren.

Im theoretischen Hintergrund dieser Arbeit werden die Grundlagen für die durchgeführten Studien und deren umfassende Diskussion gelegt. Zunächst werden dabei erkenntnistheoretische und wissenschaftlich-philosophische Überlegungen angestellt, um zu reflektieren, wie die Erkenntnisse in dieser Thesis gewonnen und die Schlussfolgerungen gezogen werden. Des Weiteren wird diese Arbeit in das Fachgebiet der Sportwissenschaft eingeordnet, um sie in einen breiteren Kontext zu stellen. Anschließend wird die individuelle komplexe Sportspielleistung im Fußball, die in dieser Arbeit zentral ist, theoretisch ausgearbeitet. Im Einzelnen werden die Hauptkomponenten der komplexen Sportspielleistung eines Spielers (physisch, technisch, taktisch, psychologisch) und deren Einflussfaktoren (interne und externe Faktoren) dargestellt. Aufbauend auf diesem theoretischen Konstrukt, wird das Erscheinungsbild einer Mannschaftsleistung, bestehend aus 11 Individuen, charakterisiert. Nach dieser Darstellung der Sportspielleistung im Fußball werden die wichtigsten Ansätze zur Analyse dieser Leistung beschrieben. Dazu gehören die subjektive Videoanalyse, die Notationsanalyse und die räumlich-zeitliche Analyse von Positionsdaten. Dieser Überblick über die verschiedenen Arten der Spielanalyse liefert eine theoretische Grundlage für die Methoden, welche in den Studien dieser Arbeit hauptsächlich verwendet wurden, um die taktische Spielleistung in der Verteidigung zu untersuchen.

Auf der Grundlage dieses theoretischen Hintergrunds werden die einzelnen Studien dieser Thesis vorgestellt, die ein Review und drei Untersuchungen umfassen.

Dabei wurde zunächst im Review der aktuelle Stand der Forschung zur räumlich-zeitlichen Analyse des Defensivspiels anhand von Positionsdaten umfassend analysiert und zusammengefasst. Die hierdurch identifizierten Ansätze zur Analyse des Defensivspiels im Fußball anhand von Positionsdaten zeigten sich als sehr heterogen.

Darauf aufbauend wurden in der ersten Untersuchung dieser Thesis die Merkmale des defensiven Drucks in der Spielphase der geordneten Defensive analysiert. Dabei wurde ein im Review identifizierter Analyseansatz zur Berechnung des defensiven Drucks genutzt. Die Ergebnisse dieser Untersuchung zeigten, dass der Defensivdruck in erfolgreichen defensiven Spielsequenzen höher war als in nicht erfolgreichen. Darüber hinaus war der Druck auf den ballführenden Spieler und die Angreifer in Ballnähe deutlich höher als der Druck auf alle angreifenden Spieler.

In der zweiten Untersuchung dieser Thesis wurde die Restverteidigung, eine spezifische Gruppentaktik in der Spielphase des defensiven Umschaltens, analysiert. Zunächst wurde mit Hilfe von Experteninterviews die Gruppentaktik der Restverteidigung definiert. Darauf aufbauend ergab die Positionsdatenanalyse, dass die Zeitspanne zur Rückeroberung des Balls nach einem Ballverlust der wichtigste Erfolgsfaktor im defensiven Umschaltspiel ist. Darüber hinaus zeigten die Ergebnisse, dass die zahlenmäßige Überzahl in der Restverteidigung und die Raumkontrolle in tiefen Räumen hinter der Abwehrkette wichtige Erfolgsfaktoren in der Restverteidigung sind.

In der letzten Untersuchung dieser Thesis wurde die kompakte Organisation der verteidigenden Mannschaft in der Spielphase der kontrollierten Defensive analysiert. Dabei zeigten die Ergebnisse eine höhere Kompaktheit der ballnahen Verteidiger und eine höhere Kontraktion der Kompaktheit der gesamten abwehrenden Mannschaft in erfolgreichen Defensivsequenzen im Vergleich zu erfolglosen.

Aus den vorgestellten Erkenntnissen lassen sich die relevanten Erfolgsfaktoren der defensiven Spielphasen (kontrollierte Defense & defensives Umschalten) ableiten. Zusammenfassend lässt sich schlussfolgern, dass es für eine erfolgreiche kontrollierte Defensive zentral ist, den ballführenden Spieler auf individueller Ebene unter Druck zu setzen. Auf Gruppenebene ist es darüber hinaus entscheidend, ballnahe Passoptionen abzudecken, indem die Angreifer in Ballnähe unter Druck gesetzt werden und die Kompaktheit der Verteidiger in Ballnähe erhöht wird. Auf Mannschaftsebene ist die Kontraktion der Kompaktheit wichtig für ein erfolgreiches Defensivspiel. Im Gegensatz zur Spielphase der kontrollierten Defensive ist es in der Spielphase des defensiven Umschaltspiels entscheidend für eine erfolgreiche Restverteidigung, tiefe Räume hinter der Abwehrkette und mögliche gefährliche Gegenspieler zu kontrollieren, um gegnerische Konter zu unterbinden.

Basierend auf den präsentierten Erkenntnissen wurden Spielprinzipien formuliert, die übergeordnete und effektive taktische Verhaltensweisen in den jeweiligen Spielphasen darstellen. Dazu gehören beispielsweise das Pressen des ballführenden Spielers und das Zustellen enger Passoptionen in der kontrollierten Defensive oder das Herstellen einer numerischen Überzahl in der

Restverteidigung im defensiven Umschaltspiel. Diese Spielprinzipien ermöglichen eine effektive Anwendung der Ergebnisse dieser Arbeit in der Praxis. So kann unter anderem die taktische Spielleistung objektiver bewertet werden, um dadurch zukünftige Spielleistungen zu verbessern und den Erfolg in der Verteidigung zu steigern.

Zusammenfassend lässt sich sagen, dass in dieser Arbeit hochkomplexe Spielanalysen durchgeführt wurden, um Positionsdaten detailliert auszuwerten. Dies macht es möglich, die Erfolgsfaktoren in der Verteidigung zu identifizieren, um tiefere Einblicke in die Sportspielleistung im Fußball zu erhalten.

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Chapter 1

Introduction

1 General Introduction

1.1 Preface

Soccer is the most popular sport in the world (Dvorak et al., 2004) and is played in every nation around the globe (Reilly & Williams, 2003). This popularity is reflected in the number of 270 million active participants including youth, recreational, and elite soccer players (last FIFA Big Count 2006) (FIFA, 2007; Kirkendall, 2020). Moreover, the number of those who watch the elite play continues to increase. For example, there were 1.5 billion spectators of the FIFA World Cup 2022 final with almost six billion engagements on social media, which makes this final the biggest single sporting event in the world (FIFA, 2023).

One of the main reasons why this sport enjoys such great popularity is that soccer is always full of surprises (e.g. underdog wins against opponents of higher leagues in cup competitions). This is also due to the fact, that to this date, little is known about what yields success and makes a team win a match. Therefore, this thesis focuses on the characteristics of successful tactical behavior.

To understand the conditions of the game is a challenging endeavor since soccer is a highly complex team sport. This complexity starts with the different facets contributing to a match performance of an individual player, including physiological, technical, tactical, and psychological performance facets (Carling, Reilly, et al., 2008; Sarmento et al., 2014; Weineck, 2007). Those four facets of match performance interact in every match situation in a soccer match. For instance, a player makes a high-intensity action such as a sprint with a change of direction (physical), to get in a position to receive a pass, control it, and execute a pass to a teammate (technical). This match situation is influenced by the quality of decision-making processes (Araujo et al., 2006) such as anticipation skills (Carling, Reilly, et al., 2008) (psychological), which results in a specific behavior of the player with a certain effectiveness on the solution of the match situation (e.g. successful pass) and the achievement of a goal (tactical).

This complex match performance is influenced by contextual factors which include internal factors (e.g. anthropometry) (Aquino et al., 2020) and external factors (e.g. score-line or crowd-noise) (Levi & Jackson, 2018; Nevill et al., 2002; Paul et al., 2015). Finally, eleven individual players interact within their team to contribute to a team's performance (Grund, 2012; Rein & Memmert, 2016). Furthermore, the team interacts with the opposing team (Balagué & Torrents, 2005; Gréhaigne & Godbout, 2014). All these stated interactions lead to a highly complex team sport in which no playing sequence looks like a previous one and those complex interactions are gradually being disclosed.

Performance analysis in soccer investigates the above-presented dependencies to get insights into the complex match performance (McLean et al., 2017). In the last decades, there was a steady increase in the research on performance analysis of soccer (Mackenzie & Cushion, 2013). With it, physical match performance was prominently analyzed by measuring, for example, the total running distance, or number of sprints (Altmann et al., 2018; Castellano et al., 2014). Technical match performance was assessed by analyzing on-ball actions (Rampinini et al., 2009) such as passing (Rein et al., 2017; Spearman et al., 2017), dribbling (Rowat et al., 2017), or shooting (Gonzalez-Rodenas et al., 2020). While there is preliminary evidence that psychological match performance is important in soccer (Abdullah et al., 2016; Krane & Williams, 2006), this facet has not yet been investigated in depth. Similarly, research on tactical match performance is also sill in its early stages (Goes, Meerhoff, et al., 2021; Low et al., 2020). Therefore, this thesis will focus on the assessment of tactical match performance of soccer players.

Tactical performance describes the behavior of players managing their actions in space and time (e.g. spatial positioning) to achieve a shared goal (e.g. win a match) by interacting with the opponent under the constraints of the game conditions (Garganta, 2009; Goes, Meerhoff, et al., 2021; Gréhaigne et al., 1997; Rein & Memmert, 2016). Those organizational principles can be differentiated into different levels of tactical performance depending on the number of players involved (Bisanz & Gerisch, 2013; Carling et al., 2005; Rein & Memmert, 2016). This includes the behavior of a single player at the individual level, of two or more players at the group level, and of a whole team at the team level.

With the evolution of player tracking in the last years, this tactical behavior becomes quantifiable in great detail. The resulting spatio-temporal tracking data includes the information about the exact spatial positioning of every player over the course of a match. The evolutions in this field have led to higher data accuracy (validity & reliability) (Hoppe et al., 2018; Linke et al., 2018) and greater availability of tracking data (Goes, Meerhoff, et al., 2021). This development is accompanied by advancements in computational methods to evaluate the resulting big data sets (Goes, Meerhoff, et al., 2021; Memmert & Rein, 2018). In contrast to the exclusive analysis of on-ball actions using event data, positional tracking data enables valuable analyses of off-ball actions since all players on the pitch are considered. All those factors have contributed to an increase in studies that analyze tactical performance using tracking data (Goes, Meerhoff, et al., 2021).

To make use of tracking data and to assess tactical match performance, one has to distinguish between different playing phases in soccer. Since tactical behavior is goal-oriented, the behavior of players in different playing phases differs depending on the possession of the ball and the goals of the respective phase. A soccer match can be basically differentiated into the playing phases of offensive play, defensive play, defensive transition, offensive transition, and set plays (Bauer et al., 2023; Escher, 2020; Hewitt et al., 2016) (see also figure 2.1, chapter 2.3 Appearance of Match Performance in Soccer). For example, the main goal of defensive play is to defend the own goal by preventing the opposing team from scoring or in the best case, regain the ball (Henseling & Maric, 2018; Moura et al., 2012). This ensues a contraction of players

(i.e. players are moving closer together) to deny space to play for the opposing attacking team and eventually regain the ball (Castellano et al., 2013; Clemente et al., 2013a; Moura et al., 2012; Welch et al., 2021). In contrast, the aim of offensive play is to score a goal. Therefore, players control the ball and interact with each other, most frequently by passing, to create space and disrupt the opponent (Henseling & Maric, 2018; Moura et al., 2012). This results in an expansion of offensive players (i.e. players spread out) (Castellano et al., 2013; Clemente et al., 2013a; Moura et al., 2012; Welch et al., 2021). The transition phases represent the time intervals of the switch from offense to defense (defensive transition), and vice versa (offensive transition) (Escher, 2020). Accordingly, the goals of the different playing phases immensely shape the tactical behavioral patterns of soccer players and should therefore be considered when analyzing tactical match performance.

In the context of the playing phases, spectators and media predominantly focus on offensive play by counting goals and assists or valuing spectacular dribblings. This trend is also reflected in the judgement of players and their match performances. For instance, Fabio Canavarro in 2006, was the last defender who was honored with the Ballon d'Or which awards the best European soccer player of the year (France Football, 2023). After Canavarro, solely offensive players have been awarded this prize. This tendency to focus on offensive play is also prominent in soccer research with a multitude of studies analyzing offensive actions such as goal-scoring (Anzer & Bauer, 2021; Lucey et al., 2015) or passing (Power et al., 2017; Szczepanski & McHale, 2016).

However, soccer in particular is a defensively emphasized team sport (Maneiro et al., 2019). It is played on a large pitch where comparable long passing streaks (i.e. in contrast to ice-hockey) (Rollins, 2010) are necessary to achieve scoring opportunities. Furthermore, since in soccer the ball has to be controlled with the feet (i.e. in contrast to handball or basketball), there occur high amounts of technical errors. The average success rate of passes, for example, is only about 70 [%] (Bradley et al., 2011; Redwood-Brown, 2008). Overall, this results in soccer being a low-scoring game that emphasizes the defense (Maneiro et al., 2019; Vilar et al., 2013). This reasoning is supported by several studies indicating that defensive variables are at least as important as offensive variables (Georgievski et al., 2019; Lepschy et al., 2021; Praça et al., 2023).

Nevertheless, research on defense in soccer is low. Moreover, most studies on defensive behavior solely analyzed event data (Freitas et al., 2023). Event data includes the time and location of the match actions, mostly on-ball actions such as passes or shots, which only give a few insights into the tactical behavior in defense where players are not in ball possession. The studies analyzing defensive play with the use of event data analyzed offensive event data by turning the variables around (e.g. shots received) (Castellano et al., 2012; Lago-Ballesteros & Lago-Penas, 2010) or counted ball gains which is only the product of a successful defense (Fernandez-Navarro et al., 2019; Gréhaigne et al., 2002). The few studies that analyzed positional tracking

data only used simple variables that neglect the complexity of the game (e.g. sole analysis of team centroids or spread) (Low et al., 2018). In conclusion, those previous approaches revealed little information about the details of successful tactical behavior in defense (Freitas et al., 2023). Additionally, research on tactical match performance in defense using the possibilities of positional tracking data is still pending. With the evaluation of tracking data all players on the pitch (especially off-ball) can be analyzed and advanced key performance indicators (KPIs) can be computed using the continuous information of their positions to gain detailed knowledge about successful defending in soccer.

Therefore, the aim of this thesis is to analyze tactical match performance during the defensive playing phases (defensive play & defensive transition) at the individual level, group level, and team level exploiting the possibilities of tracking data in a large-scale analysis of the German Bundesliga. With it, this thesis aims to identify factors of successful tactical behavior of defenders to provide detailed insights into successful defensive tactical match performance.

1.2 Outline

After introducing the topic of this thesis, its structure is outlined in the following. This work is arranged according to the hourglass method (see figure 1.1). In the beginning, the theoretical background gives a broad overview of the main topic of this thesis, the match analysis in soccer using positional tracking data to assess defensive tactical behavior. Afterward, the aims and scope of this work are presented followed by the more narrow main section of this thesis including the individual studies that investigate specific parts of successful tactical match performance in the defensive playing phases (defensive play & defensive transition). In the end, the scope is again extended with a comprehensive discussion, which summarizes all the information and concludes the findings of this thesis. This basic structure is depicted in figure 1.1.

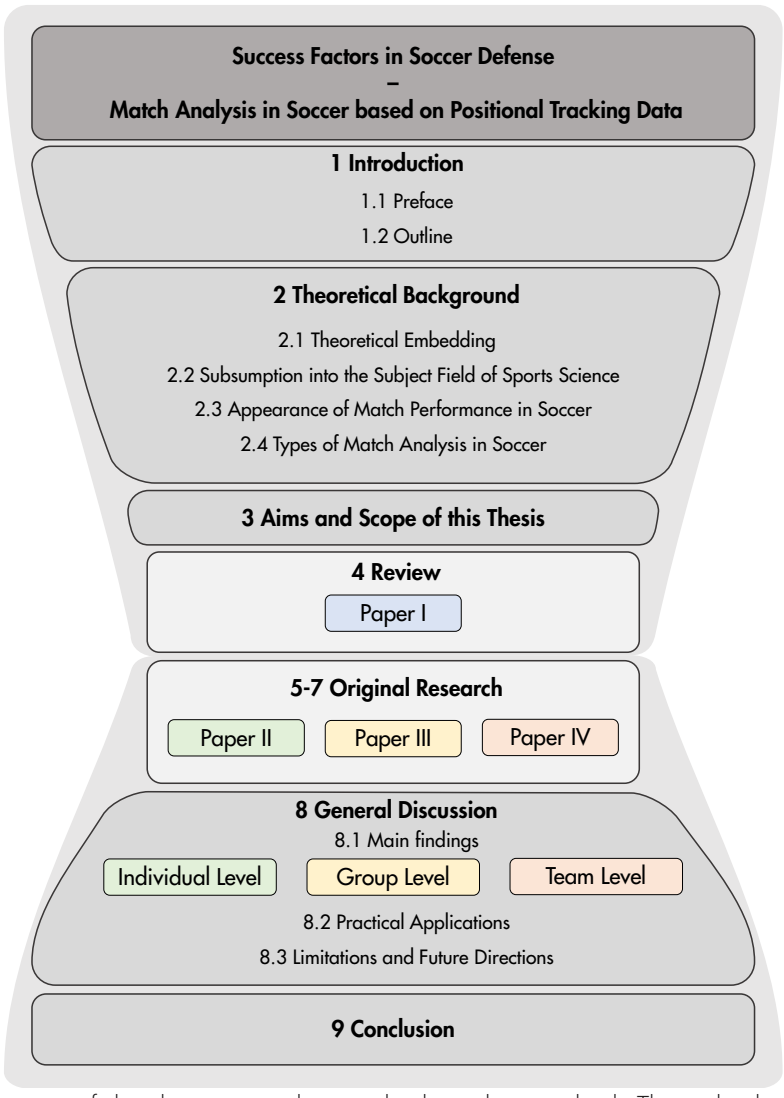

Figure 1.1: Structure of this thesis according to the hourglass method. The individual papers are colored according to their main focus on the level of tactical match performance analyzed.

Chapter 1 Introduction:
In the first chapter, the main topics of this thesis are broadly introduced including performance analysis, the complexity of match performance, or the use of tracking data in match analysis in soccer. Those topics are raised in light of the analysis of tactical match performance of the defensive playing phases (defensive play & defensive transition). The scope of the broad entry is then narrowed to indicate the main research gap of this thesis. Accordingly, the main aims of this work are formulated.

Chapter 2 Theoretical Background:
Against the background of the topics outlined in the first chapter, the theoretical background to the content of this thesis will be presented. This chapter is started by defining the epistemological and theoretical scientific positioning of this thesis. Subsequently, this thesis is subsumed in the subject field of sports science to place this thesis in a broader context. Afterward, the appearance of the match performance of an individual soccer player and the factors influencing this match performance are presented in a theoretical framework. Using this framework, the interaction of individuals to compose a team performance is discussed. In the end, different types of match analysis in soccer are outlined. Those methodological approaches of match analysis are used in this thesis to get insights into the complex match performance in soccer. Overall, this chapter provides detailed information about the main subject (match performance in soccer) and the research approaches (types of match analysis) used in this thesis.

Chapter 3 Aims and Scope of this Thesis:
In light of the research gaps outlined in the first chapter and the presented theoretical background in the second chapter, the aims and scope of this thesis are formulated in the third chapter.

Chapter 4 Review (Paper I):
The fourth chapter includes the systematic review paper, which was published in an international peer-reviewed journal. This review paper (Review (Paper I)) systematically analyzes the current status of research regarding the analysis of defensive play using positional tracking data. It considers all levels of tactical play, ranging from individual, over group, to team level tactical behavior.
Review (Paper I):
Forcher, L., Altmann, S., Forcher, L., Jekauc, D., & Kempe, M. (2022). The use of player tracking data to analyze defensive play in professional soccer – A scoping review. International Journal of Sports Science & Coaching, 17 (6), 1567–1592. https://doi.org/10.1177/17479541221075734

Chapters 5-7 Original Research (Paper II-IV):

In chapters five to seven, three original research papers are presented that have been published in international peer-reviewed journals (Paper II & IV) or are currently under review (Paper III). In those studies (Defensive Pressure (Paper II), Rest Defense (Paper III), & Compact Organization (Paper IV)) the tactical match performance in the defensive playing phases (defensive play & defensive transition) is assessed. With it, sophisticated analysis approaches are used to evaluate positional tracking data. In all papers, the results are structured according to the different levels of tactical play (individual, group, & team level) which are analyzed (illustrated in figure 3.1 in chapter 3 Aims and Scope of this Thesis).

Defensive Pressure (Paper II):

Forcher, L., Forcher, L., Altmann, S., Jekauc, D., & Kempe, M. (2022). The keys of pressing to gain the ball – Characteristics of defensive pressure in elite soccer using tracking data. Science and Medicine in Football, 1-9. https://doi.org/10.1080/24733938.2022.2158213

Rest Defense (Paper III):

Forcher, L., Altmann, S., Forcher, L., Jekauc, D., & Kempe, M. (2023). The success factors of rest defense in soccer – A mixed-methods approach of expert interviews, tracking data, and machine learning. Under review, 1-20.

Compact Organization (Paper IV):

Forcher, L., Forcher, L., Altmann, S., Jekauc, D., & Kempe, M. (2023). Is a compact organization important for defensive success in elite soccer? – Analysis based on player tracking data. International Journal of Sports Science & Coaching, 1-12. https://doi.org/10.1177/17479541231172695

Chapters 8-9 Discussion and Conclusion:

In the end, this thesis is rounded off by a superordinate discussion and conclusion. This includes a critical, summarizing discussion of the main findings of this thesis at the different levels of tactical play (individual, group, & team level). Based on those results, principles of play in the respective playing phases (defensive play & defensive transition) are derived to provide practical applications of the findings. Furthermore, the limitations of this work are disclosed to point out future directions.

Chapter 2

Theoretical Background

2 Theoretical Background

2.1 Theoretical Embedding

This chapter will present how the results of this thesis are obtained from a theoretical point of view. Thereby it is clarified under which scientific-philosophical point of view and based on which epistemological position the results are gathered. This reflects on how the conclusions are drawn in this dissertation.

Accordingly, the scientific-philosophical foundations are led for this dissertation by making epistemological considerations. Based on those considerations, the scientific-philosophical position is presented. With it, the role as a scientist is reflected and the way of knowledge generation shall be presented. This indicates the process of arriving at facts and presented theories to generate knowledge.

In general, it can be distinguished between three main epistemological positions (Haag & Mess, 2010) which describe the way of knowledge generation. They can be positioned on a continuum, with the phenomenological position between the poles of the hermeneutical and the empirical position. The hermeneutical position assumes that an individual generates knowledge through interpretation based on mental abilities (especially understanding). In contrast, the empirical position supposes that one makes unambiguous perceptions due to the perceptual property, which are exact and comprehensible. The phenomenological position characterizes an individual who perceives something and at the same time assigns a meaning to the perception (interpretation) (Haag & Mess, 2010). According to this division, the epistemological position of this thesis is empirical as the behavior of soccer players is quantified in empirical studies evaluating the precise positions of players during a match (i.e. tracking data).

Based on this continuum of knowledge generation there are distinct scientific-philosophical positions. For instance, subjective idealism, dialectical materialism, critical theory, critical rationalism, logical empiricism, and positivism (Haag & Mess, 2010). This thesis can be assigned to the philosophical position of critical rationalism which is outlined and justified in the following.

The position of critical rationalism assumes that there is nothing absolutely certain and everything has to be examined critically and rationally, because no scientific evidence is finally true. Therefore, scientific conclusions cannot be finally verified by observation. Conversely, observations can falsify the conclusions made (Haag & Mess, 2010). To advance science with falsificationism, a theory, as a speculative and provisional assumption or prediction to explain a part of reality, is built to overcome the shortcomings of previous theories. These theories are then rigorously and ruthlessly tested by experimentation and observation. This includes the position of acceptance of findings as long as they are not falsified and falsifiability is set as a criterion for good theories (Chalmers, 2007). Overall, this procedure leads to a stepwise increase in the complexity of a theory.

Overall, observable facts are the basis for scientific knowledge generation (Chalmers, 2007). However, facts and knowledge are erroneous and can therefore be subject to correction (Chalmers, 2007). To continuously expand knowledge, it is most important to provide relevant knowledge. This can be derived to science, which should ask the ideal question to make an ideal observation to provide answers to this raised question to eventually arrive at relevant facts (Chalmers, 2007). According to this idea, no observation can be made completely independently since study design is based on theories or prior knowledge to make relevant observations and contribute to the development of knowledge in a field.

Against the background of the epistemological considerations and the discussed scientific-philosophical position, the procedures of knowledge gain of this dissertation shall be presented. In the case of this thesis, at first, a theoretical approach about the composition of match performance in soccer is presented (see chapter 2.3 Appearance of Match Performance in Soccer). Afterward, distinct and specific hypotheses for the individual studies are formulated based on specific parts of this theory (see chapter 3 Aims and Scope of this Thesis). The hypotheses based on these theories are then examined and subjected to the possibility of falsification by the individual studies (see chapters 4-7). Within these studies, the tactical behavior of players is quantified in aggregated variables as a simplification of reality. This selection of performance indicators is dependent on the scientist. In the end, inferential statistics are used to objectively quantify the differences between successful and unsuccessful playing sequences (see methods in chapters 4-7). Those empirical study designs are used to make relevant observations. Those observations are objective and fallible (Chalmers, 2007). They are objective because they are traceable due to precise documentation of methods used (Chalmers, 2007) and fallible because they can be refuted or challenged by new research. In the end, the presented results of observations are interpreted to draw conclusions (see chapter 8 Discussion). Using this procedure, the theory and the hypotheses are tested for falsifiability. This interpretation is dependent on the experience, knowledge, and expectations of the scientist (Chalmers, 2007). As stated above, perception always encounters the presence of prior knowledge, theories, and expectations. With the help of conceptual knowledge about tactical behavior in soccer, practical conclusions are made about the characteristics of successful tactical performance in defense.

After the made epistemological consideration, this chapter concludes with a general classification of this thesis to place it within Hopkins' (2002) research dimensions. This is accomplished to provide a more comprehensive view of the research endeavor of this work. This thesis analyzes the behavior of soccer players. Therefore, the nature of the topic is behavioral. The investigated sample comprises the first half of the 2020/21 season of the German Bundesliga. Accordingly, the scope of inquiry is the study of a large sample to analyze general occurrences. Thereby, this thesis aims to make general statements about successful behavior in professional soccer (population) (Haag & Mess, 2010). The mode of inquiry is the observational investigation of professional soccer matches in the German Bundesliga without influencing the behavior of play-

ers. The methods used are mainly quantitative, as the analysis of tactical match performance is completed using computational methods to evaluate tracking and event data. In this context, a large variety of quantitative methodological (e.g. synchronization of tracking and event data, automatic identification of tactical formations) and statistical procedures (e.g. linear mixed model, machine learning classifier) were used and combined to analyze the tactical match performance in the defensive playing phases in great detail. This variety of quantitative methods is complemented by qualitative expert interviews in paper III (see chapter 6 Rest Defense). The data is collected by observation of tactical behavior during the competition (match) and by interviews with soccer coaches/experts.

The data analysis is numerical-oriented (statistical) (Haag & Mess, 2010) due to the quantitative nature of data collection and the big data sets used. Big data can be characterized by three V's: Volume, Variety, and Velocity (Chen & Lin, 2014; Noor et al., 2015). According to the big data nature of data sets used in this thesis (see chapter 2.4.3 Spatio-Temporal Analysis (Tracking Data)), computer technologies are needed to process and evaluate these data sets. The ideological stance is objective (see above, critical rationalism) and the political stance is neutral impartial (Hopkins, 2002). Overall, this thesis uses mainly quantitative research. However, it benefits from including qualitative data-gathering methods in research related to human behavior (Hopkins, 2002).

2.2 Subsumption into the Subject Field of Sports Science

In this chapter, the research project of this thesis is placed in the larger context of sports science. This shall indicate the importance of this work beyond its independent character. With it, the subject area of sports science is to be described and transferred to the present work.

Sports science in general can be defined as follows:

"The aim of a science of sports is to describe, understand, and explain the sport and people's sports practice." (Güllich & Krüger, 2013)

This can be transferred to this thesis, which comprises an investigation of a specific subsection of sports practice, in particular match performance in soccer. Thereby, the aim is to describe, explain, and predict match performance in soccer.

Over the course of time, a multi-layered subject area has developed in sports science based on a collection of theoretical and thematic fields with several content-related and methodological orientations (Schröder & Dose, 2010). This diversity can be classified into (1) the medical-natural scientific orientation, including sports medicine, sports biomechanics, training science, exercise science, or sports informatics, (2) the social-behavioral orientation including sports pedagogy, sports psychology, or sociology of sports, (3) the economic-political-legal orientation including sports economics, sports politics, or sports law, and (4) the historical-philosophical orientation including history of sports, or philosophy of sports. This thesis can be classified in the subject area of the medical-natural scientific orientation. This is justified by the fact that the individual papers of this thesis investigate sports performances in soccer using computer science methods to evaluate big data sets of positional tracking data.

Subsequently, the research project of this thesis shall be described in further detail. On the continuum between basic research and application-oriented research (Schröder & Dose, 2010) this thesis is placed near to the application-oriented pole. Thereby, the application-orientation is reflected in the practical orientation of the investigations and the practical conclusions made, based on the findings on successful defensive behavior (see chapter 8.2 Practical Application). However, there are also some characteristics of basic research that are present in this thesis. In detail, it is theoretically examined what match performance in soccer is composed of (see chapter 2.3 Appearance of Match Performance in Soccer). Based on this theoretical framework, hypotheses are formulated which are tested for falsifiability to gain basic knowledge about the tactical match performance in the defensive playing phases.

Concluding, the practical relevance of the presented research is fundamental to this thesis. Since sports performance is the subject area of this sports scientific work, practical relevance is one of its most important aims (Schröder & Dose, 2010). Thereby, it is the key to ensure that research results are transferred into practice and their implications can be applied there (Schröder & Dose, 2010). In this context, a theory-guided practice can be seen as an adequate requirement in terms of knowledge transfer (Haag & Mess, 2010).

By the investigation of professional soccer players during competition, the investigation of complex sports performance using the match performance data, and the drawing of conclusions relevant to practice, this thesis has high practical relevance.

2.3 Appearance of Match Performance in Soccer

This chapter addresses the complex construct of match performance in soccer. It presents a theoretical approach that describes how the match performance of soccer players is composed. The main question that is raised is what actually constitutes performance in a soccer match and how the various factors of performance interact to influence and determine the outcome of a match (McLean et al., 2017). In the first subchapter, the match performance of an individual soccer player is outlined (see chapter 2.3.1), including the main facets of the match performance of an individual and the internal and external factors that influence this match performance. In the second subchapter, it is indicated how the match performance of a team, consisting of several individuals, evolves (see chapter 2.3.2). Thereby, the interaction of individuals to contribute to a collaborative team performance is described. Overall, this chapter sets out the match performance in soccer in its entirety to form the foundation of this thesis. While this work focuses on the specific subpart of the tactical match performance in the defensive playing phases, this holistic theoretical approach of match performance gives a theoretical understanding of performances during soccer matches. According to this holistic approach of theoretically examining match performance, considerations are made for all facets of match performance (physical, technical, psychological, & tactical) and the entire internal and external factors of influence. This builds a theoretical foundation for this thesis, which is important to increase the understanding of a player's individual match performance as well as the interactions within a collaborative team performance. Both individual and team match performance in soccer are investigated in the original studies and this thesis can be classified within this theoretical framework. In addition, this chapter builds the basis for the next chapter, which introduces the types of match analysis as different ways of gaining insights into this complex match performance (see chapter 2.4 Types of Match Analysis in Soccer).

2.3.1 Individual Match Performance

As stated above, this first part will focus on the individual performance of a soccer player during a match. The main facets of the match performance of an individual soccer player will be presented and justified. Afterward, the internal and external factors that influence this match performance will be outlined. Both the main facets and influencing factors of match performance are theoretically examined and presented using study results. With it, this part aims to improve the understanding of what constitutes match performance in soccer and what a player's performance looks like in a match. This should allow one to investigate, examine, and improve the performance in soccer in a targeted manner. Furthermore, as mentioned above, the investigations and results of this thesis can be categorized in the larger context of this construct of match performance which increases the overall meaning of the findings.

In this theoretical approach, the individual match performance is derived from Newell's model of constraints. According to this model, movements (coordination & control) arise from the interaction of the environment, the person, and the task (Newell, 1986). In soccer, the environment describes external factors of influence such as the situational context (e.g. match venue, scoreline) or the opposing players. The person or, in the case of soccer the player, comprises internal factors including skills (e.g. passing skill) or anthropometry (e.g. height, muscle fiber distribution). The task in soccer concerns a match action (e.g. pass), a match situation (e.g. defensive playing sequence), or the whole match according to the different scales of the task. To clarify the application of this approach in the use case of soccer, an example of a defending action in soccer is illustrated. The environmental context could be, for example, the last minute of a match with a 2:1 lead for the defending team which is playing at home (external factors). The person in focus could be a central defender of the home team, who is 1.86 [m] tall, has a maximum velocity of 33 [km/h], and has high technical skills (internal factors). The task that this defender faces could be an opposing attacker who is dribbling the ball towards the defendants' goal. The defender has to pressurize the attacker (task of a single action) to stop this dribble and regain the ball (task of a match situation) to eventually win the match (task of the whole match).

Accordingly, the accomplishment of the task with the conditions of an individual and under the influence of the environment then leads to the execution of a movement which can also be interpreted as match performance. On the pitch in a specific match situation, a player has many degrees of freedom to perform different movements and behave (Memmert et al., 2017). For instance, the defender in the above-presented example has almost infinite possibilities to accomplish the presented task through an action or movement. The resulting movements in soccer can be structured in different main performance aspects of physical, technical, tactical, and psychological facets (Carling, Reilly, et al., 2008; Sarmento et al., 2014; Weineck, 2007). Those facets are described in detail in the next chapter. Overall, the different influencing factors (e.g. internal & external) and heterogenous tasks presented to a player during a match, combined with the different performance facets of resulting movements with a multitude of degrees of freedom result in a highly complex sports match performance which is assessed in detail in the following.

2.3.1.1 Main Facets of Match Performance

As aforementioned, the movements of a soccer player result from the processing and solution of movement tasks a player faces during a match (Hossner et al., 2015). Those movements, which can be interpreted as performance, can be completed in different dimensions. In the following, those main facets of match performance in soccer will be presented.

First, movements are executed in a physical manner, such as the velocity of limbs (Altmann et al., 2021). Second, movements can be characterized in a technical dimension, for instance, according to the ball control (Rampinini et al., 2009). Third, movements can be interpreted according to their effectiveness in the achievement of a tactical goal (Goes, Brink, et al., 2021). Fourth, movements have psychological features of cognitive functions in the planning and execution of movements (Scharfen & Memmert, 2019). Accordingly, performance can be structured in four main facets, namely physical, technical, tactical, and psychological facets of match performance (Carling, Reilly, et al., 2008; Sarmento et al., 2014; Weineck, 2007). These facets are complex in their interaction (Coutts, 2014; Dolci et al., 2020). For example, a physical movement of a high-velocity sprint with the technical action of dribbling the ball, with the tactical goal to break the opposing defensive-line, and the fast stimulus processing and anticipation of the match situation for fast, error-free, and successful movement execution under pressure as psychological performance. The mentioned main facets will be presented individually in the next paragraphs.

First, the technical facet of match performance is presented. In general, soccer has the technical difficulty of controlling the ball with the feet. This results in a large number of technical errors which is exemplarily indicated by the fact that almost every 6th pass is incomplete (Power et al., 2017). Therefore, the technical performance of a soccer player is highly important and the technical demands during a match are outlined in the following. To assess the technical performance of a soccer player mainly the on-ball actions of players such as passes, dribblings, or shots are analyzed. Over the course of a match, a player has about 50 to 100 on-ball actions (Bloomfield et al., 2007; Forcher, Forcher, Jekauc, Woll, et al., 2022). Those include up to 3 dribblings (Forcher, Forcher, Jekauc, Woll, et al., 2022), around 38 passes (most of which have a length under 39 [m]) (Forcher, Forcher, Jekauc, Woll, et al., 2022), 4 headers (Forcher, Forcher, Jekauc, Woll, et al., 2022), 10 tacklings (Dellal et al., 2010), and 1.4 shots per match (Liu et al., 2016). In recent years, there is an increase in the number of passes per match by up to 40 [%] with a simultaneous increase in the success rate of additional 10 [%] (Barnes et al., 2014). Concluding, technical match performance plays a fundamental role in soccer and mainly concerns the on-ball actions of players.

Secondly, the physical dimension of match performance is outlined. In light of the technical assessment of on-ball actions, it is evident that soccer is mainly performed without the ball (Ade et al., 2016). Solely, 1-2 minutes of 90 minutes of playing time, an individual player is in ball possession (Dellal et al., 2010; Link & Hoernig, 2017). Accordingly, to assess the match performance of a whole match the physical performance is of interest. Physical performance is predominantly analyzed by the assessment of running distance at different speeds. In detail, soccer players cover between 10 and 13 [km] during a full match (Sarmento et al., 2014; Stølen et al., 2005). The physical activity in soccer within this distance can be characterized by intermittent high-intensity incidents with various intermittent and multilateral movements (Dolci et al., 2020). Accordingly, players complete between 25 to 50 high-intensity runs per match with a distance of 300 to 800 [m] (Ade et al., 2016; Ju et al., 2022; Lago-Peñas et al., 2023). Furthermore, they cover 22-24 [%] of the total running distance over 15 [km/h], 8-9 [%] over 20 [km/h], and 2-3 [%] over 25 [km/h] (Rampinini et al., 2007). However, the typical distinction of running performance in different speed zones does not appropriately consider the physical performance of other high-intensity actions such as accelerations and decelerations, jumps, or directional changes (Dolci et al., 2020). With 43 ± 8 decelerations and 26 ± 5 accelerations per match (Russell et al., 2016), the number of accelerations and decelerations is several times higher than the number of high-intensity runs and sprints (Baptista et al., 2018). Overall, players cover about 18 [%] of the total match distance while accelerating or decelerating (> 1 [m/s^2]) (Akenhead et al., 2013). Besides, players turn 726 ± 203 during the match, with about 84 [%] of these turns occurring at an angle between 0° to 90° to the left or right (Bloomfield et al., 2007). This indicates the non-linear fashion of high-intensity runs. About half of the sprints contain at least one change of direction or are completed on a curvilinear track (Ade et al., 2016; Fitzpatrick et al., 2019). Overall, the high-intensity actions are associated with scoring opportunities (Faude et al., 2012) and goals (Martínez-Hernández et al., 2022) which indicates their importance. Further, there is an increase in high-intensity physical activity in matches in the last years (Barnes et al., 2014; Dolci et al., 2020). Overall, this highlights the increased importance of physical match performance in soccer.

Third, the tactical match performance is considered in detail. Tactical match performance describes the movement behavior of players during a match according to its effectiveness in achieving the main goal of winning a match. Besides the superordinate goal to beat the opposing team, tactical goals can also be defined at finer-grained levels. For example, on the level of single actions such as the goal of a pass to reach a teammate (Goes et al., 2018; Spearman et al., 2017) or the goal of an off-ball overlapping run to break the defensive-line (Anzer et al., 2022). In detail, in soccer, the tactical behavior of players mainly depends on distinct playing phases, which can generally be divided into offensive play, defensive play, defensive transition, offensive transition, and set plays (Bauer et al., 2023; Escher, 2020; Hewitt et al., 2016). According to the goals and conditions in the respective playing phase, the behavior of a player differs (see figure 2.1 in chapter 2.3.2 Collaborative Team Performance). The team in ball possession (i.e. during offensive play) has the goal of scoring. Therefore, players control the ball and interact with each other while attacking. During an attack, offensive players have a high movement variability to disrupt the opposing defense (Davids et al., 2005) to create open space for attacking actions to eventually create scoring opportunities (Castellano et al., 2013). In contrast, the opposing team, in defensive play, has the main goal of defending their goal and regaining possession (Henseling & Maric, 2018; Moura et al., 2012). Therefore, players show a more ordered and compact movement behavior to deny attacking spaces for the opposing team and thereby increase the defensive pressure. Those opposing patterns of offense (players move further apart = expanding) and defense (players move closer together = contracting) lead to the idea of a contraction-expansion relationship between the offensive and the defensive team (Bartlett et al., 2012; Moura et al., 2012). This tactical behavior pattern is assessed in detail for defensive play in the fourth paper of this thesis (see chapter 7 Compact Organization). The transition phases characterize the time intervals between the mentioned playing phases and describe the switch from offense to defense (defensive transition), and from defense to offense (offensive transition) (Escher, 2020). Overall, the tactical performance of players can be investigated in dependence on the effectiveness with regard to the goal of the playing phase, the match, or the action. While this chapter provides a holistic theoretical framework of the match performance, the latter studies of this thesis will focus on the tactical match performance in defense assessing the effectiveness of tactical behavior according to the goals of the defensive playing phases (defensive play & defensive transition).

Fourth, the psychological facet of match performance is contemplated. Psychological or mental facets of match performance include perceptual skills (Mann et al., 2007), psychological aspects of decision-making processes (Araujo et al., 2006) such as anticipation skills (Carling, Reilly, et al., 2008), or personality traits of a player (Carling, Reilly, et al., 2008). The decision-making process is an integral part of goal-directed behavior. The effectiveness of the movement behavior of players with a certain goal was described as tactical performance before. In contrast to the tactical facet of movements, the psychological facet describes the speed and accuracy of decision-making processes which are critical for successful match performance in soccer (Araujo et al., 2006). Furthermore, cognitive functions have been shown to be important success factors for elite soccer players (Ehmann et al., 2021; Scharfen & Memmert, 2019). Those perceptual-cognitive skills such as anticipation and decision-making are also often referred to as “game intelligence” (A. M. Williams & Hodges, 2005). In detail, perceptual-cognitive skills are about the identification and intake of information from the environment to filter and integrate this information with existing knowledge to appropriately select and execute movements (Mann et al., 2007). Amongst others, they include response accuracy, response time, number of visual fixations, visual fixation duration, and quiet eye duration (i.e. final fixation on an object prior to movement execution) (Vickers et al., 2019). Soccer match situations are highly dynamic and the

way players use those perceptual-cognitive skills has a significant effect on the quality of their decisions (Ehmann et al., 2021). In detail, it has been shown that sports experts outperform non-experts in cognitive skills. They show better response accuracy and response time (Mann et al., 2007) as well as better processing speeds (Voss et al., 2010). Accordingly, they are faster in picking up perceptual cues (Mann et al., 2007) and in anticipating opponents' intentions (Mann et al., 2007). Furthermore, experts show a distinct scanning routine with fewer fixations of longer duration, including longer quiet eye periods (Mann et al., 2007; Vickers et al., 2019). This routine allows them to process and filter more information about a match situation per fixation. Additionally, experts have a comparatively long quiet eye period. Overall, experts allocate their attention more effectively (Mann et al., 2007). Therefore, soccer players' performance in processing the most important information of a match situation is critical. For instance, to visually track the movements of teammates and opponents simultaneously is a decisive aspect of success in soccer (Ehmann et al., 2021). Besides perceptual-cognitive skills, the concentration, self-confidence, motivation, and stress management are relevant psychological skill factors for match performance in soccer (S. de Freitas et al., 2013). Overall, psychological match performance is multifaceted and of great importance in soccer. It can be decisive how fast a player can process information and make decisions on the pitch. Therefore, psychological factors of player behavior need to be considered in future work on match performance in soccer.

Concluding, match performance in soccer has four different main facets. Those facets of physical, technical, tactical, and psychological match performance are influenced by internal and external factors which are presented in the following two chapters.

2.3.1.2 Internal Factors (Person)

After the presentation of the main facets of the match performance, this chapter focuses on the internal factors of the individual person that influence a movement and thus the behavior (for the detailed derivation see chapter 2.3.1 Individual Match Performance). Those internal factors of the person represent the internal prerequisites of an individual player that influence the match performance.

While there are several different ways to classify the internal prerequisites of a person this thesis mainly distinguishes between anthropometry, personality, abilities, and skills. These prerequisites describe the basic conditions with which an individual encounters a match situation. Therefore, their influence on match performance is outlined.

The anthropometry captures the mechanical characteristics of the human body and its parts (Schwameder et al., 2013) such as the body composition (e.g. muscle, fat mass). Studies revealed that this factor influences match performance in different ways. For instance, total body mass and muscle mass are moderately positively correlated with physical match performance (e.g. total distance) (Rienzi et al., 2000). Further, somatotype characteristics and body fat percentage are discriminators between different levels of male soccer players (Slimani & Nikolaidis, 2017).

However, a recent review indicated that the relationship between anthropometric data and physical match performance is small (Aquino et al., 2020).

The personality of an individual soccer player also has an impact on his match performance. The best-known construct to assess personality are the Big-Five personality factors of extraversion, neuroticism, conscientiousness, openness, and agreeableness (Wilson & Dishman, 2015). Those personal factors have a share in improving the performance of elite soccer players (Abdullah et al., 2016). In another context, two recent studies found that individual players react differently, with differences in physical and technical match performance, on the tactical context they are exposed (tactical position & tactical formation) (Altmann et al., 2021; Forcher, Forcher, Härtel, Jekauc, et al., 2022). This finding may indicate that physical and technical match performance is depending on the personality of the player. However, this explanatory approach remains uncertain since this tendency could also be explained by the physical or technical capacities of a player. Besides, mental fatigue (psychobiological state of a person) was shown to decrease physical performance in players (Van Cutsem et al., 2017).

Besides the influence of the personality, the abilities of an individual soccer player play a major role regarding the internal factors that influence match performance in soccer. Abilities can be defined as general, overarching traits forming the basis for the execution of various movement skills (Burton & Miller, 1998). Exemplary abilities are strength or endurance. In the case of speed, there is no general overarching ability that can be defined as speed according to Altmann (Altmann, 2020). In contrast, research has tended to take the position that speed-related actions in soccer are task-specific skills (Altmann, 2020). The expression of abilities (or skills in the case of speed) can be assessed using diagnostic tests, such as field-based or laboratory-based tests. In endurance testing, there is a great variety of procedures including running protocols on a treadmill (e.g. incremental treadmill test) and field-based tests (e.g. Yo-Yo intermittent recovery test) (Aquino et al., 2020). To assess strength, there are diagnostics such as vertical jump tests (e.g. countermovement jump) or one-repetition maximum (1-RM) of lower limb muscle strength (e.g. squat) (Slimani & Nikolaidis, 2017). Diagnostics concerning speed include linear-sprint tests of different length (e.g. 30 [m]) and modifications (e.g. starting length), change-of-direction sprint tests, or agility tests (Altmann et al., 2019). The expression of abilities in an individual soccer player has an influence on his match performance. For instance, outcomes of endurance performance diagnostics (incremental treadmill test, Yo-Yo intermittent recovery test) were shown to influence physical match performance (Aquino et al., 2020). Further, regarding strength, muscular power was shown to be of particular importance for achieving high-level soccer performance (Slimani & Nikolaidis, 2017) with vertical jump height being a key requisite for professional soccer players (Slimani & Nikolaidis, 2017).

In contrast to abilities, skills can be defined as movement classes of the same form and function (Altmann, 2020). Soccer skills include passing, shooting, dribbling, heading (Davids et al., 2000), and speed-related actions (see above). Accordingly, most skills are about controlling the

ball (on-ball actions). The efficient and effective motor control of skills is highly important to master complex match situations under high spatial and temporal pressure in soccer. For instance, in elite-level soccer, on average, a player has solely two ball contacts to control and pass the ball per individual ball possession (Dellal et al., 2010). Accordingly, soccer players need to be skillful when they are on the ball (Dellal et al., 2010). Since there are few ball possessions per player (on the ball for about 1-2 [min] per match) (Dellal et al., 2010; Link & Hoernig, 2017) the execution of on-ball skills is one of the most important aspects of soccer performance (Ali, 2011). Furthermore, as stated above, speed-related actions (e.g. change of direction sprint) are presently considered as skills. It was shown that the peak velocity and repeated-sprint performance are correlated with peak sprint speed during a match (Buchheit et al., 2010) and thus influence physical match performance. On the other hand, perceptual-cognitive skills influence match performance in soccer. Better soccer players have higher perceptual and cognitive skills and thus are able to filter and record the most important information in a match situation (Ali, 2011). Overall, the mastery of skills is essential in coping with match situations and thus influences match performance in soccer. For example, high skills in receiving and controlling the ball with one initial ball contact enables the player to deal with increasing defensive pressure by the direct opposing defender who aims at regaining the ball. A skilled pass with the outside of the foot can catch the defender off guard and increases the chance of successfully reaching a teammate.

2.3.1.3 External Factors (Environment)

After discussing the main facets of match performance and the influence of internal factors of a person on this match performance, this chapter concentrates on the influence of external factors of the environment on match performance in soccer. The external factors can be distinguished into four main factors of the situational context, the opponent, the tactical factors, and the social factors. Those factors not only affect the match performance itself, but also interact within each other. This chapter presents evidence of the interactions of external factors with match performance as well as within the external factors.

The situational context comprises the current situation of the competition. It includes the match venue, the score-line, the moment of the match (e.g. minute), or across the season (e.g. last match of the season) (Hewitt et al., 2016). It was shown that the score-line affects the physical (high-intensity running distance) (Bradley & Noakes, 2013) and technical match performance (Taylor et al., 2008). Furthermore, the physical, technical, and tactical match performance is affected by the match venue (Praça et al., 2021; Tucker et al., 2005) with physical (i.e. higher total distance) and technical match performance (i.e. more passes) tending to increase in home matches (Praça et al., 2021; Tucker et al., 2005). Furthermore, the situational context also includes environmental factors such as air pollution. Air pollution has been shown to decrease a soccer player's physical match performance (Beavan et al., 2023). Further, the relative air humidity and air quality revealed effects on physical and technical match performance (Zhou et al., 2019). Next to the stated situational context, the quality of the league was shown to have an influence on the physical and technical match performance of soccer players (Bradley et al., 2013) with more high-intensity distance covered in higher-level leagues (O'Donoghue et al., 2001). Concluding, there are effects of the stated situational variables on soccer match performance (Taylor et al., 2008).

Another external factor that influences match performance is the opponent. Similar to the considered players, the opposing team also has the aim of winning a match. The actions (e.g. positioning) of the players of the opposing team have an influence on the behavior and performance of the considered players of the analyzed team. For example, the tactical formation or the quality of the opposing team were shown to influence the match performance of the analyzed players. In detail, during offensive play teams show a higher dispersion of player positioning (e.g. larger surface area) when playing against weaker teams (Castellano et al., 2013). Accordingly, the opposition quality affects the tactical match performance (Fernandez-Navarro et al., 2018). Also, the physical match performance is influenced by the quality of the opposition with an increase in jogging and walking distance against better teams (Lago et al., 2010). Accordingly, the opponent is an external factor that influences the match performance of soccer players.

Besides the opponent, also the tactical factors of the own team influence the match performance. The tactical factors include the tactical formation, the tactical position, or the playing style. The tactical formation describes the spatial positioning of players on the pitch with different positions having different tactical tasks. Further, playing style characterizes the behavioral features of a team that are repeatedly observed over time (e.g. ball possession style) (Fernandez-Navarro et al., 2016; Fernandez-Navarro, 2018; Forcher, Forcher, Härtel, et al., 2023). The tactical formation has an effect on the physical match performance. For instance, players in a 4-3-3 formation cover more high-intensity runs compared to players in a 4-4-2 formation (Aquino et al., 2017). Moreover, players in defensive formations (e.g. 4-5-1) cover 20 [%] more high-intensity runs in defense compared to players in offensive formations (e.g. 4-4-2 and 4-3-3) (Bradley et al., 2011). Next to the tactical formation, several studies found effects of tactical playing position on physical and technical match performance (Bloomfield et al., 2007). For instance, central defenders show the fewest number of dribbles, ball losses, and goal completions (Forcher, Forcher, Jekauc, Woll, et al., 2022; Liu et al., 2016). Wide players (wide defenders & wide midfielders) and central midfielders were shown to cover more total running and high-intensity distance (Bush et al., 2015; Di Salvo et al., 2006). Attackers and wide players complete the most sprints during a match (Di Salvo et al., 2006).

When analyzing the influence of tactical factors on match performance, especially the interactions of positional differences in distinct tactical formations yield interesting findings. For example, defenders in a formation with a back three (e.g. 3-5-2) are physically more demanded compared to defenders in a formation with four defenders (e.g. 4-3-3) (Forcher, Forcher, Jekauc,

Woll, et al., 2022). Another interesting finding related to tactical formation was found in another recent study, which indicated that an in-game change of the tactical formation can have a beneficial effect on match performance (e.g. more goal-scoring opportunities, goals) (Forcher, Forcher, Jekauc, Wäsche, et al., 2022). In addition to the influence of tactical formation and position, the playing style (ball possession style vs. direct play/counter attacking style) was indicated to influence physical and technical match performance (Forcher, Forcher, Härtel, et al., 2023). Concluding, the tactical factors (i.e. tactical formation or position) influence the match performance of a soccer player.

Finally, social factors are also an external factor that can influence match performance in soccer. The social factors concern the social framework in which a player behaves including the social group of a team and the coaching staff. The resulting psycho-sociological team dynamics include the creation of a team, team cohesion, networks of communication, or leadership styles (Gréhaigne, 2011). The coaching staff is indirectly influencing the match performance of players, for instance, by motivating them and building their character (Teques et al., 2019). The influence of social factors is exemplarily indicated by the short-term increase in the match performance of a team after a change of the coach (Gómez et al., 2021; Lago-Peñas, 2011). However, this effect declined after ten matches. In contrast to the coaching staff, the social group of a team describes the interactions of group members in a social network. This network is important for successful match performance, which was shown by a correlation between perceived social cohesion and soccer match performance (Tziner et al., 2003). Furthermore, teams with high-intensity networks with low centralization are associated with increased match performance (Grund, 2012).

Overall, there are multiple, different contextual factors influencing match performance to a different degree which were indicated in this chapter. Moreover, these external factors interact in a highly complex way which is indicated by a practical example. In preparation for an upcoming match, a coaching staff (social factors) is developing a match plan selecting a tactical formation and a playing style (tactical factors) dependent on the strengths and weaknesses of the opposing team which is a top-quality team (opponent). This match will be played away on a pitch in difficult conditions due to rainy weather (situational context). All those interdependent factors will have an influence on the match performance of the soccer players. Also, studies showed interaction effects of situational variables on match performance. For example, attackers (tactical factor) were shown to cover more and central defenders less high-intensity running in heavily won matches compared to lost ones (score-line) (Bradley & Noakes, 2013). Also, different effects of the situational context (e.g. score-line, match venue) on playing style (tactical factor) were found (Fernandez-Navarro, 2018).

In conclusion, to effectively analyze and understand soccer match performance, there is a need to consider the complex effects of external factors on match performance (Taylor et al., 2008). Therefore, external factors should be considered, discussed, and controlled (Haag & Mess, 2010).

Still, it has to be considered that the internal and external factors of influence and the exemplary study results outlined in this chapter represent excerpts from the literature and cannot be presented comprehensively, as they would go beyond the scope of this thesis.

2.3.2 Collaborative Team Match Performance

In the previous chapter, a theoretical framework of the individual complex match performance was presented. This framework includes a detailed consideration of the main facets of match performance (physical, technical, tactical, psychological), as well as the internal (person) and external (environment) factors that influence the performance of a player during a match. Based on that framework of individual match performance in soccer, this chapter will indicate how individual players interact with each other to create a collaborative team match performance.

In general, each of the 11 players of a team is confronted with different situations during a match. Each individual copes differently with his individual movement tasks under the influence of the inherent factors of the individual person and the external factors of the environment. In detail, every player has his own inherent presets of contextual factors. For instance, players have different internal factors including differences in skills or anthropometry, and different external factors such as different tactical playing positions. Accordingly, each player controls the match with his behavior in space and time (McGarry & Franks, 2003). This results in each of the 11 players having a distinctly different individual complex match performance.

Those 11 individual performances contribute to a group performance (subgroup of 2 or more players within a team) and ultimately to a team performance by interacting with their teammates within their team (team of 11 players). Consequently, the heterogenous players of a team interact under the constraints of the game (e.g. rules) to achieve a shared goal such as winning (Balagué et al., 2013; Gréhaigne, 2011; McGarry & Franks, 2003). Due to the interaction of players within a team, there is an immense increase in the complexity of the match performance of the team (Balagué et al., 2013). Therefore, continuous new behavior arises due to constantly changing match situations and contextual factors (Balagué et al., 2013). Besides the interaction within a team, the players of a team also interact with the players of the opposing team (McGarry & Franks, 2003). This interaction between teams can also be classified into different levels, ranging from individual level (1 vs. 1, dyads), group level (e.g. 3 vs. 3), to team level (11 vs. 11).

Following this argumentation, a team's performance is not just a sum of its individuals (Grund, 2012). It is more about a team of players working together as a unit to interact with the opponent, not just a collection of 11 individuals (Low et al., 2020).

A theoretical framework that describes the interaction behavior of soccer players within and between teams is the dynamic system theory (Low et al., 2020). This theory is repeatedly used to analyze, describe, and explain team behavior in soccer (Low et al., 2020; Welch et al., 2021) since a lot of characteristics of complex systems also are shown in a soccer match (Low et al., 2020). The main characteristics of this theory are that individuals and teams behave goal-oriented (Low et al., 2020), that the movements of the players are not independent of each other because they commonly interact with each other, and that individuals behave interdependent (interactions within & between teams), dynamically, and non-linearly (Low et al., 2020). This is accompanied by constant interactions with and changes in the environment (e.g. changing match situations) (Low et al., 2020). Thereby, the idea of interactions of interdependent players in a complex system reduces the complexity of the system as the individual players interact with one another in larger coalitions of cooperative elements (Balagué et al., 2013) which is often compared to the behavior in schools of fish (Passos et al., 2011) or flocking birds (Welch et al., 2021).

This idea reflects the self-organization in complex interacting systems (Gréhaigne & Godbout, 2014; Welch et al., 2021). Despite numerous degrees of freedom that arise in the complex system of two interacting teams with a sum of 22 individuals, there are different organizations and orders which are formed over and over again (Balagué et al., 2013). Those collective motions arise from simple rules of interaction between individuals (Welch et al., 2021). However, the main difference of soccer to the nature of dynamic complex systems (e.g. flock of birds or school of fish) is that teams train and plan to maintain a specific playing behavior (e.g. tactical formation) and apply specific group and individual tactics depending on the context (Welch et al., 2021).

In soccer, this theory of dynamic systems was used to assess inter team (= between teams) and intra team (= within teams) behavior of players. For instance, the intra team interactions were analyzed using distance measures between defender and attacker dyads (= 1 vs. 1) (Headrick et al., 2012; Laakso et al., 2017), formation lines (Goes, Brink, et al., 2021) or team centroids (Bartlett et al., 2012). Furthermore, intra-team interaction of subgroups (Goes, Brink, et al., 2021; Gonçalves et al., 2017) was investigated. Some of the findings of those studies are discussed in the review paper (see chapter 4 Review). Overall, it can be concluded that teams show quick changes between highly aligned and synchronized movements and unordered swarm behaviors which are not well aligned with individuals trying to remain part of the group (Welch et al., 2021). When investigating dynamic systems, an important aspect is to include a temporal variable within the analysis. This is essential to include the dynamic idea of dynamical complex systems and assess the behavior of players over a period of time (e.g. a possession).

The characteristic of interaction behavior of players in soccer largely depends on the playing phase according to the ball possession status. For instance, attacking patterns may influence the behavior of the defending team. In particular, the positioning of attacking players during an attack influences the behavior of the defending team (e.g. possibly by a marking behavior of defenders) (Hewitt et al., 2016). Accordingly, both teams behave in an opposing relationship (Davids et al., 2005; Gréhaigne et al., 1997) according to the ball possession (i.e. offense & defense). This tactical behavior of players is oriented to a shared goal. Further elaborated, this means that differing collective behavior of teams can be identified according to the goal of the respective playing phase. The playing phases were already presented in detail in the introduction (see chapter 1.1 Preface). It can be mainly distinguished between offensive play, defensive

play, defensive transition, offensive transition, and set plays (Bauer et al., 2023; Escher, 2020; Hewitt et al., 2016). Those playing phases have an influence on the behavior patterns of players within a team. The playing phases and their influence on the behavior of players within a team are illustrated in figure 2.1.

There are distinct differences in the tactical behavior of offense and defense. In offense, the attacking team aims to disrupt the ordered state of the system to create scoring opportunities. The offensive players intend to perturbate the opposing defensive system (McGarry & Franks, 2003) by passing (Forcher et al., 2021; Goes et al., 2018) or anti-phase (unsynchronized) movements in relation to the defending team (Goes, Brink, et al., 2021).

In contrast, in defense, a higher proportion of collective ordered team movement behavior can be detected (Welch et al., 2021). With it, the defensive team aims to close down spaces for the attacking team to secure their own goal and regain the ball. Those opposing patterns lead to an expanding positioning of the offensive player to create space and a contraction of defensive players to close down space which is also known as the contraction-expansion relationship (Clemente et al., 2013a; Gréhaigne & Godbout, 2014). This relationship is also presented in detail in the fourth paper of this thesis (see chapter 7 Compact Organization).

The transition phases are characterized by an unstable collective state with more unordered movement behavior due to the quick change of ball possession. During the defensive transition immediately after a ball loss, players try to restore the defensive order to regain control of the match situation to deny dangerous counterattacks (e.g. with rest defense, which was assessed in the third paper of this thesis, see chapter 6 Rest Defense). During offensive transition immediately after a ball gain, the offensive team tries to control the ball to make use of the unbalanced and disordered collective state of the defense to create scoring opportunities by counterattacking.

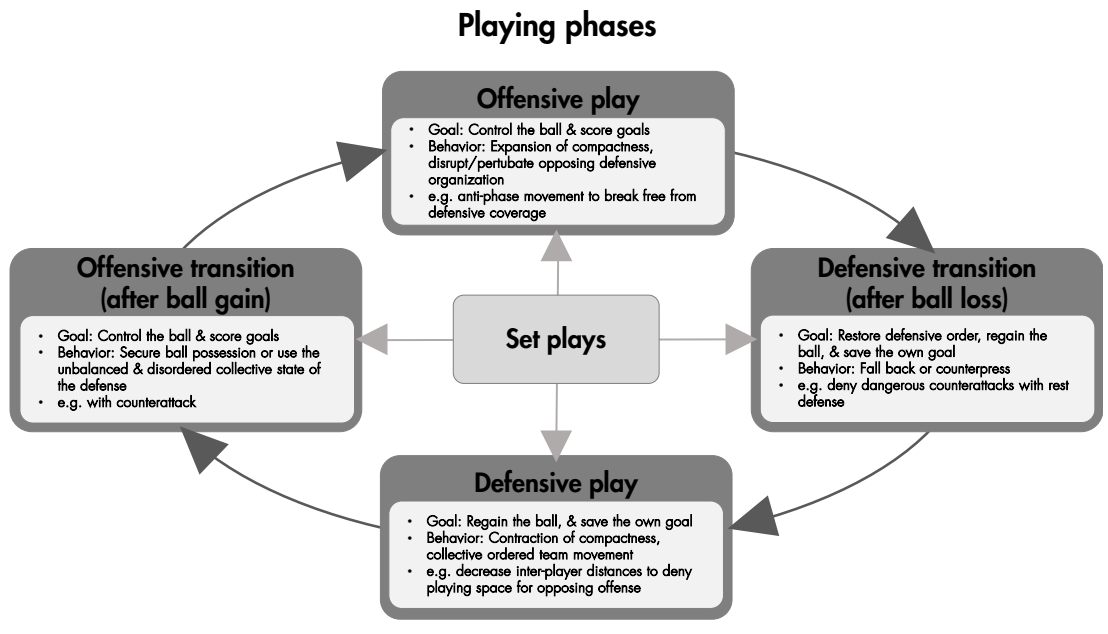

Figure 2.1: Playing phases of soccer, characterized by their respective goals and the resulting tactical behavior of players within a team.

Overall, due to the complexity of the system of 22 individual players in two opposing teams, the behavior of teams is hardly predictable. Still, the playing phases help to classify behavior patterns and are highly important to describe and assess collective movement behavior in soccer. This chapter indicated how groups of players of a team behave in a match based on their individual match performance. This group and team tactical behavior is a main topic of this work and is assessed in the individual papers of this thesis.

2.4 Types of Match Analysis in Soccer

After providing a theoretical foundation of the composition of the complex match performance in soccer, this chapter focuses on the methodological pathways to gain insights into this match performance. Those types of match analysis are used as central methodology of the investigations of this thesis to gain insights into the match performance of soccer players. Therefore, this chapter represents the theoretical foundation of the methodology used in this thesis.

All types of match analysis include the same basic idea of performance analysis to assess actual performance with the main aim to improve the performance of players (O'Donoghue, 2015). Furthermore, there are secondary aims of performance analysis such as rehabilitation or providing information to the media (O'Donoghue, 2015). Regarding performance analysis, the analysis of soccer performance has received large attention in sports science. Soccer is by far the most researched topic in sports research and this research area continues to grow (Kirkendall, 2020; McLean et al., 2017).

This research on soccer can be conducted from various standing points with different goals. From a biomechanical point of view, the movement of kicking the ball can be analyzed by examining the influence of joint angles of the support leg or the posture of the upper body and the pelvis on the kicking movement (Lees et al., 2010). In turn, from a physiological point of view, the energy expenditure during a match can be assessed (Dolci et al., 2020). Overall, each sports science discipline examines the topic of soccer performance with the goal of achieving a performance outcome that expands knowledge to ultimately improve the performance in the sports competition (McGarry & Franks, 2003). In this context, the specific field of match analysis aims at getting insights into the complex match performance of soccer players during the competition of gameplay. For example, match analysis examines the technical actions on the ball by individual players (Rowat et al., 2017), the physical performance of players in different playing positions (Altmann et al., 2021), or the tactical behavior of all 11 players that contribute to the tactical performance of a team. This thesis focuses on the match analysis of tactical match performance in the defensive playing phases.

Thereby, the major aim of match analysis is to understand and explain match performances and eventually predict future match performances. This process then enables one to gain insights into the requirements for an optimal match performance (McLean et al., 2017).

Understanding and explaining match performance identifies what makes successful soccer performance in general. This is mainly achieved by post-match analyses with differences between practical and scientific applications. In soccer practice, for example, the analysis of past matches of the own team is conducted by video analyses varying from individual, over group, to team analyses (Guadagnoli et al., 2002). In science, this thesis serves as an example of a post-match analysis of 153 matches of the German Bundesliga to identify successful defending behavior to increase the body of knowledge about tactical behavior in soccer and inform practitioners. Overall, the main aim of post-match analyses is to give feedback to players. Providing valuable feedback is one of the most crucial factors in skill acquisition (McGarry & Franks, 2003). Therefore, enhancing feedback processes, for example by objective analyses, is a key task of a coaching staff in soccer to enhance the performance of their players (Carling, Reilly, et al., 2008; Hughes & Bartlett, 2002). Furthermore, training regimes can be adjusted based on the insights gained by understanding and explaining match performance to support an optimal preparation for the match (Carling, Reilly, et al., 2008). In addition, decision-making processes can be improved by informed evidence (O'Donoghue, 2015), which, for instance, includes the decision-making of sports managers (e.g. in team squad planning) (Wiltshire, 2013).

In contrast to understanding and explaining, the prediction of match performance is mainly used in pre-match preparations. In practice, opponent analyses are conducted prior to a match to identify the strengths and weaknesses of the opposing team to design a match plan for the upcoming match. In science, machine learning models are trained to predict future performances such as the prediction of physical match performance to assess whether a player will achieve a certain running distance (Dijkhuis et al., 2021). This thesis also includes prediction approaches to analyze the tactical match performance of players (see chapter 5 Defensive Pressure and chapter 7 Rest Defense). Overall, patterns from the past are detected that can be used reliably by the coach or scientist to prescribe behaviors (or strategies) for future competition (McGarry & Franks, 2003). Increasing knowledge about what will happen in the future can be used as a competitive advantage in a match. However, predictions always assume that future performances can be derived from past performances. In soccer, this is heavily difficult since the match performance is highly complex (see chapter 2.3 Appearance of Match Performance in Soccer). For the described use of match analysis (understanding, explaining, & predicting), an increasing amount of data is being collected and new key performance indicators (KPIs) are being developed. The effective use of match analysis depends on the selection of the information that has value and the way it is applied to enhance performance (Carling, Reilly, et al., 2008). The latter chapters give an overview of what data is collected using different methods of match analysis and how we can learn the most of it to enhance match analysis research to eventually increase knowledge about the match performance of soccer players.

Generally, the different types of match analysis can be differentiated by their qualitative or quantitative nature and the resulting types of outcomes. It can be differentiated between the qualitative approach of subjective video analysis, and the quantitative approaches of notational analysis and spatio-temporal analysis of tracking data. In the following these three types of match analysis are defined, use cases are described, and types of data outcomes are illustrated to discuss the advantages and limitations of the approaches.

2.4.1 Subjective Video Analysis

In subjective video analysis, the video footage of a past soccer match is assessed by subjectively identifying important match situations and behaviors of players. This type of match analysis is used for understanding and explaining match performance. The outcomes of the analysis are most often video scenes that are shown to players for feedback purposes.

It is predominantly used in soccer practice in the daily work of a professional soccer coaching staff. To indicate this use case, the typical process in professional soccer after a match is illustrated. At first, a notational analysis (see chapter 2.4.2 Notational Analysis) of the playing phases is conducted by the coach or the analyst using a notation software that cuts video scenes automatically. This results in a comparably large number of match scenes. Afterward, the subjective video analysis is used to select specific video footage that is shown to the players to increase the value of the feedback after a match. Subjective video analysis without the described prior use of notational analysis is mostly used by soccer teams that may not afford highly expensive computational notational software to analyze video footage. The resulting video analysis is then used to highlight the strengths and weaknesses of players or teams to adapt behaviors (Groom & Cushion, 2004). Overall, there has been very little research on the use of video feedback for players. Some information about how to effectively use video feedback to players to enhance match performance is given in (Groom & Cushion, 2004).

The advantage of this type of analysis is that video is a vigorous medium to evaluate match performance and inform players in the feedback process (Carling, Reilly, et al., 2008). In this context, feedback was shown to be an effective tool in skill acquisition (Guadagnoli et al., 2002). Accordingly, the video enables detailed feedback which is easier to understand for a player compared to a table of data (Hughes, 2003). Besides the advantages of feedback, coaches can observe and analyze actions and playing sequences in detail using video footage of a match to understand and explain what happened on the pitch (Carling, Reilly, et al., 2008). The procedure of subjective video analyses can also enable real-time analysis during a match. For example, a match analyst can provide valuable feedback and video scenes to coaches and players during a match for half-time analysis (O'Donoghue, 2013). Overall, the qualitative analysis of situations can possibly provide more detailed results and provide reasons for patterns when analyzed by a skilled analyst. However, as stated previously, soccer is highly complex which introduces the limitations of this type of analysis.

Due to its complexity, match performance in soccer should be considered as a whole instead of analyzing solely a small match situation at a time (Gréhaigne et al., 2001) which may not be achieved by a single subjective analyst. Another main limitation is the subjective approach of this analyzing type. This results in analyses being highly dependent on the analyst and his expertise, knowledge, and experience which in turn leads to less objective and systematic (e.g. structured and comprehensive) analyses (Memmert et al., 2017). Also emotions can affect the assessments made from observations (Cohen et al., 2017; Hughes & Franks, 2004). Studies indicated that subjective observations of coaches are unreliable and inaccurate (James, 2006). For instance, a study revealed that qualified, experienced coaches' solely recall 59.2 [%] of critical events after a match, even though they outperform non-experts (Laird & Waters, 2008). Therefore, the improvement of informative feedback based on the subjective selection of video scenes may be reduced to chance when using this type of analysis (Hughes & Franks, 2004). Those limitations are accompanied by the fact that this type of analysis is highly time-consuming since whole matches need to be reviewed by the analyst in comparison to the high performance of software evaluating spatio-temporal tracking data (Memmert et al., 2017).

Overall, the possibility to review video footage after a match can assist with the erroneous recall of critical events, as those situations can be replayed. Furthermore, it was shown that video scenes are helpful in subjectively analyzing the off-ball actions of players after a match as coaches tend to concentrate on on-ball actions during a match (Groom & Cushion, 2004). However, personal bias and the effects of emotions can impact subjective video analysis (Carling, Reilly, et al., 2008). Concluding, while subjective video analysis holds high potential for match analysis and feedback processes, the limitations of its subjective nature lead the way to the other two, more objective methods of match analysis.

2.4.2 Notational Analysis

After the notational analysis has already been briefly mentioned in the previous chapter, it will now be explained in more detail in the following. In detail, notational analysis describes the process of defining criteria prior to the analysis. Those criteria are then used to annotate the defined events during a match (live) or using video recordings of past matches. A practical example of notational analysis is the permanent record of events (James, 2006), which results in the so-called event data. Notational event data from the German Bundesliga is used in this thesis, next to positional tracking data, to assess the tactical match performance of soccer players. Recently, this type of analysis is increasingly being used which is due to the availability of high-quality video at cheaper prices and the eased process of the analysis and data collection using notational software (Carling, Reilly, et al., 2008).

The procedure of a notational analysis typically includes four steps (Carling, Reilly, et al., 2008). It starts by defining the body of interest to select the type of information gathering. Next, a notational system (e.g. definition of criteria) is developed. Those criteria most often include the event, the performer, the position, and the time of the event (Carling, Reilly, et al., 2008). Beyond, the complexity of the notational system can be extended endlessly (James, 2006). In the following step, this analysis is checked for its accuracy (e.g. interrater reliability). Finally, the notational analysis is performed and the results are compiled.

The notational analysis is predominantly used for understanding and explaining match performance. It primarily analyzes the movement behavior of players and thus most often assesses the technical and tactical match performance (Hughes & Franks, 2004). Besides, it is also used in some prediction approaches for match performance in soccer (Wright et al., 2011). However, this use case is somehow ineffective, as data collection is highly time-consuming. Therefore, prediction approaches are most often solely used for scientific purposes to understand the predictive power of variables and their meaning for successful match performance (e.g. logistic regression of successful outcomes of defensive play). In contrast, it is primarily not used for the actual prediction of future events (e.g. live prediction during match play).

In practice, notational analysis is mainly used in the form of computer-based software which links the statistical information gathered by the notation to the video (Groom & Cushion, 2004). This procedure is applied by professional match analysts in professional soccer clubs. The result is most often automatically edited video scenes of the notated events or playing phases. In research, the notational analysis most often results in variable frequencies of tactical or technical performance depending on the complexity of the individual notation system. Typically, on-ball actions are analyzed, with the consideration of few players (e.g. notational analysis of shots) (Wright et al., 2011).

The procedure of notational analysis has several advantages. It is a quantitative approach of match analysis and, therefore, reveals objective (depending on the quality of the notational system) amounts of statistical data of a match (Carling, Reilly, et al., 2008). This enables quantitative research on match performance in soccer. With it, quantitative insights into the constraints of the complex match performance can be statistically examined using inferential statistics. Additionally, notational analyses are more objective compared to subjective video analysis (Hughes & Franks, 2004). This objective and more unbiased view on match performance can enhance feedback processes (Hughes, 2003) and decision-making (Carling, Reilly, et al., 2008). For instance, critical moments of sports performance can be identified more objectively (Hughes & Franks, 2004). However, the objectivity of the notational system has to be examined which is highly dependent on the precision of the criteria definitions (James, 2006). In addition, the notational system and the results are still dependent on the analyst to some degree. Most criteria still need expert knowledge to produce high interrater reliability in complex notational systems. This introduces the limitations of notational analyses. The main limitation of most notational approaches is that they solely scratch the surface of the complex match performance in its entirety. The majority of notational analyses solely investigate specific subparts of performance (e.g. on-ball actions) or use unprecise, aggregated features (e.g. simplification of pitch position using zones) (Carling, Reilly, et al., 2008). Analyses focusing on on-ball actions (e.g. tacklings, dribblings, passes) (McGarry & Franks, 2003) most often neglect the context of the match situation (e.g. off-ball behavior). This context may vary because of the positioning of all other 21 players on the pitch which have an effect on a specific on-ball action. The missing off-ball information is especially valuable for tactical analysis of match performance (Carling, Reilly, et al., 2008). This results in a limited description of a match situation. For instance, in a highly prominent notational analysis, the tactical behavior of a whole defense is condensed to a single variable with two expressions (i.e. balanced or unbalanced) (Tenga et al., 2010b). Accordingly, the explanatory power to increase knowledge about performance remains small which leads to a limited practical impact of results. Furthermore, notational analyses are highly time-consuming depending on the complexity of the notational system (Hughes, 2003). In this context, computerized notation has eased the process of notation. This development decreased the workload in match and video analysis in practice (Carling, Reilly, et al., 2008). Those optimized analysis processes have led to the possibility of real-time analysis of live match performances, for instance, to perform half-time video analyses. However, notations, especially live notations during a match, are erroneous as they are conducted by humans (Hughes, 2003). In the end, the video footage that is used in the notational analysis is depending on the video provider. The number of camera angles and the size of the image determine the information that can be gathered. For instance, in videos of tv broadcasting usually not all players are displayed (e.g. due to focus on on-ball actions or replays of actions).

Overall, the quantitative nature of notational analysis provides several advantages compared to subjective video analysis. However, the accuracy of the notational system developed should always be reflected and notations are not always highly objective. In the following, therefore, a

type of match analysis is presented that takes the weaknesses of notational analysis into account (e.g. time consuming procedure & objectivity).

2.4.3 Spatio-Temporal Analysis (Tracking Data)

This chapter provides an overview on spatio-temporal analysis of positional tracking data which is used as the main type of match analysis in the investigations of this thesis. Combined with notational event data, this type of match analysis is used in this work to provide deep insights into the tactical match performance of players. This is the reason for a more detailed presentation of this type of analysis in comparison to the other two types of match analysis already presented.

With the increase in data availability and accuracy of tracking data in recent years, also the research on match analysis using spatio-temporal analysis to evaluate this type of data has grown (Goes, Meerhoff, et al., 2021; Memmert & Rein, 2018). This development is also due to the precise and encompassing nature of tracking data which comprises the exact positions of all players on the pitch and the ball. Most often the positions are measured two-dimensional in length and width of the pitch (x- & y-coordinates). Besides, the German Bundesliga introduced a measure of the third dimension of height for the ball (z-coordinate). The continuous measure of the positions with a measurement frequency of up to 25 Hz results in timestamped sequences of locations (Gudmundsson & Horton, 2018).

The evaluation of tracking data in match analysis is used for understanding and explaining match performance. Furthermore, in contrast to the previous types of match analysis, it is also frequently used for the prediction of match performance using machine learning (Forcher, Beckmann, et al., 2023; Goes et al., 2019). In this case, tracking data enables big data analyses since the data collection is highly time-efficient (up to a few seconds). In this context, machine learning methodologies need vast amounts of data points to effectively learn from data, which is made easier by tracking data.

Generally, the outcomes of spatio-temporal analyses based on tracking data are cumulative metrics or values that comprise a part of the match performance, namely key performance indicators (KPIs). Additionally, machine learning models most often produce predictive values as outcomes (e.g. expected goal value, xG). Accordingly, typical outcomes of spatio-temporal analyses are either KPIs or predictions of match performance.

In practice, this type of match analysis is used to quantify tactical behavior using simple statistics of KPIs. Moreover, the use of machine learning is increased in practice, for instance, by automatically identifying playing phases (Bauer et al., 2023) to reduce time-consuming notational analyses of matches or using expected goal models to objectively evaluate scoring opportunities (Cavus & Biecek, 2022). In research, tracking data is used for the evaluation of physical and technical match performance and, in particular, to evaluate the tactical behavior of players (Rein & Memmert, 2016). Thereby, tracking data enables informative analyses of off-ball tactical behavior which includes the interaction of players within and between teams (Goes, Brink, et al., 2021). In this context, the first paper of this thesis (see chapter 4 Review) provides an overview of tactical analyzing approaches using spatio-temporal analysis of tracking data in

soccer research of defensive play. Furthermore, the other three original papers use sophisticated spatio-temporal analyses of tracking data, showing in-depth insight into tactical match performance based on this type of match analysis.

Overall, tracking data can be collected by different measurement systems and technologies including GPS (Global Positioning System), LPS (Local Positioning System), and multi-camera tracking systems. The multi-camera tracking system TRACAB (TRACAB, ChyronHego, Melville, NY, USA), which is used in this thesis to gather tracking data, was developed in the military industry to guide missiles and is based on image processing technology and enhanced mathematical algorithms (Carling, Reilly, et al., 2008). Such multi-camera systems are generally used in professional sports like the German Bundesliga or the American National Basketball Association (Gudmundsson & Horton, 2018). In addition, most professional soccer teams use device tracking systems such as GPS as a complementary assessment tool (e.g. in training). LPS systems, which use Radio-Frequency Identification (RFID), are one of the most expensive assessment tools, resulting in fewer use cases compared to other tracking systems. In summary, the various measurement systems have differences in their applicability and cost that determine their applications. In addition, the systems also bring differences in the accuracy of their measurements.

This accuracy of the measurement systems is central to be able to measure match performance in soccer accurately. To rely on the results of objective analysis of match performance, for example, to guide and improve decision-making processes, the evaluation of the accuracy of the system becomes of great importance (Carling, Reilly, et al., 2008; Drust et al., 2007). GPS systems show moderate validity (spatial precision of 96 ± 49 [cm]) (Linke et al., 2018) and adequate reliability (CV between devices: 3.1 – 7.5 [%]) (Hoppe et al., 2018; Scott et al., 2016; Waldron et al., 2011). In contrast, LPS systems appear to have higher validity (spatial precision of 23 ± 7 [cm]) (Linke et al., 2018) and higher reliability (CV between devices: 0.7 – 5.0 [%]) (Hoppe et al., 2018). Multi-camera systems display high validity with an accuracy between GPS and LPS systems (56 ± 16 [cm]) (Linke et al., 2018). In this context, the validity of the multi-camera system TRACAB that was used in this thesis, shows the highest accuracy of tracking systems (spatial precision of position measurement 0.07 - 0.18 [cm] RMSE) (Linke et al., 2020), and high reliability in assessing sports performance in soccer (between device reliability of total distance covered by players: -0.15 ± 0.37 [%]) (Linke et al., 2020). Over all measurement systems, the measurement error increases with the speed of the actions of players (Linke et al., 2018, 2020). While slow movements are assessed with higher accuracy, high-intensity movements (e.g. sprints, change of direction) are tracked with decreased accuracy. Concluding, the validity and reliability are highly dependent on the specific measurement system (e.g. of different companies, see the example of TRACAB) and its measurement frequency (Hoppe et al., 2018). Overall, the systems indicate a high validity and reliability in recording the positions of players during the match with differences between different measurement systems. Accordingly, direct comparisons of systems should be made with caution (Buchheit et al., 2014).

After explaining what tracking data comprises and how it is measured, the next paragraphs focus on the evaluation of this data type in the use case of match analysis. With it, advantages and limitations are discussed. To evaluate tracking data, typically three steps are required including the infrastructure to get data, the data storage, and the data processing (Rein & Memmert, 2016).

First, the infrastructure to collect tracking data is important to measure the positions of the players. The different tracking systems have already been outlined above. According to the affordability due to the cost of the various systems, they are applied in different settings.

Secondly, the resulting amount of data has to be stored, which is a challenging task as the resulting amount of tracking data is immense and can be described as Big Data. Big Data is characterized by the so-called three V's, including volume, variety, and velocity (Chen & Lin, 2014; Noor et al., 2015).

The first V, volume, describes the magnitude of the data (size of the data set) (Rein & Memmert, 2016). In the case of tracking data, the positions of players are tracked up to 25 times per second, which sums up to 135,000 positions per player and match resulting in more than three million locations for all players and the ball (Memmert et al., 2017). The resulting information is typically stored in xml (extensible markup language) files. This results in a volume of over 300 megabytes per match and over 40 gigabytes for the whole data set used in this thesis. The data volume even increases with the addition of synchronized event data which is used in the present investigations to complement tracking data. To evaluate this volume of data, common data analysis software (e.g. excel) reaches its limits which makes the use of programming software essential.

The second V, variety, refers to the heterogeneity of data (e.g. different data formats and data sources) (Rein & Memmert, 2016). In this thesis, the different data types of event and tracking data are evaluated, resulting in several outcome datasets comprising tactical data points of possessions, matches, and teams.

The third V, velocity, characterizes the data production rate (Noor et al., 2015) which describes the speed of the generation of novel data (Rein & Memmert, 2016). For instance, the assessed tracking data of the German Bundesliga is produced in real-time streams during each match.

According to this definition, tracking data is a Big Data problem that rises several challenges in the last step of data processing.

After collecting and storing tracking data, it can be processed using computational methods. In general, tracking data must be put into an interpretable form before final data analyses can be performed. The so-called preprocessing of the analyses in this work included, for example, a synchronization of timestamps and locations of notational event data and spatio-temporal tracking data, the alignment of coordinate systems between both data types or the identification and filtering of possessions. After preprocessing, typically key performance indicators (KPIs) that comprise a specific part of the match performance are computed from tracking data (Hughes

& Bartlett, 2002). This reduces the complexity of the data since the highly complex raw tracking data (x- & y-positions of 23 objects) is hardly interpretable. In this context, the KPIs should enable an interpretation, otherwise, the practical relevance may be minimal (James, 2006). Furthermore, KPIs should relate to successful performance or a specific outcome to be useful (Hughes & Bartlett, 2002). This connection to successful performance is one of the focal points of the papers of this thesis and is discussed in detail in the discussion (see chapter 8.1 Main Findings). Additionally, KPIs that combine aligned tracking data (spatio-temporal analysis) with other data sets (such as event data) unveil the most insightful information about match performance in soccer. This thesis is an example of how the strengths of tracking and event data can be combined by matching the objective and accurate information of tracking data with the detailed information of event data.

After the computation of KPIs, they can be used to statistically examine, report, or visualize match performance (Rein & Memmert, 2016). In the context of the statistical examination of KPIs based on tracking data, advanced machine learning techniques can be used to gain knowledge about the data. Machine learning describes software that automatically improves through experience (Jordan & Mitchell, 2015). In the use case of spatio-temporal analysis, KPIs can be used in prediction models to predict future match performances. Besides, also unstructured data (such as raw tracking data) can be analyzed using specific machine learning approaches, such as neural networks (Bauer et al., 2022, 2023). In this context, several problems arise with the increased use of machine learning in sports science. For instance, possible data leakage of modeling procedures can increase the chance of making erroneous scientific claims (Gibney, 2022; Kapoor & Narayanan, 2022). In addition, there repeatedly arise problems with the reproducibility of machine learning studies (Gibney, 2022; Kapoor & Narayanan, 2022). However, with the application of machine learning methodologies hidden patterns of successful tactical match performance can be revealed. This can identify crucial variables related to the success of a team.

Next to the identification of hidden patterns, further advantages of the use of spatio-temporal analysis are introduced in the following. Due to the accuracy of the tracking systems, the analyses based on tracking data produce highly objective outcomes (Sarmento et al., 2018). Additionally, the sophisticated evaluation of tracking data enables in-depth analyses of tactical match performance (Goes et al., 2019; Goes, Meerhoff, et al., 2021). This helps to objectively quantify the tactical performance in soccer in detail (Memmert et al., 2017). Besides, the spatio-temporal analyses are less time-consuming compared to observational analyses. When a software to evaluate a certain type of data is completed, it only takes seconds to complete data analyses for entire matches. Furthermore, in comparison to the other analysis types presented previously, the analyses are only partly dependent on the analyst since predefined outcomes can be delivered using automated evaluation software. However, the analysis (e.g. selection and computing of KPIs) is still based on the knowledge and experience of the analyst. Nevertheless, the significance and importance of the KPIs can be objectively verified by indicating their connection to successful match performance. This evaluation of KPIs can also be done using machine learning. Accordingly, another strength of spatio-temporal analysis is that the nature of tracking data (Big Data, see above) enables advanced machine learning analyses. Moreover, the data availability of large sample sizes of tracking data can overcome the limitations of notational studies of small sample sizes (Coutts, 2014). This leads to a higher generality of findings based on such large samples. With machine learning approaches to evaluate large sample sizes of tracking data, patterns in the dependencies of the complex match performance and ingredients for success may be gained. With the current abundance of data points and the flood of KPIs, this approach can help to filter the most important information which is key in today's match analysis in soccer. The resulting metrics that effectively inform coaches and their staff with substantial and objective information can enhance analysis and decision-making processes (Carling, Reilly, et al., 2008; Castellano et al., 2014). For example, highly accurate predictions of the future can help the coach in pre-match analysis by setting up a match plan for upcoming matches (McGarry & Franks, 2003). In the end, more detailed analyses of tactical match performance are possible using spatio-temporal analysis of tracking data (Castellano et al., 2014). Especially the off-ball behavior of players can be analyzed which is neglected in most notational analyses focussing on on-ball actions. The spatiotemporal information about all players (also off-ball) can reveal findings on the tactical behavior of whole teams or groups that notational analysis is not able to deliver (Sarmento et al., 2018). Overall, the spatial-temporal relations, which are the key components in team sports (such as soccer) (McGarry & Franks, 2003) can be identified to study the tactical match performance of collective teams in detail (Low et al., 2020).

Against the raised advantages of spatio-temporal analyses, some limitations should be considered. The information contained in most tracking data sets is limited. For instance, most tracking systems do not include measures for the direction of body orientation of players and are only two-dimensional (excluding height, z-coordinate). Furthermore, all players are recorded in the same form, without considering their physical appearance (e.g. height). This limits the precision of the analyses conducted using those data sets. Furthermore, the Big Data nature of complex tracking data makes the use of computational methods indispensable to be able to gain insights into the match performance of players.

Few match analysts or sport scientists hold the necessary computational knowledge and skills (e.g. programming skills) to evaluate this type of data. Therefore, the combination and collaboration of sports science and computer science holds high potential to obtain valuable insights into tracking data (Goes, Meerhoff, et al., 2021; Memmert et al., 2017).

Overall, the outlined potential of spatio-temporal analysis using tracking data makes it one of the most promising types of match analysis to evaluate tactical match performance in soccer. In this context, this thesis serves as an example of spatio-temporal match analysis using advanced

and sophisticated analyses based on tracking data. With it, this work aims to increase knowledge about tactical match performance in soccer with high practice relevance.

Chapter 3

Aims and Scope of this Thesis

3 Aims and Scope of this Thesis

This chapter builds the transition from the theoretical background to the four papers of this thesis and the comprehensive discussion of their results. In doing so, the aims of this thesis are formulated in order to set the scope of this work. With a review of the previous chapters, the individual papers are placed in the larger context of the theoretical background and, therefore, their significance is established.

In the theoretical background, the epistemological position of this work was defined and this work was placed in the context of sports science as the basis of this work and its papers. Furthermore, the appearance of the complex match performance of soccer players was assessed, analyzing the individual match performance and the composition of a team match performance. While it has been indicated that match performance in soccer has different main facets (physical, technical, psychological, & tactical, see chapter 2-3-1 Individual Match Performance), this thesis will focus on the tactical aspect of match performance. In detail, this tactical match performance can be divided into different levels depending on the number of players involved: Individual, group, and team level (see chapter 2.3.2 Collaborative Team Match Performance). The papers of this thesis will focus on different levels of tactical match performance, which is illustrated in figure 3.1 and explained in detail for each paper in the following.

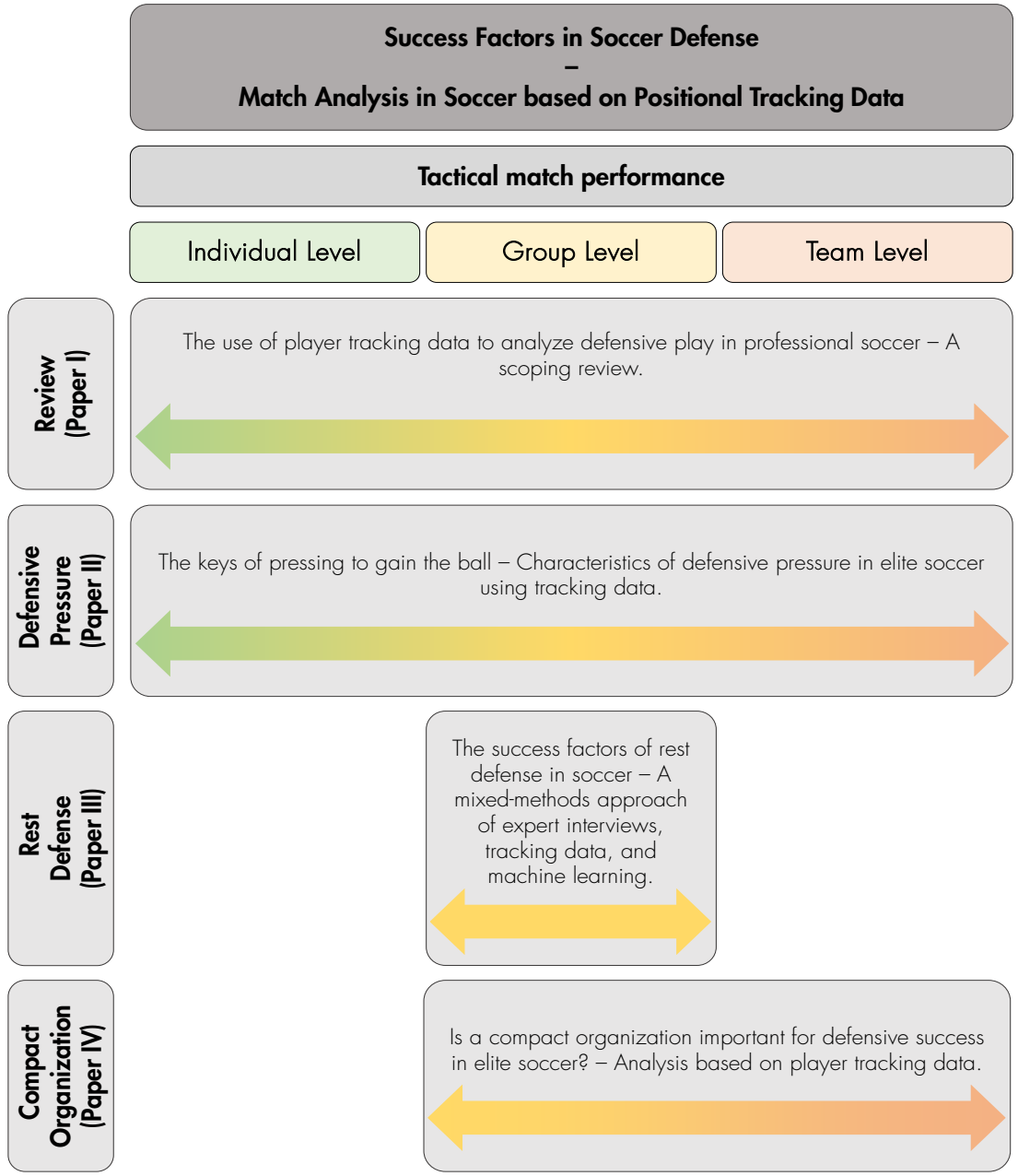

Figure 3.1: Overview of the papers included in this thesis with the illustration of the levels of tactical match performance investigated in each study (arrows) with individual (green), group (yellow), and team (red) level analysis.

Besides the differentiation between different levels of tactical match performance, it was indicated in the theoretical background that the tactical behavior of soccer players differs between different playing phases (see figure 2.1 in chapter 2.3 Appearance of Match Performance in Soccer). This thesis focuses on the playing phases of defensive play and defensive transition. For each paper individually, figure 3.2 illustrates which playing phase is assessed.

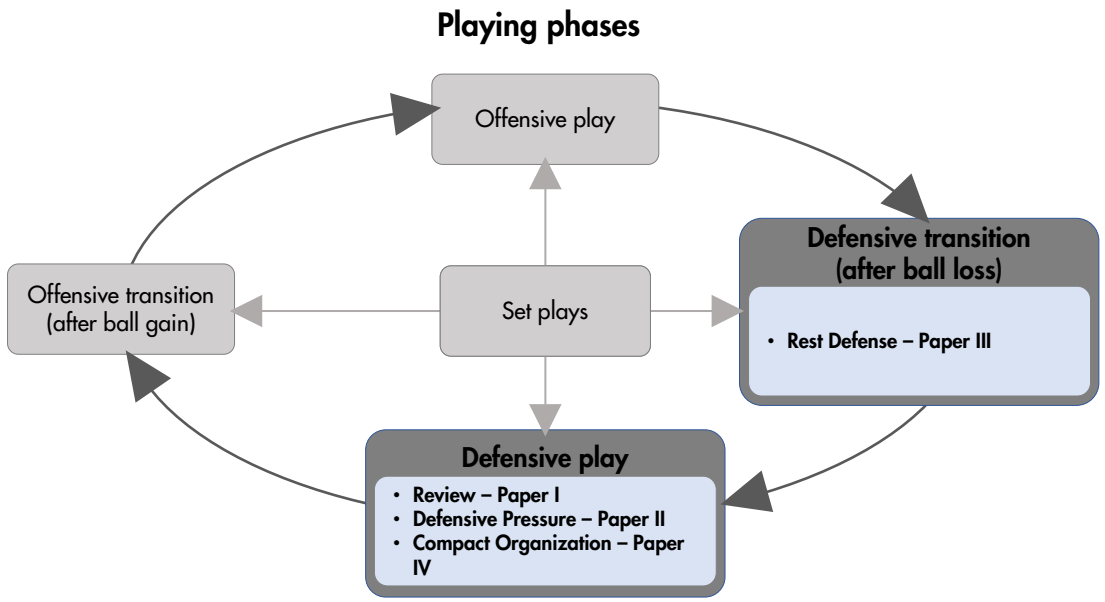

Figure 3.2: Illustration of playing phases in soccer. The papers of this thesis are highlighted according to the playing phase which was investigated.

To get insights into this complex match performance of soccer players, the types of match analysis in soccer were presented, including subjective video analysis, notational analysis, and spatio-temporal analysis using tracking data. This methodology of match performance analysis plays an important role in the analysis of tactical performance in the papers included in this thesis. All papers mainly focus on spatio-temporal analysis of positional tracking data. Further, the original studies combine this type of match analysis with other analysis types (e.g. notational event data). Which methodology used in the individual papers to assess the tactical match performance is described in detail in the following paragraphs.

After placing the papers of this thesis within the broader context of the theoretical background to indicate the scope of this work, the research gap is briefly outlined to derive the general aims of this thesis.

In the analysis of tactical match performance in soccer, the magnitude of research on defensive play is low compared to the diverse analyses of offensive play. With recent developments in the analysis techniques (e.g. positional tracking data), the analysis of tactical behavior, especially the off-ball behavior of players, becomes possible at a fine-grained level (research gap is explained in detail in chapter 1.1 Preface). Therefore, this thesis aims (1.) to comprehensively

review the current state of the literature on spatio-temporal analysis of defensive play using tracking data, and (2.) to analyze the tactical match performance during the defensive playing phases (defensive play & defensive transition) at the individual level, group level, and team level and, thereby, use the possibilities of the spatio-temporal analysis based on positional tracking data to identify factors of successful tactical behavior of players in the defensive playing phases. After presenting the overarching scope and aims of this thesis, the following sections outline the scope of each paper and their respective aims individually.

3.1 Review (Paper I)

With the rapid development of tracking systems in the last years the possibilities to analyze the tactical match performance of players increased. Against this background, there has been an increase in the number of studies analyzing defensive play. Therefore, this scoping review comprehensively reviews the current state of research on the examination of defensive play using spatio-temporal analysis based on positional tracking data.

With it, this paper aims (1.) to identify the methodological approaches used to analyze defensive play using spatio-temporal analysis based on positional tracking data, and (2.) to identify the tactical characteristics of successful defensive play using these approaches.

It focuses on all levels of tactical match performance, ranging from individual, group, to team level defending behavior in the playing phase of defensive play. Thereby, this paper concentrates on spatio-temporal analysis using positional tracking data, since it is the main type of match analysis to capture the off-ball behavior of players, which is especially valuable to analyze defensive play when the opposing team is in ball possession (further details see chapter 2.4.3 Spatio-Temporal Analysis (Tracking Data)).

Overall, this study summarizes approaches that are used to analyze defensive play to provide a basis for subsequent studies and to demonstrate the importance of analyzing defense in soccer, which has been shown to be highly important to a team's success (see chapter 1.1 Preface).

3.2 Defensive Pressure (Paper II)

In the comprehensive review of the first paper (Review (Paper I)), a sophisticated analyzing approach of individual defensive pressure was identified. This methodological approach includes the distance, angle, and orientation between defenders and the attacker to assess the individual defensive pressure on an attacker. This first original study uses this approach to quantify the defensive pressure on attackers to analyze the defensive play. It aims to examine successful defending at a possession level by analyzing the space (where) and time (when) characteristics of defensive pressure.

This paper focuses on the analysis of the defensive pressure of individuals by measuring the individual defensive pressure exerted by each individual defender. Therefore, tactical behavior is

measured at the individual level by analyzing the defensive pressure on the ball-leading player. Furthermore, comprised metrics are derived for group level and team level tactical behavior in defense. Group level tactical behavior is analyzed by computing defensive pressure on the five closest attackers to the ball and team level tactical behavior is measured by analyzing defensive pressure on all attacking players. All tactical levels are analyzed in the playing phase of defensive play.
To measure defensive pressure, spatio-temporal analysis based on positional tracking data of the German Bundesliga is used. This type of match analysis is accompanied by a notational analysis of game events. The notational event data is synchronized to the positional tracking data to enrich the analysis with further detailed information (e.g. selection of deliberate possessions, definition of start/end of a possession).
It is hypothesized that successful defensive plays are characterized by higher defensive pressure compared to unsuccessful defensive plays at the individual, group, and team level (see chapter 5.3 Defensive Pressure Introduction).
Overall, the analysis of pressing behavior indicates successful tactical behavior to regain the ball in defense. This approach to analyze defensive pressure shows a sophisticated methodology to analyze tactical behavior in defensive play.

3.3 Rest Defense (Paper III)

In general, there is a lack of research about the playing phase of defensive transition (i.e. the tactical behavior of defending players after a ball loss). This is accompanied by a sparse knowledge base about successful tactical match performance at the group level in this playing phase. Therefore, paper three focuses on the group tactic of rest defense in defensive transition. Rest defense describes the behavior of the deep defending players after a ball loss to prevent opposing counterattacks by securing dangerous areas (e.g. deep areas) or controlling dangerous counterattackers. Since, to this date, no study concentrated on the group tactic of rest defense in defensive transition, the first aim of this study is (1.) to use expert knowledge to define rest defense. Furthermore, this work aims (2.) to identify tactical behavior which is important for the success of the defensive transition phase regarding rest defense.
This study used a mixed-methods design, in which different quantitative types of match analysis are combined with qualitative expert-interviews. In detail, similar to the second Paper (Defensive Pressure (Paper II)), spatio-temporal analysis is applied as the main type of match analysis. In this case, the tracking data is used to calculate several KPIs (key performance indicators) that describe and summarize the tactical behavior during the analyzed match situation (e.g. space control, defensive pressure). This type of match analysis is enriched with synchronized event data to identify the match situations of rest defense (i.e. ball loss in the opposing last third, when the opposing midfielder-line is outplayed, and the ball stays in play). Besides the two types of match analysis, semi-structured expert interviews were conducted to define rest defense and enrich the data analysis with expert knowledge on the subject of rest defense.
In contrast to the other studies, this study focuses on the playing phase of defensive transition. Furthermore, it exclusively analyzes the group level of tactical match performance as the rest defense is a group tactic. In detail, the average size of the group of rest defenders (all defenders in the identified "area of rest defense", see chapter 6.3 Methods) is 3.70 ± 0.76. Accordingly, the individual and team tactical match performance is not considered.
In the case of this study, no hypotheses were formulated prior to the determination of the subject of this study. Due to the novelty of this topic, the group tactic of rest defense has to be initially defined using expert interviews in the first part of this paper.
This study is an example of a mixed-methods study and shows a combination of qualitative and quantitative research to gain valuable insights into tactical match performance in soccer. Therefore, this paper demonstrates how to collect and use expert knowledge to enhance an up-to-date analysis of tactical behavior based on positional tracking data.

3.4 Compact Organization (Paper IV)

The first paper of this thesis (Review (Paper I)) revealed that one of the most important principles of defensive play at the team level is the compact organization of the defending team. Therefore, the last study of this thesis aims (1.) to gain insights into the tactical principle of defensive play: defensive compact organization by investigating the composed parts of this principle of play: compactness, contraction of compactness, and organization.
This study focuses on the playing phase of defensive play. Thereby, consistent with the previous original studies, the same types of match analysis are used to assess tactical match performance. Spatio-temporal analysis of positional tracking data is used to compute several KPIs (key performance indicators) that describe the compactness, the contraction of compactness, and the organization of the defending team during defensive play. This analysis is enriched by synchronized event data based on a notational analysis.
This study concentrates on the group and team levels of tactical match performance while the individual level is not considered. The compact organization of the whole team (team level) and of two subgroups (group level: defensive collective close to the ball & defensive collective of defending- and midfielder-line) is assessed.
It is hypothesized that defending teams show higher compactness, contraction of compactness, and better organization at the group and team level in successful defensive plays compared to unsuccessful defensive plays.
This original study indicates how to measure the compact organization as a key tactical principle of play in defensive play by exploiting the possibilities of tracking and event data. With it, it is illustrated what contributes to successful tactical performance in defense at a group and team level.

Chapter 4

Review (Paper I)

The use of player tracking data to analyze defensive play in professional soccer – A scoping review.

Published version of the review article

Forcher, L., Altmann, S., Forcher, L., Jekauc, D., & Kempe, M. (2022). The use of player tracking data to analyze defensive play in professional soccer – A scoping review. International Journal of Sports Science & Coaching, 17 (6), 1567–1592. https://doi.org/10.1177/17479541221075734

4 Review (Paper I)

4.1 Abstract

The analysis of tracking data in tactical match analysis is a topic of rising interest, as more detailed insights into performance structure in soccer can be obtained compared to traditional (e.g. notational) analyses. Compared to the variety and detailed analyses of offensive play, the number of studies analyzing the defensive play is low. However, in recent years, an increasing number of studies investigating defensive play have been published, so it seems useful to provide an overview of the current state of research in this area. Therefore, this study aims to identify the approaches that have been used to analyze the defensive play in professional soccer using player tracking data and to reveal the findings on successful defensive play.

A systematic literature search of electronic databases (PubMed (n=604), Web of Science (n=593), and SPORTDiscuss (n=872)) was conducted according to the PRISMA extension for Scoping Reviews (PRISMA-ScR). Studies that were included used tracking data of professional adult male soccer and analyzed defensive play. The result is a total of 23 studies that were analyzed in detail using the standardized quality assessment checklist for systematic reviews in sports science. The synthesis of results was carried out descriptively by organizing the results into different levels of tactical play (individual level, group level, team level).

All included studies were of good methodological quality. The approaches to investigate defensive play using tracking data are highly heterogeneous (e.g. analysis of defensive pressure, analysis of synchronization, behavioral analyses, ball recoveries). Successful defensive play is characterized by high pressure at the individual level, by high inter-team and intra-team synchronization and balanced defense at the group level, and by a compact coordinated organization at the team level.

By summarizing the state of research on defensive play in soccer using sophisticated analysis approaches that showcase the possibilities of tracking data, this study provides an important foundation for future research in this area.

Key words: soccer, football, match analysis, defensive play, tracking data, position data

4.2 Highlights

- The approaches to analyze defensive play in soccer using tracking data are highly heterogenous.
- Most promising approaches to analyze defensive play are the analysis of defensive pressure (at the individual level) and the quantification of compact organization (at the group & team level).
- Successful defensive play is characterized by high defensive pressure (at the individual level), inter-team and intra-team synchronization as well as a balanced defense (at the group level), and the contraction of organization (at the team level).

4.3 Introduction

Match analysis in soccer has been in the focus of interest for the scientific community and coaches for more than seventy years (Rein & Memmert, 2016). The majority of publications in science and practice are based on notational analysis, which typically identifies the who, what, where, and when of key match events (Vilar et al., 2013). While this approach provides a basis for quantitative match analysis, it provides little information about the interactions within and between teams (Herold et al., 2019). In contrast, recent reviews highlight the benefits of the use of tracking data (Memmert & Rein, 2018; Goes, Meerhoff, et al., 2021) to achieve this. The tracking data include the positions of all players on the pitch and the ball using multiple measurement techniques like multiple camera tracking systems, global positioning systems (GPS), or radio-frequency identification (RFID) (Gudmundsson & Horton, 2018). The use of tracking data helps to produce more complex and reliable performance metrics compared to traditional analyses (Link et al., 2016; Szczepanski & McHale, 2016) and take the opponent interaction more precisely into account (Gréhaigne et al., 1997). This is crucial to evaluate the performance in soccer and improves the validity of new performance indicators (Tenga et al., 2010b) that can help to understand the dynamics of the game and the underlying factors of success. This illustrates the importance of tracking data for match analysis in soccer.

Earlier research using tracking data focused on the physical performance of soccer players (Carling, Bloomfield, et al., 2008; Moura et al., 2012). However, in recent years, the analysis of tactical performance with player tracking data received more attention, predominantly investigating the offensive play (Fernandes et al., 2020) focusing on actions from the attacking team's perspective (Hewitt et al., 2016). These offensive and defensive soccer tactics can be divided into different levels: Individual tactics, group tactics, and team tactics (Rein & Memmert, 2016). This classification is used to structure the findings in this paper in order to provide a structured overview of the contributions to the different levels of individual, group and team tactics.

Subjects of interest in attacking play in soccer on an individual level were the evaluation of passes (Chawla et al., 2017; Goes et al., 2018; Gudmundsson & Wolle, 2012; Rein et al., 2017; Spearman et al., 2017), shots on goal (e.g. expected goals) (Goes et al., 2019), the danger of every attacking action (Link et al., 2016), or the space control of offensive players (Taki & Hasegawa, 2000). On a team level the organization on the pitch was investigated (Moura et al., 2013).

In contrast, there is a lack of a comparable multitude of defensive analyses (Toda et al., 2021). Some studies already draw attention to the importance of defensive actions (e.g. ball recovery) as a starting point of the offensive phase (Maneiro et al., 2019; Winter et al., 2017). However, various authors support the idea that soccer has a primarily defensive focus as it is played on a larger pitch with the difficulty of controlling the ball with the feet resulting in low numbers of scored goals compared to other team sports (Maneiro et al., 2019; Vilar et al., 2013). This idea can be supported by the results of Lepschy et al. (2021) and Georgievski et al. (2019) both showing that most of the critical success factors in soccer are defensive actions. Furthermore, Winter et al. (2017) mentioned the behavior after the loss of possession to be important for success and Bosca et al. (2009) reported that it is more important to improve defensive rather than offensive efficiency to be successful. Accordingly, Vilar et al. (2013) strengthened the idea of the defensive characteristic of soccer by detecting the numerical superiority of defensive players to offensive players in sub-areas closer to the own goal. This illustrates the importance of defense in soccer and that it is essential to focus more on defensive match analysis.

However, the majority of studies evaluating defensive play use simple match statistics (e.g. tacklings, fouls, interceptions, yellow & red cards) or inverted offensive statistics (e.g. goals conceded, shots against) to analyze defensive play (Gavião et al., 2020; Hirotsu & Wright, 2003; Lepschy et al., 2020). With the lack of quantity and quality (e.g. percentage of ball possession reveals little information about the actual match) of the used defensive statistics (Toda et al., 2021) those studies are not able to portray the complexity of defensive play in a highly dynamic team sport like soccer.

However, in recent years, there is a rising number of studies that investigated defensive play using tracking data in a sophisticated way (Matsuoka et al., 2020; Santos & Lago-Penas, 2019; Stöckl et al., 2021).The novelty of this topic leads to a high diversity in study designs missing a common basis as starting point of the research. Those heterogeneous studies investigated different aspects of defensive play (e.g. defensive pressure, synchronization, ball recoveries) and use different analyzing approaches (e.g. use of performance indicators, use of computational models) to extract important information out of tracking data. Following the PRISMA guidelines' extension for scoping reviews (PRISMA-ScR) (Tricco et al., 2018), where a scoping review is characterized as a summary of a body of knowledge that is heterogeneous in methods, it appears meaningful to summarize the variety and nature of the evidence in the analysis of defensive play using tracking data in a scoping review to build a basis for future research in this area (Tricco et al., 2018).

Therefore, the aim of this study is twofold. First, this study aims to discover the approaches used for the analysis of defensive play at different tactical levels (individual level, group level, team level) in professional soccer using tracking data. Secondly, this study aims to reveal the findings about successful defensive play at different tactical levels (individual level, group level, team level) that have been obtained by analyzing defensive play in professional soccer using player tracking data.

To the best of the authors' knowledge, this study is the first to summarize the contributions to defensive analysis in professional soccer with up-to-date analysis methods (using tracking data).

4.4 Methods

4.4.1 Study Design / Search Strategy

The scoping review was conducted according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) (Tricco et al., 2018) and the guidelines for performing systematic reviews in sports science (Rico-González et al., 2021). It was preregistered on open science foundation (osf.io) (DOI 10.17605/OSF.IO/29MWZ).
The literature search was conducted on 06/02/2021 using the following electronic databases: PubMed, Web of Science, and SPORTDiscuss. Every database was examined with the following combination of keywords in the same structure of code lines:
("defensive" OR "defense" OR "defence" OR "defending") AND ("soccer" OR "football")
AND ("performance analysis" OR "game analysis" OR "match analysis" OR "match analytics" OR "game performance" OR "match performance" OR "observation" OR "sports analytics" OR "team sports evaluation")
In addition, a secondary literature scan was executed by examining the reference lists of retrieved full-text articles to identify additional articles not identified by the initial search.
The exclusion and inclusion criteria for the decision on the inclusion of a study in this review are depicted in table 4.1.

Table 4.1: Eligibility criteria.

Criteria	Inclusion criteria	Exclusion criteria
Population	- Studies in professional adult male soccer	- Studies in other sports than soccer (e.g. futsal, beach soccer, handball, basketball, american football) - Studies in other than profes-sional level (e.g. amateur soccer) - Studies in other than adult male soccer (e.g. woman soccer, youth soccer)
Analysis	- Analysis of defensive play in 11 vs 11 matches	- Analysis of small sided games (SSGs)
	- Analysis of open play situations	- Analysis of dead ball situations (set pieces)
Data	- Studies using spatiotemporal tracking data	- Studies using other data than tracking data (e.g. notational data) - Studies analyzing simple match statistics (e.g. yellow/red cards, conceded goals)
Study design	- No restrictions with regard to study design	
Other	- Studies written in English	- Not available in English
	- Studies published in a peer-reviewed journal	- Not published in a peer-reviewed journal

4.4.2 Data Extraction

After the initial literature search, the study selection consisted of four phases as shown in figure 4.1. The first phase consisted of the removal of duplicates. In the second phase, the abstract screening was conducted. Thereafter, the full texts of the remaining studies were screened. The aforementioned inclusion and exclusion criteria were applied to the inclusion and exclusion of studies in the second and third phases. The selection process from phase one to three was conducted by the first author of this review (LF). The final decision of inclusion of all remaining studies was discussed with two additional experienced researchers (MK, SA, LF). In the fourth phase, the full texts included in this review were assessed and data were extracted using a Microsoft Excel 2016 spreadsheet (Microsoft Corporation, Redmond, Washington, USA) containing the following information: Sample size (league, season), study design (performance indicator), defensive performance analysis, main results, quality assessment (see table 4.2). The items *study design* and *defensive performance analysis* account for main aim of this review about the data analyzing approaches to analyze defensive play and represent the primary outcome. The item *main findings* shows the outcomes for the secondary aim of this study about the findings on effective defensive play.
In addition, the connection to success in every study was detected and shown in the main results as this connection to success is highly important to validate and examine the actual significance of the new processing approaches evaluating position data (Memmert & Rein, 2018). To provide a structure to this heterogeneous body of knowledge, all included studies are divided into the different levels of tactical defensive play (individual level, group level, team level) according to the work of Rein and Memmert (2016). Furthermore, all studies that did not fit the above classification because they used measures at different levels of tactical play were assigned to the mixed approaches section. This subdivision was determined by the first author (LF) and two experienced researchers (MK & SA).

4.4.3 Quality Assessment

The quality of the included studies was assessed using the standardized quality assessment checklist provided by the authors of the Guidelines for performing systematic reviews in sports science (Rico-González et al., 2021). Of the 23 items of this checklist examining the overall quality of sport science articles, 20 items were identified as applicable for this review and were used for the assessment. Two items of technology used were excluded because no technology guidelines were used in the considered studies and one item of method regarding dropouts was excluded because dropouts are not expected in studies using tracking data of professional soccer matches. Each item could be answered either yes or no, with a score of 1 for yes and 0 for no. The total score was obtained by summing these scores across all items. Following the procedure of similar quality assessments (Faber et al., 2015), the final scores were rated

as: low methodological quality for final scores below 50 [%] (final score: 1-9 of 20), good methodological quality for final scores between 50-75 [%] (final score: 10-15 of 20), excellent methodological quality for final scores over 76 [%] (final score: 16-20 of 20).
A risk of bias assessment across the included studies was not applied because it is not applicable to the expected heterogeneity of studies in scoping reviews (Tricco et al., 2018).

4.5 Results

4.5.1 Search Results

The initial literature search resulted in a total of 2,072 records (PubMed n=604, Web of Science n=593, & SPORTDiscuss n=872) of which 4 records were added through the scan of secondary literature. In phase one, 792 duplicates were removed. The following title and abstract screening (phase two), using the inclusion and exclusion criteria, excluded 1,168 records for different reasons (see figure 4.1). The full texts of the remaining 109 records (full texts of 5 records could not be retrieved) were screened also using the defined inclusion and exclusion criteria (phase three). Finally, a total of 23 studies were included in this review.

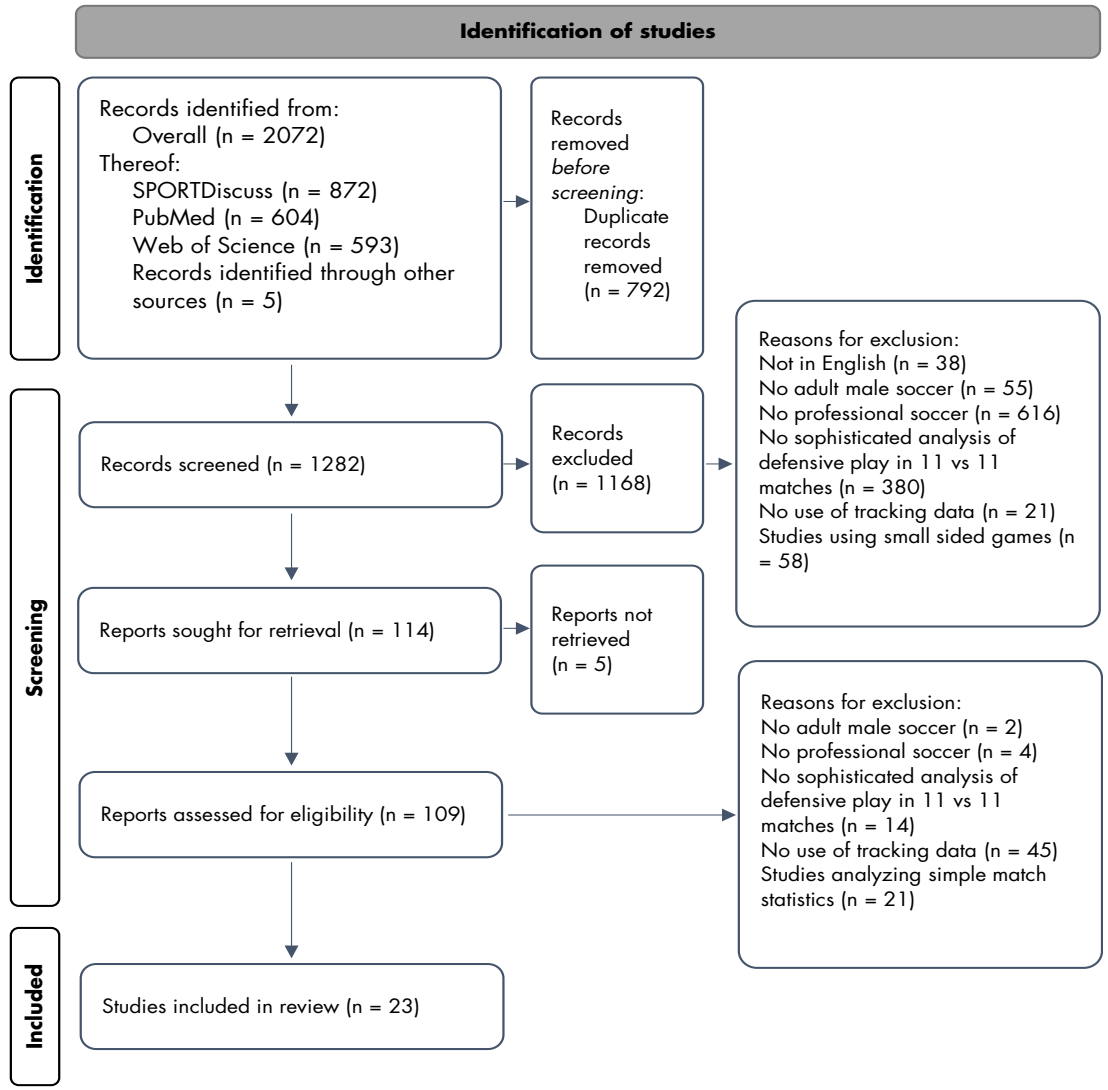

Figure 4.1: Literature search results.

4.5.2 Quality Assessment

All studies reached at least good methodological quality (50-75 [%]; final score: 10-15 of 20) (see table 4.2). Beyond that, 14 studies reached excellent methodological quality (76-100 [%]; final score: 16-20 of 20).

4.5.3 Sample Characteristics

The study characteristics are depicted in table 4.2. All included studies were published after 2011 with the most studies being published in 2017 (n = 5) and 2021 (n = 4). The number of published studies increased from 8 between 2012-2016 to 15 between 2017-2021.

The studies had an average sample size of 145 matches. The majority of 15 studies used less than 30 matches as a sample.

Most analyses were carried out using data from the big European soccer leagues. There were five investigations in Spanish La Liga, three in English Premier League, three in Dutch Eredivisie, and two in German Bundesliga. Furthermore, there were nine studies using data from other leagues (e.g. 3x Eredivisie, 2x Japanese J1 league) and four studies where no specific league was mentioned and therefore remained unknown.

Tracking data measurement systems were predominantly provided by tracking companies. 14 studies used data providers such as ChyronHego, AMISCO, TRACAB, OPTA, STATS, or ProZone. Three studies used their own camera systems with transformations and calculations returning tracking data. The tracking systems of six studies remained unknown.

Table 4.2: Study characteristics of individual studies.

Study	Sample size (league, season)	Study design (performance indicator)	Defensive performance analysis	Main results	QA
Individual level					
Defensive pressure					
Andrienko et al. (2017)	4 matches (of Borussia Dortmund of German Bundesliga, season 2015/16)	Validation of the developed pressure model (comparing mean pressure values with pressure values in successful defensive pressure situations). Analysis of pressure behaviors in case studies. (Defensive pressure or Pressing)	1. Pressure on the ball 2. Pressure on attacking players	Validity: - Association of high pressure values (on the ball & on the attacking players) with successful defensive actions due to high pressure (prove of validity) Pressure analysis: - Pressure on opposing players is higher in the defending team's half and in close distance from the ball (0-15m) - Pressure analysis can help to investigate and provide additional insights into defensive tactics Relation to success: - Yes: Success of defensive pressing is defined as ball possession regain, ball going out of play, or ball turning away from the defended goal	17 (20)
Analysis of offense with opponent interaction (defensive pressure)					
Goes et al. (2021)	299 matches (of Dutch Eredivisie, season 2018/19)	Computation of pass risk and pass reward. Analysis of the effect of positional role on the risk and reward of passing decisions. Pass risk: Classifier of the probability of a pass being successful. Identification of alternative pass options. Predicting the probability of successful passes to all pass options. Pass reward: Longitudinal outplayed opponents, potential of scoring opportunity, & Euclidean distance. (pass risk & pass reward with variables: Pass length, pass angle, path density, passer direction, receiver direction, forward displacement, goal distance pass, goal angle pass, goal distance reception, goal angle reception, pressure on pass, & pressure on receiver)	Defensive pressure on passer & defensive pressure on receiver	- Successful passes are characterized by higher predicted probability of being successful - Higher pass risk is not correlated with higher pass rewards - Defenders took the least amount of pass risk while forwards took the most pass risk - The model can accurately model pass risk and reward (validity) Relation to success: - No (but risk and reward of successful and unsuccessful passes are compared)	18 (20)
Lago-Ballesteros et al. (2012)	12 matches (of one professional Spanish soccer team, season 2009/10)	Analysis of effects of different (offensive, defensive and situational) variables on score box possessions of one soccer team. (Offensive: duration, starting zone, team possession type, pass number, players in possession, and passing options, defensive: opponent number, and defensive pressure, situational: match location, quality of opposition, and match status)	Opponent number (Number of defending players located between the ball and their goal), defensive pressure (distance between the player with the ball and a direct pressing opponent player(s))	- Of all considered possessions, 33.4% produced score-box possessions, 52.5% achieved progression, and 14.1% did not reach any progression - Direct attacks and counterattacks are three times more effective than elaborate attacks (in achieving a score-box possession) - Attacks are more successful when starting from middle pitch zones and playing against less than six defending players compared to attacks starting in defensive pitch zones and against a balanced defense - No differences in the possession outcome were found for defensive pressure Relation to success: - Yes: Score box possession is defined as success criterion	16 (20)

Study	Sample size (league, season)	Study design (performance indicator)	Defensive performance analysis	Main results	QA
Link et al. (2016)	64 matches (of German Bundesliga, season 2014/15)	Validation of Dangerousity by comparing the Dangerousity values to the evaluation by semi-professional football coaches in 100 match scenarios. Exemplary game analysis based on the Dangerousity calculations. (Dangerousity: 1. Position of the ball, 2. Ball control, 3. Pressure that is put on the player by the opponent, 4. Density of opponent players in front of the goal)	Two defensive variables in Dangerousity: 3. Pressure that is put on the player by the opponent, 4. Density of opponent players in front of the goal	Validity: - Dangerousity quantification is in the same range as human observers Dangerousity: - Dangerousity shows higher correlation with betting odds compared to other key performance indicators - The derived metrics of Dangerousity (Action Value, Performance, Dominance) portray the match performance more accurate than traditional performance indicators (e.g. ball possession, shots, tackles, pass rates) because they better rule out effects of chance Relation to success: - Yes: Success is defined with betting odds	15 (20)
Szczepanski & McHale (2016)	760 matches (of English Premier League, seasons 2006/07 & 2007/08)	Development of passing model, calculating various predictions and estimating the passing ability of players. (Passing ability model: Based on the probability of a pass being successful Variables: time since the previous pass & the pass number in the current sequence of passes for that team, game time, type of pass, action followed a duel, player is at his home ground, players' average position)	Defensive pressure on passer (proxied with variables: origin of the pass, time since the previous pass & pass number, game time, action followed a duel, player's average position), defensive pressure on pass receiver (proxied with variables: intended destination of the pass, time since the previous pass & pass number, game time)	Validity: - The passing model shows a better fit to the logistic regression model of the end result compared to simple completion rate of passes Game analysis: - Headed passes are less accurate compared to passes played by foot and further have negative effects on the following pass - Passes are more likely to be accurate when played immediately after a ball recovery - The completion probability of a pass is about 76% for half of the passes and 90% for a quarter of the passes - Only about a quarter of the passes are more likely to be unsuccessful than to be successful Relation to success: - Yes: Success is defined with game outcome (logistic regression)	16 (20)
Group level					
Behavioral analyses					
Castellano & Casamichana (2015)	655 matches (of Spanish BBVA (first-division) & Adelante League (second-division), season 2013/14)	Division of all teams into four groups using the end table of the season: top 10 teams in BBVA, bottom 10 teams in BBVA, top 10 teams in Adelante Leagues, bottom 12 teams in Adelante Leagues. Analysis of differences between the four groups. (Width, depth, height of defense, total running distance covered by team, centre kicks, shots at goal, corner kicks, total passes made, & percentage of successful passes)	Height of defense (distance between the furthest-back defender and the defended goal)	- Higher ranked teams of BBVA performed better than the other three groups (for almost all variables) - In variables width and depth of play and height of defense lower ranked teams of BBVA performed significantly better than higher ranked teams of Adelante League - Teams in top half of BBVA league positioned their players closer to the opponents' goal compared to teams in the bottom half - Defense line of teams in top half of BBVA was closer to their own goal than that of both groups of Adelante league Relation to success: - Yes: Success is defined with end result of the season (top teams, bottom teams) and different leagues (1st and 2nd division)	19 (20)

Study	Sample size (league, season)	Study design (performance indicator)	Defensive performance analysis	Main results	QA
Clemente et al. (2016)	3 matches (of Portuguese Primeira Liga, season 2012/13)	Analysis of the influences of final score and half of the match factors on positions, defensive area of play and the number of triangulations in a given region of a defensive area of play. (Tactical position (estimation of the number of defensive, midfield and attacking players), defensive play area (partial surface area between tactical positions))	Tactical position while defending & defensive play area	Tactical position: - Game ended in a draw: Highest number of defensive players (3.51) - Game ended in a loss: Smallest number of defensive players (3.05), highest number of midfielders (3.39) and attacking players (3.56) - Game ended in a win: Smallest number of attacking players (3.30) - No statistical differences between the first and second halves. Defensive play area: - Greatest defensive pressing occurred in the midfield region (compared to the backward and attacking region) - Greatest amount of defensive coverage was identified in the first half comparing both halves Relation to success: - Yes: Influence of end result (success criterion) on the variables is considered (but no effectiveness of results of performance indicators is discussed)	19 (20)
Synchronization					
Folgado et al. (2018)	4 matches (of English Premier League, season 2010/11)	Measurement of intra-team movement synchronization tendencies in 2 levels: 1. Between opposing teams, by comparing the winning and losing team in each match, 2. Within the analyzed team, by comparing different matches of one team according to the final outcome. (Intra-team synchronization on dyad level (2 players)	Intra-team synchronization between 2 players (dyads) with defensive role (all dyads formed by 2 defenders or by a defender and a midfielder)	- Teams losing tend to exhibit a lower value of movement synchronization - More synchronized behavior in defensive dyads compared to offensive dyads (indicating varying cooperating strategies across the pitch) - Synchronization comparisons are more useful when comparing the same team when the formation used is more likely the same (compared to between team analyses) Relation to success: - Yes: Effect of synchronization on end result is discussed	19 (20)
Goes et al. (2021)	118 matches (of Dutch Eredivisie, 4 seasons (years unknown))	Identification of subgroups using an automated formation descriptor. Calculation of centroids of subgroups (intra-team (between subgroups of one team) & inter-team (between subgroups of opposing teams, e.g. defense of one team and offense of other team)) and comparison between unsuccessful and successful attacks (using a spatiotemporal tool determining the probability of an attack resulting in a scoring opportunity). (Dynamic sub-group interaction)	Subgroup interaction of defending teams and their relation to attacking subgroups	- Defenders on the attacking team and attackers on the defending team show a decreased inter-team synchronization - Inter-team subgroup interactions were characterized by in-phase synchronous behavior - During successful attacks a slightly a-synchronous behavior on a team-level especially in the longitudinal direction was found - Analysis of subgroup interactions provides more in-depth information compared to team-level variables (e.g. centroids of full team) Relation to success: - Yes: Success of an attack is defined with a spatiotemporal tool determining the probability of an attack resulting in a scoring opportunity	17 (20)

Study	Sample size (league, season)	Study design (performance indicator)	Defensive performance analysis	Main results	QA
Team level					
Behavioral analyses					
Bartlett et al. (2012)	10 matches (of elite European soccer (league unknown), season unknown)	Four categories of open attacking plays. The various measures of team centroid and dispersion between the two teams were correlated and compared between successful (goals & shots and headers on goal) and unsuccessful attacks (tackles & other losses of possession). (2 measures of team centroid, 9 measures of dispersion)	Measures of centroid and dispersion while defending	Centroid: - Strong positive correlations between attacking and defending team centroids for all four types of attacks - Little evidence for the decrease of inter-team distances between team centroids before critical match events (almost no crossing of the centroids) Dispersion: - No contraction of defenders in successful defensive play compared to unsuccessful defensive play - Expansion contraction relationship (contracting in defense and expanding in offense) is not supported Relation to success: - Yes: Success of an attack is defined (successful: goal, shot on goal / unsuccessful: defensive tackle, turn-over of ball possession)	15 (20)
Clemente et al. (2013)	3 matches (of one professional football team (league unknown), season unknown)	Analysis of the influence of halves of a match and possession status on five collective metrics was conducted. (no statistic is mentioned) (Weighted centroid, weighted stretch index, surface area, & effective area of play)	Collective metrics while defending	Teams' dispersion and average position on the field decrease during the 2nd half of the match - Tendency of expansion of players' placement on the field in ball possession (stretch index, surface area and effective area of play) - Tendency of contraction of players without ball possession - Support of the expansion contraction relationship Relation to success: - No	14 (20)
Moura et al. (2012)	8 matches (of Brazilian First Division Championship, season unknown)	Analysis of team's coverage area and spread on the pitch when teams were attacking or defending. Analysis of difference of both measures between possession outcomes shot on goal and successful tackle. (Teams' coverage area (convex hull area) & teams' spread (Frobenius norm))	Teams' coverage area and spread while defending	- Decrease of coverage area and spread during defensive play (after loss of ball possession) - Increase of coverage area and spread during offensive play (after win of ball possession) - Support of the expansion contraction relationship - Teams present a greater surface area and spread in unsuccessful defending play sequences (shots on goal) compared to successful ones (successful tackles) - Teams present a greater surface area and spread in unsuccessful attacking sequences (successful tackle) compared to successful ones (shots on goal). Relation to success: - Yes: The success of an attack is defined with attack outcomes (successful: shot on goal, unsuccessful: successful tackle)	13 (20)

Study	Sample size (league, season)	Study design (performance indicator)	Defensive performance analysis	Main results	QA
Welch et al. (2021)	2 matches (of Norway Elfteseien, in 2013 (season unknown))	Determination of the durations spend in each observed form of collective strife during each phase of play (attacking, defending, or out-of-play). Investigation of global analysis, collective movement analysis by game phase, and collective strife transitions. (Collective behavior/strife (order parameter: polarization & angular momentum, mean group speed, team surface area))	Collective behavior in defending phase (order parameter: polarization & angular momentum, mean group speed, team surface area)	- Teams form polar and swarm collective states and switch between those collective states through direct and relatively fast transitions - With well aligned motion with polar nature teams achieve higher average group speeds - In the defensive phases of play the collective movement is more ordered, compact (i.e. lower surface area, high level of collective order) and faster moving in contrast to the attacking and out-of-play phases Relation to success: - No	17 (20)
Synchronization					
Frencken et al. (2012)	1 match (of Champions League, season 2008/09)	Calculation of longitudinal and lateral inter-team distances for both halves. Identification of critical match periods (periods of high variability of inter-team distances over a moving 3-second window). (Inter-team distances (distance between longitudinal and lateral team centroids)	Inter-team distances (distance between longitudinal and lateral team centroids) (changes in inter-team distance might reflect changes in team pressure or switches between attacking and defensive pressure)	- High inter-team interactions of teams are discovered in both halves (strongest in longitudinal compared to lateral direction) - Inter-team distances are minimally related to critical match events (variability threshold was exceeded before three of sixteen critical match events (goals, goal scoring opportunities)) - The identified match periods with high variability of inter-team distances were predominantly (93%) connected with collective defensive pressure on the opponents (defending players moving forward to pressurize players of the attacking team) Relation to success: - Yes/No: Relation to critical match events (e.g. goals and goal-scoring opportunities), but no analysis or consideration of performance/success	16 (20)
Ball recoveries					
Fernandez-Navarro et al. (2019)	10 matches (of Spanish La Liga, season 2010/11)	Clustering of general defensive behaviors used by teams based on different quantitative defensive variables. Examination of the influence of categorial variables on this defensive behavior and the defensive outcome. (Categorical variables: Team analyzed, match status, venue, quality of opposition, match period Quantitative variables: Distance from the least advanced outfield defender to his goal line when defending teams gained the ball, distance between the player in possession of the ball to the nearest defender, length of the last pass that attacking teams made when conceded possession of the ball to defending teams, number of passes made before defending teams gained the ball, duration of defensive pieces of play, outcome of defensive pieces of play, outcome of offensive pieces of play following ball gains)	Defensive quantitative variables: Distance from the least advanced outfield defender to his goal line, duration of defensive pieces of play initiated in the opposing half, distance between the player in possession of the ball to the nearest defender, length of the last pass that attacking teams made when conceded possession of the ball to the last defender, number of passes made by attacking teams before analyzed teams gained the ball	Defensive playing styles: - Defense close to the own goal, mid-positioned defense with less intense pressure to attacking players, mid-positioned defense with more intense pressure, high-pressure defense Influence of categorial variables: - Defensive play was effected by match status and quality of opposition - Teams winning recovered more balls in pitch zones closer to their own goal - Teams losing recovered more balls in pitch zones closer to the opponents' goal - The weaker the quality of the opponent the more balls are recovered in advanced zones of the pitch Relation to success: - Yes/No: Influence of context variable match status is considered (winning, losing, drawing), but solely descriptive analysis of defending behavior according to match status	20 (20)

Study	Sample size (league, season)	Study design (performance indicator)	Defensive performance analysis	Main results	QA
Santos & Lago-Peñas (2019)	13 matches (of one elite Spanish soccer team, season unknown)	Investigation of the effect of three situational variables on five positional variables throughout ball recovery situations. Use of linear regression model to investigate how the situational variables affected each positional variable. (Ball recovery situations with positional variables: team compactness, compactness behind ball location, compactness forward ball location, team width, game center index situational variables: match location, quality of opposition, match status)	Ball recovery situations with positional variables: team compactness, compactness behind ball location, compactness forward ball location, team width, game center index	- Match location has no influence on the analyzed positional performance indicators in ball recovery situations - Match status and strength of opposition has an influence - Teams winning, had a greater approach between players and the ball compared to even scores - Teams winning or losing reduce their game center index and advance their team width compared to even scores - Teams playing against strong opponents advance their compactness forward (distance between the ball recovery and the player closest to the opponents goal line) Relation to success: - Yes/No: The influence of match status on ball recovery variables is considered, but no effectiveness of different ball recovery variables on performance/success is discussed	18 (20)
Santos et al. (2017)	13 matches (of one elite Spanish soccer team, season unknown)	Investigation of the influence of the situational variables on the team performance variables during ball recovery. (Team performance variables: ball recovery location in the field, position of the defensive line, position of the offensive line situational variables: match location, quality of opposition, & match status)	Defensive team performance variables: ball recovery location in the field, position of the defensive-line	- Match status, match location, and quality of opposition have an influence on team variables during ball recovery - Teams losing (compared to winning or even scores), playing at home (compared to playing away), and against a weaker opponent (compared to stronger opponents) advance their ball recovery location as well as the position of the defensive and offensive lines further to the opponents' goal Relation to success: - Yes/No: The influence of match status on ball recovery variables is considered, but no effectiveness of different ball recovery variables on performance/success is discussed	18 (20)
Analysis of offense with opponent interaction (teams' organization)					
Goes et al. (2018)	18 matches (of Dutch Eredivisie, season 2017/18)	Validation of D-Def (measure of passing effectiveness) with 3 steps: 1. Examination of connection between D-Def and the overall movement of the players of the defending team, 2.Investigation whether D-Def score can differentiate the performance of different passers and passes, 3. Assessment of predictive value of pass attributes (pass velocity, pass length, pass angle) on D-Def. (D-Def: Passing effectiveness computed with the defensive disruption following a pass)	Defensive disruptiveness (changes in defensive organization) following a pass	Validity: - Overall individual movement of the defending team is highly correlated with the D-Def score - D-Def is able to clearly distinguish between different passes and passers - Passing angle is not a determining factor for the D-Def score - Passing length and passing velocity are prominent factors to achieve a decrease in defensive organization Relation to success: - No	19 (20)

Study	Sample size (league, season)	Study design (performance indicator)	Defensive performance analysis	Main results	QA
Mixed approaches (individual, group, & team level)					
Computational models					
Matsuoka et al. (2020)	2 matches (of Japanese J1-League, in 2016 (season unknown))	Construction of defensive items (variables) via qualitative analysis (causal structure was extracted by soccer specialists using the Delphi method and the causal-effect analysis). Successful defensive play was defined as ball gain and unsuccessful defensive play was defined as a play that failed to gain the ball. Set of split value to differentiate between successful and unsuccessful defensive play by classification binary tree to reveal success criteria of defensive tactical play. (24 variables of defensive play)	24 variables of defensive play	Defensive playing styles: - Set defense (maintain defensive organization), control defense (restrict and guide the opponent's offence move), and concentration defense (increase player density around the ball) Model: - Fourteen valid items (of all 24 items) are selected by evaluating item characteristics of soccer defensive tactical play items (unidimensionality of items, reliability, validity) - Ability score of soccer defensive tactical play is significantly higher in successful defensive play (with ball gain) compared to unsuccessful defensive plays (without ball gain) - The introduced ability score is a valid measurement of defensive play Relation to success: - Yes: Success of a defensive play was defined (successful: ball gain, unsuccessful: other than ball gain)	14 (20)
Toda et al. (2021)	45 matches (of Japanese J1-League, in 2019 (season unknown))	Validation of the classifier (VDEP) by comparing the prediction of true events compared to existing classifiers. Examination of the relationship between VDEP and the team performance in actual matches and during a season. Demonstrating of examples of game evaluation or complete season evaluation of a team. (Valuating Defense by Estimating Probabilities (VDEP) evaluates the potential increase in the number of ball recoveries and the potential decrease in the number of effective attacks with 73 variables (not all included variables are clearly stated))	VDEP (but no specific performance indicators)	- The VDEP method predicts true positives of events correctly - The VDEP value shows moderate correlation to the season outcome (winning points) - The introduced model can be a consistent indicator to evaluate both attacks (after the ball recovery) and defense itself (prevention of being attacked and the ball recovery) Relation to success: - Yes: Success is defined with season outcome (VDEP method correlated with season outcome)	25 (20)
Prediction models					
Le et al. (2017)	100 matches (of professional soccer league (league unknown), season unknown)	Automatic identification of the tactical formation (player role alignment). Use of recurrent neural networks and a popular deep-learning tool to learn the fine-grained behavior model for each role in the tactical formation for each time step. Prediction of motion patterns of the league average team or of a particular team. (Defensive ghosting (prediction of defending behavior))	Defensive ghosting (prediction of defending behavior)	- The ghosting model is able to maintain solid defensive formation and structure - The average level of deviation from the actual defending behavior across all players and teams is comparatively low (~4 meters) - The total expected goal value coming from different ghosting styles is highly correlated with the overall number of goals conceded in reality Relation to success: - Yes/No: Expected goals is defined as success criterion. Relationships between ghosting models and resulting expected goal values are discussed.	10 (20)

Study	Sample size (league, season)	Study design (performance indicator)	Defensive performance analysis	Main results	QA
Stöckl et al. (2021)	1200 matches (of the top 5 European football leagues (leagues unknown), season unknown)	Split of dataset into 90% train and 10% test set. Execution of the predictions xReciever, xPass, and xThreat. Presentation of approach in case studies. (1. xReceiver: likelihood of a player receiving the next pass 2. xThreat: likelihood that there will be a shot on goal in the next 10 seconds 3. xPass: likelihood of the success of the pass 4. Player Availability: availability of every attacker off the ball at each frame using outputs of xReceiver and xPass 5. Defensive Impact: Detection of high level defensive concepts (e.g. ball and man orientated defending), defensive position play and off ball runs 6. Disruption Maps: Global visual representations of defending teams' ability to disrupt the oppositions attacking strategy)	5. Defensive Impact: Detection of high level defensive concepts (e.g. ball and man orientated defending), defensive position play and off ball runs 6. Disruption Maps: Global visual representations of defending teams' ability to disrupt the oppositions attacking strategy	- The accuracy of all three models (xPass, xReciever, xThreat) is satisfying - Different defensive styles (man and ball orientated defending) and off ball runs are identified - Exemplary single game analysis with the calculated model values can reveal how a forward of one team was nullified by the other team's defense (e.g. forwards probability of receiving a pass was below average, only 3 runs were attacking forward runs) Relation to success: - No: Just analysis of one game where the end result is considered with no calculations	10 (20)

4.5.4 Main Findings

A summary of all included studies is provided in table 4.2. A summary of the approaches used to analyze defensive play using tracking data is depicted in table 4.3 and a summary of findings on successful defensive play is presented in table 4.4.

Table 4.3: Approaches used to analyze defensive play using tracking data.

Level of tactical play	Analyzing approach	Explanation	Metrics used	Aim of analysis
Individual level	Defensive pressure (see figure 4.2, d)	- The magnitude of pressure exerted from all pressers on the pressure target - Andrienko et al. (2017) used the distance and the direction of the closest defender(s) to the pressure target	- Pressure on ball (Andrienko et al., 2017) - Pressure on opponents (Andrienko et al., 2017)	- Quantification of the space a attacker has to perform actions - Quantification of the influence of defenders on the attackers
Group level	Numerical superiority	- Difference in the number of players between both teams in the same subarea of the pitch	- Numerical superiority in subareas of the pitch (Vilar et al., 2013)	- Measurement of pitch areas where a team is more dominant - Measurement of pitch areas where a team has a higher probability for gaining the ball or maintain ball possession
	Behavioral analysis (see figure 4.2, c)	- Analysis of the defensive behavior of subgroups	- Positioning of defensive line (Castellano & Casamichana, 2015) - Tactical position while defending & defensive play area (Clemente et al., 2016)	- Analysis of subgroups (e.g. defensive line)
	Synchronization (see figure 4.2, a)	- Synchronous behavior is characterized by players moving in the same direction with the same speed and the same acceleration	- Intra-team synchronization on dyad level (pairings of two players) (Folgado et al., 2018) - Inter-team subgroup interactions (Goes et al., 2021)	- Analysis of the synchronization of movement behavior of subgroups - Identification of coordination patterns of subgroups
Team level	Behavioral analysis	- Analysis of the defensive behavior of the whole team	- Centroids, surface area, spread of full team (Bartlett et al., 2012; Clemente et al., 2013; Moura et al., 2012) - Polarization and angular momentum (Welch et al., 2021)	- Analysis of the whole team
	Synchronization (see figure 4.2, b)	- Synchronous behavior is characterized by players moving in the same direction with the same speed and the same acceleration	- Inter-team distances of centroids of both teams (Frencken et al., 2012)	- Analysis of the synchronization of movement behavior of the whole team - Identification of coordination patterns of the whole team
	Ball recovery	- The goal of defending play is to regain the ball from the opponent, also called ball recovery	- Ball recoveries (Fernandez-Navarro et al., 2019; Santos et al., 2017; Santos & Lago-Penas, 2019)	- Analysis of the goal of defensive play (to regain the ball)
Mixed approaches	Computational models	- Use of computational methods to develop a model about defensive play	- Ability score of soccer defensive tactical play (Matsuoka et al., 2020) - Valuating Defense by Estimating Probabilities (VDEP) (Toda et al., 2021)	- Identification of hidden patterns in unstructured data
	Prediction models	- Use of computational methods to predict defensive play	- Defensive ghosting (Le et al., 2017) - xReceiver, xThreat, xPass (Stöckl et al., 2021)	- Predictions of defensive behavior

Every level of tactical play (individual level, group level, team level, mixed approaches) is structured in the following way. First, the details of the approaches to analyze defensive play are presented to account for the first research question to give an overview of the heterogeneous study approaches. Second, it is shown whether the approaches were presented in connection to success, which is important to show the actual significance of the new processing approaches and substantial for the interpretation of the results which are presented third in every section. Both the second and third paragraphs account for the second research question of this paper about the findings on successful defensive play.
Due to the heterogeneous study designs of the included papers, the results are only comparable with each other to a limited extend and are therefore only presented if applicable.

Table 4.4: Main findings of successful defensive play.

Level of tactical play	Analyzing approach	Finding
Individual level	Defensive pressure	- Successful defensive plays are characterized by high defensive pressure (on the ball & on the attackers) (Andrienko et al., 2017)
Group level	Numerical superiority	- Teams place more players than their opponents in sub-areas closer to their own goal - Teams rarely place more players than their opponents in sub-areas more distant from their own goal - Winning teams maintain higher defensive stability while concurrently risk more players to offensive sub-areas of field compared to losing teams (Vilar et al., 2013)
	Synchronization	- Winning teams show more intra-team synchronization on dyade level (2 players) compared to losing teams (Folgado et al., 2018)
		- Defenders on the attacking team and attackers on the defending team show a decreased inter-team synchronization in successful attacks (Goes et al., 2021)
	Positioning of defensive-line	- Better teams position their defensive-line further up the pitch (Castellano et al., 2012)
	Number of defenders	- Attacks are less successful when starting in defensive pitch zones and playing against more than five defenders (balanced defense) (Lago-Ballesteros et al., 2012)
Team level	Synchronization	- Slightly a-synchronous behavior on a team-level especially in the longitudinal direction during successful attacks (Goes et al., 2021)
	Contraction expansion relationship	- Contraction of players during defensive play (out of ball possession) and expansion of players during offensive play (in ball possession) –> Support of contraction expansion relationship (Clemente et al., 2013; Moura et al., 2012; Welch et al., 2021) - Teams present a stronger contraction (smaller surface area and spread) in successful defending play sequences compared to unsuccessful ones (Moura et al., 2012)
	Influence of categorial variables	- Teams recover more balls closer to their own goal when winning (compared to even scores or losing), playing away (compared to playing at home), and playing against a stronger opponent (compared to weaker opponents) (Fernandez-Navarro et al., 2019; Santos et al., 2017; Santos & Lago-Penas, 2019)

4.5.4.1 Individual Level

Five studies investigated defensive play at an individual level. All studies used defensive pressure (on the ball and on the opponents) to investigate defensive play. Andrienko et al. (2017) developed a method to quantify pressure with two different pressure measures (1. pressure on the ball, 2. pressure on the attacking players) based on the idea that pressing is the magnitude of pressure exerted from all pressers on a pressure target (visualized in figure 4.2, d). This study was the only one to focus solely on the analysis of defensive pressure. In contrast, the other four studies analyzed offensive play considering defensive pressure as a variable of opponent interaction. Goes et al. (2021) used the pressure model of Andrienko et al. (2017) among other variables to evaluate passing ability, Szczepanski and McHale (2016) only proxied the pressure on the passer and receiver (without giving exact calculations) also evaluating passing ability. Both Lago-Ballesteros et al. (2012) and Link et al. (2016) used similar approaches to Andrienko et al. (2017) by measuring the distance to attackers and the pressure on the ball leading player, respectively.

Regarding the investigation in connection to success Szczepanski & McHale (2016) and Link et al. (2016) used the end result as success criterion at a match level. At a possession level, Lago-Ballesteros et al. (2012) defined the success of an attack as score box possession and Andrienko et al. (2017) defined the success of defensive play as ball possession regain, ball going out of play, or ball turning away from the defended goal. In contrast, Goes et al. (2021) did not consider success in their investigation.

With regards to the findings to defensive play, Andrienko et al. (2017) showed that the mean pressure values during a whole match were notably lower than the pressure values during successful defensive play (Andrienko et al., 2017). This difference was evident for pressure on the ball as well as for pressure on the attacking players. The authors also found that the pressure is higher in areas close to the ball (0 - 15 [m] from the ball) compared to areas further away from the ball. The other four studies taking the opponent interaction of defensive pressure into account did not aim to reveal outcomes for defensive play and therefore did not present relevant results.

4.5.4.2 Group Level

At a group level, seven studies analyzed defensive play. The used approaches include behavioral analyses (Castellano & Casamichana, 2015; Clemente et al., 2016), synchronization (Folgado et al., 2018; Goes, Brink, et al., 2021), analysis of numerical superiority (Vilar et al., 2013), and analysis of offense including the density of players behind the ball as opponent interaction. In behavioral analyses, Castellano and Casamichana (2015) investigated the height of the defensive-line (visualized in figure 4.2, c) and Clemente et al. (2016) used the tactical formation to define the defensive area of play. To evaluate synchronization (interaction) between or within teams, Goes et al. (2021) assessed the intra-team and inter-team synchronization of subgroups (defensive-, midfield-, & attacking-line) and Folgado et al. (2018) investigated the intra-team movement synchronization at dyad level (pairings of 2 players) (visualized in figure 4.2, a). Vilar et al. (2013) investigated numerical superiority in dynamical sub-areas of the pitch. The other two studies explored offensive play considering the opponent interaction as the number of defensive players still able to defend an approaching attack. While one study defined this as density of defensive players (Link et al., 2016) another referred to the term as opponent number (Lago-Ballesteros et al., 2012).

Six of the seven studies analyzing defensive play at a group level investigated their approaches in connection to success. Castellano and Casamichana (2015) used the end result of a season. At the match level, the end result (Clemente et al., 2016; Folgado et al., 2018; Link et al., 2016) was used as success criteria. At the possession level, the success of an attack was defined by the score box possession (Lago-Ballesteros et al., 2012) and with a spatiotemporal tool determining the probability of an attack resulting in a scoring opportunity (Goes, Brink, et al., 2021). Solely Vilar et al. (2013) did not consider success in their investigation.

Regarding the results of the studies, group level behavioral analysis of defensive play revealed that stronger teams positioned their defensive-line further up the field compared to weaker teams (Castellano & Casamichana, 2015). Additionally, greater defensive pressure occurred in the midfield region, compared to attacking and defensive regions (Clemente et al., 2016). Looking at the synchronization at a group level, successful attacks are characterized by a decreased inter-team synchronization between the defenders of the attacking team and attackers of the defending team (Goes, Brink, et al., 2021). Furthermore, Folgado et al. (2018) revealed that losing teams tend to have lower inter-team synchronization compared to winning teams and that defensive dyads (pairings of two players) are more synchronized than offensive dyads. Vilar et al. (2013) found that soccer teams place more players than their opponents in areas closer to their own goal, especially in the center-back sub-areas of play. Furthermore, their analysis revealed that winning teams were able to risk more players in sub-areas closer to the opponents' goal (forward areas) while concurrently maintaining higher stability in sub-areas closer to their own goal (defensive areas) compared to the losing team. Taking the opponent interaction into account, solely one study showed results regarding defensive play. Lago-Ballesteros et al. (2012) indicated that attacks are more successful when playing against less than six defending players compared to attacks against a balanced defense (six or more defenders).

4.5.4.3 Team Level

Nine studies analyzed defensive play at a team level. The approaches used to analyze defensive play in this tactical level were the investigation of ball recoveries (Fernandez-Navarro et al., 2019; Santos et al., 2017; Santos & Lago-Penas, 2019), behavioral analyses (Bartlett et al., 2012; Clemente et al., 2013b; Moura et al., 2012; Welch et al., 2021), analyses of synchronization (Frencken et al., 2012), and analyses of offense with the defensive organization as a measure of opponent interaction (Goes et al., 2018). All three studies exploring

ball recoveries focused on the influence of situational variables (match status, match location, or quality of opponent) on the ball recoveries (Fernandez-Navarro et al., 2019; Santos et al., 2017; Santos & Lago-Penas, 2019). Investigations focusing on defending behavior at a team level used collective metrics of the full team to describe the movement of players on the field, e.g. team centroids, coverage area, spread (Bartlett et al., 2012; Clemente et al., 2013b; Moura et al., 2012). Solely Welch et al. (2021) used other order measures to investigate team behavior (polarization and angular momentum). Frencken et al. (2012) assessed the inter-team distances between the team centroids to measure synchronization of opposing teams (visualized in figure 4.2, b). Analyzing passing effectiveness Goes et al. (2018) calculated the defensive disruptiveness following a pass using measures to describe the defensive organization (centroids, surface area, and spread).

Regarding the connection to success, solely Bartlett et al. (2012) and Moura et al. (2012) defined success at a possession level with attack outcomes (e.g. shot on goal). Additionally, four studies partially considered the relation to success, for example by investigating the influence of match status on measurements without the discussing effectiveness (Fernandez-Navarro et al., 2019; Frencken et al., 2012; Santos et al., 2017; Santos & Lago-Penas, 2019). The remaining three studies did not consider success in their investigations (Clemente et al., 2013b; Goes et al., 2018; Welch et al., 2021).

Regarding the results on defensive play, the studies on ball recoveries show that teams gain more balls closer to their own goal when playing away (vs playing at home), winning (vs losing or drawing), and playing against a stronger opponent (vs weaker opponent), and vice-versa (Fernandez-Navarro et al., 2019; Santos et al., 2017; Santos & Lago-Penas, 2019). Solely Santos and Lago-Peñas (2019) could not find an effect of match location on ball recovery situations. Investigating defensive behavior, Moura et al. (2012) showed that in ball possession, the coverage area and the spread increase compared to sequences of play without ball possession (contraction-expansion relationship). They also identified that in successful defensive plays, the teams showed smaller coverage areas and spreads compared to unsuccessful defensive plays (Moura et al., 2012). Clemente et al. (2013b) also found a decreasing trend in dispersion and coverage measures of teams without ball possession (contraction-expansion relationship). Welch et al. (2021) showed that the movement of players in the defensive phase is more ordered and compact (supporting the contraction-expansion relationship) and faster-moving compared to the other phases of play. In contrast, Bartlett et al. (2012) could not find evidence supporting the mentioned contraction-expansion relationship. Furthermore, they could identify only a few critical events (e.g. shots, goals) by analyzing the interactions of team centroids. Similarly, Frencken et al. (2012) reported that inter-team distances of the opposing teams are rarely related to critical match events (e.g. scoring opportunities, goals). However, those critical match periods identified by inter-team distances were associated with collective defensive actions (e.g. pressurize players of the attacking team) (Frencken et al., 2012). Goes et al. (2018) did not discuss results regarding defensive play.

4.5.4.4 Mixed Approaches

Four studies using a combination of individual, group, and team tactical variables and were assigned to this section. The used approaches were computational models (Matsuoka et al., 2020; Toda et al., 2021) and prediction models (Le et al., 2017; Stöckl et al., 2021). Regarding the computational models, Matsuoka et al. (2020) introduced a model of defensive tactical play and Toda et al. (2021) presented a model called Valuating Defense by Estimating Probabilities estimating the probability of a ball gain. Predicting defensive play, Le et al. (2017) demonstrated a real-time prediction of defending behavior using team or league average behavior predictions (ghosting) and Stöckl et al. (2021) used different predictions (xPass, xReceiver, xThreat) to measure the defending teams' ability to disrupt the oppositions attacking strategy and to detect high-level defensive concepts (e.g. ball or man orientated defense).

To measure their models in connection to success, Toda et al. (2021) used the season outcome and Matsuoka et al. (2020) defined success of defensive play as gain of ball possession. Stöckl et al. (2021) only partially took success into account and Le et al. (2017) did not consider the effects of success at all.

Concerning the findings of the included studies, Matsuoka et al. (2020) identified three sub-defensive tactical types of play, which were set defense (maintaining defensive organization), concentration defense (increasing player density around the ball), and control defense (restricting or guiding the attacking play). Furthermore, they demonstrated that their model shows higher values for successful defensive play (ball gain) compared to unsuccessful (no ball gain) defensive play (Matsuoka et al., 2020). Toda et al. (2021) found that the distance of the closest defender to the ball had the highest impact on their model and the values calculated from this had a moderate positive correlation with the season outcome, defined as winning points. Le et al. (2017) focused on the characteristics of their predictions and showed that their movement predictions for the players can maintain solid defensive formation and therefore can quantify, analyze and compare defending behavior on a fine-grained level. By analyzing a single-match situation they showed that the ghosting model of a good defense reduced the expected goal value from around 70 [%] (of the actual sequence where the analyzed team conceded a goal) to around 40 [%] (Le et al., 2017). Similarly, Stöckl et al. (2021) demonstrated that their predictions were able to create a compact visual representation of the teams' defensive performance. Moreover, the single-match analysis using the predictions could show how one team's defense was able to negate the offensive actions of the other team's forwards (e.g. striker's probability of receiving a pass was below average).

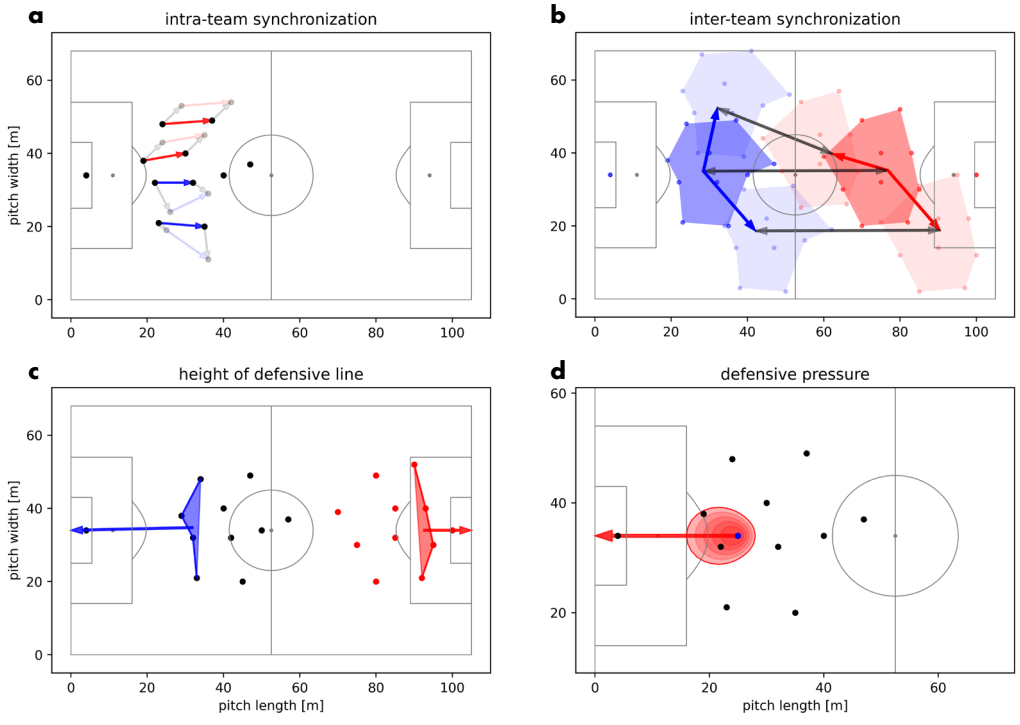

Figure 4.2: Visualization of exemplary key performance indicators:
a: Visualization of intra-team synchronization on dyad level (Folgado et al., 2018), with perfect synchronous movement behavior at the top (red) and asynchronous movement behavior at the bottom (blue).
b: Visualization of inter-team movement synchronization of opposing teams' centroids (Frencken et al., 2012), with perfect synchronous movement behavior at the bottom and asynchronous movement behavior at the top.
c: Visualization of the measurement of the height of the defensive-line (blue) (Castellano & Casamichana, 2015) respectively, with high defensive-line on the left (blue) and deep defensive-line at the right (red).
d: Visualization of the measurement of defensive pressure (Andrienko et al., 2017): Two defending players (black) exerting defensive pressure on an attacking player (blue) with the threat direction towards the goal (red arrow).

4.6 Discussion

The aim of this scoping review was twofold. First, we aimed to explore the approaches used to analyze defensive play in professional soccer using player tracking data. Secondly, we wanted to reveal the findings about successful defensive play using those approaches.
Following the aims, the discussion is structured as follows. First, the approaches analyzing defensive play are discussed in the different levels of tactical play (individual, group, team level) to account for the first research question. Second, the findings on successful defensive play are presented in the same structure to answer the second research question. Then, overlapping limitations of included studies are discussed and future directions are derived accordingly. Finally, practical implications of the results of this review are exemplified.

4.6.1 Approaches

The approaches used to analyze defensive play are widespread. The range of approaches is depicted in table 4.3. The analysis of defensive pressure appears to be an informative indicator of defensive play. While the analysis of synchronization and defending behavior provide information about the defending process, the investigations on ball recoveries focused on the moment of a ball gain and did not consider the course of the defensive play. Both computational and prediction models include promising data processing approaches that can reveal hidden information about unstructured data but do not provide practice-relevant information.

4.6.1.1 Individual Level

The only approach used to analyze defensive play at the individual level was defensive pressure (visualized in figure 4.2, d). However, the results of Andrienko et al. (Andrienko et al., 2017) indicate that this defensive pressure is a substantial part of successful defending. Also, the widespread use of defensive pressure as an opponent interaction in the analysis of offensive play indicates the awareness of the importance of defensive pressure in soccer (Goes, Schwarz, et al., 2021; Lago-Ballesteros et al., 2012; Link et al., 2016; Szczepanski & McHale, 2016). Therefore, the analysis of defensive pressure is a promising performance indicator for defensive play that should be further investigated.

4.6.1.2 Group Level

The analysis of defending behavior at the group level is more informative compared to team interactions (Frencken et al., 2012; Goes, Brink, et al., 2021), as the measurement of team interactions might be too simplistic for the portray of complex match situations. This is especially true to the analysis of defending behavior and synchronization. Both approaches can reveal important information about the defending process on a fine-grained level. However, the behavioral approaches on a group level (height of the defensive-line & defensive playing area)

in particular are very simplistic and reveal very little information about defensive tactical play. The analysis of numerical superiority, which describes the placement of players in defined areas of the pitch, is related to the approach of measuring the density of players behind the ball who are still able to defend an approaching attack. Both measures are very simple measurement techniques that help to analyze the tactics of defensive play. However, due to their simplicity, they cannot reveal detailed information about the spatial relation of players to each other, so the information gain using these approaches remains low.

4.6.1.3 Team Level

The approaches to analyze defensive play at the team level were diverse. Three studies focused on the influence of situational variables on ball recoveries. As ball recoveries are one of the main goals of defensive play (next to prevent goals of opponents), they can provide important information about defensive playing tactics. However, they merely consider the moment of the ball recovery (outcome of defensive play) and not consider the whole defending process, although Fernandez-Navarro et al. (2019) used some variables related to the whole defensive play. Furthermore, all three studies focused on the influence of situational variables and not on the tactics of successful defensive play. Therefore, little information can be obtained about the tactics of the defending process.

The approaches to analyze defending behavior and synchronization at the team level, as mentioned before, are expected to provide fewer insights compared to the analysis at the group level. However, both approaches (analysis of synchronization and behavior) help to analyze the team's spatial organization on the pitch. Accordingly, Goes et al. (2018) introduced the quantification of defensive organization in a sophisticated way analyzing passing effectiveness. This quantification of defensive organization, which is crucial for successful defensive play (Moura et al., 2012), holds great potential for future research in defensive play at the team level.

4.6.1.4 Mixed Approaches

Both the computational models and the prediction models used a vast amount of variables at different levels of tactical play (e.g. individual parameters, group parameters, team parameters). In both approaches, the computational data processing methods help to extract the most important information from the great amount of unstructured data. This procedure can help to identify hidden patterns in the data and provide new insights in the constraints of successful defensive play from a computational perspective. To reveal this information the studies need to report all included parameters and discuss the resulting weights of the individual parameters. This is crucial for other researchers and practitioners to retrace the data processing and to gain practice-relevant information. However, it is the weighting of individual parameters that is largely lacking, severely limiting the usefulness of these approaches. Therefore, computational models and prediction models can help to deal with the huge amount of unstructured tracking data and to reveal hidden patterns but fail to reveal practice-relevant results, which needs to be addressed in the future.

4.6.2 Successful Defensive Play

The results on successful defensive play are depicted in table 4.4. Successful defensive play is characterized by high defensive pressure on the ball and on the opponents. With more players behind the ball and numerical superiority in areas closer to the own goal, the amount of spatial defensive pressure increases which is also related to successful defensive plays. Furthermore, success in defensive play is indicated by the contraction of the team's organization. Ultimately, a higher inter-team and intra-team synchronization is a good indicator for successful defensive play.

4.6.2.1 Individual Level

The main findings on successful defensive play at the individual level are that successful defensive plays are characterized by high defensive pressure (on the ball & on the attackers) (Andrienko et al., 2017).

There is a big research potential in this area, as the mentioned studies using the opponent interaction of defensive pressure did not discuss results regarding defensive play and Andrienko et al. (2017) only exemplarily showed the measurement of pressure using a small sample size (4 matches). The conditions of pressure, team differences depending on different tactics, and the how/when/where of efficient defensive pressure need to be addressed in the future.

4.6.2.2 Group Level

The main findings of successful group tactical defensive play are as follows. Winning teams maintain higher defensive stability (numerical superiority) while concurrently risking more individual players to offensive sub-areas of the field compared to losing teams (Vilar et al., 2013). Furthermore, attacks are less successful when played against a balanced defense (more than five defenders) (Lago-Ballesteros et al., 2012) and better teams position their defensive-line further up the pitch (Castellano et al., 2012). Furthermore, intra-team as well as inter-team synchronization of defensive players is an important factor of successful defensive play (Folgado et al., 2018; Goes, Brink, et al., 2021).

As teams place more players than their opponents in sub-areas closer to their own goal (Vilar et al., 2013), the spatial and temporal pressure on the opponents in those areas rises due to this numerical superiority. Therefore, those findings describe the tendency of teams applying higher defensive pressure on opponents when they are closer to their goal and indicate the importance of defensive pressure.

The findings of Lago-Ballesteros et al. (2012) that attacks are less successful when played against more than five defenders are supported by the work of Castellano et al. (2012), who identified

the fewest offensive players when a team won compared to a draw or loss. This higher number of defending players is also considered in the study of Link et al. (2016) taking the density of defenders in front of the ball into account. However, Link et al. (2016) revealed no results regarding successful defensive play.

The finding of higher placement of the defensive-line in better teams compared to weaker teams indicates a high pressing playing style applied by better teams. This defensive tactical playing style, where teams try to quickly regain the ball in areas closer to the opponents' goal to control the match or to achieve scoring opportunities is therefore associated with success.

Regarding the synchronization during defensive play winning teams show more intra-team synchronization on dyad level (2 players) compared to losing teams (Folgado et al., 2018) and defenders on the attacking team and attackers on the defending team show a decreased inter-team synchronization in successful attacks (Goes, Brink, et al., 2021).

Overall, the positioning of defensive players and their synchronization is important for the success of defensive play.

4.6.2.3 Team Level

At a team tactical level, the main finding is that in successful defensive plays teams present a stronger contraction compared to unsuccessful defensive plays (Moura et al., 2012).

Three studies showed this contraction of players in defensive playing phases (players moving closer together) compared to an expansion in offensive playing phases (players diverge) (Clemente et al., 2013b; Moura et al., 2012; Welch et al., 2021). This indicates the defensive principle to close gaps between defenders, thus narrowing the possible space for attackers in order to prevent the opponent from creating scoring opportunities. This contraction-expansion relationship depending on ball possession was not found in one study (Bartlett et al., 2012). However, in this context, solely one study focused on the connection to success and revealed that the contraction is stronger in successful defensive play (Moura et al., 2012). The measurement of defensive organization on the pitch in the context of success needs to be addressed in the future as the contraction of the organization during defensive play is indicated to be a highly important performance indicator for defensive success. The presented approaches show possibilities for how team tactical variables can be used to quantify this defensive organization. Team level analysis of ball recoveries revealed that defensive play is affected by situational variables but provides little information about successful defensive play. Teams recover more balls closer to their own goal when winning (vs losing or drawing), playing away (vs playing at home), and playing against a stronger opponent (vs weaker opponents) (Fernandez-Navarro et al., 2019; Santos et al., 2017; Santos & Lago-Penas, 2019). This highlights that teams adapt their defending playing style to contextual factors. For example, winning teams tend to defend in areas closer to their own goal and focus on quick counter-attacking after ball gains in order to save the score.

Another finding is that the inter-team synchronization (short distances between team centroids) is not clearly related to critical match events (e.g. shots, goals) (Bartlett et al., 2012; Frencken et al., 2012). Rather, it is evident that those moments of exceptional interactions indicate high defensive pressure (Frencken et al., 2012).

4.6.2.4 Mixed Approaches

The findings on successful defensive play of the mixed approaches were sparse. Both the computational models and the prediction models focused on the model characteristics and the results regarding their model. For example, Matsuoka et al. (2020) showed that their model indicates higher values in successful defensive play (ball gain) compared to unsuccessful defensive plays (without ball gain). Solely Toda et al. (2021) reported a resulting weighting of parameters and found that the distance of the closest defender to the ball had the highest impact on their model. This distance can be interpreted as defensive pressure on the ball and once again shows the importance of this defensive performance indicator. This example points out that the weighting of individual parameters can contribute to the understanding of the models and can provide insights into the measurement of defensive play to increase their practical value.

4.6.3 Limitations and Future Directions

The majority of the studies included in this review used insufficiently small sample sizes (fewer than 30 matches). The highly dynamic team sport soccer leads to a great variability of performance indicators and in this context smaller sample sizes lead to a diminished overall generality of results (Sarmento et al., 2014). Furthermore, almost half of the studies did not investigate their approaches in connection to success. This is important to show the actual significance and importance of the developed performance indicators or processing approaches. Both limitations lead to a diminished general validity of the results. Those studies taking the connection to success into account defined success at different levels (season, match, possession level). Thereby, the analysis of success at a possession level can reveal the most fine-grained insights into tactical play because it is subject to the slightest effects of chance compared to match or season level. Depending on the study design the definition of success at a match level can be informative as well. The analysis of success at a season level can only provide rough insights into tactical play as the conditions of an attacking or defending sequence cannot be viewed. Therefore, the advantages of the different levels of success analyzed in the different studies should be considered in future investigations.

Accordingly, it is important to investigate the whole defending process and not just a snapshot of a playing situation, e.g. a ball recovery situation. To increase the practical relevance, it is important to find performance-determining factors of defensive play. Yet, most studies lack the practice-oriented discussion of results, so that the practical relevance of most publications remains low.

However, with the possibilities of the evaluation of tracking data, these issues can be counteracted. The availability of large amounts of data from competitive matches at the professional level (e.g. German Bundesliga, British Premier League) and the possibility of time-saving and fine-grained analysis compared to traditional (e.g. notational) analysis methods indicates an interesting potential for future match analysis. In this context, it should be noted that most of the studies included in this review used tracking data from tracking companies. This shows that researchers in soccer using tracking data rely on tracking companies to measure and to provide the tracking data.

Overall, the approaches and study designs shown in this review are very heterogeneous and build various starting points for future research. These future investigations should use sophisticated data processing approaches and focus on practice-orientated discussion and usability of their results. Future research in defensive play using tracking data should focus on the following:

1. The conditions of defensive pressure. Team differences depending on different tactics and the how/when/where of efficient defensive pressure.
2. Quantification of the compact organization during defensive play in connection to success.
3. The practice-oriented evaluation and discussion of results to increase the practical impact of introduced approaches evaluating tracking data.

4.6.4 Practical Implications

The usage of new analyzing approaches in soccer, such as the evaluation of tracking data, has the potential to provide new insights into the performance structure of defensive play. Yet, there is a widespread lack of implementation in practice of this new analytic approach about performance in soccer. Therefore, the next section shows examples of how the gained information of this review can impact practice.

The results of this review on successful defensive play referring to the second research question are summarized in table 4.4. Those findings can help practitioners (e.g. coaches, analysts, managers) in designing match tactics, planning training content, or analyzing opponents. In this context, the connection of the used approaches of the different studies to success (e.g. end result of a match) is important. Solely studies that discuss their results in connection to success can reveal findings of successful tactics in soccer and draw conclusions of the success factors in soccer. This is highly important for the practical impact of the results in this research area. Subsequently, some examples how to use the results of this review are presented in more detail.

The purpose of defensive play is to protect the own goal and recover the ball (Matsuoka et al., 2020). This ball recovery is impacted by situational variables (match status, match location, quality of opponent). Therefore, practitioners should bear these situational variables in mind when analyzing match performance (Fernandez-Navarro et al., 2019).

Successful defensive play is characterized by applying high pressure on attackers (Andrienko et al., 2017) and attaining a coordinated compact team organization. This contraction of organization in defensive playing phases (Folgado et al., 2018; Moura et al., 2012; Santos et al., 2017; Santos & Lago-Penas, 2019; Welch et al., 2021) is important to minimize the space for the attacking team to advance their attack and thereby enable the defenders to quickly put pressure on the attackers after a ball move. Furthermore, the intra-team synchronization is important for defensive success (Folgado et al., 2018; Goes, Brink, et al., 2021). Therefore, these tactics should be considered by coaches, experts, and analysts.

Findings like these can impact the game of soccer if discussed in a practical manner and implemented by practitioners.

4.7 Conclusion

Overall, the approaches used to analyze defensive play were highly heterogeneous ranging from the analysis of ball recoveries to computational models. Most promising approaches to analyze defensive play were the analysis of defensive pressure and the quantification of defensive compact organization. The findings on successful defensive play using those approaches were that successful defensive play at the individual level is characterized by high defensive pressure. At the group level, inter-team and intra-team synchronization as well as a balanced defense are important for successful defensive play. At the team level, the contraction of the spatial organization is important for success.

In general, defensive play is highly important for success in soccer (Georgievski et al., 2019; Lepschy et al., 2021). However, so far it has received less attention compared to offensive play. This review highlights the importance of defensive play and builds a basis for future research in this area. Furthermore, it presents important aspects that should be taken into account when conducting research in this area (e.g. sample size, connection to success, practical discussion of results). In conclusion, there are various starting points for future research on the analysis of defensive play in soccer using the possibilities of tracking data to improve the understanding of defensive play.

Chapter 5

Defensive Pressure (Paper II)

The keys of pressing to gain the ball – Characteristics of defensive pressure in elite soccer using tracking data.

Published version of the original research article

Forcher, L., Forcher, L., Altmann, S., Jekauc, D., & Kempe, M. (2022). The keys of pressing to gain the ball – Characteristics of defensive pressure in elite soccer using tracking data. Science and Medicine in Football, 1-9. https://doi.org/10.1080/24733938.2022.2158213

5 Defensive Pressure (Paper II)

5.1 Abstract

Recently, the availability of big amounts of data enables analysts to dive deeper into the constraints of performance in various team sports. While offensive analyses in soccer have been extensively conducted, the evaluation of defensive performance is underrepresented in this sport. Hence, the aim of this study was to analyze successful defensive playing phases by investigating the space and time characteristics of defensive pressure.
Therefore, tracking and event data of 153 matches of the German Bundesliga (second half of 2020/21 season) were assessed. Defensive pressure was measured in the last 10 seconds of a defensive playing sequence (time characteristic) and it was distinguished between pressure on the ball-carrier, pressure on the group (5 attackers closest to the ball), and pressure on the whole team (space characteristic). A linear mixed model was applied to evaluate the effect of success of a defensive play (ball gain), space characteristic, and time characteristic on defensive pressure.
Defensive pressure is higher in successful defensive plays (14.47 ± 16.82 [%]) compared to unsuccessful defensive plays (12.87 ± 15.31 [%]). The characteristics show that defensive pressure is higher in areas closer to the ball (space characteristic) and the closer the measurement is to the end of a defensive play (time characteristic), which is especially true for successful defensive plays.
Defensive pressure is a valuable key performance indicator for defensive play. Further, this study shows that there is an association between the pressing of the ball-carrier and areas close to the ball with the success of defensive play.

Key words: football, team sports, match analysis, performance analysis, tracking data, defensive behavior, machine learning

5.2 Highlights

- The results of this study indicate that defensive pressure is a valuable key performance indicator for defensive play.
- Defensive pressure is higher in successful defensive plays (ball gain) compared to unsuccessful defensive plays (no ball gain).
- Over all defensive plays, defensive pressure on attackers close to the ball (pressure on the ball-leading player, five players closest to the ball) is higher compared to defensive pressure on all attacking players.
- Over all defensive plays, defensive pressure increases with the course of a defensive play and is the highest at the end of a defensive play.

5.3 Introduction

The importance of detailed match analyses in all team sports has increased over the last years. In soccer, most analyses have focused on the offensive play by evaluating scoring opportunities (e.g. expected goals) (Rathke, 2017) and attacking tactics (Goes et al., 2018; Szczepanski & McHale, 2016). Furthermore, the majority of analyses focus solely on goal scoring (Gonzalez-Rodenas et al., 2019; Kempe & Memmert, 2018), which are rare events that neglect most of the dynamics of the game (Duarte et al., 2013). However, in addition to attacking play, there are three other phases of play: defensive play, defensive transition (after losing the ball), & offensive transition (after gaining the ball). As there is a lack of a comparable number of studies focusing on defensive analyses, there exits an imbalance between offensive and defensive key performance indicators (Forcher, Altmann, Forcher, Jekauc, et al., 2022). This imbalance leads to (offensive) biased match analyses and biased modeling of match performance as defending play is mostly not considered (Radke et al., 2021).

However, the importance of defense in soccer is repeatedly pointed out in various research (Georgievski et al., 2019; Lepschy et al., 2021). Soccer in general, could even be characterized as a primary defensive team sport (compared to e.g. handball or basketball) due to the increased difficulty in controlling the ball (by playing with ones feet) and the relative large pitch, resulting in few scoring opportunities per match (Maneiro et al., 2019; Vilar et al., 2013).

According to its importance, there are first studies that analysed defensive play. Most of them focussed on the characteristics of ball recoveries (e.g. zones or type of ball recoveries) (Almeida et al., 2014; Barreira et al., 2014; Santos et al., 2017). In contrast, Grehaigne et al. (2002) analysed not solely the situation of a ball recovery but also focussed on the defensive behavior that lead to ball recoveries. They found that, to regain the ball, the defense should be in a block between the attacker and their own goal, in numerical superiority, and the defenders should have a higher velocity compared to the ball leading or receiving attacker. Low et al. (2021) investigated the collective defending behavior of two different defending formations (4-4-2 & 5-3-2) in an experimental approach calculating the dispersion, width, length of the team, and inter-line distances. They were able to show that 5-3-2 has a smaller team dispersion and inter-line distances and therefore is a more conservative defending formation. Next to the analysis of different defensive formations, Fernandez-Navarro et al. (2016) analysed defensive (& offensive) playing styles using the pitch zone of the achieved ball gains in defense amongst other variables. In another study, Low et al. (2021) also assessed defensive playing styles. Using an experimental approach, they compared two defending playing styles (high pressing & deep defending) using the performance indicators team dispersion, width, length, inter-team distance, trial duration, distance to nearest opponent, space control gain, and individual area. They could show that high pressing is more demanding compared to deep defending.

Furthermore, defensive tactics like the above stated high-intensity pressing (during the defensive playing phase), counter-pressing (during the defensive transition phase) to regain the ball as starting point for fast counter attacking (during the offensive transition phase) (Harper et al., 2021; Nassis et al., 2020) are considered the most important tactical concepts in how the defensive game will be played in the future.

As these concepts illustrate, (defensive) pressure is generally associated with defensive performance. Therefore, a suitable starting point for the evaluation of defensive play is the investigation of defensive pressure. Defensive pressure is defined as spatial pressure that a defending player exerts on an attacking player to prevent the actions the attacker is able to make. Defensive pressure is a substantial part of defending (Andrienko et al., 2017; Link et al., 2016) and offers the possibility to analyze single players and actions.

There have been first rudimental approaches to measure defensive pressure in recent years. While Tenga et al. (2010b) used a notational approach that solely differentiates between loose, mixed, and tight pressure, Fernandez-Navarro et al. (2019) used the distance between the player in ball possession to the nearest defender to quantify defensive pressure. Tenga et al. (2010b) could show that significantly fewer goals were scored against a “tight” defensive pressure (6.2 [%]) compared to “mixed” (13.3 [%]) or “loose” pressure (7.4 [%]). In contrast, Fernadez-Navarro et al. (2019) solely revealed differences in the exertion of pressure depending on the playing style without providing results about the effectiveness of different pressing behavior of defending players.

Therefore, those approaches did not adequately quantify defensive pressure in detail and to a comparable scale.

In comparison, Andrienko et al. (2017) introduced a more sophisticated metric to analyze defensive pressure using the distance, the angle, and the orientation between defenders and the attackers. While this study only exemplarily showed the validity of this metric using a small sample size (4 matches), Herold et al. (2022) recently validated this measurement approach to quantify defensive pressure by comparing match scenes selected by experts based on a detected pressure change (e.g. break away from the opponent by changing direction) to the results of the pressure measurement approach.

To this day, Andrienko and colleagues’ pressure metric was used in several other investigations primarily evaluating offensive play. Radke et al. (2021) used this approach to analyze puck possessions in Ice Hockey and Goes et al. (2021) used it to analyze passing effectiveness in soccer. Moreover, other defensive pressure computations were used to evaluate passing (Szczepanski & McHale, 2016) and the danger of an attack (Link et al., 2016). All these investigations analyzed offensive play and used defensive pressure as an opponent interaction in order to rate the quality of an attack.

However, investigations of defensive pressure to evaluate defensive play are still pending (Forcher, Altmann, Forcher, Jekauc, et al., 2022). Furthermore, the detailed characteristics (where, when, and how) of successful defensive pressure remain unknown so far.

In general, the knowledge about space and time patterns of specific performance variables in soccer are low, due to a lack of analyses at a possession level compared to match level (Low et al., 2020). Most analyses at a match level fail to portray the complex nature of soccer by providing solely cumulative metrics of a whole match, thereby missing effects of single possessions or single actions (Dufour et al., 2017; Lepschy et al., 2020). In contrast, analyses at a possession level investigate consecutive actions or the time course of single possessions. They consider the high variability of single possessions in soccer as every single possession looks considerably different due to the use of the foot to control the ball causing a high rate of technical errors. Hence, those analyses can reveal insights about interactions and key findings on a more fine-grained level. Those specific and detailed results enable coaches, players and managers to make the right decisions on more informative metrics.

Furthermore, the analysis of tracking data enables more time-efficient, and in-depth analyses (Goes et al., 2019; Power et al., 2017), e.g. taking the complex interactions between opposing teams into account (Folgado et al., 2018; Frencken et al., 2012). The opportunity to take the exact positions of all players and the ball into account to analyze specific events (e.g. passes) make more detailed analyses possible.

Therefore, the aim of this study is to analyze the characteristics of successful defending at a possession level by analyzing the space (where) and time (when) characteristics of defensive pressure using tracking data. Our main hypothesis was that successful defensive plays show higher defensive pressure compared to unsuccessful defensive plays.

5.4 Methods

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the local ethics committee (Human and Business Sciences Institute, Saarland University, Germany, identification number: 22-02, 10 January 2022).

5.4.1 Data

We used an observational study design, analyzing tracking data and event data of 153 matches of the 2020/21 season of German Bundesliga (all matches of the second half of this season after the winter break). The tracking data composed the positions of all 22 players and the ball recorded by a semi-automatic optical tracking system (TRACAB, ChyronHego, Melville, NY, USA) that measures the X- and Y-coordinates of all players and the ball with a sampling frequency of 25 Hz. This multicamera tracking system was found to be a valid technology for soccer specific performance analyses (Linke et al., 2020).

The associated event data was manually collected by Sportec Solutions (Sportec Solutions AG, Ismaning, Germany) on basis of the definition catalog of the German Soccer League (DFL) (DFL, 2014).

Both tracking data and event data were imported in Python 3.8 and data processing, data analyses, and data visualization were conducted using the NumPy, Pandas, Math, and Matplotlib libraries.

5.4.2 Synchronization

Due to the manual event tagging by the official data provider of the German Bundesliga (Sportec Solutions AG, Ismaning, Germany) on basis of the definition catalog of the German Soccer League (DFL) (DFL, 2014), a synchronization of events with tracking data was essential to effectively combine both data types. Before the actual data analysis, we therefore identified the matching time-point (frame) of tracking data for every event (pass, tackling, etc.) of the event data using an algorithmn.

5.4.3 Success of Defensive Plays

All ball possessions of both teams were identified using the event data. A ball possession started with a team starting a ball possession (e.g. throw-in) or gaining control over the ball (e.g. after a pass interception) and ended whenever the opponent gained control over the ball again, there was a stoppage of play (foul, offside, goal, final whistle), or the ball went out of play (ball out of bounds) (Goes et al., 2018). To investigate the characteristics of defensive pressure, we focussed on deliberate possessions only (possessions in which several deliberate actions were conducted). Therefore, based on previous studies, we selected possessions with a minimum duration of 5 seconds and a minimum of three consecutive passes (Forcher et al., 2021).

To differentiate between successful and unsuccessful defensive plays, we used the attacking outcome of an opponents' attack. The ultimate goal of defensive play, besides defending the own goal, is to gain the ball possession. Therefore, and in accordance with other investigations of defensive play (Bartlett et al., 2012; Matsuoka et al., 2020), we classified possessions as successful defensive plays that ended in a ball gain of the defending team (1. Ball claiming, 2. Tackling with possession change). All other possessions that did not end in a ball gain were classified as unsuccessful (e.g., possessions that ended in a shot on goal of the attacking team, that ended with the ball going out of play, and that ended in a stoppage of play like a foul, offside, or the final whistle).

5.4.4 Defensive Pressure

To quantify defensive pressure we used an improved defensive pressure model of Herold et al. (2022) that is based on Andrienko and colleagues' pressure model (Andrienko et al., 2017) that was used in several studies (Goes, Schwarz, et al., 2021; Radke et al., 2021). The basis of the model is an elliptical (pressure) area around the attacking player (see Equation (1) & (2)). This elliptical area is shaped around the attacker who is oriented to a threat direction (see figure 5.1). The threat direction describes the orientation of the ellipse, which is always oriented towards the goal of the defending team. The outer boundary of this area is the closest behind the attacker (opposite direction of the threat direction, Dback) and is the farthest away in front of the attacker (exact direction of the threat direction, Dfront). This shape is justified by the difficulty of exerting pressure on the attacker when the defender is placed behind him.

According to the updated model of Herold et al. (2022), the size of the elliptical pressure area decreases with the decreasing distance from the attacker to the defendants' goal (GoalDis, see Equation (3). Additionally, the reduction of the size of the pressure area is accelerated in case an attacker enters the penalty box (see GoalDis). This improved model is based on the idea that the closer the ball gets to the goal, the closer a defender has to be to an attacker to deny space for shooting or passing actions, which is especially true for on ball actions in the penalty area. This updated approach was recently validated by Herold et al. (2022).

Defensive pressure increases from 0% to 100%, the closer a defender gets to the attacker inside this defined pressure area (with distance = d) and depending on the angle between them (see Equation (3)). We determined the speed of pressure increase (from 0 [%] to 100 [%]) inside the defined pressure area with q = 1.75 (see Equation (5)). This value was validated with expert judgements and real data experiments in a previous study by Andrienko et al. (2017). Moreover, we determined the threat direction as the direction between the attacking player and the middle of the attacked goal. A visualization of the described quantification is depicted in figure 5.1.

(1) $L = D_{back} + (D_{front} - D_{back}) (z^3 + 0.3z) /1.3$

(2) $z = (1 - \cos \alpha) /2$

(3) $D_{front} = 9 - 0.05 * (105 - GoalDis)$

(4) $D_{back} = D_{front} * (1/3)$

(5) $Pr = (1 - d/L)^q * 100$ [%]

L ≙ Shape of the pressure area

α ≙ Angle between defender and attacker

D_{front} ≙ Length of pressure area in front of attacker (in threat direction)

D_{back} ≙ Length of pressure area behind attacker (in opposite direction to threat direction)

GoalDis ≙ Distance of the player in ball possession to the goal, if attacker enters penalty box (GoalDis = GoalDis/2) to further decrease the pressure area)

Pr ≙ Pressure value in [%]

d ≙ Distance from defender to attacker

q ≙ Speed of pressure increase from 0 to 100 [%] inside the pressure area

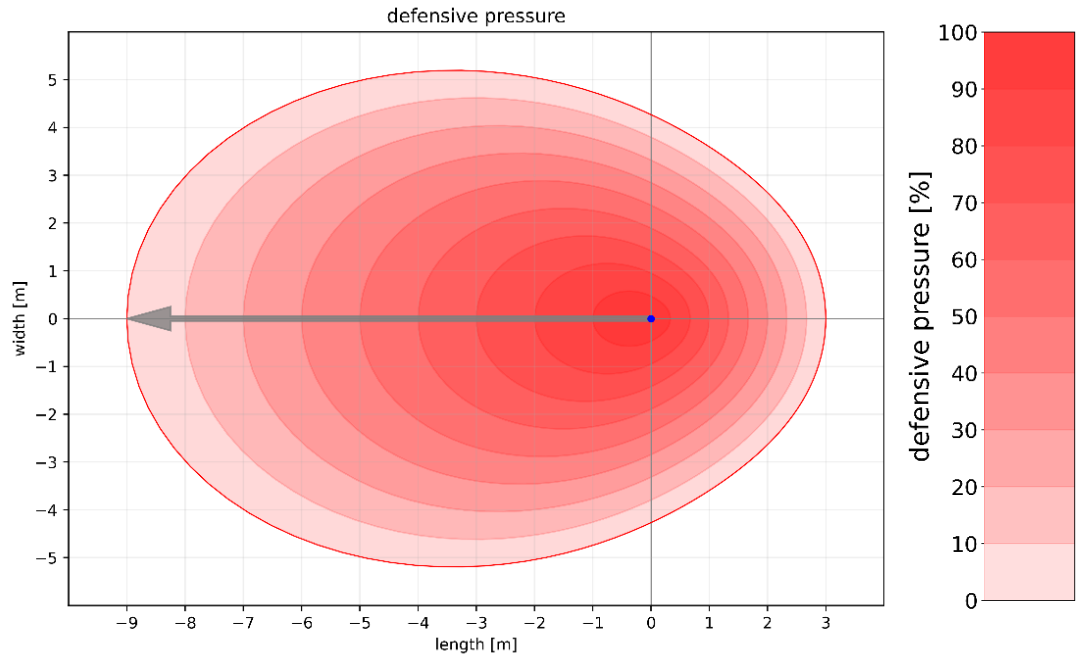

Figure 5.1: Defensive pressure quantification (at GoalDis = 105 [m], resulting in D_{front} = 9 [m] and D_{back}= 3 [m]) with threat direction (grey arrow) and elliptical pressure area around the attacker (blue point) with rising pressure values from 0-100 [%] (red).

To investigate the characteristics (time & space) of defensive pressure we used the described pressure quantification as follows. To apply for the space characteristics of defensive pressure we calculated the defensive pressure on the ball (pressure on the ball-carrying player), defensive pressure on the group (mean pressure on the five attackers closest to the ball), and defensive

pressure on the team (mean pressure on the whole attacking team). To account for the time characteristics of defensive pressure, we quantified the described pressure metrics for every second of the last 10 seconds of an attack.

5.4.5 Statistics

A linear mixed model (LMM) with defensive pressure as dependent variable was conducted using the statsmodels library in Python 3.8.

We applied a general modelling strategy according to previous investigations (Fernandez-Navarro et al., 2018), where we started with the simplest model and stepwise added fixed and random effects to gradually increase the complexity of the model. Therefore, we started with an intercept only model, where only the dependent variable was considered. Afterwards, we added additional fixed (e.g. success of defensive play) and random effects (e.g. random intercept for possessions) to the model to increase model complexity. We deducted the model comparison after each increase of model complexity using the Akaike information criterion (AIC), with lower values representing a better model (Akaike, 1998). Consequently, the final model was chosen according to lower values of AIC and significant effect of variables. For model fitting we used restricted maximum likelihood (REML) estimation. The level of significance was set to $p < 0.05$.

To statistically examine the influence of success of defensive play and the space and time characteristics of defensive pressure on the magnitude of defensive pressure, success of defensive play (successful/unsuccessful), space (pressure on the ball/pressure on the group/pressure on the team), and time (repeated measure: 11 measurement time-points of the last 10 seconds of a defensive play) were used as fixed effects.

The grouping variable possession was considered as a random effect, allowing a random intercept for every single possession in the data set. Furthermore, a random effect of time was used to allow a random slope over the 11 time-points for every possession.

Additionally, the longitudinal field position of the ball-carrier (x-position in [m]) was used as co-variable, with x-position of 0 representing the longitudinal positions on the defending team's goal line (close to the goal) and x-position of 105 representing the longitudinal position on the attacking team's goal line (far away from the goal). This co-variable was applied because tactical patterns are dependent on the field position and it is expected that more pressure is put on players when the ball is close to the defendants' goal (small value of x-position) compared to situations where the ball is far away (large value of x-position) from the defendants' goal.

5.5 Results

Within the 153 included matches a total of 16,151 deliberate plays were observed. Thereof, 2,599 (16.1 [%]) plays were classified as successful defensive plays (with ball gain), with a mean duration of 21.70 (± 13.15) seconds and allowing an average of 6.44 (± 3.90) opponents' passes. In comparison, 13,552 (83.9 [%]) plays were classified as unsuccessful defensive plays (no ball gain) with a shorter average duration of 19.78 (± 13.34) seconds and 6.60 (± 4.17) allowed passes of the opponent.

The results of the linear mixed model with defensive pressure as dependent variable are depicted in table 5.1. The results of defensive pressure characteristics are depicted in figure 5.2.

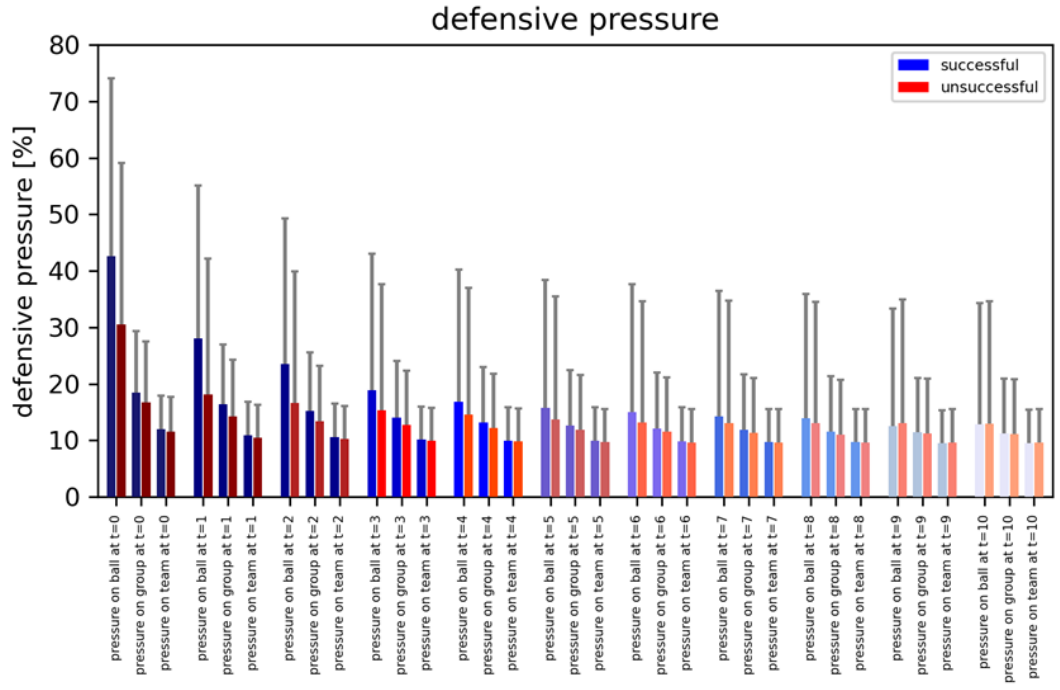

Figure 5.2: Mean and standard deviation of defensive pressure for successful defensive plays (blue) and unsuccessful defensive plays (red) at the measurement time-points (time characteristics) from right to left (with t=0 being the end of a defensive play) and distinguished between the pressure on the ball, on the group, and on the team (space characteristics).

5.5.1 Success of defensive play

Successful defensive plays showed higher average defensive pressure (14.47 ± 16.82 [%]) compared to unsuccessful defensive plays (12.87 ± 15.31[%]). Accordingly, in the linear mixed model unsuccessful defensive plays had a significant negative effect ($\beta = -8.39$, $p < 0.001$) on defensive pressure as dependent variable.

5.5.2 Time Characteristics

The average defensive pressure peaked at the end of a defensive play (t=0, 20.37 ± 20.42 [%]) and became gradually smaller from 1 to 5 seconds before the end of a defensive play (t=1, 14.94 ± 16.30 [%]; t=2, 13.92 ± 15.56 [%]; t=3, 12.96 ± 14.81 [%]; t=4, 12.37 ± 14.70 [%]). However, the average defensive pressure levelled off at between 11 [%] and 12 [%] from 5 to 10 seconds before the end of a defensive play (t=5, 11.92 ± 14.36 [%]; t=6, 11.61 ± 14.21 [%]; t=7, 11.46 ± 14.22 [%]; t=8, 11.31 ± 14.24 [%]; t=9, 11.30 ± 14.19 [%]; t=10, 11.21 ± 14.18 [%]).
Accordingly, the linear mixed model shows a significant negative effect of time ($\beta = -1.95$, $p < 0.001$) which indicates the decrease of defensive pressure with measurement time-points further away from the end of a defensive play.

5.5.3 Space Characteristics (defensive pressure on the ball, on the group, & on the team)

In relation to space, it can be observed that the average defensive pressure on the ball was the highest (16.61 ± 23.89 [%]) compared to defensive pressure on the group (12.75 ± 10.01 [%]). Average defensive pressure on the team was comparatively the lowest (10.03 ± 5.94 [%]). In accordance, the linear mixed model showed a significant negative effect for defensive pressure on the group ($\beta = -14.17$, $p < 0.001$) and a larger significant negative effect for defensive pressure on the team ($\beta = -19.80$, $p < 0.001$).

5.5.4 Interactions

Both triple interactions (Success*Time*Space) showed significant negative weights ($-0.95 < \beta < -1.10$, $p < 0.001$), indicating that defensive pressure is smaller in unsuccessful defensive plays (compared to successful defensive plays), the further away the measurement time-point is to the end of a defensive play, and the further away the measurement is to the ball.
In contrast, all dual interactions (Success*Time, Success*Space, & Time*Space) showed smaller significant positive weights ($1.06 < \beta < 8.89$, $p < 0.001$).

5.5.5 Longitudinal Field Position (co-variable)

The longitudinal field position of the ball-carrier contributes significantly to the modelling of defensive pressure, showing a negative weight ($\beta = -0.12$, $p < 0.001$). Accordingly, defensive pressure increases with smaller distances from the ball-carrier to the goal line of the defendants' goal.

Table 5.1: Results of the linear mixed model with defensive pressure as dependent variable. The coefficients of the effects (β), the standard error (SE), the 95 [%] confidence interval and the z- and according p-values are presented. Further, it is distinguished between fixed effects (success of defensive play, time characteristics, space characteristics, & x-position of ball-carrier) their interactions, and random effects (random intercept for every possession, random slope over the 11 measurement time-points).

	β	SE	95 [%] CI		z	p
fixed effects						
Intercept	35.1	0.26	34.59	35.6	135.13	<0.001
Success (unsuccessful)	-8.39	0.27	-8.92	-7.85	-30.69	<0.001
Time	-1.95	0.04	-2.03	-1.87	-49.19	<0.001
Space (pressure on the group)	-14.17	0.21	-14.59	-13.76	-66.83	<0.001
Space (pressure on the team)	-19.8	0.21	-20.21	-19.38	-93.34	<0.001
X-Position	-0.12	0.01	-0.13	-0.12	-58.18	<0.001
fixed effects (interactions)						
Success (unsuccessful)*Time	1.06	0.04	0.97	1.14	24.64	<0.001
Success (unsuccessful)*Space (pressure on the group)	7.38	0.23	6.92	7.83	31.81	<0.001
Success (unsuccessful)*Space (pressure on the team)	8.89	0.23	8.44	9.34	38.35	<0.001
Time*Space (pressure on the group)	1.66	0.04	1.59	1.73	45.25	<0.001
Time*Space (pressure on the team)	2.12	0.04	2.05	2.19	57.96	<0.001
Success (unsuccessful)*Time*Space (pressure on the group)	-0.95	0.04	-1.03	-0.87	-23.62	<0.001
Success (unsuccessful)*Time*Space (pressure on the team)	-1.1	0.04	-1.17	-1.02	-27.3	<0.001
random effects						
Possessions (random intercept)	99.9	0.11				
Time (random slope)	2.14	0.01				
R^2	0.24					

5.6 Discussion

The aim of the current study was to investigate the characteristics of successful defending in soccer by exploring the space and time characteristics of defensive pressure at a possession level. This is the first study that analyzes the detailed characteristics (space & time) of defensive pressure over the course of a possession. Overall, the results indicate that defensive pressure is higher in successful defensive plays compared to unsuccessful defensive plays. Further, the investigated characteristics of defensive pressure indicate that defensive pressure increases during the course of a defensive play and is higher in areas closer to the ball.

The general results of this current study are in line with findings of earlier research as, for example, the discovered average duration of defensive playing sequences (≈20 [s]) is comparable to the results of Casal et al. (2016), who found that 89.8 [%] of defensive plays in FIFA World Cup 2010 in South Africa lasted between 0 and 30 seconds. Similarly, Vogelbein et al. (2014) reported that teams need 10 to 14 seconds to recover the ball, assessing data of German Bundesliga season 2010/11. This slightly shorter average durations of defensive plays in this investigation can be traced back to the sharp inclusion criteria of deliberate attacks (minimum of 3 passes & minimum of 5 seconds) in the current study that excluded short possessions. In the same way, the average of about 6.5 allowed opponents' passes in the in the present study are similar to findings of Forcher et al. (Forcher et al., 2021) who identified an average of 5 to 7 passes in successful attacks in Dutch Eredivisie season 2018/19 using the same inclusion criteria for deliberate attacks. Following this argumentation, the general results of defensive plays show that the data used for the current investigation is comparable to other data of other competitions and seasons. Concluding, the following results can be interpreted with a greater generality.

In this context, it is noteworthy that this study did not find differences between the pressure behavior of different teams as the use of teams as nesting group in the linear mixed model did not improve the model. This can also be traced back in the exclusion of short attacks and thereby diminished possible effects of playing styles of different team (Fernandez-Navarro et al., 2019).

The following sections comprise the results regarding the characteristics of success of defensive play in relation to time and space. Our main analysis did confirm our initial hypothesis showing that successful defensive plays show higher defensive pressure compared to unsuccessful defensive plays. This is in line with the findings of Andrienko et al. (2017) who used a similar methodology to measure defensive pressure in four matches of Borussia Dortmund in German Bundesliga 2015/16 season. They showed that the pressure values during successful defensive plays are higher than average pressure values during a whole match (Andrienko et al., 2017). Based on those identified association it can be concluded that higher defensive pressure may increase the chance to (re)gain the ball and accordingly defensive pressure is an important performance indicator of defensive play.

Besides the success also time had a significant influence on defensive pressure. Defensive pressure increases with the course of defensive play and is the highest at the end of a defensive play. However, the descriptive analysis shows that the changes of defensive pressure further away from the end of a defensive play (more than 5 seconds) are marginal (6 [%] increase of pressure from t=10 to t=5, see figure 5.2). Those findings indicate that the rise of defensive pressure leads to the end of a defensive play (70% increase of pressure from t=5 to t=0). However, this could also be interpreted vice-versa: Increasing defensive pressure over a certain threshold (e.g. over 30 [%] of defensive pressure on the ball) leads to the termination of an attack and therefore to the end of a defensive play. In contrast, another explanation for the increase of defensive pressure towards the end of a possession could be that proceeding opposing attacks tend to come closer to the opponent's goal. This could lead to increased pressure due to the accumulation of players in front of their own goal. This relationship of increasing defensive pressure depending on the pitch position is taken into account by the x-position of the attacker which has a small influence on the prediction of the magnitude of defensive pressure, which will be analysed below.

The space characteristic reveals that defensive pressure is higher in areas closer to the ball. Pressure on the ball shows the highest pressure values, followed by pressure on the group, while pressure on the team shows the lowest pressure values. Comparably, Andrienko et al. (2017) found that defensive pressure is higher in areas close to the ball (0-15 [m] from the ball) compared to areas further away from the ball. Accordingly, defensive pressure measured in near ball areas (and especially on the ball-carrier) are important and informative performance indicators. In comparison, defensive pressure on all attacking players (pressure on the team) seems not very insightful.

In the light of the results of the single effects discussed above, the interactions of all three variables (success, time, space) yield the most interesting outcomes of this investigation. The triple interactions (success*time*space) indicate that the closer the measurement time-point is to the end of a defensive play, the closer the measurement is to the ball and in successful defensive plays (compared to unsuccessful) the higher is defensive pressure. Summarizing these found associations, one can conclude that to win the ball, it may be important to pressurize the ball leading player and near ball areas (pressurize attackers close to the ball to cover possible passing options) and increase this pressure towards the end of a defensive play to cause ball gains. Moreover, the longitudinal field position of the ball-carrier (x-position) showed a significant contribution to the LMM. In the measurement methods of defensive pressure, with the pressure area getting smaller around the attacker the closer the attacker proceeds towards the defendants' goal (see 5.4.4 Defensive pressure), this influence was already taken into account. Still, it can be shown that defensive pressure slightly increases with attacker getting closer towards the defendants' goal. This could be due to the accumulation of players in front of their own goal to prevent opposing scoring opportunities which was indicated before. However, the small **β**-value

(-0.12) indicates that this influence is marginal. Especially in the defendant's half of the pitch (x-position < 52.5 [m]) the change of defensive pressure is negligible small (< 6.3 [%]). Therefore, the tactical characteristics of defensive pressure in the defendants' half are not severely dependant on the longitudinal ball position.

After discussing the results of the current investigation, there a several practical applications that can be derived. For practitioners, the revealed associations indicate that for the success of a defensive play it may most important to pressurize the ball-carrier. However, the significant effects of pressure on the group show that it may also important to pressurize possible passing options for the attackers to win the ball. The time characteristic shows practitioners that higher pressure might lead to ball losses of the opponents. Overall, the results indicate that defensive pressure is a valuable key performance indicator for defensive play and, therefore, can help coaches and analysts to evaluate defensive performances (Goes, Meerhoff, et al., 2021; Memmert & Raabe, 2019; Rein & Memmert, 2016).

5.6.1 Limitations and Future Directions

To enable an objective interpretation of the results discussed above, the main strengths and limitations of this study should be noted. The first weakness of this study is the focus on deliberate attacks (minimum of five seconds & three passes). This approach leads to the exclusion of short possessions. Therefore, our findings are only representative for deliberate attacks. However, this procedure of filtering specific attacking types helps to identify meaningful results without mixing and blurring effects. Additionally, the investigation of only one performance indicator of defensive play does not depict all aspects of defending (e.g. compact organization, numerical superiority). For instance, Grehaigne et al. (2002) showed that numerical superiority is important to regain possession in defensive play. A higher numerical superiority could lead to a higher defensive pressure, since more defenders are in close proximity to the attackers. Future investigations about more defensive indicators and their relationships with each other could provide deeper knowledge about the success criterions of defensive play.

Furthermore, one can argue that the use of ball gains as the only success criterion of defensive play is another weakness, because other attacking results (e.g. ball going out of play, offside) could be defined as successful defensive plays as well as they prevent the opponent from scoring. However, this study design was chosen to investigate the ultimate goal of defending to gain the ball.

The disregard of the influence of contextual factors (e.g. playing style, match status, venue, quality of opposition) is another weakness of this study as those factors were shown to influence the characteristics of defensive play (Almeida et al., 2014; Santos et al., 2017). However, this procedure of the exclusion of contextual factors was chosen to provide general knowledge about defensive pressure during defensive play valid for different teams with different playing styles or at different match status. However, further studies should investigate the differences resulting from the influences of the contextual factors to provide scientifically validated findings also for specific individual cases (e.g. playing with a high pressing playing style, at home, and against a strong opponent).

Finally, since this is an exploratory study, no causality of the relationships found can be verified. Therefore, future studies should examine the causality of those associations in confirmation studies.

In contrast, the indication of the importance of defensive pressure by showing the connection to success (higher pressure in defensive plays with ball gain) is a major strength of this study. Furthermore, this study is the first to show defensive pressure characteristics assessing a large sample size (153 matches). Lastly, the approach of performance analysis at a possession level reveals insights on a finer-grained level compared to analyses at match level or season level (Barnes et al., 2014; Bush et al., 2015).

Accordingly, future research should focus on a wider range of aspects of defending and indicate the importance of new performance indicators by using similar study designs with large sample sizes and evaluating their connection to success.

5.7 Conclusion

Overall, this study investigated the characteristics of defensive pressure in connection to the success of a defensive play at a possession level. The results show that defensive pressure is higher in successful defensive plays compared to unsuccessful defensive plays. Therefore, defensive pressure is a valuable key performance indicator for defensive play. Furthermore, our findings suggest that, if the causality of these found associations will be confirmed, it may be important to pressurize both the ball-leading player and ball near areas and to increase this pressure towards the end of a defensive play to gain the ball.

This study introduced new insights into the dependencies of defensive play (defensive pressure in this case) using a large sample size and indicating representative results. By showing the connection of the investigated defensive performance indicator with the success of a defensive play, this study showcases an approach to identify valuable performance indicators of defensive play and indicate their importance in the highly complex team sport soccer.

Chapter 6

Rest Defense (Paper III)

The success factors of rest defense in soccer – A mixed-methods approach of expert interviews, tracking data, and machine learning.

Version of the original research article currently under review

Forcher, L., Forcher, L., Altmann, S., Jekauc, D., & Kempe, M. (2023). The success factors of rest defense in soccer – A mixed-methods approach of expert interviews, tracking data, and machine learning. Under review, 1-20.

6 Rest Defense (Paper III)

6.1 Abstract

While the tactical behavior of soccer players differs between specific phases of play (offensive play, defensive play, offensive transition, defensive transition), little is known about successful behavior of players during defensive transition. Therefore, this study aims to analyze the group tactic of rest defense in defensive transition.
A mixed-methods approach was used, involving both qualitative and quantitative analysis. Semi-structured expert interviews with seven professional soccer coaches were conducted to define rest defense. In the quantitative analysis, several KPIs were calculated, based on tracking and event data of 153 matches of the 2020/21 German Bundesliga season, to predict the success of rest defense situations in a machine learning approach.
The qualitative interviews indicated that rest defense can be defined as the positioning of the deepest defenders during ball possession to prevent an opposing counterattack after a ball loss. The final machine learning model showed satisfactory prediction performance of the success of rest defense (Accuracy: 0.97, Precision: 0.73, f1-Score: 0.64, AUC: 0.60).
Analysis of the individual KPIs revealed insights into successful behavior of players in rest defense, including controlling deep spaces and dangerous counterattackers. The study concludes regaining possession as fast as possible after a ball loss is the most important success factor in defensive transition.

Key words: team sports, performance analysis, tactics, defensive play, football

6.2 Highlights

- Combination of qualitative expert interviews and up-to-date quantitative data analysis using tracking data and machine learning revealed insightful results of successful tactical behavior in defensive transition in soccer.

- According to experts, rest defense can be defined as behavior of the deepest defending players during ball possession with the goal to prevent an opposing counterattack after a ball loss during defensive transition.

- To be successful in defensive transition, players in rest defense should control deep spaces and dangerous counterattackers to successfully prevent dangerous opposing counterattacks.

- Most important success criterion in defensive transition is to regain possession after a ball loss as quickly as possible to stop an opponent's counterattack in the early stages.

6.3 Introduction

In soccer practice it is well known that a single attack can make the difference between victory and defeat. Especially when one team seems to dominate the other, but fails to take the lead, the other team waits for a decisive counterattack after gaining possession. This is why the safeguarding of possible counterattacks plays such a large role in deciding matches, which will be examined in detail in this study.

While soccer performance can be analyzed in the sub-areas of physical, technical, psychological, and tactical performance (Hohmann, 1983; Weineck, 2007), this study will assess the tactical behavior of soccer players in the outlined match situation. In doing so, the increasing amount of data collected, especially during matches, allows to get deeper insights into the complex performance structure in soccer (Forcher, Altmann, Forcher, Jekauc, et al., 2022; Goes, Meerhoff, et al., 2021).

In the context of the growing amount of data being collected, the continuously measured spatio-temporal tracking data of all players on the pitch enables researchers and practitioners to analyze the tactical movement behavior in soccer in particular (Forcher, Altmann, Forcher, Jekauc, et al., 2022; Goes, Meerhoff, et al., 2021).

The tactical behavior of the players differs depending on the playing phase of the match and their respective goals. Accordingly, the match situations can be divided into four distinct playing phases (offensive play, defensive play, defensive transition, offensive transition) which occur in sequence depending on the course of the game (Fernandez-Navarro, 2018; Hewitt et al., 2016). In offensive play, a team controls the ball with the goal of attacking the opponent's goal to eventually score. In defensive play, a team organizes itself to prevent the opposing team in ball possession from scoring and, in the best case, to regain the ball. The transition phases describe the switch between offensive and defensive playing phases after losing the ball (defensive transition) or gaining the ball (offensive transition). Consequently, there are differences in behavior of players depending on the playing phase of the match, which should be taken into account when analyzing tactical performance.

Compared to the other playing phases, offensive play has recently received the most attention from practitioners, the media, and soccer research. In detail, studies have predominantly investigated offensive on-the-ball actions such as shots (Anzer & Bauer, 2021; Lucey et al., 2015; Rathke, 2017) or passes (Chawla et al., 2017; Power et al., 2017; Szczepanski & McHale, 2016). However, tracking data is particularly valuable for analyzing defensive play, as players' behavior off the ball is recorded and can thus be analyzed. Furthermore, defensive play has been revealed to be at least as important for a team's success as offensive play (Georgievski et al., 2019; Lepschy et al., 2021). Consequently, the number of studies analyzing defensive play has increased (Forcher, Altmann, Forcher, Jekauc, et al., 2022). For instance, defensive pressure has been assessed to analyze defensive play (Bojinov & Bornn, 2016; Forcher, Forcher,

Altmann, Jekauc, et al., 2022; Merckx et al., 2021).

Next to offensive and defensive playing phases, the transition playing phases have been shown to be highly important for success in soccer. Several studies have indicated that short transitions after a ball gain/ball loss have the greatest probability to end in a scored/conceded goal (Gonzalez-Rodenas et al., 2015; Lago-Ballesteros et al., 2012; Tenga et al., 2010b). One reason for these effects is the increased vulnerability of an unbalanced defense after losing the ball (Gonzalez-Rodenas et al., 2015; Tenga et al., 2010b).

As most studies focussed on the offensive transition there is little research about the defensive transition playing phase. Therefore, this study investigates the players' behavior in defensive transition.

Defensive transition describes the behavior of players after losing the ball to restore the defensive organization and thus reach the defensive phase of the match (Bauer & Anzer, 2021). The main goal of this playing phase is to prevent an opponent's counterattack by securing dangerous pitch areas and, if possible, to achieve a direct regain of the ball by increasing the defensive pressure in ball proximity (DFB-Akademie, 2022). While the defensive behavior of high pressure in close ball proximity after a ball loss is known as counter-pressing (Bauer & Anzer, 2021; Fernandez-Navarro, 2018), the behavior of players behind the ball protecting dangerous pitch areas is often referred to as rest defense (DFB-Akademie, 2022).

As stated earlier, there has been little research on defensive transition in soccer. Nevertheless, two studies have examined defensive transitions in general (Casal et al., 2016; Vogelbein et al., 2014) and one study investigated the specific group tactical behavior of counter-pressing (Bauer & Anzer, 2021). Vogelbein et al. (2014) analyzed the time it took for a defending team to recover a ball (so-called defensive reaction time) in 306 German Bundesliga matches. They found that top teams recovered the ball faster in defensive transition compared to other teams. Similarly, Casal et al. (2016) showed that the duration of the defensive transition is a valuable key performance indicator for defensive transition. In detail, they predicted the success of the defensive transitions of eight matches of UEFA World Cup 2010 using a notational approach (Casal et al., 2016). Concluding, while these studies provide some initial approaches to analyze defensive transitions, their methodological approach does not allow for a detailed analysis of the tactical behavior of defending players (e.g. specific pressing behavior of defending players).

In contrast, approaching defensive transition in more detail, Bauer and Anzer (2021) automatically identified counter-pressing situations and identified crucial variables for the effectiveness of defensive transitions by analyzing over 4000 matches of the German Bundesliga. For instance, their results revealed that having four or more players behind the ball is important to the success of a defensive transition. This study is a great example of how the use of player tracking data to get insights into the tactical behavior of players during the defensive transition phase and on the specific group-level counter-pressing in areas close to the ball.

Overall, the detailed knowledge of player behavior in defensive transition is still limited. Especially, none of the abovementioned studies analyzed the group tactical behavior of the players that are not in ball proximity with the task to save their own goal by controlling dangerous areas to deny fast counterattacks. As mentioned above, this tactical principle can be referred to as rest defense in practice. However, there is no generally accepted definition of rest defense in soccer. Accordingly, the aims of this study are (i) to define rest defense as tactical behavior at a group level and (ii) to identify crucial variables (tactical measures) that are important for the success of the defensive transition phase regarding rest defense.

To achieve this goal, we will use a mixed-methods approach via interviews and an observational study. Using expert interviews, we aim to establish a clear definition of the term rest defense and variables that characterize it. In a second step, we will use this information to analyze data of professional soccer matches to identify the determinants of successful rest defense using state-of-the-art analytics (tracking data and machine learning).

6.4 Expert Interview

6.4.1 Methods

This expert interview was conducted according to the guidelines of the Declaration of Helsinki and approved by the local ethics committee (Karlsruhe Institute of Technology, Germany, 21. January 2022).

6.4.1.1 Participants

Seven professional soccer coaches were interviewed as experts. They were included according to the following inclusion criteria. To be included in this study, experts had to:
(1) have at least four years of practical experience in a professional soccer club (first division or national team) as a head coach, assistant coach, or match analyst,
(2) hold a UEFA soccer coaching license (at least a UEFA B license),
(3) and work as a coach at the time of the interview or have worked as a coach within the last year.
On average, the considered experts were 36.48 (± 4.48) years old and in sum had 74.75 years of coaching experience in a professional soccer club. Three experts held a UEFA B- or A-license, respectively, and one expert held a UEFA Pro license.
For the recruitment of the experts, the authors' contacts to German Bundesliga clubs and the German Football Association (DFB) were used to contact the experts directly. Of the eight contacted experts, one dropped out.
Theoretical sampling was used. Accordingly, the sample size was determined based on the knowledge gained by the inclusion of additional participants (Blöbaum et al., 2014). Therefore, we stopped expanding the sample when we could no longer expect to gain additional information.

6.4.1.2 Procedures

To gain information about rest defense, we used a semi-structured expert interview. The guideline for the interview was developed by the main author (LeaF) according to Blöbaum et al. (2014) and Helfferich et al. (2019). The guideline was then discussed with the four co-authors (LeoF, SA, MK, DJ) and adapted if deemed necessary. Finally, the guideline consisted of:
(1) basic personal information request before the start of the interview,
(2) one icebreaker question at the start of the interview,
(3) three entry-level questions about rest defense in general,
(4) and eight questions about detailed information on rest defense (e.g. goals, characteristics, success) (please see appendix 1).
Prior to the interview, each participant was provided with a privacy policy document and

participant information regarding the procedures of this study and was then asked to provide informed consent. The interviews were conducted in individual one-to-one conversations and were conducted online via video call or in person. The interviewer remained the same for each expert interview, which lasted on average 15.45 (± 1.56) minutes.

6.4.1.3 Analysis

The interviews were audio recorded. Afterward, since the goal of expert interviews was to collect objective information, the interviews were transcribed using the following procedures (Blöbaum et al., 2014):
(1) Conversation pauses, body language or other non-verbal signals were not documented,
(2) the interview was grammatically corrected (e.g. dialect),
(3) and sentences were summarized according to the meaning structure of the statement (e.g. repetitions in direct succession are not reported) and put into grammatically correct order.
A qualitative content analysis according to Mayring was conducted on the basis of the transcripts (Mayring, 2022). This approach integrates quantitative and qualitative analysis methods. First, deductive categories are built according to the topics of the interview (e.g. goals of rest defense). Next, as the largest unit of analysis, the answer to a question was determined. Afterwards, inductive subcategories were formed based on the analysis units and according to the deductive categories. In the end, all analysis steps were summarized in a reduction table including the number of the interview, page, line, question, category (deductive), and subcategory (inductive) (please see appendix 2). This table was then used to count the frequencies of a certain subcategories in each category.

6.4.2 Results

The results of the expert interviews are presented in table 6.1.
According to the experts, the goal of rest defense is to prevent opponent's counterattacks by securing dangerous areas (e.g. deep areas) or controlling dangerous attackers and to regain the ball. Players proceed into the rest defense when they no longer have tasks in the attack. This happens, for example, in match situations where the ball is controlled in the attacking third or when the defending midfielder-line is overplayed. Accordingly, the players in rest defense position themselves during the attack (i.e. offensive play). However, rest defense only comes into play when the ball is lost and the team is in defensive transition.
Which players are involved in rest defense depends on the tactical formation (e.g. 3-4-3), the opponent (e.g. number of strikers of the opposing team), and the match situation (e.g. ball position). In general, the central defenders, wide defenders (both also referred to as defensive-line), and central midfielders are most often involved in rest defense.
The most stated tactical approach of rest defense was man-to-man defense. The majority situations (+1 & +2 majority) were also identified, with the differentiation of the tactical approach

(sandwich: defenders in front and behind the attacker, flat: all defenders behind the attacker).

Table 6.1: Results of expert interviews.

Category	Subcategory	Quantity
Goal of rest defense	Prevent opposing counterattacks	5
	Safe deep areas	4
	Regain of the ball	4
	Control dangerous players for counterattack	3
	Enable counter-pressing	2
	Safe own goal	1
	Prevent opposing scoring opportunity	1
	Safe dangerous areas	1
	Safe areas far from the ball (weakside)	1
	Slow down opposing counterattack	1
Playing phase of rest defense	Offensive play (in ball possession) - after the midfielder line is overplayed & players do not longer have a task in attacking play - when ball is in opposing attacking third and players are no pass option - when the ball is on opposing half or opposing attacking third - when the ball is not in the last line or ball is in attacking third	7 (2) (2) (1) (1)
	Defensive transition - after a ball loss - until the opposing attack is finished (e.g. ball out of play, shot on goal) - until the first pass of the opposing team after the ball loss	7 (5) (1) (1)
Players involved in rest defense	Dependencies: - Dependent on the match situation (e.g. ball position) - Dependent on the opponent - Dependent on the tactical formation	 3 2 2
	Tactical position/role: - Central defenders - Central midfielder - Wide defender (on the weakside) (solely with a back four formation) - Goalkeeper	 7 7 7 (3) (1) 2
	Defensive line	4
	Penultimate line	1
	All players not involved in offensive play	1
	4 players	1
Tactics of rest defense	Man-to-man coverage	7
	+1 majority: - sandwich - flat	6 (4) (2)
	+2 majority	2
	Space defending: 3+1 (diamond)	2
	Space defending: 2+3 (trapezium)	1
	-1 (outnumbered)	1

Successful/unsuccessful rest defense (outcome)	Best: - Ball regain	 7
	Good: - Ball out of play - Delay counterattack - Foul (in harmless situation (e.g. opposing half))	 4 4 2 (1)
	Okay: - Foul - Opposing switch of attacking side - Stop opposing attack	 3 1 1
	Worst: - Opposing scoring opportunity - Opposing goal - Being overplayed - Successful opposing deep pass on the deepest attacker	 5 3 1 1

6.5 Observational Study

6.5.1 Methods

This data analysis was conducted according to the guidelines of the Declaration of Helsinki and approved by the local ethics committee (Human and Business Sciences Institute, Saarland University, Germany, identification number: 22–02, 10 January 2022).

6.5.1.1 Data

An observational study design (post-event) was used for this analysis. Tracking and event data from 153 matches of the 2020/21 German Bundesliga season were analyzed.
The tracking data include the positions of all 22 players on the pitch and the ball. The X- and Y-coordinates are tracked by a semi-automatic multi-camera tracking system (TRACAB, Chyron-Hego, Melville, NY, USA) with a sampling frequency of 25 Hz. Recently, this technology was found to be valid for the analysis of soccer-specific performance (Linke et al., 2020).
The event data are annotated based on the official match data catalog of the German Soccer League (DFL) (DFL, 2014) by Sportec Solutions (Sportec Solutions AG, Ismaning, Germany). This catalog defines over 30 events with more than 100 attributes (Bauer & Anzer, 2021).

6.5.1.2 Data processing

All data processing, visualization, and statistical analysis were performed in Python 3.8 using the NumPy, Pandas, Math, Matplotlib, SciPy, SHAP, and scikit-learn libraries.
First, the tracking and event data were synchronized. Due to inaccuracies in the manual annotation of event data the timestamps and origins of events vary from the tracking data. To effectively combine both types of data, we used a synchronization algorithm that has been shown to provide high accuracy in matching the events of event data with the exact time frame of tracking data (Forcher, Forcher, Altmann, et al., 2023).
Second, the tactical formation of a team (e.g. 4-4-2) and the individual tactical positions of players (e.g. central defender, wide midfielder) were identified. For the tactical formation, offensive and defensive formations were differentiated depending on the ball possession of the teams (Bialkowski et al., 2016). Further, we defined the tactical formation for three time windows: first half (0-45 [min]), first interval of second half (45-62.5 [min]), and second interval of second half (62.5-90 [min]). Those time windows were used to account for in-game formation changes. It has been shown that 95 [%] of in-game formation changes during the match occurred in the second half (Forcher, Preine, Forcher, Wäsche, et al., 2022). Overall, following this procedure we collected six formations per team per match. We used a formation descriptor based on a KMeans clustering algorithm to cluster the mean longitudinal x-positions of outfield players (excluding the goalkeeper) for the considered time window (e.g. in ball possession and first half)

into three formation lines (e.g. 4-3-3) (Goes, Brink, et al., 2021). To define the tactical position, we used the vertical y-positions of players to discriminate between wide and central positions resulting in the following seven possible tactical positions (goalkeeper, central/wide defender, central/wide midfielder, central/wide striker).

6.5.1.3 Rest Defense Situations & Success

To identify rest defense situations, we used the information from the expert interviews (see section 6.4 Expert Interview). Accordingly, we identified ball possession changes while the ball stayed in play and the ball-gaining team had a minimum of one intentional action on the ball using the event data. This procedure was chosen to exclude unintentional ball possessions by the ball-gaining team (such as ball deflections) where no rest defense match situation occurs. Furthermore, we focused on ball possession changes in the opposing attacking third when the opposing midfielder-line was overplayed (using the mean x-position of the midfielder-line & the x-position of the ball) utilizing the tracking data (see section 6.4.2 Results: Playing phase of rest defense).

To assess rest defense we considered all players (attackers and defenders) located in the area ten meters in front of the defender closest to the own goal line (see figure 6.1).

Furthermore, to define the success of a defensive transition situation we applied the results of the expert interview (please see section 6.4.2 Results: Successful/unsuccessful rest defense (outcome)). In detail, to focus on the effects of defensive transition, we considered only opposing ball possessions after a considered change of possession with a maximum duration of twelve seconds (Bauer & Anzer, 2021). Accordingly, successful rest defense situations were defined as a ball regain in the following twelve seconds after the identified ball loss. Unsuccessful rest defense situations were defined as an opposing shot on goal in the following twelve seconds after an identified ball loss. All other results of an opposing counterattack (e.g. ball out of play, stoppage of play) were not considered, because according to the expert interview they could not be clearly assigned to either successful or unsuccessful rest defense.

6.5.1.4 Variables

All variables used to analyze the rest defense situation were measured in the identified moment of a considered ball possession change. This moment of a ball loss was identified as the most important situation of rest defending behavior, as it characterizes the change from the offensive playing phase to the defensive transition. Both of which were indicated in the expert interviews as defining phases of the rest defense (see expert-interview: Playing phase of rest defense).

First, the tactical positions of players in the considered area of rest defense (ten meters in front of the deepest defender, see figure 6.1) were considered. This procedure was conducted to investigate whether this approach identified the players with the tactical position, which was also indicated by the experts in the expert interviews (see expert-interview: Players involved in rest defense).

Second, the number of defenders, the number of attackers, and the numerical superiority of the defending team in the defined rest defense area were analysed.

Third, the marking of attackers in this area was analyzed.

Thereby, the defensive pressure on attackers (mean, min) was measured from 0-100 [%] using a pressure model of Andrienko et al. (2017) that was expanded by Herold et al. (2022). Further, the closest distance of the defenders to the attackers [m] (mean, max) was determined.

Fourth, the spatial formation of the rest defending players (defenders in the area of rest defense) was measured using the surface area [m2] (area of the convex hull) (Moura et al., 2012), the width and length of the surface area [m], and spread [m] (square root of the sum of squared standard deviation from their average position (centroid)) (Bartlett et al., 2012; Bourbousson et al., 2010) (see figure 6.1).

Fifth, the height of the rest defense was computed by calculating the distance of the deepest defender to the team's own goal-line [m].

Sixth, the space control of both teams from the area of rest defense to the defendants' goal line was calculated using Voronoi diagrams (absolute [m2] & relative [%]) (see figure 6.1).

Finally, the duration of the rest defending situation (defensive transition), the number of passes, and the number of actions (e.g. tacklings) of the opponent's counterattack were measured.

6.5.1.5 Statistics

We deployed several classifiers to best solve our binary problem (successful vs unsuccessful) to predict the success of a rest defense situation (defensive transition). Accordingly, we used logistic regression (ridge regression, elastic net regularization), Random Forest Classifier, Gradient Boosting, XGBoost Classifier, and AdaBoost Classifier and used a train-test-split of 70 [%] and 30 [%], respectively.

To evaluate the performance of the prediction models we calculated the Accuracy, Precision, f1-Score, and Area Under the Curve (AUC). Since our dataset is unbalanced (97 [%] successful & 3 [%] unsuccessful), we used f1-Score for model optimization. To gain insights into the dependencies of the prediction we computed Shapley values for the final model.

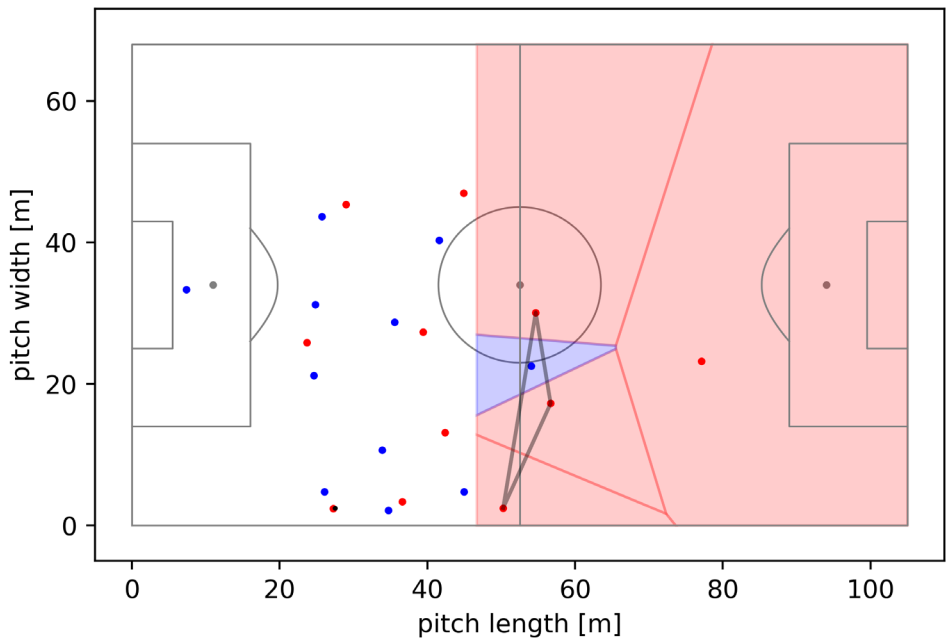

Figure 6.1: Illustration of an identified rest defense situation with the blue team gaining the ball (black) and the red team losing the ball in the attacking third with the opposing midfielder-line being overplayed. The considered area of rest defense is shown in grey (ten meters in front of the deepest defender), the surface area of rest defending players is depicted with grey lines, and the space control of the teams in the rest defending playing area is depicted in blue and red, respectively.

6.5.2 Results

Overall, we identified n = 2951 rest defense situations. 2425 of them were classified as successful and 75 were classified as unsuccessful which were considered for the prediction model. 451 match situations did not result in a ball regain or a shot on goal and therefore were not considered (e.g. ball out of play, see methods section: Rest defense situations & success).

The tactical playing positions identified in the area of rest defense were 70.1 [%] central defenders (n=6459), 13.4 [%] wide defenders (n=1227), 9.5 [%] central midfielders (n=866), 5.9 [%] wide midfielders (n=541), and 0.2 [%] wide strikers (n=19). The identified attackers in the area of rest defense were 78.5 [%] central strikers (n=3520), 8.3 [%] central midfielders (n=370), 6.5 % wide strikers (n=291), 5.2 [%] wide midfielders (n=234), 1.0 [%] central defenders (n=46), and 0.5 [%] wide defenders (n=23).

On average, the opponent's counterattack after the ball loss lasted 10.92 ± 0.61 [s], had 6.41 ± 1.50 actions, and 3.55 ± 1.29 passes.

In the moment of the considered possession change, we identified 3.70 ± 0.76 defenders and 2.01 + 0.93 attackers in the area of rest defense, resulting in a defensive numerical superiority of 1.69 ± 1.00.

The spatial formation of the rest defending players resulted in a surface area of 85.98 ± 60.09 [m^2] which was 7.35 ± 1.92 [m] long and 28.21 ± 7.43 [m] wide. The spread was 13.93 ± 2.86 [m], on average.

On average, the rest defense was positioned 43.56 ± 10.00 [m] ahead of their own goal line. The mean distance of the closest defender to the attackers was 5.08 ± 2.23 [m] and the longest distance from a defender to the attackers was 6.89 ± 4.19 [m]. This resulted in a mean pressure on the attacking players of 6.66 ± 12.59 [%] and a minimum pressure of 2.77 ± 11.09 [%].

The space control of the attacking team from the area of rest defense to the defendants' goal line was 390 ± 299.99 [m^2] resulting in a ratio of 11.51 ± 9.82 [%] relative to the defensive team.

The results of the classifiers predicting the success of rest defense situations are shown in table 6.2. Furthermore, the final model (AdaBoost Classifier (excluding distance variables)) with the best prediction performance (based on f1-Score) was chosen for further analysis. For this model, Shap values were computed which are depicted in figure 6.2.

Table 6.2: Results of models predicting the success of rest defending situations (successful/unsuccessful rest defense).

Classifier	Number of features	Accuracy	Precision	f1-Score	AUC
Logistic regression (ridge regression regularization)	17	0.87	0.56	0.57	0.76
Logistic regression (elastic net regularization)	17	0.82	0.54	0.54	0.74
Random Forest Classifier	17	0.84	0.55	0.56	0.78
Gradient Boosting	17	0.97	0.48	0.49	0.50
XGBoost Classifier	17	0.92	0.59	0.62	0.75
AdaBoost Classifier	17	0.96	0.63	0.61	0.60
AdaBoost Classifier (excluding distance variables)	15	0.97	0.73	0.64	0.60

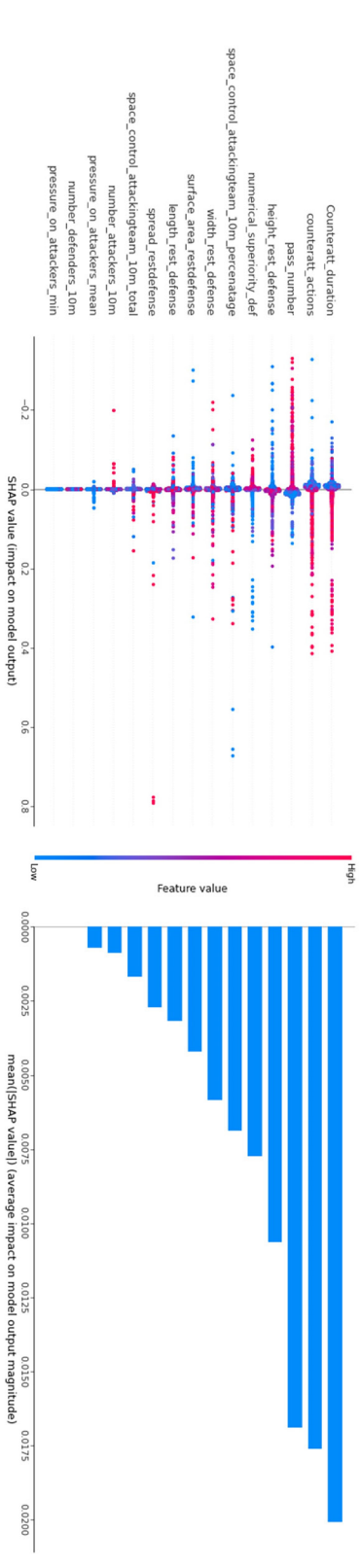

Fig. 6.2: Depiction of the SHAP values (on the left) of all features included in the final model, AdaBoost Classifier excluding the distance variables, and their feature importance (on the right).

6.6 Discussion

The aim of this study was twofold. First, we conducted expert interviews with professional soccer coaches to define rest defense as a group tactic in soccer. Second, based on the gained knowledge of the interviews, we developed a data analysis to identify critical variables that are important to the success of rest defense in defensive transition.

This mixed-methods approach of qualitative and quantitative methods is a prime example of how to gain detailed insights into the conditions of tactical behavior in soccer. The cornerstone is laid by qualitative expert interviews, the gained knowledge from which is then used for a differentiated quantitative and state-of-the-art analysis in connection to success of the respective playing phase.

Moreover, to logically structure the findings of this mixed-methods study, the discussion begins with a definition of rest defense based on the qualitative study. Next, the quantitative analysis is discussed in light of comparable research on defensive transition in soccer. The findings on rest defense are then transferred to indicate practical applications. Finally, the limitations of our approach are discussed to point out future research areas.

According to the results of the qualitative interviews, rest defense is defined as the positioning of the deepest defending players (usually last line & central midfielder) in own ball possession, when the players have no more task in attacking play (the ball is in the attacking third / the opponent's midfielder-line is overplayed). The rest defending players control deep spaces and potentially dangerous counterattacking players for the possibility of a ball loss to prevent opposing counterattacks or, in the best case, to quickly regain the ball in defensive transition.

Having defined rest defense based on the qualitative approach, we proceed to the quantitative approach used in this study. To illustrate its quality, we provide some general information. The approach to detect rest defense situations identified players with the same tactical positions as those named by the experts as being involved in rest defense, as indicated by a high degree of agreement (93 [%] defensive-line & central midfielder). Accordingly, this approach using the area of rest defense seems to be valid for identifying rest defense situations and rest defending players.

The machine learning approach to predict the success of defensive transitions using information about rest defending players showed satisfactory predictive performance. Our final model (AdaBoost (excluding distance variables)) outperformed the previous approach to model the success of defensive transition by Casal et al. (2016), which showed an accuracy of 0.58 (our model: 0.97). In comparison to Bauer and Anzer's (2021) prediction of defensive transition success, our model showed a comparable prediction performance (Precision: 0.72 (our model: 0.73), f1-Score: 0.67 (our model: 0.64)), however, poorer performance in distinguishing between the classes (AUC: 0.87 (our model: 0.60)). Their analysis included information of all players involved in defensive transition, also the behavior of defending players in ball proximity. Re-

cent studies on defensive behavior in soccer showed that especially the behavior of players in close ball proximity is important for defensive success (Forcher, Forcher, Altmann, Jekauc, et al., 2022). In contrast, our study used predominantly information about the rest defending players who are not in ball proximity in the moment of a ball loss. Therefore, this study especially indicates the importance of players in rest defense (not neccessarily in ball proximity) for the defensive success in defensive transition.

After demonstrating the quality of our approach, the prediction model is discussed by evaluating each variable according to its value for the prediction. The most important variable in the prediction of rest defense situations during defensive transition was the duration of opposing counterattacks. The analysis of SHAP values (see figure 6.2) suggests that a decrease in the duration of counterattacks increases the probability of successful rest defense. This finding is supported by the results of Casal et al. (2016) and Vogelbein et al. (2014), both of which found that the time to recover the ball in defensive transition is an important indicator of successful performance. Furthermore, Bauer and Anzer (2021) indicated that the chance of conceding a goal is greatly increased if the ball is not regained within five seconds. Overall, this supports the conclusion that regaining the ball quickly increases the success of the defensive transition by giving the counterattacking team less opportunity to build their attack and deny their actions early.

Moreover, the prediction model yielded further insights that support the conclusion that duration is a critical success factor for defensive transition. In detail, the number of actions and the number of passes of the opposing counterattack were also highly important for the prediction (2nd and 3rd most important variables, see figure 6.2). While the number of actions showed a similar distribution as the duration of the counterattack (fewer opposing actions increase the probability of success of rest defense), the number of passes showed an opposite trend. This opposing trend could be due to high correlation between the variables pass number, number of actions, and the duration of the counterattacks which could have influenced the results of the prediction model. To sum up, the time it takes a defending team to recover the ball after a ball loss is a crucial success factor in defensive transition.

Besides, the height of the rest defense was the 4th most important variable for the prediction of rest defense success. With it, the distribution of SHAP values in figure 6.2 suggests that a deeper rest defense (closer to the own goal line) is beneficial for the success of rest defense. A possible reason for this is the smaller space behind the defense, which decreases the chance for an opposing counterattack to play in behind this deep rest defense. Following this idea, the deep spaces could be better secured by the rest defending players. This is in line with the stated primary goals of rest defense by experts, to safe deep spaces (see table 6.1: Goal of rest defense). Additionally, this is an interesting finding when comparing the stated ideas to the group tactic of counter-pressing after a ball loss (in defensive transition). If a team aims to counter-press deep in the opposing attacking third after a ball loss one could argue that it is helpful that the last line is also high up the pitch to decrease the space for the counterattacking team to play

and increase the pressure on the opponents. However, our result suggests kind of an opposing trend where it seems to be helpful for the success of defensive transition that the rest defending players are closer to their own goal. This might be a perfect example of risk and reward in a particular match phase in soccer, where opposite tactical behaviors can have both benefit and risk depending on the goal to be achieved (e.g. defensive-line moved high up the pitch to enhance counter-pressing, which is assumed to decrease the performance of rest defense). Summing up, the effects of a deeper rest defense enhancing the success in defensive transition should be analyzed in the combination of counter-pressing in ball proximity.

Furthermore, the variable numerical superiority was the 5th most important variable in our prediction with a higher defensive numerical superiority suggesting an increase in the success of rest defense. This finding is supported by the results of Bauer and Anzer (2021) who indicated that it is beneficial for the success in defensive transition when four or more players are behind the ball after a ball loss. This seems intuitive, as more defenders can more easily control possible counterattacking players and dangerous spaces (e.g. deep spaces). On average, we determined defensive majority of + 1.7 (± 1) defenders in the rest defense area. With the present study design, however, no conclusions can be drawn to the tactical positioning of rest defending players (e.g. flat or sandwich, see expert interview: Tactics of rest defense). However, the variables number of defenders and attackers are less important for the prediction as they are partly already mapped in the superiority measure.

The 6th most important variable for defensive success in rest defense was the ratio of space control of attacking players with respect to the defenders in the area of rest defense to the defendants' goal line (see figure 6.1). In detail, the SHAP values indicate that a low space control of the attacking team enhances defensive success in rest defense. By denying space control of the attackers, the defenders control dangerous counterattackers and deep spaces. Therefore, the metric space control appears to optimally quantify the idea of controlling deep spaces and areas around counterattackers. Both principles were stated to be highly important goals for experts in rest defense (see expert interview: Goals of rest defense). However, the results of outliers with extremely high space control of attackers seem to be counterintuitive, suggesting a positive effect on rest defense success (see SHAP values in figure 6.2). A possible explanation for this pattern could be counterattackers standing behind the rest defenders (in offside), which would increase the space control tremendously, but decrease the chance of a successful counterattack as they cannot legally intervene in the match situation.

The spatial formation of the rest defense was partially important for the prediction of success in rest defense (7th – 10th most important variables for prediction, see figure 6.2). The trend of SHAP values indicates that lower values of spread, surface area, length, and width of rest defending players (higher compactness) are advantageous for success of rest defense.

Finally, defensive pressure showed only a weak predictive performance for rest defense success in comparison to the other metrics in the present study. In contrast to our findings, it was previ-

ously shown to be a good indicator for defensive success (Forcher, Forcher, Altmann, Jekauc, et al., 2022). This could be due to the other variables (such as space control) that might represent the metric of defensive pressure with other measurement approaches (e.g. high defensive pressure possibly results from large space control). However, higher pressure on the attackers (to deny their actions) in the rest defense area (see figure 6.1) seems to increase the probability of a successful transition.

6.6.1 Practical Application

The present study provides valuable information that can be practically applied in various circumstances. Specifically, the findings can be utilized in training sessions to focus on the tactical components that have been identified as critical success factors in rest defense. This, in turn, can improve the overall performance of players in this particular group tactic. Coaches are advised to emphasize the positioning of rest defending players to control deep spaces and potential counterattackers by marking them. Additionally, the rest defense should maintain a high level of compactness while allowing defenders to control opposing attackers within the rest defense area. Defensive majority situations may be advantageous as they offer greater control over space around attackers, thus reducing their actions. Ultimately, the defending team should strive to minimize the opponent's actions following ball loss to regain possession as quickly as possible. In conclusion, the principles of play outlined in this study can enhance coaches' understanding of the key aspects of rest defense.

Furthermore, the presented variables used in the quantitative study can be applied to objectively analyze the performance of rest defense during defensive transitions in post-match, live, or opponent analysis. Thereby, the presented prediction model can be applied to evaluate each individual match situation of rest defense by analyzing the identified patterns. Finally, this analysis can help the coaching staff to assess which specific parts of the tactical behavior were beneficial in a specific match situation and what should be adjusted to enhance success of the defensive transition.

6.6.2 Limitations and Future Research

In addition to the practical implications discussed earlier, the current study has certain limitations. Firstly, our analysis of successful outcomes of defensive transition was limited to ball gains, despite other outcomes, such as the ball going out of play, also being potentially successful. Secondly, we only examined a specific group tactic (rest defense) in defensive transition, without taking into account the interactions among all eleven players, which can impact the team performance. Future research should focus on combining rest defense with counter-pressing to explore multiple group tactics in defensive transition and their risk and reward trade-offs. Thirdly, our dataset was highly unbalanced, with only 3% of defensive transitions leading to an opposing shot on goal, which may have influenced our results. However, our large dataset and optimization of the machine learning approach using the f1-Score helped mitigate this issue. Fourthly, the metric used to quantify pitch control (Voronoi diagrams) was a basic approach that did not account for player orientation and speed. Future studies could explore advanced methods for quantifying space control, given the significance of this factor in defensive transition. Lastly, our study only analyzed rest defense in the crucial moment of ball loss, simplifying player behavior. However, expert interviews suggested that player behavior in rest defense is essential in both offensive and defensive transition playing phases. Therefore, future research could examine the behavior of players in rest defense immediately before and after losing possession of the ball.

6.7 Conclusion

This study showed how to combine qualitative and quantitative research in soccer, and how to use expert knowledge to enhance an up-to-date analysis of tactical behavior. With it, we presented practically important knowledge about how to behave in rest defense. Concluding, rest defense is defined as behavior of the deepest defenders during ball possession with the goal to prevent an opposing counterattack after a ball loss during defensive transition. Our results suggest that rest defending players should control deep spaces and dangerous counterattackers to successfully prevent a fast opposing counterattack. This could allow the defensive team to regain possession as quickly as possible in defensive transition to stop an opponent's counterattack in the early stages, which was shown to be most important for success in defensive transition.

Chapter 7

Compact Organization (Paper IV)

Is a compact organization important for defensive success in elite soccer? – Analysis based on player tracking data.

Publicated Version of the original research article

Forcher, L., Forcher, L., Altmann, S., Jekauc, D., & Kempe, M. (2023). Is a compact organization important for defensive success in elite soccer? – Analysis based on player tracking data. International Journal of Sports Science & Coaching, 1-12.

7 Compact Organization (Paper IV)

7.1 Abstract

The interest in tactical analysis in soccer has increased in the latest years, especially with the growing availability of player tracking data. With it, the defending team's compact organization, which is considered by practitioners to be an important factor in defense, was repeatedly examined. However, the connection between this defensive principle of play and the defending success remains unclear. Therefore, this study aims to investigate the relation of the principle of play *defensive compact organization* to the success of the defense.

Based on tracking and event data of 153 matches of the German Bundesliga (season 2020/21), the compactness (surface area, spread of the team, and of defending subgroups) and the organization (distances between formation lines) of the defending team were compared between successful and unsuccessful defensive plays.

There were almost no differences in the *compactness* of the whole team, and the *organizational* measures between successful and unsuccessful defensive plays. The defending subgroup of five defenders closest to the ball showed a higher *compactness* (smaller surface area & smaller spread) in successful defensive plays compared to unsuccessful ones ($-0.08 \leq d \leq -0.16$).

Our results indicate that the compactness of players in areas close to the ball seems crucial for defensive success. However, the *compact organization* of the entire team does not seem important to regain the ball in defense.

Key words: soccer, defense, compact organization, principle of play, tracking data, performance analysis, tactics

7.2 Highlights

- Successful defensive plays are characterized by higher *compactness* in areas close to the ball (represented by the 5 defenders closest to the ball) to pressurize the attacking player in control of the ball and close pass options.

- In contrast, no evidence is found that the *compactness* of the whole defending team is related to the success of a defensive play.

- All elite soccer teams studied show a good *compact organization* in defense across all defensive plays considered, exemplified by small inter-line distances (Ø distance def-mid = 10.22 ± 3.76 [m]) and a small surface area of the defending team (Ø surface area = 792.54 ± 227.24 [m^2]).

- Analyzing the distances between the formation lines, no differences are found between successful and unsuccessful defensive plays.

7.3 Introduction

Due to the development of spatio-temporal tracking data of high resolution, the analysis of tactical performance enjoys growing interest. This analysis of tracking data enables researchers to investigate complex interactions between all players to understand the emerging patterns of the game (Low, Rein, Schwab, et al., 2021).

These investigations mostly focused on offensive play with a tendency to analyze on-ball actions such as shots (e.g. expected goals) (Rathke, 2017) or passes (Goes, Schwarz, et al., 2021). However, soccer is a low scoring game (Wright et al., 2011), which is also reflected in practice, where coaches often spend more time teaching defensive principles.

Accordingly, several studies have emphasized the importance of defensive play, with defensive variables considered at least as important as offensive variables (Georgievski et al., 2019; Lepschy et al., 2021). Furthermore, a recent review (Forcher, Altmann, Forcher, Jekauc, et al., 2022) showed that there is an increasing number of studies on defensive play. Still, studies on cooperative defending of the entire team (at a team-level) or subgroups (at a group-level) are sparse. Therefore, this study will investigate if specific measures of cooperative defending at a team- and group-level (organization and compactness) differ between successful and unsuccessful defensive plays. It is noteworthy that the tactical behavior of players in team sports can be distinguished into the behavior of the whole team (team-level), the behavior of a subgroup consisting of at least two players (group-level), and the behavior of single players (individual-level) (Forcher, Altmann, Forcher, Jekauc, et al., 2022).

The collective behavior of soccer players can be analyzed using the dynamic system theory, which states that both teams behave in an opposing relationship (Davids et al., 2005) depending on the ball possession. The players of the defending team coordinate their actions to prevent the opponent from scoring and eventually regain possession. In contrast, the players of the attacking team coordinate their actions towards maintaining possession and achieving scoring opportunities to eventually score. Accordingly, there are differences in the characteristics of the movement behavior of players between these different match phases.

While the offensive team is characterized by high movement variability to disrupt the opposing organization (Davids et al., 2005) and create open space for passing options or scoring opportunities (Castellano et al., 2013), the defending team is characterized by more ordered and compact movement behavior. These characteristics result in the players of the attacking team moving further apart (expanding), while the players of the defending team move closer together (contracting), which is also referred to as the contraction-expansion relationship between the attacking and defending teams (Bartlett et al., 2012; Moura et al., 2012).

The contraction-expansion relationship was found by four of five individual studies analyzing tracking data of professional soccer players in official 11 vs. 11 matches (Castellano et al., 2013; Clemente et al., 2013a; Moura et al., 2012; Welch et al., 2021). To quantify the compactness of a team they used the surface area (Castellano et al., 2013; Clemente et al., 2013a; Moura et al., 2012; Welch et al., 2021), the spread (Clemente et al., 2013a; Moura et al., 2012), the width and length (Castellano et al., 2013), and the effective area of play of a team (Clemente et al., 2013a). Solely one study found no proof of the defending team contracting while the attacking team expanding using surface area and spread measures (Bartlett et al., 2012).

While the aforementioned studies described collective defending behavior in general, only two studies related their analysis of compact defending to performance (successful vs. unsuccessful defending). Moura et al. (2012) found a higher compactness (represented by smaller surface area & spread) of defending players in the last moment of a successful defensive play (tackle) compared to the last moment of an unsuccessful defensive play (shot on goal). In contrast, Bartlett et al. (2012) found no effects in the average spread and surface area over a possession between successful (tackle or other possession regain) and unsuccessful (shot on goal) defensive plays. Given these contradicting results, the importance of defensive compactness to defensive success remains unclear.

The above-presented knowledge can be summarized in one tactical principle: *defensive compact organization* (DFB, 2016). A tactical principle of play describes the superordinate and general behavioral patterns in solving problems that arise in specific playing phases (e.g. offense, defense) (Costa et al., 2009; Ouellette, 2004). With it, the specific behavior of the players is caused to optimally achieve the goals in the respective playing phase (Costa et al., 2009; Ouellette, 2004). However, principles of play could be associated with particular playing styles (e.g. deep defending) and little is known about which principles of play are connected to success and therefore are beneficial.

The tactical principle of play *defensive compact organization* (DFB, 2016) can be defined by three main parts: *compactness, contraction of compactness,* and *organization* within this compactness. While *compactness* describes the current spatial proximity of players of a team at a given time point (which was investigated by the mentioned studies above), the *contraction of compactness* describes the change of compactness over a time period (Costa et al., 2009). High compactness represents players in close proximity to each other (e.g. small surface area) and a high contraction is defined as a process of players moving closer together thus increasing the compactness (e.g. decreasing size of surface area). In contrast, the *organization* describes the formation and coordination of players within this compactness (e.g. distances between formation lines) with players in different positions having different tasks (tactical formation). A structured organization makes it harder for the opposing team to play within or through this compact organization and eventually achieve dangerous goal scoring opportunities.

This *defensive compact organization* is characterized by players maintaining an optimal and small distance between each other (Castellano et al., 2013), precise structure in the spatial or tactical formation (e.g. small distances between formation lines), and clear distribution of tasks

between the different playing positions or groups (e.g. central midfielders prevent central passes, wide midfielders push the ball-carrying player to the outside of the pitch).
In summary, as mentioned above the knowledge about this tactical principle of play remains unclear, as one study showed that increased *compactness* is connected to defensive success and one study did not find this result. However, as both studies solely investigated the *compactness* of a team at a given time point, the aspects of *contraction of compactness* and *organization* are not captured. This limits the outcomes regarding the detailed knowledge about this tactical principle of defensive play. Furthermore, both studies examined fewer than eleven matches, which is a very small sample size that makes it difficult to generalize the results. Further, both studies solely used two measures to describe the teams' *compactness* at a team level (surface area & spread) without considering the group level. It can be argued that it is necessary to include more variables (e.g. distance between formation lines) and also variables on the group-level enabling one to get more informative insights into defensive play.
Therefore, the aim of this study is to gain more detailed insights into the tactical principle of defensive play: *defensive compact organization*, exploring the differences of *compactness, contraction of compactness,* and *organization* at a team- and a group-level between the successful and unsuccessful defensive plays using a large sample size.
We hypothesized that successful defensive plays show higher *compactness* (e.g. smaller surface area) and higher *contraction of compactness* and better *organization* (e.g. smaller distances between formation lines) compared to unsuccessful defensive plays.

7.4 Methods

This study was approved by the local ethics committee (Human and Business Sciences Institute, Saarland University, Germany, identification number: 22-02, 10 January 2022) and all procedures were conducted in accordance with the guidelines of the Declaration of Helsinki.

7.4.1 Data

We used an observational and explorative study design in which tracking data and event data of all 153 matches of the second half of the German Bundesliga season 2020/21 were included.
The tracking data was officially collected with a semi-automatic multi-camera system (TRACAB, ChyronHego, Melville, NY, USA) which has a sampling frequency of 25 Hz. Thereby the X- (length) and Y-coordinates (width) of all players on the pitch and the ball are collected in meters [m]. In addition, the Z-coordinate (height) for the ball is measured. All positions are tracked on a standardized pitch with 68 meters of pitch width (on the y-axis) and 105 meters of pitch length (on the x-axis) with the bottom left corner of the pitch representing the origin of the coordinate system. This tracking system was found to be a valid measurement technique to analyze soccer-specific performance (Linke et al., 2020).
The associated event data was officially annotated by Sportec Solutions (Sportec Solutions AG, Ismaning, Germany) using a manual tagging based on the definition catalog of the German Soccer League (DFL) (DFL, 2014).
Both data sets (tracking & event data) were imported to Python 3.8 and all data processing, visualization, and statistical analysis were accomplished using the NumPy, pandas, math, SciPy, scikit-learn, and Matplotlib libraries.

7.4.2 Data Processing

7.4.2.1 Synchronization of Tracking and Event Data

Due to the manual annotation of event data (human inaccuracy), the raised timestamps and origins of events vary from the automatically raised tracking data, and a synchronization of both data types is necessary to combine both data types. Therefore, we determined the matching time-point (frame) of tracking data for every event (pass, tackling, etc.) of the event data. To achieve this, we defined a search time window of eight seconds before to eight seconds after the tagged time-point of an event in the event data. For every resulting time-point (frame) of tracking data in this time window, we calculated the distance between the involved player(s) to the ball (distance of player(s) to the ball) and their distance to the tagged origin of an event in the event data (distance of player(s) & ball to event origin). The distance of player(s) to the ball was weighted ten times over the distance of player(s) and ball to the event origin because

deviations were expected in the manually tagged event origin. The searched time-point (frame) was identified using the smallest value that resulted from the described calculations.
In a partial sample of 50 events, our algorithm was able to reach an almost perfect agreement with the observed event time of an experienced match analyst in soccer (intraclass correlation coefficient: > 0.99, $p < 0.001$) (Landis & Koch, 1977). The average deviation between both raters (match analyst & algorithm) was detected to be 0.081 seconds with a RMSE of 0.21 [sec]. Therefore, we are able to effectively combine both data types.

7.4.2.2 Success of Defensive Plays

All ball possessions were identified based on the event data. A possession started at the moment a team gained control over the ball and ended at the moment the opposing team regained the ball, the ball went out of play, or there was a stoppage of play (e.g. foul). Thereby, it is assumed that the team that performs active actions on the ball (e.g. pass, won tackling) is in ball control. This study concentrated on deliberate (intentional) possessions to exclude the effects of undeliberate possession, such as short possessions in which solely one player deflects or blocks the ball. Further, we excluded short possessions since these phases could possibly be assigned to the playing phase of defensive transition. However, this study concentrated on the effects of the playing phase of defensive play. Therefore, in accordance with previous studies (Forcher et al., 2021; Forcher, Forcher, Altmann, Jekauc, et al., 2022), we exclusively included possessions that had a minimum of three consecutive passes and a minimum duration of five seconds.
Furthermore, as a team's defending style changes with the number of players involved (e.g. after player dismissals) (Badiella et al., 2022; Carling & Bloomfield, 2010; Chowdhury, 2015; Lago-Peñas et al., 2016), we excluded all match situations in which a regular 11vs11 was not detected (e.g. red cards, injured players who are treated outside the pitch) to avoid biasing the results.
The success of a defensive play was defined by the outcome of possession and in line with previous studies (Bartlett et al., 2012; Forcher, Forcher, Altmann, Jekauc, et al., 2022; Matsuoka et al., 2020). As the ultimate goal of defending is to gain the ball (Forcher, Forcher, Altmann, Jekauc, et al., 2022; Moura et al., 2012), besides preventing opponents' scoring opportunities, all possessions in which the defending team gained the ball in open play were defined as a successful defensive play. All other outcomes were classified as unsuccessful defensive play (e.g. shot on goal, stoppage of play).

7.4.3 Tactical Formation

To determine the tactical formation of a team, we used an approach that has already been used to identify formation lines (Forcher et al., 2021; Goes, Brink, et al., 2021; Shaw & Glickman, 2019). However, we expanded this approach by an increasing number of time windows and a dynamic assignment of players to account for in-game formation changes (Forcher, Preine, Forcher, Wäsche, et al., 2022) and substitutions. We defined two tactical formations (one defending formation & one attacking formation) for each of the two teams over a ranging window of 15 minutes (resulting in six defending and six attacking formations for every team per match). This approach was chosen to account for tactical formation changes during the match (Forcher, Forcher, Jekauc, Wäsche, et al., 2022) and the differences between offensive and defensive formations (Praça et al., 2022). The tactical formation was identified using the average x-positions of all players of a team which were clustered in three formation lines (defending-line, midfielder-line, attacking-line) using a K-Means unsupervised clustering algorithm. The goalkeeper was also identified, but not assigned to one of the three formation lines. This procedure for identifying subgroups was shown to be adequate (Goes, Brink, et al., 2021).
Afterward, we dynamically assigned the players of each team to the formation lines for every individual possession to account for dynamical changes in the formation (e.g. a winger switches with a full back for one possession).

7.4.4 Variables

7.4.4.1 Team Variables

The compactness of a team was defined on the basis of previous investigations to measure team compactness and was operationalized by the measures of surface area and spread of the whole team (excluding the goalkeeper). The surface area of all outfield players (excluding the goalkeeper) (Bartlett et al., 2012; Castellano et al., 2013; Frencken et al., 2011) was calculated using the area of the convex hull (Moura et al., 2012) (see figure 7.1). The spread of all outfield players was calculated using the sum of the squared standard deviation from their average position (team centroid) (Bartlett et al., 2012; Bourbousson et al., 2010) (see figure 7.1). The teams' length (distance in the longitudinal direction of the pitch) and teams' width (distance in the lateral direction of the pitch) of the surface area were also calculated (Castellano et al., 2013; Folgado et al., 2014; Low, Rein, Schwab, et al., 2021).

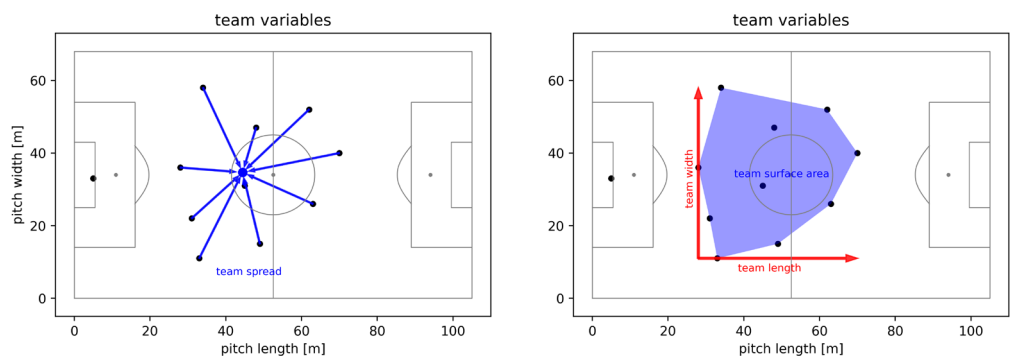

Figure 7.1: Team variables with team spread on the left and team surface area on the right.

7.4.4.2 Defensive Collective (Subgroup) Variables

Further, we quantified the compactness of two subgroups, both referred to as defensive collective (DC). To operationalize the compactness of the subgroups we used the measures of surface area and spread of the players assigned to the particular subgroup. This procedure was done because the analysis of movement behavior of subgroups was shown to give greater insights into coordination dynamics compared to team-level analysis (Bartlett et al., 2012; Goes, Brink, et al., 2021; Low, Rein, Schwab, et al., 2021).

We expected that strikers are mostly not decisive in defending compactness (e.g. a team can still maintain compactness even though a striker stays in front after he is outplayed, as many strikers seem to be not defensively active when outplayed). Therefore, we defined the first defensive collective ("DC defender & midfielder") as all outfield players assigned to the defending-line and the midfielder-line (all outfield players except the attackers) using the identified tactical formation (see 7.4.3 Tactical formation).

As previously shown, it is important to pressurize areas close to the ball to gain the ball (Forcher, Forcher, Altmann, Jekauc, et al., 2022). Therefore, we have defined the second defensive collective, which comprises the five defenders closest to the ball ("DC ball nearness").

For both defensive collective variables, the surface area and the spread were calculated as described above (see 7.4.4.1 Team variables, see figure 7.2).

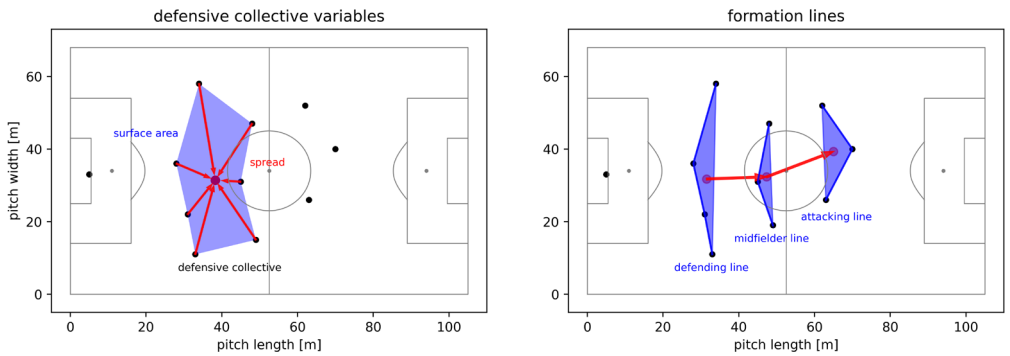

Figure 7.2: Defensive collective variables on the left and distances between formation lines on the right.

7.4.4.3 Distances between Formation Lines

To operationalize the organization within a defending team, we measured the distances between the centroids of the three formation lines (see Figure 2) identified using the formation descriptor (defending-line, midfielder-line, & attacking-line, see 2.2.3). Inter-line distances were used in several other studies (Goes, Brink, et al., 2021; Gonçalves et al., 2014; Low, Rein, Raabe, et al., 2021; Low, Rein, Schwab, et al., 2021).

For all computed variables we quantified different measures to account for the differences between the compactness of a defending team, the organization of a defending team, and the contraction of a defending team (defined in the introduction).

To quantify the compactness of the defending team (operationalized by team variables & defensive collective variables) and the organization of a defending team (operationalized by distances between formation lines), the average over a possession (mean), the last local maximum of a possession (max), the ensuing minimum (min), and the last moment of a possession (last moment) were measured. The measurement time points were determined by 2 experienced match analysts in soccer.

To account for the contraction of a defending team, two contraction measures for every variable were computed using the difference between the start of a possession and the end of a possession (contraction start-end), and the difference between the last local maximum of a possession and the ensuing minimum of a possession (contraction max-min).

7.4.5 Statistics

To explore the defensive compact organization, a one-way ANOVA was conducted between successful and unsuccessful defensive plays for every measure (mean, max, min, last moment, contraction (start-end), contraction (max-min)) of every variable (team, DC lines, DC ball nearness, distance between formation lines) (Ross & Willson, 2017). Prior, we checked for homogeneity of variances and normal distribution. Levene's test for homogeneity of variances was performed and if significant the correction was used. Due to the size of the sample investigated ($n > 5000$), the normal distribution was checked visually (Ghasemi & Zahediasl, 2012). Furthermore, the Bonferroni-Holm correction was used to avoid alpha error.

As effect size, Cohen's d was determined with $d < 0.5$ representing a small effect, $0.5 \leq d \leq 0.8$ representing a medium effect, and $d > 0.8$ representing a large effect (Cohen, 1988).

The significance level was set to $p < 0.05$.

7.5 Results

Overall, 2889 (18.3 [%]) defensive plays were classified as successful and 12899 (81.7 [%]) were classified as unsuccessful. The results are structured according to the aim of this study and, therefore, are differentiated into the facets of the tactical principle of play defensive compact organization: compactness, the contraction of compactness, and the organization of the defending team.
The descriptive statistics of the results and the outcomes of all comparisons are depicted in table 7.1.

7.5.1 Compactness

7.5.1.1 Team

Regarding the compactness of the whole defending team, almost all measures showed no significant differences between successful and unsuccessful defensive plays, such as surface area (mean, max, min, last moment), spread (mean, max, min, last moment), length of the surface area (mean, max, min, last moment), and width of the surface area (mean, max, min, last moment). Solely the surface area (d = 0.11) and the width of the surface area (d = 0.08) of the whole team were significantly larger at the last moment of successful defensive plays compared to unsuccessful defensive plays showing small effect sizes.

7.5.1.2 Defensive collective ("DC defender & midfielder")

On average, there were 7.12 ± 0.99 players assigned to the DC defender & midfielder.
For the compactness of the DC defender & midfielder, we found a larger surface area at the last moment of successful defensive plays in comparison to unsuccessful defensive plays (d = 0.11). Accordingly, we also found a larger spread of the DC defender & midfielder at the last moment (d = 0.09) and the maximum (d = 0.08) of successful defensive plays compared to unsuccessful ones.
For all other compactness measures (max, min) DC defender & midfielder there were no significant differences between successful and unsuccessful defensive plays.

7.5.1.3 Defensive collective ("DC ball nearness")

In contrast, for the DC ball nearness, we found a significantly smaller surface area (mean, max, min, last moment) in successful defensive plays compared to unsuccessful ones (-0.08 < d < -0.16). In line, we found a smaller spread (mean, max, min) of the DC ball nearness in successful defensive plays compared to unsuccessful defensive plays (-0.07 < d < -0.14). Solely the spread of the collective showed no differences in the last moment of a possession.
Furthermore, we found smaller surface area values and spread values for the DC ball nearness (surface area Ø = 195.70 ± 72.97 [m^2]) compared to the corresponding values of the DC defender & midfielder (surface area Ø = 395.24 ± 182.26 [m^2]).

7.5.2 Contraction of Compactness

For the first contraction measure between the start and the end of a possession (contraction start-end), there were no significant differences between successful and unsuccessful defensive plays for all variables.
For the second contraction measure between the last maximum and following minimum of a possession (contraction max-min), we found a higher contraction of the surface area and the spread in successful defensive plays compared to unsuccessful defensive plays for the whole team (0.09 < d < 0.12), and the DC defender & midfielder (0.11 < d < 0.14). Additionally, the contraction (max-min) of the distances between the formation lines def-att and def-mid were higher in successful defensive plays compared to unsuccessful ones (d = 0.09). All other variables (DC ball nearness, width and length of surface area team, and distance between formation lines mid-att) showed no significant difference in this contraction measure (0.204 < p < 0.999).

7.5.3 Organization

Regarding the distances between the formation lines (defensive-, midfielder-, and attacking-line), no significant differences were found between successful defensive plays and unsuccessful defensive plays for every combination (def-mid, mid-att, & def-att).
The distance between the defensive-line and midfielder-line (def-mid) was smaller (Ø = 10.17 ± 3.87 [m]) compared to the distance between the midfielder-line and attacker-line (mid-att) (Ø = 13.21 ± 4.21 [m]) (F = 4479.22, p < 0.001, d = -0.75).

Table 7.1: Descriptive statistics and comparisons between successful and unsuccessful defensive plays of team variables, defensive collective variables, and distances between formation lines (red: significant differences with positive effect sizes = larger values in successful defensive plays compared to unsuccessful defensive plays, green: significant differences with negative effect sizes = smaller values in successful defensive plays compared to unsuccessful defensive plays).

Variables			successful		unsuccessful		ANOVA		
			Mean	SD	Mean	SD	F	p (Bonferroni-Holm correction)	Cohen's d
team	surface area [m²]	mean	792.54	227.24	779.06	233.42	7.94	0.214	0.06
		max	876.87	306.03	865.63	300.84	3.28	>0.999	0.04
		min	711.85	263.25	717.15	275.80	0.89	>0.999	-0.02
		last moment	799.36	302.78	767.18	284.66	29.45	<0.001	0.11
		contraction (start-end)	28.32	386.32	42.22	349.24	3.59	>0.999	-0.04
		contraction (max-min)	165.03	187.57	148.47	179.97	19.66	<0.001	0.09
	spread [m]	mean	2542.25	682.10	2507.33	702.67	5.89	0.61	0.05
		max	2890.47	937.32	2837.43	922.39	7.76	0.225	0.06
		min	2317.78	835.27	2341.42	868.33	1.77	>0.999	-0.03
		last moment	2589.05	940.38	2531.73	914.11	9.18	0.115	0.06
		contraction (start-end)	64.78	1212.45	56.05	1119.56	0.14	>0.999	0.01
		contraction (max-min)	572.69	632.78	496.01	598.69	37.91	<0.001	0.12
	length [m]	mean	32.49	8.69	32.22	9.16	2.09	>0.999	0.03
		max	35.46	10.66	34.94	10.94	5.27	0.824	0.05
		min	31.07	9.65	30.87	10.25	0.94	>0.999	0.02
		last moment	34.07	9.56	33.65	10.27	4.01	>0.999	0.04
		contraction (start-end)	-0.44	11.34	-0.47	10.87	0.02	>0.999	0.00
		contraction (max-min)	4.39	5.57	4.07	5.27	8.10	0.204	0.06
	width [m]	mean	37.34	4.83	37.14	4.86	4.18	>0.999	0.04
		max	39.72	6.46	39.34	6.42	7.97	0.214	0.06
		min	34.20	6.72	34.06	6.74	0.98	>0.999	0.02
		last moment	36.21	7.29	35.62	7.03	16.73	0.002	0.08
		contraction (start-end)	1.35	9.73	1.67	9.43	2.54	>0.999	-0.03
		contraction (max-min)	5.52	5.71	5.29	5.64	4.13	>0.999	0.04
defensive collective („DC defender & midfielder")	surface area [m²]	mean	395.24	182.26	390.40	181.95	1.67	>0.999	0.03
		max	441.77	243.94	433.43	235.85	2.91	>0.999	0.03
		min	325.94	200.45	332.80	204.67	2.67	>0.999	-0.03
		last moment	388.53	247.12	363.22	216.79	30.51	<0.001	0.11
		contraction (start-end)	61.95	286.61	75.89	260.94	6.49	0.444	-0.05
		contraction (max-min)	115.83	142.84	100.63	132.63	30.11	<0.001	0.11
	spread [m]	mean	1896.73	558.49	1872.20	564.62	4.47	>0.999	0.04
		max	2185.31	811.60	2124.19	778.80	14.31	0.008	0.08
		min	1630.19	743.02	1650.80	746.27	1.80	>0.999	-0.03
		last moment	1854.97	875.69	1781.64	798.48	19.20	<0.001	0.09
		contraction (start-end)	189.54	1121.90	208.18	1038.04	0.74	>0.999	-0.02
		contraction (max-min)	393.80	598.90	473.39	578.84	46.46	<0.001	0.14
defensive collective ("DC ball nearness")	surface area [m²]	mean	195.70	72.97	201.53	76.42	13.99	0.009	-0.08
		max	204.37	115.93	217.78	121.80	29.10	<0.001	-0.11
		min	129.10	88.92	144.27	98.98	57.40	<0.001	-0.16
		last moment	153.30	109.23	162.31	110.07	15.87	0.004	-0.08
		contraction (start-end)	50.32	158.75	41.36	153.65	7.93	0.214	0.06
		contraction (max-min)	75.26	84.36	73.51	81.68	1.07	>0.999	0.02
	spread [m]	mean	1070.32	370.11	1096.09	383.10	10.81	0.049	-0.07
		max	1126.14	595.86	1201.10	614.36	35.52	<0.001	-0.12
		min	732.34	455.64	801.06	495.56	46.71	<0.001	-0.14
		last moment	852.87	564.48	877.15	537.81	4.73	>0.999	-0.04
		contraction (start-end)	284.42	816.89	247.68	758.76	5.38	0.796	0.05
		contraction (max-min)	393.80	439.34	400.04	423.97	0.50	>0.999	-0.01
formation lines	distance def-mid [m]	mean	10.22	3.76	10.16	3.89	0.55	>0.999	0.02
		max	11.61	5.17	11.37	5.12	4.94	0.974	0.05
		min	8.39	4.68	8.48	4.79	0.82	>0.999	-0.02
		last moment	9.71	5.11	9.37	5.08	10.61	0.054	0.07
		contraction (start-end)	1.16	6.50	1.32	6.05	1.66	>0.999	-0.03
		contraction (max-min)	3.22	3.64	2.90	3.30	21.80	<0.001	0.09
	distance mid-att [m]	mean	13.30	4.22	13.19	4.21	1.57	>0.999	0.03
		max	15.51	5.86	15.43	5.90	0.36	>0.999	0.01
		min	12.11	5.67	12.19	5.86	0.51	>0.999	-0.01
		last moment	14.04	6.07	14.17	6.18	1.05	>0.999	-0.02
		contraction (start-end)	-1.13	7.74	-1.44	7.62	3.95	>0.999	0.04
		contraction (max-min)	3.40	3.85	3.24	3.85	4.02	>0.999	0.04
	distance def-att [m]	mean	23.50	5.88	23.33	6.05	1.81	>0.999	0.03
		max	26.01	7.77	25.68	7.80	4.38	>0.999	0.04
		min	21.70	7.16	21.79	7.41	0.33	>0.999	-0.01
		last moment	23.70	7.49	23.50	7.80	1.72	>0.999	0.03
		contraction (start-end)	-0.02	9.14	-0.16	8.64	0.56	>0.999	0.02
		contraction (max-min)	4.31	4.88	3.88	4.57	19.78	<0.001	0.09

7.6 Discussion

This explorative study aimed to gain more detailed knowledge about the distinctive parts of the tactical principle of play defensive compact organization in connection to defensive success.
Overall, this study showed that for defensive success it seems to be important that a subgroup of defending players close to the ball form higher compactness to gain the ball. In contrast to the importance given by practitioners to the compact organization of the entire defending team, this team compactness did not show a connection to the success of a defensive play in this study. The analysis of the defensive organization showed that the attacking-line is more distant from the rest of the defending team compared to the proximity of defensive- and midfielder-line. However, the organization measures did not differentiate between successful and unsuccessful defensive plays.
Overall, the differences found between successful and unsuccessful defending in this study are small indicated by the comparatively small effect sizes ($-0.16 \leq d \leq 0.14$). This could be due to the complexity of the team sport soccer with 11 vs. 11 matches, where 22 individual players influence each match situation. Ultimately, no possession is similar to a previous one, which leads to a great dispersion of values. Nevertheless, these small effect sizes are comparable to other studies in this context (Forcher et al., 2021; Forcher, Forcher, Altmann, Jekauc, et al., 2022) and are therefore meaningful. Further, since the compact organization is only a small subset of a team's tactical behavior in defense, its importance is made clear by the differences found.

7.6.1 Compactness

The compactness of the whole defending team predominantly showed no differences between successful and unsuccessful defensive plays. This result is consistent with the findings of Bartlett et al. (2012), who found no differences in the compactness of a defending team between successful and unsuccessful defensive plays over the average of an opposing possession. Beyond that, our results partially indicated that the defending team shows even lower compactness (e.g. larger spread of players) in the last moment of successful defensive plays compared to unsuccessful ones. This outcome is in contrast to the results of Moura et al. (2012) who identified higher compactness (e.g. smaller surface area) of successful defensive plays in the last moment of an attack. However, the current results do not show a clear relation between the compactness of the whole defending team and defensive success.
The compactness of the defending subgroup excluding the strikers ("DC defense & midfield") showed similar results to the whole defending team, suggesting no relation to the success of a defensive play. In difference to all other results, the defensive collective that included the five nearest defenders to the ball ("DC ball nearness") showed contrary results. The compactness of the DC ball nearness was higher (e.g. smaller surface area) in successful defensive plays for almost every variable showing the comparably largest effect sizes in this investigation ($d \geq -0.16$).

Taking these results into account, the defending team should potentially show high compactness (e.g. small spread) in areas close to the ball to increase the potential to gain the ball. This finding shows the importance of the defending behavior in areas close to the ball to pressurize the attacking player in control of the ball and close pass options in ball proximity. This principle of pressurizing areas close to the ball is supported by an earlier study that showed that it is more important for defensive success to pressurize areas close to the ball compared to pressurizing all opposing attackers (Forcher, Forcher, Altmann, Jekauc, et al., 2022). Additionally, the players that are not in direct ball proximity protect dangerous pitch areas further away from the ball (pitch areas behind the defensive-line = deep spaces, pitch half opposing to the ball possession = weakside) to prevent the opposing team to overplay the pressured areas close to the ball and achieve the other goal of defensive play: protect the own goal. This tactical interpretation is supported by the analysis of an actual exemplary match situation in figure 7.3.
Accordingly, our initial hypothesis that successful defensive plays show higher compactness (e.g. smaller surface area & spread) can solely be confirmed for a subgroup of defenders in areas close to the ball.
Summarizing these results, it seems to be important for the success of a defensive play to not solely form high compactness of the entire defense but to create an optimal degree of compactness. This allows the defending team to control the space within its' organization without allowing opposing passes through it while also controlling other dangerous pitch areas (e.g. deep spaces or weak side, see above). Therefore, our results suggest that soccer teams should create an optimal defensive compact organization for the whole defending team and increase the compactness in ball proximity to increase the chance of being successful in defensive play.

7.6.2 Contraction of Compactness

For the contraction of compactness, which describes the change of compactness over a time period, this study showed first evidence supporting the idea that a higher contraction is connected to defensive success.
The contraction of compactness (contraction max-min) of the whole team (surface area & spread), the defensive collective consisting of defenders and midfielders (surface area & spread), as well as the distance between the defending line and the other two formation lines (dis-def-mid & dis-def-att) was higher in successful defensive plays. Therefore, one could argue that a rebuild of compactness (whole team & defender, and midfielder collective) is important to regain the ball. With it, we can confirm our initial hypothesis, where we expected a higher contraction of compactness in successful defensive plays (for max-min contraction). However, since contraction could be shaped by temporal and spatial characteristics and the time window of the contraction variables was not controlled this result is solely a first indication of the influence of spatial contraction.
Therefore, future studies should investigate this performance indicator of rebuilding of a com-

pact organization by contracting in more detail and by considering both temporal and spatial contraction.

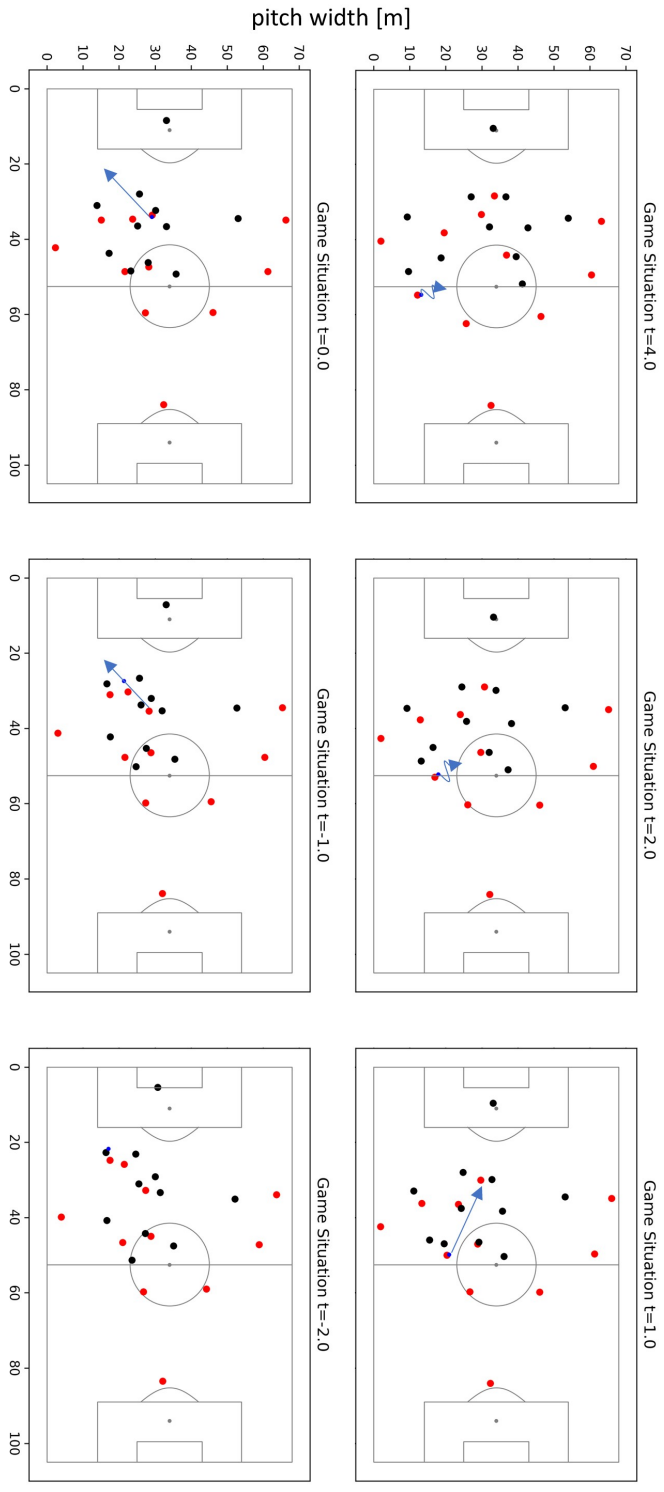

Figure 7.3: The course of an actual match situation in the German Bundesliga season 2020/21 with the ball-possessing team (red), the defending team (black), and the ball (blue). The left full-back of the attacking team (red) is dribbling toward the middle (t=4 & t=2) and subsequently, two passes are played through the defending team (t=1 & t=0). The defending team (black) is pressurizing areas close to the ball with the defenders in ball proximity while securing the deep spaces behind the defensive-line (central defenders) and the weakside (left full back). This results in high compactness near the ball and optimal but less compactness of the whole defending team (the full-back is further away from the team's center) which ultimately results in a ball gain (t=-2).

7.6.3 Organization

Concerning the defensive organization, quantified by the distances between the formation lines, the results revealed that the defensive-line and the midfielder-line are closer to each other (Ø = 10.22 ± 3.76 [m]) compared to the distance of the attacking-line to the rest of the team (Ø = 13.30 ± 4.22 [m]). This supports our initial idea that the defensive compact organization is not decisively shaped by the position of the attackers (e.g. attackers might not take part in the defending play when they are overplayed). However, we found no differences in the organization patterns between successful and unsuccessful defensive plays. Accordingly, it can be concluded that the distances between the formation lines, in the discovered range of very small inter-line distances (10 - 13 [m]), seem not decisive for the success of a defensive play. These discovered very small inter-line distances (10 - 13 [m]) could indicate that all teams in German Bundesliga are able to create and maintain a good organization in defense. However, it could be expected that increasing inter-line distances above the discovered range (> 15 [m], e.g. in lower-quality leagues) could lead to more unsuccessful defensive plays as the areas inside the defending organization increase which should be assessed in future studies. In the end, this could lead to a disrupted organization allowing for more dangerous opponent passes and dribblings within that organization, which was previously shown to be important for attacking success (Goes et al., 2018).

7.6.4 Limitations and Future Directions

The procedures of this study have led to some limitations. First, this study focussed solely on deliberate possessions excluding short attacks. Therefore, the results are exclusively representative for possessions longer than five seconds. This methodology was chosen to exclude unintentional actions as well as short defensive transitions (in which other tactical behavior of players is expected) which allows identifying tactical patterns representative of the defensive playing phase. Second, this study did not assess the influence of contextual variables (e.g. playing style, venue, match status, quality of teams) which have been shown to influence tactical behavior in defensive play (Almeida et al., 2014; Santos et al., 2017). In detail, we did not include information about different teams with different tactical formations and different playing styles in our study. Though, Low et al. (Low, Rein, Schwab, et al., 2021) showed in a first experimental approach that there is no difference in the defensive compactness between two different tactical formations. Furthermore, an earlier study found no clear differences in defending behavior between different teams, however, analyzing a distinctly different defensive principle of play defensive pressure (Forcher, Forcher, Altmann, Jekauc, et al., 2022). Nonetheless, contrasting defending playing styles (e.g. deep defending or high pressing) have different principles of play that have been shown to influence the compactness of a team (Low, Rein, Raabe, et al., 2021). For instance, high pressing to achieve ball gains close to the opposing goal leads to a larger team length

(Low, Rein, Raabe, et al., 2021) (= smaller compactness) as the attacking-line is pressuring the ball carrying opposing defenders deep in the opposing half. However, the procedure of this study leads to a greater overall generality of the results that can be applied to every defending playing style for different teams at different match statuses. Still, future studies should investigate the mentioned differences (e.g. playing styles) to gain more detailed knowledge complementing the current findings.

7.7 Conclusion

Summing up, creating high compactness of defenders in areas close to the ball (e.g. smaller surface area) seems to be crucial for defensive success. In addition, we found preliminary evidence that a higher contraction of compactness (for the whole team & the defender and midfielder collective) could be beneficial for defensive success. In contrast to the importance given by practitioners to the compact organization of the entire team in defense, we found no evidence that a higher compactness in the whole defending team (e.g. smaller surface area and spread) and a better organization (smaller inter-line distances) would increase the probability to gain the ball in defensive play.

Overall, we showed that the group-level defending in areas close to the ball is more important than the whole defending team concerning the defensive compact organization. Furthermore, rebuilding a compact organization (operationalized using contraction variables) appears to be a meaningful performance indicator whose connection with defensive success was suggested by our results.

Those findings are of significant interest to coaches and practitioners. For instance, the results can be applied to training regimes where subgroups of the defending team need to put pressure on the opposing ball carrier by increasing the compactness in those areas. Furthermore, the provided information can assist match analysts to be able to evaluate the defensive performance in more detail. For instance, in matches analysts should check the compactness of defenders in ball proximity and the contraction of compactness of the whole team.

Chapter 8

General Discussion

8 General Discussion

With the increase in the accuracy in tracking technologies (Linke et al., 2020) and the increase in the availability of tracking data, the developments in the match analysis of tactical match performance have accelerated. This has led to an increase in sports science studies analyzing match performance using positional tracking data (Goes, Meerhoff, et al., 2021; Low et al., 2020; Mackenzie & Cushion, 2013). Thereby, the accurate positional tracking data enables in-depth analyses of the tactical match performance. For instance, especially, the off-ball behavior of players can be investigated (for detailed discussion about this type of match analysis see chapter 2.4.3 Spatio-Temporal Analysis (Tracking Data)).

The tactical match performance shows differences in the playing behavior of soccer players depending on the playing phase (see chapter 2.3.1.1 Main Facets of Match Performance). While offensive tactical behavior has been studied frequently, there is a lack of comparable variety in analysis approaches and knowledge in the analysis of defense. In addition, most studies that analyze tactical match performance lack a connection to success. However, it is highly important to analyze the goal-directed tactical behavior with regard to its effectiveness to identify the characteristics of successful behavior in the respective playing phases. Therefore, the aims of this thesis are (1.) to comprehensively review the current state of the literature on spatio-temporal analysis of defensive play using tracking data, and (2.) to analyze the tactical match performance during the defensive playing phases (defensive play & defensive transition) at the individual level, group level, and team level and, thereby, use the possibilities of spatio-temporal analysis based on positional tracking data to identify factors of successful tactical behavior of players in the defensive playing phases. This thesis is one of the first comprehensive works that investigates the defensive playing phases exploiting the possibilities of tracking data and focusing on tactical match performance at all levels of tactical play from individual, over group, to team level.

In order to pursue those objectives, this chapter discusses the summarized results of the presented empirical studies (see chapters 4-7). These empirical studies present accurate and comprehensible findings interpreted by clear perceptions (epistemological position is empirical, see chapter 2.1 Theoretical Embedding). Additionally, in the comprehensive discussion, the hypotheses formulated prior to the studies are exposed to the possibility of falsification in each chapter of the main findings (see chapter 8.1 Main Findings). This ultimately serves to provide valuable knowledge about successful tactical behavior in defensive playing phases (scientific-philosophical position of falsificationism, see chapter 2.1 Theoretical Embedding).

Since this thesis focuses on the tactical match performance of soccer players in the defensive playing phases (further details see chapter 2.3 Appearance of Match Performance in Soccer), the discussion is started by a comprehensive discussion of the main findings of this thesis differentiated in the different levels of tactical match performance of individual, group, and team level. Afterward, the practical impact of the findings on defensive play is discussed by defining principles of play that are associated with successful tactical match performance in the respective playing phases. This practical application of empirical findings is highly important for this sports scientific work since one of the goals of sports science is to apply the knowledge gained in practice (see chapter 2.2 Subsumption into the Subject Field of Sports Science). In the end, the limitations of this thesis are reflected which introduces future perspectives of the research in match analysis using tracking data to assess tactical match performance in defense.

In addition to the original research presented in this thesis (Paper I-IV), it is noteworthy that there are several other publicated original studies and collaborative works on the topic of match analysis in soccer. This includes one original study about defending behavior (Forcher, Beckmann, et al., 2023), one original study about offensive passing behavior (Forcher et al., 2021), and six collaborative studies about tactical factors (e.g. tactical formation & position) in connection to the match performance in soccer (Forcher, Forcher, Härtel, et al., 2023; Forcher, Forcher, Härtel, Jekauc, et al., 2022; Forcher, Forcher, Jekauc, Woll, et al., 2022; Forcher, Forcher, Jekauc, Wäsche, et al., 2022; Forcher, Forcher, Wäsche, Jekauc, et al., 2022; Forcher, Preine, Forcher, Wäsche, et al., 2022).

8.1 Main Findings

In this chapter, the main findings of this thesis are comprehensively discussed. Besides, it also presents important overarching arguments about the methodology of this thesis. This provides an understanding of the fundamental methodological procedures, which distinguish this work from comparable scientific research. Against this background, the main findings on tactical defensive match performance are discussed which are differentiated into the levels of tactical play: individual, group, and team level. Those subchapters will summarize the findings of the review and of the original studies that were examined in the respective level of tactical play. The levels that were analyzed in each individual paper were also illustrated in figure 3.1 in chapter 3 Aims and Scope of this Thesis.

Several overarching methodological aspects differentiate this thesis form comparable work about tactical match performance in soccer. Those aspects represent the methodological conception of the empirical studies examined in this thesis to generate relevant findings about successful tactical behavior in soccer and are outlined in the following.

One highly important aspect of this thesis that should be acknowledged is its variety of heterogenous analysis methods (e.g. different types of match analysis, see chapter 2.4 Types of Match Analysis in Soccer) and its diversity in statistical methods used (e.g. linear mixed model or supervised machine learning classifiers). The heterogenous types of analysis methods used in this thesis were combined and mutually enriched to provide deeper insights into the tactical match performance of soccer players. This primarily includes the combination of two types of match analysis, namely notational analysis and spatio-temporal analysis. While the studies of this thesis focused on the evaluation of tracking data using spatio-temporal analysis, the procedures were enriched using event data which was collected with a notational analysis (e.g. to select the studied match situations). This combination of objective and accurate tracking data (Linke et al., 2020) with the detailed information of event data enables detailed, thorough, and comprehensive analyses of successful tactical behavior in soccer. However, this comes with the difficulty of synchronizing the different data types which introduces a main strength of this work. With the effective synchronization of event data with tracking data in this thesis the major drawback of erroneous notational analysis due to human error is diminished. The synchronization procedure is described in detail in chapter 7 (see 7.4.2.1 Synchronization of Tracking and Event Data).

Next to the combination of the two quantitative types of match analysis, also qualitative expert interviews were conducted to extract tactical knowledge from professional soccer coaches. This variety in the combination of different sources of information provides an insightful novel and comprehensive way to analyze tactical match performance in soccer.

This mix of methods to analyze match performance in this thesis is accompanied by a highly heterogenous diversity in statistical analyzing methodologies of the resulting data. This includes the computation of a linear mixed model in the first original study (see chapter 5 Defensive Pressure) or the training of several different machine learning classifiers (e.g. Random Forest, XGBoost) in the last original study of this thesis (see chapter 6 Rest Defense). This diversity allows a comprehensive view on the effects of successful tactical behavior in the defensive playing phases.

Using those heterogeneous methods, the tactical match performance in soccer is analyzed in its whole. Thereby, this thesis investigates all levels of tactical match performance, which range from individual tactical behavior, over the tactical behavior of a group of players, to the behavior of a whole team. With it, a comprehensive view of tactical behavior in the defensive playing phases can be gained which enables the discussion of detailed findings on a fine-grained level.

Another overarching methodological aspect that is crucial to all findings in this thesis, is the relationship of tactical behavior to success. In general, the tactical behavior of players is goal-oriented and, therefore, tactical behavior should be analyzed in the context of its effectiveness on the achievement of a given goal (see chapter 2.3.1.1 Main Facets of Match Performance). However, most studies that analyze tactical behavior lack this connection of tactical performance to success. For instance, almost half of the studies analyzed in the review paper of this thesis (see chapter 4 Review) did not investigate their approaches in connection to success (= 11 of 23). Furthermore, only 2 of all 23 studies analyzed defensive tactical behavior in relation to the particular goals of the defensive playing phases (e.g. ball gain). Though, this connection to success is important to demonstrate the actual significance of the analyzing approaches and substantial for the interpretation of the results with regard to the effectiveness of goal-oriented tactical behavior. Therefore, the original studies of this thesis focused on this connection of tactical behavior to success which is one of the main strengths of this thesis. Overall, the connection of tactical behavioral variables to success enables the investigation of the effectiveness of tactical behavior that goes beyond the mere description of what happens on the field. This also allows to draw specific assumptions about effective behavior that can be applied in practice (see chapter 8.2 Practical Application).

A fourth overarching methodological aspect of this work is its characteristic of a large-scale analysis. The original studies each assessed 153 matches of elite-level match data of the German Bundesliga. This sample significantly exceeds the small sample size of most comparable analyses in this field. For instance, the presented review revealed that two thirds of all considered studies (15 of 23) used less than 30 matches as a sample. Further, soccer match performance is highly variable (O'Donoghue, 2004). Therefore, small samples may not accurately collect information about general performance patterns. By investigating this large sample size of 18 teams playing against each other once, this thesis can reveal representative results of a typical match performance.

The evaluation of such a large sample size combined with the Big Data nature of tracking data (see 2.4.3 Spatio-Temporal Analysis (tracking data)) entails the challenge of requiring computational methods to process the match data. Therefore, this thesis applied computational methods (e.g. python) and machine learning (e.g. identification of team formation in chapter

7 Compact Organization, or prediction of successful rest defense in chapter 6 Rest Defense) to analyze the tactical match performance of players. Nevertheless, the application of machine learning in performance and match analysis comes with chances and risks which are briefly outlined. Those computational methods can reveal quantitative and objective information (e.g. predictions) to complement decision-making processes (e.g. about team tactics (Anzer et al., 2022) or substitutions (Dijkhuis et al., 2021)). Furthermore, this objective information can be used to analyze identified success factors of tactical match performance to possibly enhance player performances (e.g. identification of success factors in chapter 6 Rest Defense). Moreover, the application of machine learning can identify hidden patterns in highly complex systems (Rein & Memmert, 2016) such as soccer match performance (see chapter 2.3 Appearance of Match Performance in Soccer). However, the application of machine learning also comes with risks. For instance, the possibility of data leakage in modeling (Gibney, 2022; Kapoor & Narayanan, 2022) can cause problems in the model outcomes. Therefore, the separation of dependent and independent variables (e.g. no blending of information) is highly important concerning scientific claims made based on the results of the machine learning approaches. Further, machine learning models have the risk of reproducing human decisions that are subjective and biased. Artificial intelligence that is trained on data that involves human decisions (e.g. selection of players for the squad or substitutions) holds high risks of copying tendencies of human decisions. In contrast, if the artificial intelligence is trained on objective success criteria (e.g. ball gains in defense) there is a lower risk, as the prediction maps objective success in the target variable (for example see chapter 7 Rest Defense). Overall, the accuracy of developed machine learning models is often overestimated. For instance, the expected goal model of the German Bundesliga, which is presented in television broadcasting, is interpreted as an objective metric by spectators that perfectly describes scoring opportunities in their entirety. However, the model solely correctly predicts about 20 [%] of all goals scored (Anzer & Bauer, 2021). Following this example, all machine learning models have a varying but existing degree of uncertainty. This should be considered especially in soccer, where the complexity of match performance is high and no passage of play looks like a previous one. In the end, machine learning is often seen as a black box which questions its use in science for the advancement of knowledge. However, the insights gained into a machine learning model depend on the prediction algorithm. With explainable AI methods, such as SHAP values (see chapter 7 Rest Defense) the explainability of models is increased which provides insights into the machine learning models (e.g. feature importances) (Marcílio & Eler, 2020). Overall, the quality of quantitative analyses (e.g. predictions of a specific machine learning model) is highly dependent on the quality of the input data. Concluding, in the case of this thesis, the accuracy of tracking data allows for deep and objective insights into tactical match performance of soccer (Linke et al., 2020).

The last overarching issue that should be acknowledged is the magnitudes of effect sizes that were identified in empirical studies of this thesis. The identified effect sizes in the differences

between successful and unsuccessful tactical behavior in the defensive playing phases were found to be small (e.g. small effects of Cohen's $d < 0.5$ in chapter 7 Compact Organization). Even though their magnitude is small, the effect sizes are comparable to other studies about tactical match performance in soccer (Forcher et al., 2021; Goes, Brink, et al., 2021). The small magnitude of effect sizes can be traced back to the complexity of the team sport soccer (individual complex performance, & interactions within and between teams) and the many degrees of freedom in the movements of the 22 individual players. This results in high variability in the resulting tactical behavior of players with a large distribution of resulting values (e.g. defensive pressure). Therefore, found patterns have a large variance which results in decreased effect sizes. Furthermore, each of the original studies of this thesis solely analyzed a small subset of the tactical match performance in defense (e.g. defensive pressure in chapter 5 or compact organization in chapter 7). Therefore, the effects of the small subsets of the whole match performance found on the effectiveness of overall successful tactical behavior in the respective playing phase are highly meaningful. Those small differences in the tactical behavior of soccer players that is related to success can be seen as an important factor in the game of chance (Aoki et al., 2017). Against the presented background of overarching methodological aspects of this work, the findings on the different levels of tactical match performance (individual, group, & team level) are outlined in the following.

8.1.1 Individual Level

This chapter comprehensively discusses the findings of this thesis on tactical match performance at the individual level. First, the main findings are summarized, followed by the results of the review discussing the analyzing approaches to analyze defensive play at the individual level. In the end, the results of successful individual tactical behavior in defensive play are discussed including the results of the first original study about defensive pressure.

The following bullet points summarize the findings on tactical match performance in defensive play at the individual level. They are structured according to the approaches used to analyze defensive play and the main findings on tactical match performance.

- Analysis approaches at the individual level:
  - Defensive pressure to analyze tactical behavior at the individual level is a valuable key performance indicator for defense
- Findings on defensive play at the individual level:
  - Defensive pressure is higher in successful defensive plays compared to unsuccessful defensive plays
  - To press the ball-leading player is highly important to regain the ball in defensive play

The presented review (see chapter 4 Review) solely identified one methodological approach, namely defensive pressure, to analyze defensive tactical behavior at the individual level. Defensive pressure measures the magnitude of pressure exerted by all pressers (= defenders) on the pressure target (= attacker). In detail, the computation includes the distance and the angle between the defender and the attacker depending on the direction to the defendants' goal (see chapter 5.4.4 Defensive Pressure). Even though it is the only individual measure, defensive pressure is one of the most used variables to assess defensive behavior (Andrienko et al., 2017; Goes, Schwarz, et al., 2021; Herold et al., 2022; Lago-Ballesteros et al., 2012; Link et al., 2016; Szczepanski & McHale, 2016). However, solely one of the studies that used defensive pressure focused on the analysis of defensive play while all other five studies used defensive pressure as a variable of opponent interaction to assess offensive play.

Therefore, the first original paper (see chapter 5 Defensive Pressure) used this metric to investigate the space and time characteristics of successful defensive pressure in defensive play. This analysis was completed at a possession level by investigating the differences between successful and unsuccessful defensive plays attributed by the outcome of a playing sequence (i.e. ball gain vs. other than ball gain, e.g. opposing shot at goal). This analysis at a possession level allows for more detailed analyses compared to match level or event level analyses. Match level analyses are highly influenced by the randomness of the final outcomes in a low-scoring game such as soccer (Brechot & Flepp, 2020; Gauriot & Page, 2019; Wunderlich et al., 2021). Furthermore, the connection of a specific tactical behavior within a playing sequence to the outcome of a whole match is only weak and therefore no direct conclusion on effective behavior can be drawn (Freitas et al., 2023). In contrast, event level analyses may not account for the contribution of a single action to the achievement of the goal of the playing phase, which usually requires several actions to achieve success (e.g. a series of passes to score a goal). The presented study at a possession level addressed those issues by analyzing individual possessions with a series of actions that are meaningfully related and less influenced by chance compared to match level analyses.

The findings of this study indicated that defensive pressure is higher in successful defensive plays compared to unsuccessful defensive plays. Consequently, decreasing the distance to the pressed attacker or improving the angle to pressure the attacker (e.g. standing directly between the attacker and the own goal) can possibly increase the chance to regain the ball in defense. This finding is in line with the results of Andrienko et al. (2017) who revealed that successful defensive plays are characterized by higher defensive pressure (on the ball & on the attackers) analyzing the same pressure metric. Accordingly, defensive pressure can map successful defending and, therefore, is a valuable key performance indicator for defensive play. Moreover, in accordance with the results of Andrienko et al., the presented study could indicate that defensive pressure on the ball-leading player was higher (pressure on the ball 16.61 ± 23.89 [%]) compared to areas further away from the ball (e.g. pressure on the team: 10.03 ± 5.94 [%]). This difference was shown to be greater for successful defensive plays compared to unsuccessful ones. Accordingly, for successful defending it seems most important to pressurize the ball-leading player to terminate the opposing attack.

Besides, there are several other studies on defensive pressure to assess tactical match performance. For instance, a notational analysis of Szczepanski (2008) that roughly differentiated between pressured and not pressured attackers showed that pressing an opposing attacker decreases the possibility of an opposing score. Further, Robberechts (2019) and Merckx et al. (2021) presented a risk-reward model of defensive pressing by computing the probability of regaining the ball and the risk of leaving the defensive structure. While defensive pressure on the ball-leading player was used as one feature in the prediction approach, both studies focussed on the performance of the computational approach and did not present insights about individual features (e.g. feature importance or feature interpretation). Therefore, no conclusions on effective tactical defensive behavior can be drawn. Similarly, the other five studies that assessed defensive pressure as a variable of opponent interaction to investigate tactical behavior in offensive play (e.g. passing) (Goes, Schwarz, et al., 2021; Herold et al., 2022; Lago-Ballesteros et al., 2012; Link et al., 2016; Szczepanski & McHale, 2016) did not present results on defensive behavior.

Overall, it can be concluded that successful defensive plays are characterized by higher defensive pressure at the individual level (e.g. defensive pressure on the ball-leading player). Therefore, the hypothesis that successful defensive plays show higher defensive pressure compared to

unsuccessful defensive plays can be confirmed at the individual level (see chapter 3.2 Defensive Pressure).

Accordingly, the defensive pressure metric that was used in the original study based on the approach of Andrienko et al. (2017) allows to effectively analyze the individual defensive behavior of players. Therefore, detailed insights into defensive tactics at the individual level can be provided, such as the importance of pressing the ball-leading player for defensive success. Beyond the individual assessment of defensive pressure, this thesis also used this metric to analyze defending behavior at the group level, by analyzing the mean pressure on the five closest attackers to the ball, or at the team level, analyzing the mean pressure on the whole attacking team. Both ideas are presented in the next chapters.

8.1.2 Group Level

After discussing the aspects of individual successful defending, this chapter focuses on the tactical match performance of collective groups of players in defense. Thereby, groups of players are considered that represent a collective of at least 2 players.

All three original studies of this thesis investigated variables that comprise tactical behavior at a group level. Two of them investigated the playing phase of defensive play (see chapter 5 Defensive Pressure & chapter 7 Compact Organization) and one focused on a specific group tactic in the playing phase of defensive transition (see chapter 6 Rest Defense). Due to the distinctly different characteristics (e.g. match conditions & goals) of the playing phases different tactical behavior of players is expected (see figure 2.1 in chapter 2.3.2 Collective Team Match Performance). Consequently, the discussion will analyze those two playing phases separately.

In detail, this chapter is started with presenting the main findings of this thesis at the group level. Afterward, the results of the review are presented by introducing the approaches that were used to assess the tactical match performance in defense at the group level. This is followed by a comprehensive discussion of the findings on successful tactical behavior at the group level differentiated by the playing phases. Thereby, the findings of the three original studies of this thesis regarding group level defending are discussed comprehensively.

The results of tactical match performance in defensive play and defensive transition at the group level are summarized in the following bullet points. They are structured according to the approaches used to analyze defensive behavior at the group level and the findings on successful tactical match performance in both defending playing phases (i.e. defensive play & defensive transition).

- Analysis approaches at the group level:
  - The approaches to analyze tactical behavior in defense at a group level are highly heterogenous, ranging from the analysis of positional measures of subgroups of players (compactness, numerical superiority, or inter-line distances) to the analysis of synchronization of subgroups (intra- & inter-team)
- Findings on defensive play at the group level:
  - Successful defensive plays are characterized by higher defensive pressure on the attackers close to the ball and higher compactness of the defenders in ball proximity
- Findings on defensive transition at the group level:
  - To regain the ball as quickly as possible is crucial for the success of defensive transition
  - Rest defending players should control deep spaces and potentially dangerous counterattackers to be successful

The review that was presented in this thesis identified highly heterogeneous approaches to

analyze defending behavior of groups of players. Those approaches include the analysis of numerical superiority in subareas of the pitch (Vilar et al., 2013), the positioning of the defensive-line (Castellano & Casamichana, 2015), and the determination of the defensive playing area (Clemente et al., 2016). Further, several studies analyzed group level defending behavior by assessing the extent of synchronization of subgroups within a team (Folgado et al., 2018) and between teams (Goes, Brink, et al., 2021). Those analyses measured the synchronization of dyads (pairings of players) or centroids of formation lines (e.g. midfielder-line). The results of the review regarding successful defending will be discussed in the light of the original studies in the following.

After outlining the different analysis approaches, the tactical match performance of subgroups in the playing phase of defensive play is of interest. The first original study of this thesis analyzed defensive pressure characteristics in defensive play and was presented in the previous chapter. Next to the analysis of individual defending this study also assessed tactical behavior at the group level. This defensive behavior was examined by measuring the defensive pressure on the five attackers closest to the ball (= pressure on the group). The results indicated that the defensive pressure on the group was higher in successful defensive plays compared to unsuccessful ones. Consequently, defensive pressure on attackers in areas close to the ball should be higher to be successful in defensive play. This pressing behavior of the subgroup of defenders closes down near pass options around the ball-leading player. With it, the effective pressing of the ball-leading player is supported by denying an easy escape from the pressing situation with a short pass to a close teammate. However, the mean pressure values on the group of five attackers closest to the ball (12.75 ± 10.01 [%]) were significantly smaller than the pressure on the ball carrier (16.61 ± 23.89 [%], β = -14.17, $p < 0.001$). Therefore, the results suggest that for defensive success it is most important to pressurize the ball-leading player, followed by the pressure on the group of attackers close to the ball. Still, the initial hypothesis with higher defensive pressure expected in successful defensive plays can be confirmed for the group level of defensive pressure in areas close to the ball (see chapter 3.2 Defensive Pressure).

The other original study of this thesis that focused on the playing phase of defensive play and analyzed tactical match performance at the group level assessed the compact organization of the defending team (see chapter 7 Compact Organization). Similar to the previous study about defensive pressure, this study analyzed the differences between successful and unsuccessful defensive plays. In this study, three main parts of the defensive compact organization were investigated including the compactness, contraction of compactness, and organization within this compactness (for a detailed discussion about those three parts see chapter 7.3 Introduction (Compact Organization)). Regarding the organization this study indicated that the defensive-line and midfielder-line are spatially positioned closer to each other (def-mid: Ø = 10.17 ± 3.87 [m]) compared to the distances to the attacker-line (mid-att: Ø = 13.21 ± 4.21 [m]) (d = -0.75). However, no differences were found between this organizational measure (inter-line distances) between successful and unsuccessful defensive plays. In two experimental studies Low et al. (2021; 2021) found comparable magnitudes of inter-line distances within the defending team (around 10-15 [m]) by investigating the differences in defensive tactical behavior between different defensive playing styles (deep defending vs. high press) and different tactical formations (4-4-2 vs. 5-3-2). However, Low et al. (2021; 2021) did not indicate effects of those organizational measures on defensive success. According to this state of research, the hypothesis of a better organization in successful defensive plays has to be falsified for the measure of inter-line distances (see chapter 3.4 Compact Organization).

Next to the organization of the defending team, the fourth original study about compact organization in defense did also analyze the compactness of two defending subgroups. Regarding the compactness (surface area & spread), the subgroup of players belonging to the defending- and midfielder-line ("DC defense & midfield") showed no differences between successful and unsuccessful defensive plays. In contrast, the compactness of the defensive collective of defenders in ball proximity ("DC ball nearness") was higher (e.g. smaller surface area) in successful defensive plays ($d \geq -0.16$) compared to unsuccessful ones. This finding suggests that higher compactness in areas close to the ball is beneficial for defensive success. This higher compactness of the subgroup of players close to the ball might generate a numerical superiority in those areas which could assist in pressurizing the ball-leading player and covering close pass options to achieve a ball gain. In this context, Vilar et al. (2013) found that winning teams show a higher numerical superiority in defense to maintain defensive stability. Furthermore, in a comprehensive study, it was shown that numerical superiority in areas close to the ball (i.e. 10 [m] and 20 [m] around the ball) is a crucial indicator for defensive success (Forcher, Beckmann, et al., 2023). A possible explanation approach for those findings could be the tactical behavior of players on the far side of the ball (e.g. full back on the pitch side opposing to the ball position) or in the last line (e.g. central defender) which are not in ball proximity. In detail, those players aim to protect the weakside (= opposing to the ball position) and the deep spaces behind the defensive-line to cover possible dangerous areas and to prevent the opposing team to overplay the pressured areas close to the ball (see figure 7.3. chapter 7.6 Discussion (Compact Organization)). According to the findings, the initial hypothesis that successful defensive plays show higher compactness can solely be confirmed for the subgroup of defenders in areas close to the ball. For the subgroup of players in the defensive- and midfielder-line this hypothesis has to be rejected (see chapter 3.4 Compact Organization).

Besides the organization within the defending team and the compactness of the defending subgroups, also the contraction of compactness of those subgroups was investigated by the fourth original study about compact organization in defensive play. The results showed that successful defensive plays are characterized by a higher contraction of compactness of the subgroup of defenders and midfielders ("DC defense & midfield"). This spatial contraction of compactness over a time period may support to increase the spatial and temporal pressure on the attackers

to regain the ball in defensive play. In contrast, no significant effects were found for the contraction of compactness for the other subgroup of defenders in ball proximity ("DC ball nearness"). Therefore, the initial hypothesis of the contraction of compactness to be higher in successful defensive plays compared to unsuccessful ones can be confirmed for the "DC defense & midfield" and has to be rejected for the "DC ball nearness" (see chapter 3.4 Compact Organization).
Overall, the results of both studies on the playing phase of defensive play (defensive pressure & compact organization) potentially are highly related to each other. For example, the increase of compactness around the ball may entail a higher defensive pressure on attackers in ball proximity. Combining both studies' results it can be concluded that the tactical behavior of the subgroup of defenders in areas close to the ball is highly important for the success of a defensive playing phase.
Contrary to the analysis of tactical match performance in defensive play, the second original study of this thesis focused on the playing phase of defensive transition after a ball loss (see chapter 6 Rest Defense). In detail, the group tactic of rest defense was assessed. According to the conducted expert interviews, rest defense can be defined as the positioning of the deepest defending players (usually last line & central midfielder) in own ball possession, when the players have no more task in attacking play (i.e. when the ball is in the attacking third / the opponent's midfielder-line is overplayed). The rest defending players control deep spaces and potentially dangerous counterattacking players for the possibility of a ball loss to prevent opposing counterattacks or, in the best case, to quickly regain the ball in defensive transition. Since the presented study is the first investigation on the specific group tactic of rest defense the results are discussed in the light of studies that investigated defensive transition in general or focused on other group tactics in defensive transition such as counter-pressing. The analysis of the input features of the machine learning model that was trained to predict the success of the defensive transition in the present study showed that it is most important for success in the defensive transition to reduce the duration of the opposing counterattack. Thus, to regain the ball quickly after a ball loss increases the success of the defensive transition by giving the counterattacking team less opportunity to build their attack by denying their actions early. Moreover, with the ball possession change (i.e. ball gain or ball loss) the tasks of the two teams change instantly from defending the own goal towards controlling the ball to attack the opposing goal, and vice versa. In this case, the teams are disorganized for a short moment. This unstable situation can be used by the team in defensive transition to quickly regain the ball without allowing the opposing team to proceed to the own goal which can be decisive in a match. This finding is supported by Casal et al. (2016) and Vogelbein et al. (2014), who both identified the time to recover the ball after a ball loss as an important indicator of successful performance in defensive transition. Furthermore, Bauer and Anzer (2021) revealed that the chance of conceding a goal is greatly increased if the ball is not regained within five seconds after a ball loss. Concluding, to quickly regain the ball after a ball loss is a main success factor of the playing phase of defensive transition.

Besides this assumption about fast possession regains in defensive transition in general, there are several findings on the specific group tactic of rest defense. Most importantly, the results of the presented original study in defensive transition suggested that a higher defensive numerical superiority increases the success of rest defense. In this regard, Bauer and Anzer (2021) indicated that it is beneficial for successful defensive transition when four or more players are behind the ball after a ball loss. They analyzed counter-pressing which is a different group tactic (i.e. refers to a different tactical goal of a subgroup of players) in defensive transition compared to rest defense. In detail, counter-pressing describes the behavior of defending players in ball proximity immediately after a ball loss to regain the ball as fast as possible. Therefore, the results are only partially comparable to the findings of the original study about rest defense which should be noted.
On average in the presented study of this thesis, a defensive numerical superiority of +1.7 (± 1) defenders in the rest defense area (i.e. difference between the number of attackers and defenders 10 [m] in front of the deepest defender) was identified. Comparably, Vilar et al. (2013) also found +1 player superiorities in the center-back sub-areas of defense which can be interpreted as rest defense area. This numerical superiority of defenders in rest defense enables them to control possible counterattackers and dangerous spaces (e.g. deep spaces) more effectively. With it, the defense can be described as more balanced which has been shown to be important to reduce the effectiveness of counterattacks (Tenga et al., 2010b). For instance, another study demonstrated that attacks are less successful when played against more than five defenders (Lago-Ballesteros et al., 2012). In this regard, the space control of rest defending players was also shown to be crucial for rest defense to be successful in defensive transition. By denying space control of the attackers, the defenders control dangerous counterattackers and deep spaces. By placing more defenders in the area of rest defense, the space control of rest defending players can possibly be increased. In conclusion, those results suggest that rest defending players should control deep spaces and dangerous counterattackers to successfully prevent a fast opposing counterattack. This tactical behavior can assist in a fast possession regain to stop an opponent's counterattack in the early stages which is most important for success in defensive transition.
Overall, the analysis of subgroup tactical match performance in the defending playing phases revealed detailed and comprehensive results. The studies showed that specific group behaviors can be effectively identified using summarized KPIs (e.g. defensive pressure on the group, or space control of rest defending players). In comparison to team level analyses (e.g. centroids of the full team, see following chapter 8.1.3 Team Level), the assessment of tactical match performance of subgroups provides more in-depth information (Goes, Brink, et al., 2021). This is especially indicated by the set of effects of subgroup variables associated with successful tactical match performance in the defensive playing phases.
Subsequently to the presented discussion of group level defending, the following chapter will present the findings of this thesis on tactical match performance at the team level.

8.1.3 Team Level

Following the comprehensive discussion of group level defending behavior, this chapter focuses on the team level of tactical match performance. In contrast to the previous chapters about individual and group defending behavior, the tactical match performance of all players of the defending team is considered in the following.

At the beginning, the main findings of this thesis at the team level are summarized followed by the presentation of approaches to analyze the defensive tactical match performance of the whole team. In the end, the original studies about defensive pressure and compact organization regarding their findings on the tactical performance at the team level are presented. In contrast to the previous chapter, this chapter focuses solely on the playing phase of defensive play since both original studies assessed the tactical match performance of the defending team in this playing phase. Those results are comprehensively discussed with comparable research regarding the effectiveness of defending behavior at the team level.

Below, the main findings of tactical match performance in defensive play at the team level are presented in bullet points. They are differentiated in the approaches used to analyze team level tactical behavior and the findings on successful defensive play at the team level.

- Analysis approaches at the team level:
  - The approaches to analyze defensive play at the team level are heterogenous and include organizational measures of the whole team (e.g. surface area & spread), the analysis of inter-team synchronization, or the analysis of ball recoveries
- Findings on defensive play at the team level:
  - Successful defensive plays show a higher contraction of compactness (e.g. decrease in surface area) of the defending team compared to unsuccessful defensive plays
  - There is no evidence that a higher compactness (e.g. smaller surface area) of the whole defending team or a higher defensive pressure on all attackers would increase defensive success

The review paper identified several different approaches to analyze tactical match performance in defense at the team level. Several studies analyzed the influence of contextual variables (e.g. match venue, match status) on ball recoveries (Fernandez-Navarro et al., 2019; Santos et al., 2017; Santos & Lago-Penas, 2019). Further, one study analyzed inter-team synchronization using the centroids of both teams (Frencken et al., 2012). Besides, most studies analyzed the organization of the whole defending team using comprised performance indicators such as the centroid, the surface area, the spread (Bartlett et al., 2012; Clemente et al., 2013a; Moura et al., 2012), or the polarization and angular momentum of the team (Welch et al., 2021). Concluding, there are heterogenous approaches to analyze defending behavior at the team level with the majority of studies investigating the organization of the defense.

Those comprised team metrics (e.g. surface area, spread) were used in the last original study of this thesis to analyze the principle of a compact organization in defensive play (see chapter 7 Compact Organization). With it, the organizational measures (e.g. surface area, spread) were used to analyze successful defending behavior at the team level. As explained before, this presented study differentiated between the main three parts of the principle of compact organization (compactness, contraction of compactness, & organization). Since the defensive organization was assessed using subgroup measures (inter-line distances) solely compactness and contraction of compactness were examined with team level variables.

Regarding compactness, this original study found no evidence suggesting that higher compactness of the whole defending team would increase success in defensive play. Those results are in line with the findings of Bartlett et al. (2012). However, Moura et al. (2012) found a higher compactness (e.g. smaller surface area) of successful defensive plays compared to unsuccessful ones in the last moment of an opposing attack. According to those contrary results, the relationship between the compactness of the entire defending team and success in defensive play remains questionable. Therefore, the initial hypothesis of higher defensive compactness of the whole team in successful defensive plays compared to unsuccessful ones cannot be verified and must be further examined in future studies to draw a clear conclusion (see chapter 3.4 Compact Organization). In contrast to compactness, the present study indicated that the contraction of compactness of the whole defending team was higher in successful defensive plays compared to unsuccessful ones ($0.09 \leq d \leq 0.12$) . Therefore, the rebuild of compactness seems to be important to regain the ball which confirms the initial hypothesis of a higher contraction of compactness in successful defensive plays (see chapter 3.4 Compact Organization). Overall, the organizational analysis of the tactical behavior of the defending team can be classified in the contraction-expansion relationship between the tactical positioning of the offensive and the defensive team (Clemente et al., 2013a; Moura et al., 2012; Welch et al., 2021). Briefly summarized, this relationship is about the attacking team expanding to create space while the defending team is contracting to reduce the playing space (further details see chapter 2.3.2 Collaborative Team Match Performance). The presented findings of the last original study indicated that it seems to be beneficial for defensive success to increase compactness over a time period (contraction of compactness). However, it remains doubtful that higher compactness of the defending team alone would drive defensive success.

In the same way, the second original study of this thesis (see chapter 5 Defensive Pressure) which assessed defensive pressure found only minimal differences between the magnitude of defensive pressure on the whole attacking team between successful and unsuccessful defensive plays. Furthermore, the pressure on the team showed the lowest values of defensive pressure (10.03 ± 5.94 [%]) compared to the pressure on the ball-leading player at the individual level (16.61 ± 23.89 [%]) and the pressure on the five attackers closest to the ball at the group level (12.75 ±

10.01 [%], **β** = -19.80, p < 0.001). Consequently, the defensive pressure on all attacking players at the team level seems to have a marginal effect for defensive success. In comparison to the individual pressure on the ball-leading player and group pressure on the attackers in ball proximity, the initial hypothesis of higher defensive pressure in successful defensive plays compared to unsuccessful ones has to be rejected at the team level (see chapter 3.2 Defensive Pressure).

The presented results at the team level can be complemented by two studies analyzing inter-team synchronization. Goes et al. (Goes, Brink, et al., 2021) found a slightly a-synchronous behavior on a team-level, especially in the longitudinal direction in successful attacks. When interpreted conversely, one could conclude that the defensive team should maintain a synchronous behavior at the team level with regard to the opposing team to may increase defensive success. Besides, Frencken et al. (2012) solely indicated a minimal relation between inter-team distances and critical match events. Based on those minimal effects it remains uncertain whether a higher inter-team synchronization at the team level can be beneficial for defensive success. Over all study results regarding the team level, for instance, the compactness of the whole defending team and the defensive pressure on all attackers, the effects on the success of defensive play were marginal.

This could be traced back to the goal of players who are not in direct ball proximity, which was explained in detail in the previous chapter. Those defenders aim to control dangerous spaces further away from the ball (e.g. deep spaces or weak side) without directly pressurizing attackers in those areas or increasing the overall compactness of a team. Therefore, it can be concluded that the tactical behavior of defenders who are not in direct ball proximity needs to be examined with further investigation approaches. For instance, the defenders' pitch control in the aforementioned spaces could be of interest (e.g. space control of deep spaces behind the defensive-line).

In the end, all levels of tactical match performance in defense depend on each other (individual, group, & team level). For example, the contraction of compactness of the whole defending team (team level) may increase the compactness of players close to the ball (group level), which might lead to a player being positioned in ball proximity to individually pressurize the ball-leading player (individual level). Still, based on the effects found in the different levels, individual and group level analyses showed more insights compared to team level analyses.

In conclusion, the results of the presented studies indicate that group and individual levels showed more decisive results regarding beneficial tactical behavior for successful defensive play (e.g. defensive pressure on the ball-leading player, defensive compactness in areas close to the ball). In comparison, there were only small indicators for successful defense at a team level (solely contraction of compactness).

8.2 Practical Applications

This chapter builds the transition from the discussion of the findings of this thesis to their practical application. The findings on the tactical match performance in the defensive playing phases that were presented in the previous chapters will be transferred to draw practical conclusions with value for soccer coaches or analysts. This transfer of findings to their practical relevance is one of the most important aims for sports scientific research (Schröder & Dose, 2010) (see chapter 2.2 Subsumption into the Subject Field of Sports Science). Therefore, it is crucial for this sports scientific work with its predominant applicational orientation to interpret the results of this thesis in a practice-relevant way to enable an application in practice (Schröder & Dose, 2010). Accordingly, this chapter shifts the orientation from the discussion of the findings of this thesis towards their transfer into practice.

In this chapter principles of play are formulated based on the most important findings about tactical match performance in defense. They are constructed to build the gap from theory to practice by increasing the usefulness and meaningfulness of this sports scientific thesis. This procedure aims at a theory-guided practice which can be seen as an adequate requirement in terms of knowledge transfer (Haag & Mess, 2010). This reduction of the research-practitioner gap (Drust & Green, 2013; McLean et al., 2017) is a widespread lack of comparable performance analyses (Wright et al., 2017) which is especially true for match analyses using tracking data.

This chapter starts with a brief definition of principles of play in soccer. With it, their advantages are presented to justify the procedure. Subsequently, the principles of play based on the findings of this thesis are formulated. They are differentiated between the separate playing phases of defensive play and defensive transition. In the end, this chapter closes by outlining how those principles of play can be applied in practice.

In general, principles of play can be defined as general and superordinate principles of tactical behavior that, dependant on the match context, are advantageous in solving match situations in soccer (Costa et al., 2009; Hewitt et al., 2016; Ouellette, 2004). In this thesis, the context that moderates the expression of the principles of play is a particular playing phase (such as defensive play or defensive transition). Accordingly, different general beneficial behavior is expected in different playing phases according to the respective goals in this phase (see figure 2.1 in chapter 2.3 Appearance of Match Performance in Soccer). Thus, the principles of play formulated in this thesis describe and comprise the advantageous tactical behavior to optimally achieve the goals in the respective playing phase. Concluding, this chapter summarizes the findings of this thesis in principles of play depending on the playing phase.

This procedure of translating the presented findings into principles of play has several advantages that make their application in practice effective. Since they are based on the findings of the original studies in this thesis, the principles have been illustrated to be related to successful match performance in the defensive playing phases. Therefore, their significance is scientifically

indicated. Furthermore, the characteristics of the original studies of this thesis are highly important to increase the value of the formulated principles of play, including the large sample size, the use of up-to-date analysis methods based on tracking data, and the connection to success. The characteristic of a large-scale analysis allows for more general conclusions about tactical match performance. The use of spatio-temporal analysis using tracking data enables to gain detailed insights into successful tactical behavior patterns. The connection to success in this thesis is essential to be able to derivate principles of play. This allows to reveal findings of successful tactics and draw conclusions of the success factors in soccer. Therefore, the formulated principles of play hold a high general validity and can enhance coaches' understanding of the key aspects of tactical behavior in the defensive playing phases (Mackenzie & Cushion, 2013).
After describing the meaning of principle of plays in general, the principles of play derived of the findings of this thesis are formulated in the following and are illustrated in figure 8.1. They are differentiated between the playing phases of defensive play and defensive transition. This distinction is due to different tactical behavior which is expected due to different match conditions (e.g. player positioning) and goals of the respective playing phase (see figure 2.1 chapter 2.3 Appearance of Match Performance in Soccer).

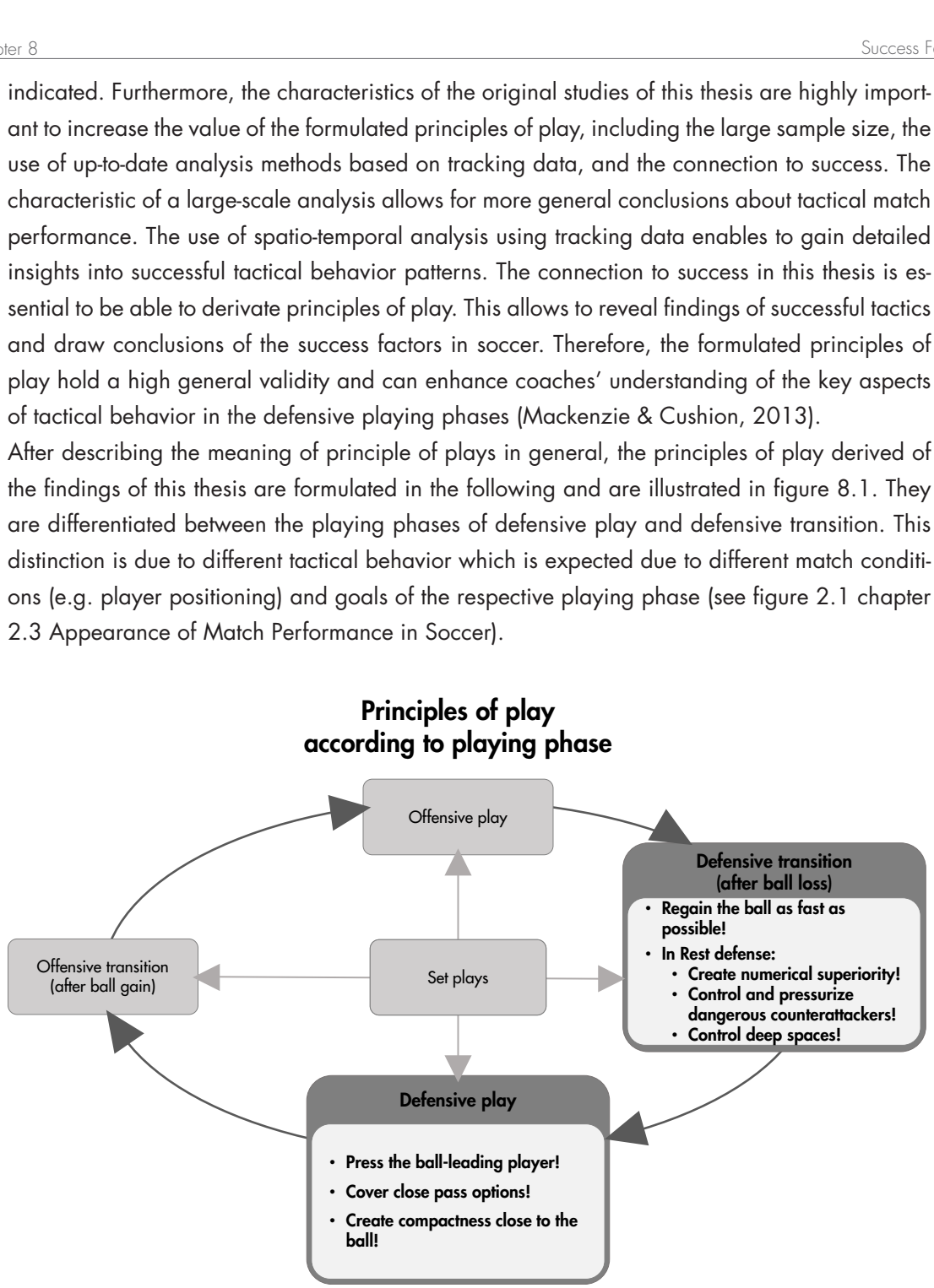

Figure 8.1: Principles of play according to the playing phases of defensive play and defensive transition. The principles are derived from the findings of the original studies of this thesis.

8.2.1 Principles of Defensive Play

In the following, the principles of play in the playing phase of defensive play are derived from the results of the presented original studies (see chapters 5 & 7 Papers II & IV).

- Press the ball-leading player!

The main finding of the first original study of this thesis indicated that in defensive play it is most important to pressurize the ball-leading player to regain the ball (see chapter 5 Defensive Pressure). In detail, this defensive pressure on the opposing attacker in control of the ball increases the spatial and temporal pressure for this attacker which reduces the space and time for actions on the ball. This can force the attacker to make technical mistakes and enables the defending team to regain the ball. Without pressing the ball-leading player the attacker in control of the ball can proceed to dangerous pitch zones (e.g. dribble in front of the goal to create a dangerous scoring opportunity).

- Cover close pass options!

In addition, the results of this first original study showed that is seems crucial for success in defensive play to cover close pass options by pressurizing the five closest attackers to the ball (see chapter 5 Defensive Pressure). In this context, two other studies indicated that numerical superiority around the ball is an important success criterion in defensive play (Forcher, Beckmann, et al., 2023; Gréhaigne et al., 2002). Due to this numerical superiority, close pass options can be covered more effectively (e.g. by covering passing lanes or double coverage). With successfully covering close pass options, the defense can effectively put pressure on the ball-leading player and can intercept played passes. Moreover, if a pass cannot be intercepted directly, the pass receiver can be put under direct pressure shortly after the pass reception without allowing the attacker to control the ball.

- Create compactness close to the ball!

The main finding of the last original study of this thesis showed that it is most important for the compact organization of the defense to create compactness in areas close to the ball (approximately 15 [m] around the ball) to be successful in defensive play (see chapter 7 Compact Organization). This compactness in areas close to the ball enables the defenders to quickly put pressure on the attackers after a ball move. Thereby, the compactness around the ball increases temporal and spatial pressure on the ball-leading player by simultaneously increasing the coverage of close pass options. Combining those tactical behavior patterns in defense can increase the chances of gaining the ball in defensive play.

8.2.2 Principles of Defensive Transition

The main findings of the second original study of this thesis are comprised in principles of play of the playing phase defensive transition (see chapter 6 Paper III). They are differentiated in a general principle of play for defensive transition and three principles of play especially for the group tactic of rest defense in defensive transition.

In defensive transition in general:

- Regain the ball as fast as possible!

In accordance with previous studies (Bauer & Anzer, 2021; Casal et al., 2016; Vogelbein et al., 2014) the results of the original paper (see chapter 6 Rest Defense) indicated that it is most important for success in defensive transition to regain the ball as fast as possible. Denying the actions of the counterattacking team early after their ball gain gives them less opportunity to build their attack.

In group tactic of rest defense in defensive transition:

- Create numerical superiority!

The results of the original study about rest defense (chapter 6 Rest Defense) showed that it is highly important for the success of rest defense after a ball loss to create numerical superiority in the area of rest defense (i.e. 10 [m] in front of the last defender). This numerical superiority facilitates the rest defending players to achieve the other two principles of play in rest defense to pressurize dangerous counterattackers and control deep spaces. Overall, this tactical behavior pattern can contribute to stop dangerous opposing counterattacks more effectively.

- Control and pressurize dangerous counterattackers!

Further, the results of this study about rest defense in defensive transition (see chapter 6 Rest Defense) showed that it is important to control possible dangerous counterattackers placed close to the own goal. By controlling the space around those attackers through advantageous positioning (e.g. by placing one defender behind and before the attacker, "sandwich rest defense", see chapter 6.4 Expert Interview) one of the main goals of rest defense, to prevent opposing counterattacks, can be achieved more successfully. Besides the advantageous positioning, the possible counterattackers can be controlled by directly pressuring them with reducing the spatial distance to them. This tactical behavior can assist in denying their actions such as a pass reception. Overall, by controlling dangerous counterattackers the rest defense ensures that the opposing team is not able to play a direct pass to a counterattacking player close to the defendants' goal. Therefore, a possible dangerous counterattack (fast and direct transition) can be controlled.

- Control deep spaces!

Additionally, to be successful in rest defense and prevent an opposing counterattack after a ball loss the presented study indicated that the rest defending players should control deep spaces behind the last defender. A characteristic of the rest defense is that the space behind the last defender is usually large since the own attack prior to the ball loss is often developed far in the opponent's half. Those areas behind the last defender (deep spaces) are unoccupied since the defenders control this space by taking advantage of the offside rule (see figure 6.1 in chapter 6.5 Observational Study). However, those deep spaces are dangerous since they are in front of the own goal and can be exploited by the counterattackers with a deep run. Therefore, rest defending player should secure those deep spaces by positioning themselves behind a possible dangerous counterattacker. This tactical positioning of rest defenders closer to the own goal to control deep spaces results in the opponent not being able to easily penetrate these dangerous spaces in order to create goal-threatening actions in front of the own goal.

8.2.3 Application of Principles of Play in Practice

After the formulation of the principles of play derived from the main findings of this thesis, the next paragraph presents use cases of those principles in practice.

The principles of tactical behavior in the defensive playing phases can be applied in the analysis of match performance in soccer. For instance, the metrics (e.g. defensive pressure, or space control) connected to those principles of play (e.g. press the ball-leading player, or control deep spaces) can be used to objectively analyze match performance of players and teams. Using this information the own team can be analyzed. For example, post-match analysis to assess and evaluate the match performance of the own players and the own team can benefit from objective information granted using those metrics. This objective information about tactical match performance which was shown to be connected to success can possibly improve the feedback processes in professional soccer (e.g. make feedback processes more reliable). Another example could be the use case of live-analysis to analyze the current tactical match performance to adjust tactics to possibly enhance success of the own team. Therefore, the presented principles of play can enhance the coaching process with information gained by performance analysis (Wright et al., 2017).

Next to the use of the principles of play and their associated metrics to analyze the own team, the principles and metrics can be used to analyze the opponent. For instance, they can assist in the pre-match analysis to identify defensive strengths and weaknesses of upcoming opponents to design specific match tactics.

Additionally, the principles of play can be used in training sessions, for example, to plan training regimes to eventually enhance the tactical behavior in the defending playing phases. Those training regimes can possibly benefit from the scientific validated principles of play and their relation to success in matches. With focus on the tactical principles of play that have been iden-

tified as critical success factors in the defensive playing phases the tactical match performance of players can possibly be enhanced.

Overall, practical use cases of the defined principles of play and the metrics presented to objectively quantify tactical match performance in the defensive playing phases include the analysis of the own team, the opposing team, and their application in training. In the end, the use of the findings of this thesis can possibly assist in the enhancement of performance of players to increase success in the defensive playing phases.

8.3 Limitations and Future Directions

This thesis also features some limitations that should be noted when interpreting the findings of the presented review and the original studies. At the beginning of this chapter, those limitations are outlined. Against this background, future directions of research and match analysis in general are derived at the end of this chapter.

Overall, there is a lack of comparable research in the analysis of tactical match performance in the defensive playing phases. Therefore, the comprehensive discussion of the findings of this thesis with other literature is only possible to a limited extent. With few comparable research on the analysis of defensive play with sophisticated analyzing methods such as the analysis of positional tracking data, the results of this thesis cannot be compared with other studies extensively. For instance, only 23 studies were included in the review presented in this thesis which assessed this topic (see chapter 4 Review). Moreover, most of the considered studies in this review either analyzed defensive play from an offensive point of view (i.e. defense as opponent interaction) without presenting results concerning the tactical behavior of defense or analyzed defensive play without the consideration of success. Accordingly, few conclusions can be drawn about successful tactical behavior in defense. Thus, a comparative and overarching discussion of insights into successful tactical behavior in defense is limited. Therefore, most of the associations of successful tactical match performance in defense found in this thesis need to be confirmed in the future. In this context, it should be noted that the original studies of this thesis were exploratory studies. Accordingly, the relations found with successful tactical match performance do not prove causality. Therefore, future research on successful tactical match performance in the defensive playing phases should examine the causality of the presented findings.

Another limitation of the original studies of this thesis is the small consideration of contextual factors. While the second original study (see chapter 5 Defensive Pressure) considered the influence of individual teams and the longitudinal field position of the ball as contextual factors on the defensive pressure characteristics, the other two original studies hardly considered contextual factors. However, those contextual factors (e.g. internal and external factors of match performance) were indicated to have an impact on soccer match performance (see chapter 2.3.1.1 Internal Factors (Person) and 2.3.1.2 External Factors (Environment)). Therefore, it seems meaningful for match analysis to contextualize results or control for the influence of contextual factors (Haag & Mess, 2010). In general, there is a trade-off between experimental control (e.g. for contextual factors), for instance in the studies of Low et al. (2021; 2021), and ecological validity in sports performance analysis (O'Donoghue, 2015). In this context, this thesis analyzed actual match performances of competitive matches at the highest level and, therefore, features a high ecological validity (O'Donoghue, 2015).

Moreover, by investigating a large sample size (of an entire half of a season) every team has a match-up with every other team competing in this league (i.e. external factor: opponent).

Furthermore, every team has the same amount of home and away matches match (i.e. external factor: match venue). Since the data analysis was done over all match situations of the whole data set, the influence of contextual factors was expected to decrease. Further, this thesis aimed to provide generally valid and applicable results which can be interpreted independently of context and thus are generalizable over all contextual situations. For instance, the results aimed at being valid for different teams, with different playing styles, tactical formations, or individual skilled players. As opposed to assessing overriding contextual factors (e.g. score-line, match venue), the presented studies focused on providing context to the specific match situations that were examined to assess the tactical behavior in defense. For instance, the rest defense was assessed in match situations after a ball loss in the opposing half with the opposing midfielder-line being overplayed. Those strong restriction criteria of the analyzed match situations allow to specifically analyze the tactical behavior in specific playing phases without blurring results.

In addition, there are some exemplary studies that did not find an influence on specific contextual factors on match performance. For instance, several studies found that there are no differences of the successful defending behavior between different teams. This is suggested by the results of the first original study of this thesis (see chapter 5 Defensive Pressure) which found no effects of the individual teams on the spatial and temporal characteristics of defensive pressure. In a comparable study, the quality of teams did not influence the characteristics of successful defending (Forcher, Beckmann, et al., 2023). Moreover, this study revealed it is rather the case that higher quality teams more often achieve beneficial tactical situations (e.g. more often pressurize the ball-leading player). Accordingly, more successful teams create successful defensive situations more often and, therefore, are more successful while the characteristics of successful tactical match performance in defense do not vary between teams. In the end, the disregard of most contextual factors is a limitation of this thesis that should be noted (e.g. external factors: playing style, match status, venue, quality of opposition, or internal factors: skills of individual players). Therefore, future studies should focus on the influence of contextual factors on the identified results concerning successful defensive performance (e.g. principles of play). To provide more detailed insights an examination of specific cases (e.g. playing against a strong opponent or leading/trailing) could complement the presented findings.

Next to the few possibilities to compare the study results of this work and the little consideration of contextual factors, this thesis mainly focussed on ball gains as a success criterion of the defense. However, there are two main goals in defensive play. In detail, the defending team aims to defend the own goal by preventing the opposing team from scoring and to regain the ball. In accordance with this thesis, most studies on defensive play focussed on ball gains as the main success criterion in defense (Bartlett et al., 2012; Matsuoka et al., 2020) (see chapter 4.5.4 Main Findings (Review)). On the other hand, focusing on the other main goal of defense, to secure the own goal, could potentially blur the results of successful defending (Freitas et al., 2023). For instance, the attacking team is may becoming most decisive compared to the defense when scoring or goals (which are offensive attributes) are considered as success criterion. Furthermore, shots at goal or goal themselves are rare events in a match and the randomness in soccer is especially high for scoring which is indicated by the poor prediction quality of goals of only about 20 [%] (Anzer & Bauer, 2021). Therefore, and based on previous research on tactical match performance in defense, ball gains of the defending team were used to attribute successful defensive plays and defensive transitions. It was expected that most ball gains result from successful tactical behavior in defense. Still, there are several other outcomes of playing sequences that can be attributed to a successful defense (e.g. pressurizing the opponent to play the ball out of play) which should be investigated in upcoming approaches.

One approach to overcome this limitation and comprehensively assess both main goals of the defending team, to regain the ball and save the own goal, could be risk-reward models. In detail, the creation of high pressure on the opponent or playing high pressing to achieve a fast regain of possession as a reward might also come with the risk of being overplayed (e.g. when pressing performance is poor) which increases the chance of conceding a goal. This trade-off between the reward of a ball gain in defense and the risk to concede a goal could be an exciting approach to analyze tactical match performance in defense. An exemplary approach to assess risk and reward in defense was implemented by Robberechts (2019). However, this study focused on the performance of the prediction models rather than revealing practical relevant information which is one of the reasons why this promising approach did not reveal insights about successful defensive tactical behavior.

In the end, there are two minor limitations that should be noted when interpreting the presented results. The original studies of this thesis were conducted using tracking and event data of the German Bundesliga. Therefore, the results are only meaningful for comparable samples in elite soccer (e.g. other professional soccer leagues). Furthermore, the complexity of match performance (see chapter 2.3 Appearance of Match Performance in Soccer) is reduced by comprising the tactical behavior in key performance indicators (e.g. defensive pressure) in specific match situations (e.g. defensive playing sequences) (Mackenzie & Cushion, 2013). This is a reduction of the complexity of match performance and should be noted when interpreting the results of this thesis.

The presented limitations point the way for future investigations in this research area. Future studies could use the presented methods or findings to study other topics in match analysis in soccer. In this way, the feedback process between coaches and players could be analyzed using the gained objective information about tactical match performance (Mackenzie & Cushion, 2013). The results could also be applied in intervention studies to assess the effectiveness of tactical training regimes derived from the current findings. This also includes the analysis of performance enhancements based on objective analyses of tactical match performance in defense such as opponent analysis or player recruitment. Thereby, the outcomes could be compared to the results of subjective video analyses to analyze the effectiveness of different types of match

analysis.

Besides those applications of the findings, future research should focus more on the defensive part of tactical match performance in soccer. For instance, in a review about performance analysis in sport, of 60 studies considered, solely 6 articles were identified that included defensive variables (Mackenzie & Cushion, 2013). All of those articles still focused on offensive play while considering the defense as opponent interaction (e.g. balance of defense to study scorebox possession (Tenga et al., 2010a)). The same tendency was found in the presented review in this thesis. Half of the 23 studies identified, assessed defense only as opponent interaction to analyze offensive play. However, the off-ball behavior of players in the defensive playing phases is crucial for understanding the game of soccer to eventually enhance the tactical match performance in soccer. Therefore, future research should focus more on the defensive side of the game and this thesis has shown its importance.

Besides, there are some relevant trends in match analysis in soccer. While most studies in match analysis in soccer focus on physical and technical actions, there is a need for more analyses of the tactical aspect of match performance (Sarmento et al., 2018). In this context, this thesis is an example of a tactical analysis. This analysis of tactical match performance in soccer should develop from a description of tactical behavior towards a prediction of performance (Sarmento et al., 2018). This could help to understand the ingredients for successful match performance. Therefore, future studies in match analysis should take this thesis as an example to analyze tactical match performance in connection to the success of the respective playing phase to provide meaningful results. Moreover, further machine learning prediction approaches can be used to identify hidden patterns in the tactical match performance that drive success.

In this context, machine learning and big data analysis will increase their importance in the analysis of match performance in soccer. With the evaluation of big data sets of positional tracking data, in-depth analyses of tactical behavior can be performed. Though, those big data sets come with challenges in the computational methods needed to process and evaluate those data sources. Therefore, collaborations of sports science and computer science (Goes, Meerhoff, et al., 2021; Rein & Memmert, 2016) should bridge gaps between sports scientific research and computational analysis methods to provide practice-relevant results. Those collaborations could provide guidance for non-experts in computational methods and could lead away from a method-oriented to a content-oriented focus of research in this field.

Overall, exciting times are ahead for tactical match analysis in soccer. More and more data is becoming available with higher accuracy than ever before. Furthermore, new developments in the near future could add more detailed information to tracking data such as the orientation of players or more individual information about player appearances (e.g. height, constitution of athletes). With this information, more detailed insights can be gained into the match performance. With a growing computational background in sports science (e.g. with more cooperation between sports and computer science) causing a stronger multi-disciplinary approach the understanding of tactical match performance will increase in the future.

Chapter 9

Conclusion

9 Conclusion

This thesis analyzed the tactical match performance in elite soccer combining sports science research and computational evaluation methods. In detail, the defensive playing phases (i.e. defensive play & defensive transition) were examined evaluating positional tracking data. With it, the components of successful tactical behavior in the defensive playing phases were investigated. Moreover, the tactical match performance in those playing phases was assessed at different levels of tactical play from individual, over group, to team level.

Summarizing the results for the playing phase of defensive play, the behavior of defenders in pitch areas close to the ball was identified as crucial for defensive success. For instance, higher defensive pressure on the ball-leading player and the attackers close to the ball and a higher compactness of defenders in ball proximity were identified as success factors in defensive play. Furthermore, the contraction of compactness to create higher defensive pressure seems also important. Concluding, it is decisive to pressurize the ball-leading player and cover close pass options to regain the ball in defensive play.

In the playing phase of defensive transition after a ball loss, the quick regain of possession was identified as the most important success factor. Further, for the group tactics of rest defense in defensive transition the numerical superiority of the rest defending players and their pitch control were identified as success factors. Concluding, rest defending players should control deep spaces behind the defending-line and control potential dangerous counterattackers to deny counterattacks as fast as possible to be successful.

Overall, the results of this thesis indicated that the analysis of individual and group level defensive behavior was more insightful compared to team level analyses. In detail, successful defending was more decisively shaped by individual (e.g. defensive pressure on the ball-leading player) and group level defending (e.g. defensive pressure and defensive compactness in areas close to the ball) compared to team level behavior (e.g. no influence of compactness of the whole defending team on defensive success).

To increase the practical impact of this work, the results of this thesis were used to formulate general principles of play for the defensive playing phases. In detail, this includes principles of play such as “press the ball-leading player” in defensive play, or “create numerical superiority” in rest defense during defensive transition. Those principles derived from the findings of this thesis can enhance coaches’ understanding of the key aspects of tactical behavior and provide useful guidance for practitioners. Since the principles are based on the results of this thesis their significance and connection to successful match performance is scientifically indicated. Overall, this enables an effective application of the results of this work in practice (e.g. objective analysis of tactical match performance).

In conclusion, this thesis presented enhanced match analyses using positional tracking data to uncode the game of soccer. In this way, the success factors of soccer defense were identified by analyzing past match performances. Those success factors enable objective quantifications of player performances in the present and could assist in improving future match performances. Therefore, this thesis presents a pathway to learn from the past to create the present and evolve in the future.

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Appendices

Appendix 1: Paper III Rest Defense Supplement 1: Interview guidelines expert interview.

Institut für Sport und Sportwissenschaft
Fußballforschung

Expert Interview Guidelines Rest Defense

Prior Interview:
- informed consent, privacy policy, participant information
- Basic information:
  - Age
  - Type of coaching license
  - Coaching experience (years, team, league, role)

Interview Start (Ice-Breaker Questions):
- What led you to become a soccer coach/ soccer analyst?
- What coaching experience do you have in professional soccer (years, team, league, role)?

Questions:

Open questions to start the conversation:
1.1 What is your experience with rest defense?
1.2 What do you understand by the term rest defense?
1.3 From your perspective, how would you describe rest defense?

Follow-up questions if not answered before:
Objective:
2.1 In your opinion, what is the goal of rest defense?

Characteristics:
2.2 In your view, when does the rest defense occur? When does it come into play? How long does the rest defense action last? (temporal: playing phase)
Difference: When is rest defense coached, when does it come into play?
2.3 Which players do you think are involved in the rest defense? (spatial: number of players, position group)
2.4 In your opinion, how should the rest defense be positioned on the pitch? (spatial: positioning)

Tactics:
2.5 Do you know tactical approaches in rest defense?
2.6 What tactical variations do you use in rest defense?

Success:
2.7 In your opinion, what is important to be effective/successful in rest defense (also compared to an unsuccessful/ineffective rest defense)?
Difference: success based on the result of the rest defense, success based on behavior of the players involved in the rest defense.

Definition:
2.8 How would you define rest defense?

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	Interview	Page	Line(s)	Quote	Category	Subcategory
Playing phase of rest defense	1	1	31-32	wenn wir die Mittelfeldreihe überspielt haben, dann gehe ich als Abwehrspieler in die Restverteidigung	Playing phase	- Offensive play (in ball possession), after the midfielder line is overplayed and players do not longer have a task in attacking play
	1	1	34-36	wenn ich zum Beispiel als Innenverteidiger oder als Ballferner Sechser keine Aufgabe mehr im Angriffsspiel habe, zum Beispiel als Verlagerungsspieler, dann gehe ich in eine Restverteidigung		
	1	1	40-42	Ich denke mal, es ist ein relativ kurzer Zeitraum: 5 bis 10 Sekunden, bis der Angriff abgeschlossen ist oder der Ball im Aus ist. Also bis die Situation dann schließlich für uns geklärt wurde.	Playing phase	- Defensive transition, until the opposing attack is finished (e.g. ball out of play, shot on goal)
	2	6	3-5	wenn mein Team in Ballbesitz ist, vorrangig im Angriffsdrittel, dann habe ich als Spieler der nicht anspielbar ist und gerade mit Ball niemanden bindet und auch ohne Ball niemanden binde, die Aufgabe einem Gegenspieler zuzuordnen.	Playing phase	- Offensive play (in ball possession), when ball is in opposing attacking third and players are no pass option
	2	6	5-7	Prinzipiell verstehe ich als Restverteidigung, dass ich in Ballbesitz, wenn ich eine der anderen Aufgaben nicht erfüllen kann, dass ich dann die Aufgabe erfülle mich einem Gegenspieler zuzuordnen, dass ich im Falle eines Ballverlustes agieren kann.	Playing phase	- Defensive transition, after a ball loss
	3	9	39-45	Trotzdem ist für mich immer das entscheidende bei der Restverteidigung, diese schon zu organisieren, wenn du in Ballbesitz bist. Du kannst dich nicht erst nach Ballverlust darum kümmern, wie stehen wir in der Restverteidigung. Also du musst das organisieren, in dem Moment in dem du in der gegnerischen Hälfte oder im letzten Drittel bist und dort noch den Ball hast.	Playing phase	- Offensive play (in ball possession), when the ball is on opposing half or opposing attacking third
	3	10	1-2	Du schaust eben schon, wie sind wir hinten organisiert, um im Falle eines Ballverlustes abgesichert zu sein und verteidigen zu können.	Playing phase	- Defensive transition, after a ball loss
	4	13	30-31	Also Restverteidigung ist für mich in der Spielphase eigener Ballbesitz anzusiedeln. Ich unterscheide zwischen drei unterschiedlichen Arten der Restverteidigung.	Playing phase	- Offensive play (in ball possession)
	4	13-14	40-45 & 1-2	Also für mich ist die klassische Restverteidigung im eigenen Ballbesitz. Wenn man dann in der Spieleröffnungsphase ist, sind viele Spieler in Doppelfunktionen unterwegs, da sie mit der Spieleröffnung beschäftigt sind aber auch gleichzeitig die Restverteidigung sind. Das heißt, da würde ich es weniger coachen und es mehr über die Startposition abdecken. Und je mehr ich dann in eine Ballzirkulation komme, desto mehr geht diese Rolle von der Ballbesitzrolle in eine Restverteidigungsrolle, gerade bei Kettenspielern. In der letzten Phase im eigenen Ballbesitzt, also in der Angriffsphase, ist es von einigen Spielern der ausschließliche Hauptjob und dann würde ich bei diesen Spielern diese Restverteidigungsaufgaben coachen.		
	4	14	37-39	Ja, das ist eine Definitionssache. Dann sind wir für mich schon einer anderen Phase. Da kommen wir in das ausschließliche Verteidigen rein. Dabei sind dann aus meiner Sicht auch andere Aufgaben für die Spieler zu bewältigen. Also nach meiner Definition geht es wirklich um den ersten Pass	Playing phase	- Defensive transition, until the first pass of the opposing team after the ball loss
	5	17	36-37	Restverteidigung in dem Punkt als Grundvoraussetzung im Offensivspiel. In Ballbesitz zu sein und die Restverteidigung bildet deine Raumaufteilung in den letzten beiden Linien.	Playing phase	- Offensive play (in ball possession), when the ball is not in the last line or ball is in attacking third - Defensive transition, after a ball loss
	5	17 & 18	44-45 &	Im Mittelfelddrittel dann behaftet schon, dass der Ball nicht mehr in der letzten Linie ist. Sondern dass im Mittelfelddrittel die jeweiligen Positionsräume besetzt sind und jedem seine Aufgabe schon bewusst ist, was passiert, wenn der Ball verloren wird. Dieser Übergang vom Mittelfelddrittel ins Angriffsdrittel, dass diejenigen die hinter dem Ball sind schon wissen, die nächste Aktion die ich habe ist möglicherweise eine defensive Aktion und wie stehe ich im Raum. Wie muss ich explizit auch durchverteidigen in der Konstellation, die ich habe.		

	Interview	Page	Line(s)	Quote	Category	Subcategory
Playing phase of rest defense	6	22	4-7	Gut, die Spielphase ist immer auf den eigenen Ballbesitz bezogen. Die Definition ist ja bei jedem anders. Deshalb sowohl Spielaufbau, umschalten nach Ballgewinn, die Umschaltphase nach Ballgewinn, also Ballbesitz und Standards mit eigenem Ballbesitz. Dort hat es natürlich den größten Schwerpunkt, hat aber auch Überlappungspunkte im Umschalten nach Ballverlust.	Playing phase	- Offensive play (in ball possession) - Defensive transition, after a ball loss
	7	25	42-43	Ich verstehe unter Restverteidigung im Prinzip die Positionierung der Spieler die am nähesten zu unserem eigenen Tor sind eigentlich zu jedem Zeitpunkt des Spiels.	Playing phase	- Offensive play (in ball possession), after the midfielder line is overplayed & players do not longer have a task in attacking play, when ball is in opposing attacking third and players are no pass option - Defensive transition, after a ball loss
	7	26	21-22	Aber ich gehe natürlich schon von dem Moment aus in dem wir den Ball haben und dem Fall, dass wir den Ball im vorderen Drittel haben		
	7	28	1-6	Nein, also für mich geht es darum: Die Restverteidigung beginnt für mich dann, wenn wir quasi im Spielaufbau die erste Linie des Gegners überspielt haben. Ab diesem Zeitpunkt achte ich extrem darauf, was meine ballfernen Spieler machen. Das heißt, ich möchte dann nicht, dass zu viele Spieler zu breit positioniert sind. Sondern es geht in diesem Moment dann schon um ein Einrücken, um dann einerseits für die Offensivaktion Richtung Tor anspielbar zu sein, torgefährlich zu werden, bzw. dann auch Zugriff zu haben auf einen Gegner, um den Gegenangriff möglichst zu unterbinden.		
Players involved in rest defense	1	1	24	Spieler der hintersten Reihe	Players involved	- Dependant on the opponent - Defensive line - Central defenders - Central midfielder - Wide defenders - 4 players
	1	1	34-36	wenn ich zum Beispiel als Innenverteidiger oder als Ballferner Sechser keine Aufgabe mehr im Angriffsspiel habe, zum Beispiel als Verlagerungsspieler, dann gehe ich in eine Restverteidigung		
	1	2	12	Das finde ich total schwierig zu definieren und auch extrem gegnerabhängig.		
	1	2	18-20	in der Regel die beiden Innenverteidiger, ein Sechser und dann die Außenverteidiger, was stark davon abhängig, was die äußeren Mittelfeldspieler oder die äußeren Stürmer des Gegners machen.		
	1	2	20-22	Wir hatten schon Spiele, in denen wir drei Spieler in der letzten Reihe und einen davor zur Restverteidigung hatten.		
	2	6	14-19	Gerade wenn du Ballbesitz im Angriffsdrittel hast, dass die Innenverteidiger nicht abschalten, sondern das Bewusstsein haben, ich habe jetzt noch eine Aufgabe, auch wenn ich nicht anspielbar und bin und niemanden binde. In dem Fall muss ich trotzdem schauen, wer ist der gefährlichste Umschaltspieler. Das gilt nicht nur für die Innenverteidiger, sondern das gilt auch für die Spieler, die jetzt nicht unmittelbar in ballnähe mit einbezogen sind und eine der anderen Aufgaben erfüllen.	Players involved	- Central defenders - Central midfielder - Wide defender (weakside) - All players that are not involved in offensive play - Dependant on the ball position - Dependant on the opponent
	2	6	30-35	Es kann, wie in dem skizzierten Beispiel, mal ein Sechser sein. Es sind aber natürlich vorrangig die Innenverteidiger, aber es kann auch mal der ballferne Außenverteidiger sein, der dann einrücken muss und den Gegenspieler, der in dem Moment für ballfern steht, aber nach Ballverlust auch ein gefährlicher Umschaltspieler sein kann, wenn er diagonal angespielt wird. Ich finde es ist immer abhängig von der Position des Balles und von der Positionierung der gegnerischen Mannschaft, welche Spieler beteiligt sind.		
	3	10	33-29	Ja, also grundsätzlich sind die Innenverteidiger der Hauptbestandteil der Restverteidigung. Eigentlich sind zusätzlich immer noch ein Außenverteidiger oder/und ein Sechser beteiligt, je nachdem wie du spielst. Wenn du mit Doppelsechs spielst, müssen nicht beide in der Restverteidigung sein. Aber wenn du mit nur einem Sechser und zwei Achtern spielst, dann ist der eine Sechser auch Teil der Restverteidigung. Plus, wenn du über den Flügel angreifst und hinten mit einer 4er Ketter spielst, dass der ballferne Außenverteidiger nicht mit hochschiebt. Wenn du mit einer 3er Kette spielst ist es natürlich nochmal etwas anderes.	Players involved	- Central defenders - Central midfielder - Wide defender (weakside) - Dependant on the tactical formation

	Interview	Page	Line(s)	Quote	Category	Subcategory
Tactics of rest defense	5	18	25-29	Mit zwei drei meine ich, dass du in der letzten Reihe zwei stehen hast und drei davor. Eine Absicherung zwei drei könnte beispielsweise sein: Vier und fünf, also die beiden Innenverteidiger und davor dann je nach Verlauf der Sechser im Zentrum in der Dreierreihe und daneben möglicherweise der Außenverteidiger, der Achter oder auf der anderen Seite, je nach dem was der andere Außenverteidiger macht, der Zweier oder der Zehner aus einem 4-3-3 System.	Tactics	- Space defending: 2+3 3 (trapezium) - Man-to-man coverage - Space defending: 3+1 (diamond)
	5	18 & 19	44-45 & 1-2	Für mich, neben der eine räumlichen Aufteilung, kann man es auch sehr mannorientiert spielen. Das macht oftmals Salzburg in der Champions League. Dabei ist dann der ballferne Raum frei, weil sie sehr mannorientiert agieren und damit auch der jeweilige Gegenspieler dann explizit verfolgt und dann vorverteidigt wird auch in viel höhere Räume, die nicht der Position entsprechend sind.		
	5	19	4	Die schieben eins gegen eins durch, genau.		
	5	19	36-41	Wenn du eine drei eins Absicherung hast, bist du eher in einer Rautenform, in der meistens der zentrale Innenverteidiger in der 3er Kette, beziehungsweise der linke oder rechte Innenverteidiger in der 4er Kette ist eben mannorientiert, die anderen dann eher ballorientiert mit Bindung zu ihm, dass sie automatisch auch der Absicherungsspieler werden können, wenn beispielsweise der lange Zielspielerball auf Neun gespielt wird.		
	6	22	34-37	Ja, ich meine die ganz klaren Beispiele sind Mann gegen Mann, dass du eine klare Gleichzahl gegen einen Gegner hast. Oder dass du plus eins stehst, also immer einen Spieler Überzahl hast, dass du eine Mischform hast aus Manndeckung und Spielern die den Raum davor decken oder den Raum dahinter absichern.	Tactics	- Man-to-man coverage - +1 majority
	7	26	27-32	Ja, ich kann das Ganze natürlich eher mit einem gewissen Sicherheitsdenken angehen. Das heißt, viele sagen ich brauche zwischen dem offensivsten Gegenspieler und dem eigenen Tor immer zwei Spieler, die diesen Raum dazwischen sichern. Es gibt aber sicherlich auch Herangehensweisen, wozu ich mich zählen würde, die es eher mutiger angehen. Das heißt, ich brauch Einen der zwischen dem letzten Gegner und unserem Tor steht und die Anderen dürfen dann auch davorstehen. Das Ganze eben offensiver interpretiert.	Tactics	- +1 majority (sandwich) - Man-to-man coverage
	7	26	38-41	Ja, mit jeweils einem Spieler hinter dem Gegner. Das heißt, zwei dahinter und einem davor. Der muss aber nicht unmittelbar davorstehen. Da geht es meistens um den Sechser, der soll meistens den Anschluss an die vorderen Spieler halten. Er steht dann schon zwischen meinen letzten Spielern und den Vorderen aber muss jetzt nicht direkt vor den Innenverteidigern stehen.		
Successful/unsuccessful rest defense (characteristics)	1	2	7-9	Also gibt es genau diese zwei Möglichkeiten: bleibe ich dran zum Vordenken, bzw. zum Kontrollieren oder sichere ich eher die Tiefe im Zentrum.	Successful rest defense (characteristics)	- Decision making in rest defense - Coverage with forechecking - Safe deep space
	1	3	6-15	Das bedeutet für die Positionierung sowohl horizontal als auch vertikal. Also wie weit schiebe ich ins Zentrum, zu welchem Grad habe ich die innere Linie? Welchen Abstand habe ich zu meinem direkten Gegenspieler? Wie viele Meter sind das? Was natürlich auch von der Ballposition abhängt. Je weiter der Ball weg ist, desto weiter kann ich auch vom Gegner weg stehen. Je näher der Ball ist, muss ich näher am Gegenspieler dran sein. Hierbei muss natürlich auch noch Risiko abgeschätzt werden. Wie schnell ist mein Gegenspieler? Ist er schneller als ich? Muss ich ein bisschen weiter weg stehen? Auch hier das Thema von vorhin, wie hoch ist der Druck auf dem ballführenden Spieler? Wenn also der Druck auf den Ball hoch ist, muss ich auch näher am Gegner stehen, damit ich ihn auch bei der Ballannahme erwische und dadurch vordenken kann. Ist der Druck auf den Ball gering, muss ich natürlich eine andere Position wählen. In höheren Abstand.	Successful rest defense (characteristics)	- Positioning (vertically and horizontally) - Distance to the attacker - Dependant on the ball position and match situation
	1	3	16-17	Eine erfolgreiche Restverteidigungsaktion macht für mich gerade auch individuelle Faktoren im Zweikampf aus, gerade beim Thema Timing im Vordecken.	Successful rest defense (characteristics)	- Individual duels - Timing in forechecking

	Interview	Page	Line(s)	Quote	Category	Subcategory
Successful/unsuccessful rest defense (characteristics)	1	3	19-21	Also das Vorausdenken, das Spiel mit dem Deckungsschatten und das Spiel mit dem Balldruck. Das finde ich ist die größte Erfolgsformel bei der Restverteidigung. Wenn du wirklich erkennst, wann ist Druck drauf.	Successful rest defense (characteristics)	- Distance to opposing counter attackers/ dangerous players - Pressure on attackers - Space control -Safeguarding
	6	23	28-32	Ja, also Abstand zu dem Gegenspieler ist glaube ich immer ein Thema. Wenn man über Anschlussverhalten oder Gegnerbindung spricht, was häufig in der Restverteidigung fällt, ist Abstand ein elementares Thema. Natürlich dann auch Druckverhalten in gewissen Zonen, aber auch die Raumkontrolle in gewissen Bereichen. Dann hast du eher diese Absicherung davor oder dahinter, bei der dann auch zum Torhüter reinspielt.	Successful rest defense (characteristics)	- one player safes the deep space & pressures the attacker from behind to deny a turn of the attacker - one player positioned before or besides the attacker to deny a pass towards the attacker or to regain the ball
	7	27	35-40	Ich habe gerne Einen dahinter und Einen davor. Im Endeffekt Zugriff sollte in der Regel der Spieler haben, der vor oder neben dem Gegner steht. Der Spieler der dahinter steht sollte eher sichern, bzw. dafür sorgen, dass der Gegner den Ball dann nicht ganz in Ruhe annehmen kann bzw. auf gar keinen Fall aufdrehen kann. Einer hat also diesen sicheren Part und der Andere hat dann eher den aktiven Balleroberungspart. Wenn eben der Spieler der daneben oder davor steht es schafft sogar vor dem Gegner an den Ball zu kommen, dann wäre es natürlich ideal.	Successful rest defense (characteristics)	
Successful/unsuccessful rest defense (outcome)	1	3	33	Die erfolgreichste Restverteidigung ist die direkte Ballrückeroberung.	Successful rest defense (outcome)	- Best: Ball regain - Good: ball clearance, delay of opposing attack, foul in harmless position (e.g. opposing half) (prevent opposing attack) - Worst: Opposing shot on goal
	1	3	38	Der Worst case wäre, dass der Gegner durchbricht und zu einem Abschluss auf unser Tor kommt		
	1	3	41-44	Auch eine erfolgreiche Restverteidigung ist die Aktion, wenn sie den Angriff des Gegners unterbindet. Durch das Klären des Balls, oder das Lenken des Gegners in eine Spur, um wieder hinter den Ball kommen zu können. Dadurch können wir wieder in die Ordnung kommen. Das kann selbst im schlimmsten Fall ein Foul in einer Position, die weiter vom Tor entfernt ist, sein.		
	2	7	5-6	Aus meiner Sicht ist es das Ziel, dass du einen schnellen Gegenangriff unterbindest und dass du nach Ballverlust möglichst schnell wieder in Ballbesitz kommst.	Successful rest defense (outcome)	- Best: Ball regain - Good: slow down opposing counter attack (prevent deep passes) - Okay: Foul - Worst: Successful opposing deep pass on deepest attacker
	2	7	10-14	Ich könnte mir vorstellen, dass wenn du es schaffst, dass die gegnerische Mannschaft schon mal nicht den ersten Pass tief spielen kann und vielleicht auch nicht den zweiten oder dritten. Das du es schaffst den Gegenangriff zu verlangsamen, dass nicht die maximale Dynamik entstehen kann. Da hast du aus meiner Sicht auch schon viel gewonnen.		
	2	7	17	Ich finde es (ein Foul) besser als in einen Konter zu laufen.		
	2	7	19-20	Ich finde, wenn es die gegnerische Mannschaft schafft den tiefsten Punkt anzuspielen und du es dann nicht schaffst Druck auf diesen Gegner auszuüben, dann hast du vorher etwas falsch gemacht.		
	3	11	21-24	Das Ziel war natürlich wieder hoch den Ball zu gewinnen, um dann weiterzuspielen. Aber genau das Gegenteil ist dann eingetreten. Union spielt lang und Jonathan Tah ist schlecht positioniert und rutscht sogar noch weg und Kevin Behrens läuft durch und wir verlieren damit in der 88. Minute 1:0.	Successful rest defense (outcome)	- Best: Ball regain - Okay: Stop opposing attack - Worst: opposing goal
	3	11	32-34	Wenn du vielleicht tiefer stehst ist das primäre Ziel den gegnerischen Angriff zu stoppen, indem du viele Spieler hinter den Ball bekommst, um das Tempo des gegnerischen Angriffs rauszunehmen.		

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Successful/unsuccessful rest defense (outcome)	6	23	6-8	Gut, der worst case ist das Gegentor. Das muss immer als worst case gesehen werden, dann kannst du ja die Schritte zurück gehen. Wenn du ins Detail reingehst, dass der Gegner nach deren Ballgewinn einfach kontrolliert den Angriff vortragen kann, bis zum eigenen Tor.	Successful rest defense (outcome)	- Best: Ball regain - Good: Ball out of play, foul - Worst: Opposing goal, opposing scoring opportunity
	6	23	12	Dann wieder in eigenen Ballbesitz zu kommen.		
	6	23	16-20	Wenn wir ein Foul begehen, kann es negativen Touch haben, weil das Foul unnötig war. Das Foul kann aber auch ein bisschen den Konter unterbinden, dadurch eher einen positiven Bezug haben. Grundsätzlich ist es schwierig zu bewerten, aber ein Ausball oder eine Unterbindung von einem Konter ist eher mal Positiv zu sehen, anstatt dass der Gegner ins letzte Drittel kommt oder zum Tor und zum Abschluss kommt.		
	7	27	5-9	Ja, wie gesagt ich will permanent Zugriff haben auf den Gegner. Das heißt, wenn der Gegner in Ballbesitz kommt, will ich den Gegner möglichst schnell so unter Druck setzen, dass wir den Ball wieder zurückgewinnen. Das heißt, im Prinzip, habe ich gerade Gegenpressing definiert, worum es bei mir auch geht, wenn es um Restverteidigung geht. Wenn ich das jetzt auf die Spieler der letzten Reihe beziehe, dann sollten sie so Zugriff auf ihre Gegner haben, dass diese den Ball nicht bekommen.	Successful rest defense (outcome)	- Best: Ball regain - Good: Ball out of play (by opponent), deny opposing fast counter attack (rebuild defensive block) - Okay/Bad: Foul - Worst: Opposing scoring opportunity /opposing goal
	7	27	12-15	Der worst case wäre natürlich das der Gegner den Ball so bekommt, dass er unmittelbar eine Torchance hat. Das heißt, das ich es in diesem Moment nicht schaffe ihn bei der Ballannahme so zu stören oder zu stellen, dass er den Ball nach hinten spielen muss oder er nach außen weggedrängt wird. Sondern wenn er eben zum Torabschluss kommt oder im schlimmsten Fall zum Torerfolg kommt.		
	7	27	21-31	Ja, Foulspiel idealerweise vermeiden. Es gibt sicherlich Situationen, da ist es nicht zu vermieden, da muss ich mal Foul spielen. Aber gerade, wenn wir über Restverteidigung sprechen, da sind dann nicht mehr allzu viele Spieler hinter dem Ball, da möchte ich natürlich Foulspiele vermeiden, da wir entweder in unmittelbarer Tornähe sind oder eben dann auch eine gelbe Karte oder sogar eine rote Karte zur Konsequenz hat. Deshalb Foulspiel idealerweise vermeiden. Das heißt, in solchen Situationen, wenn möglich, immer aus einer Gleichzahl eine Überzahl machen. Das heißt, einfach die Verteidigungsaktion sichern oder zum Doppeln kommen. Wenn der Gegner es schafft den Ball in den eigenen Reihen zu halten, aber nicht nach vorne spielen kann ist das ein Teilerfolg. Das heißt, wenn der Gegner den Ball ins Aus spielt wäre es dann wieder ein Ballgewinn für uns, das heißt es wäre auch in Ordnung. Am liebsten würde ich aber den Ballgewinn haben um den Ball im Spiel zu halten, um direkt wieder nach vorne spielen zu können, wenn es möglich ist.		