Investigation of key tactical variables impacting on elite netball performance

by

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DOCTOR OF PHILOSOPHY

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ABSTRACT

The collective positioning and behaviours of elite netball players are an important concept to understand, as they relate to the tactical plans and overall performance of a team. However, this is currently an under-researched field in most indoor team sports owning to previous limitations in indoor tracking systems. Thus, this thesis investigated the use of collective tactical variables in elite netball matches and training, captured using a local positioning system (LPS). Collective tactical variables were used to explore collective movement and positioning behaviours in matches, examining the more successful movement patterns and how these varied in small sided games (SSGs), commonly used in training. Study 1 assessed the validity of the Catapult T6 LPS to measure inter-unit distance. Eight recreationally-active, female indoor team-sport players completed a circuit comprised of seven movements (walk, jog, jump, sprint, 45° change of direction and shuffle), on an indoor court. Participants wore a receiver tag (ClearSky T6, Catapult Sports) and seven reflective markers, allowing for comparison with the reference system (©Vicon Motion Systems, Oxford Metrics, UK). The criterion validity against the reference system resulted in a root mean square error of 0.20 ± 0.05 m. Additionally, analysis was conducted on five distance bands to assess the association between distance and inter-unit distance validity. The resulting mean bias presented an overestimation for the LPS in all distance bands, while the percentage of variance accounted for remained stable for all distance bands, excluding the > 20 m band. These results suggest the Catapult T6 LPS has acceptable accuracy - within 20 cm - for measuring inter-unit distance, as such opening up opportunities for further research into collective tactical variables for indoor team sports.

Study 2 of this thesis used the validated ClearSky LPS to explore collective tactical variables during seven elite netball matches at the team and sub-group level. Collective

tactical variables were explored during attacking and defending possessions and included; inter-player distance, width, length, surface area, centroids, width-per-length ratio and stretch indices. During attack, the team and all sub-groups adopted greater lateral dispersion between players, while on defence there was generally greater longitudinal dispersion. Additionally, greater irregularity (measure of predictability within time-series data) was observed in sub-groups most present and active in the play (forwards on attack, defenders on defence).

Study 3 followed on from the results of the previous study, by modelling the effects of collective tactical variables and contextual predictors on scoring probability in elite netball. The effects were estimated via a logistic-regression version of the generalized linear mixed model, with adjustments for several predictor variables. Extremely short possessions were associated with decreased scoring probability, while lateral dispersion negatively affected the probability of scoring for both teams. These results indicated that, in general, it is more favourable to maintain positioning and ball movement in the middle of the court.

Finally, Study 4 focused on SSGs, which are commonly used in training to replicate match outputs. The collective tactical variables of four attacking and four defending elite netball players were analysed to compare three SSG conditions: 4v4, 5v5 and 6v6. Two, 20-min SSGs for each condition were analysed using a linear mixed model. The irregularity of width-per-length ratio of the four attacking and four defending players was greatest in 4v4, the attackers' inter-player distance and length variability was greatest in 5v5, while the four attacking players had the smallest mean surface area in 6v6.

This thesis provides an exploration into the use of collective tactical variables in elite netball. As a combination of studies, this thesis is an important investigation into methods available for performance analysis research in netball and other indoor team sports. The key findings showing tactical analysis via collective tactical behaviours hold useful information for elite netball. Of interest, different patterns of positioning and movements exist between attacking and defending phases of play and sub-groups. All sub-groups displayed increases to their lateral dispersion during attack and active sub-groups presented greater irregularity, aligning with the positional dependencies and restrictions of netball. Also, certain collective tactical variable outputs are more successful than others, most prominent being shorter possession associated with decreased score probability, suggesting maintaining ball possession early is a key driver in score probability. Finally, in training SSGs differ tactically with different number of players included in the drills, with lower numbers causing defenders to exhibit greater irregularity while for greater numbers, players were closer to their teammates, both results displaying specific coaching principles that can be trained.

STUDENT DECLARATION

I, Ryan W. Hodder, declare that the PhD thesis entitled "Investigation of key tactical variables impacting on elite netball performance" is no more than 80,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work. I have conducted my research in alignment with the Australian Code for the Responsible Conduct of Research and Victoria University's Higher Degree by Research Policy and Procedures.

Signature: [redacted] Date: 10/02/2022

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DETAILS OF INCLUDED PAPERS

The following work has been published in peer-reviewed journals/presented at scientific meetings in support of this thesis

Chapter No.	Publication Title	Publication Status	Publication Details
Chapter 3	Criterion Validity of Catapult ClearSky T6 Local Positioning System for Measuring Inter-Unit Distance	Published	**Hodder, R. W.**; Ball, K. A.; Serpiello, F. R., Criterion Validity of Catapult ClearSky T6 Local Positioning System for Measuring Inter-Unit Distance. Sensors 2020, 20 (13), 3693.
Chapter 4	Exploration of Collective Tactical Variables in Elite Netball: an analysis of team and sub-group positioning behaviours.	Under review	Submitted to PlosOne for peer review process
Chapter 5	Effects of Collective Tactical Variables and Predictors on the Probability of Scoring in Elite Netball.	Under review	Submitted to PlosOne for peer review process
Chapter 6	Collective Tactical Variables in Elite Netball Training. Differences between Small-Sided Game Conditions 6v6, 5v5 and 4v4.	Manuscript ready for submission	

PREFACE

Chapter 1

Chapter 1 is a general introduction to netball performance, electronic performance tracking systems (EPTS) and collective tactical variables. These topics combine to create the base of the thesis, which focuses on the use of EPTS in elite netball to collect player positioning data that is used to calculate collective tactical variables (representing tactical behaviours). This chapter is important for setting up the foundations of the thesis to ensure comprehension of the current research in elite netball, the advances in EPTS and the popularization of collective tactical variables in sport science research.

Chapter 2

Chapter 2 thoroughly covers collective tactical variables, from their theoretical origins, calculation consideration, recent research and future use suggestions. In this chapter, an exploration of theoretical perspectives of ecological dynamics, dynamical systems and superorganisms underpinning collective tactical variables is undertaken. Furthermore, an inspection of team sports tactics and collective player behaviours is undertaken to understand the mechanisms behind collective tactical variables. Finally, a review of the literature about tactical variables, specifically previous research, use cases, limitations and future suggestions, is presented.

Chapter 3

Chapter 3 represents the first experimental study of this doctoral thesis, and it is linked to the published manuscript "Criterion validation of Catapult ClearSky T6 Local Positioning System for measuring inter-unit distance". The study focuses on methods and procedures of the validation of inter-unit distance from ClearSky T6 LPS. It also presents the results from the study, a mean error in inter-unit distance between ClearSky T6 LPS and the reference system (Vicon) of 0.20 ± 0.05 m. These results, along with previous investigations into the LPS validation of position (Luteberget et al., 2018), suggest that LPS has acceptable accuracy for measuring inter-unit distance, and thus additional collective tactical variables.

Chapter 4

Chapter 4 provides the second experimental study of this thesis; "Exploration of Collective Tactical Variables in elite Netball: an analysis of team and sub-group positioning behaviours". The study explores the use of the different collective tactical variables outlined in Chapter 2, such as inter-unit distance, surface area, width-per-length ratio and centroids. These are used to explore the inter-player, inter sub-group and team interactions and tendencies. Having validated the use of the LPS for measuring inter-unit distance, this chapter analyses collective tactical variables from one season of Suncorp Super Netball player tracking data of the Melbourne Vixens Netball Team.

Chapter 5

Chapter 5 presents the third study of this thesis; "Effects of Collective Tactical Variables and Predictors on the Probability of Scoring in Elite Netball". With an introductory understanding of collective tactical variables in elite netball matches, this study expands on Chapter 4 by investigating the collective tactical variables influence on the probability of scoring. Additionally, several contextual variables adjusted for in Chapter 4 are used as predictors in this study to further understand their impact on scoring probability.

Chapter 6

Chapter 6 focuses on the fourth and final study of the thesis; "Collective Tactical Variables in Elite Netball Training. Differences between Small-Sided Game Conditions 6v6, 5v5 and 4v4". Following on from the studies in Chapters 4 and 5, and utilizing the results of relevant collective tactical variables in matches, this study investigates collective tactical variables during training drills. Specifically, the output of collective tactical variables during three different SSG conditions (4v4, 5v5 and 6v6). This study aims to provide coaches and performance staff with a greater understanding of the collective behaviours in different drill conditions, allowing for more informed drill and training periodization.

Chapter 7

Lastly, Chapter 7 provides a general discussion and conclusion of the previous four chapters representing the four studies of the thesis. In this chapter, the overarching themes, results and key points of interest are presented. Providing a summary and encapsulation of the thesis as a whole and its novel findings. Additionally, based on the findings of the thesis, this chapter provides future research recommendations and practical applications.

AWARDS

Best Poster Award (2019) – Higher Degree Research Conference (Victoria University)

Second Place Short Presentation Category (2020) – Higher Degree Research Conference (Victoria University)

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LIST OF ABBREVIATIONS

4v4	Four attackers vs four defenders
5v5	Five attackers vs five defenders
6v6	Six attackers vs six defenders
ApEn	Approximate Entropy
CL	Compatibility Limits
COD	Change of Direction
EPTS	Electronic Performance and Tracking Systems
GA	Goal Attack
GD	Goal Defence
GK	Goal Keeper
GPS	Global Positioning System
GS	Goal Shooter
Hz	Hertz
ID	Identity
LPS	Local Positioning System
m^2	Metres Squared
m	Metres
min	Minute
RMSE	Root Mean Square Error
SAS	Statistical Analysis System

SD	Standard Deviation
SSG	Small-Sided Game
UWB	Ultra-Wide Band
%VAF	Percentage Variance Accounted For
WA	Wing Attack
WPLratio	Width per Length Ratio

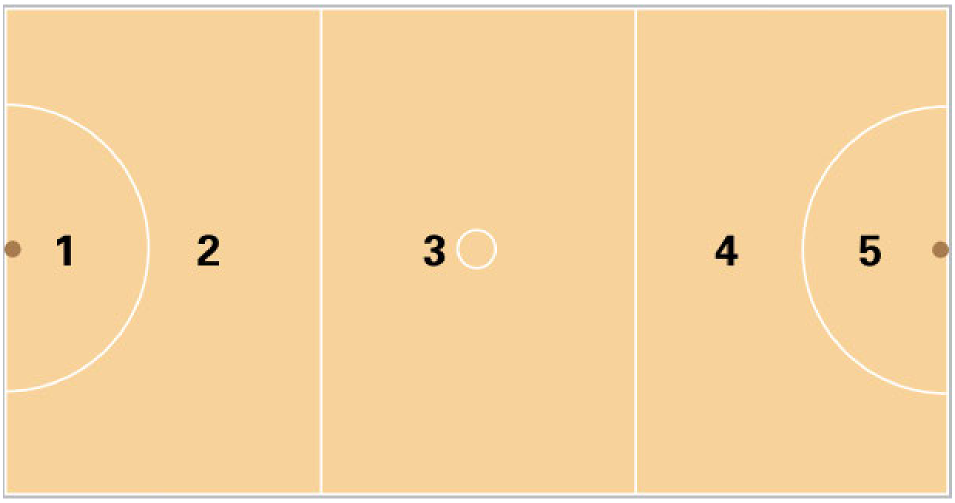
CHAPTER 1 - GENERAL INTRODUCTION

1.1 Netball performance

1.1.1 Netball overview

Netball is a professional sport played between two teams of seven players, predominantly in Commonwealth countries. The main goal of the game is to score by shooting into the goal ring (3.05 m high) and maintain or regain possession of the ball. Netball matches consist of four quarters of 15 min in length, with a five-minute break at quarter and three-quarter time and a 20-min break at half time. Netball is played predominately in indoor stadia on parqueted floors measuring 30.25 m (length) and 15.25 m (width) per the regulation standards of the International Netball Federation Rules (International-Netball-Federation, 2020). The court is split into thirds and has two goal-shooting circles (Figure 1.1). The markings represent the zones in which player positions are restricted to. Unlike sports like basketball and hockey, netball players are restricted to areas on the court based on their positions:

- The Goal Keeper (GK) is restricted to the defending third and defending goal circle,
- The Goal Defender (GD) to the defending and midcourt thirds and the defending goal circle,
- The Wing Defence (WD) to the defending and midcourt thirds,
- The Centre (C) can move through all thirds,
- The Wing Attack (WA) is restricted to the attacking and midcourt thirds,
- The Goal Attack (GA) to the attacking and midcourt thirds and the attacking goal circle and finally,
- The Goal Shooter (GS) to the attacking third and attacking goal circle.



Position	Playing Areas				
Goal Shooter	**1**	**2**			
Goal Attack	**1**	**2**	**3**		
Wing Attack		**2**	**3**		
Centre		**2**	**3**	**4**	
Wing Defence			**3**	**4**	
Goal Defence			**3**	**4**	**5**
Goal Keeper				**4**	**5**

Figure 1.1. Playing positions and playing areas allowed (International-Netball-Foundation, 2020)

The seven positions are usually grouped into three sub-groups as forwards (GS, GA and WA), midcourts (WA, C and WD) and defenders (WD, GD and GK). Each position in netball has specific roles, mostly owning to the restriction of court space which also influences the body shapes and types of players which make up each position (Fox et al., 2014, Graham et al., 2020, van Gogh et al., 2020). Notably, effective playing time for each position is greatly influenced by court restrictions, with the most restricted positions showing the least amount of active time (Fox et al., 2013). Also unlike other team sports, court restrictions cause different movement patterns as the ability for netball players to accrue distance and high-speed running in limited (King et al., 2018, van Gogh et al., 2020). Specific positional movement patterns, roles and anthropometric characteristics are detailed below.

GOAL SHOOTER

The GS is one of only two players who are allowed in the attacking shooting circle and to shoot for goal; this causes the GS's movement sequences to be the most dissimilar compared to all other positions (Figure 1.2), displaying the greatest shuffling load (horizontal movement whilst facing the same direction) and the most jumps, with low match-to-match variation (82.7 ± 6.8 jumps) (Bailey et al., 2017, Brooks et al., 2020a). At the elite level, the GS displayed the least amount of distance covered and the lowest distance per minute (35.1 ± 1.7 m · min^{-1}) (Brooks et al., 2020a), while at state-level GSs have poorer intermittent endurance (assessed via the Yo-Yo intermittent recovery test level 1) compared with midcourt and defenders (Graham et al., 2020).

GOAL ATTACK

The GA is the other shooting position, although has more freedom than the GS, displaying movement characteristics closer to those of a midcourt player. The GA displayed the third-highest acceleration density of 0.76 $m·s^{-2}$ (Brooks et al., 2020a), representing their positional role to provide passing options in the midcourt as well as an option in the shooting circle (Fox et al., 2014).

WING ATTACK

The WA is similar to the GA in terms of game movements, distance and speed (van Gogh et al., 2020). However, since it is not allowed in the shooting circle, the WA's

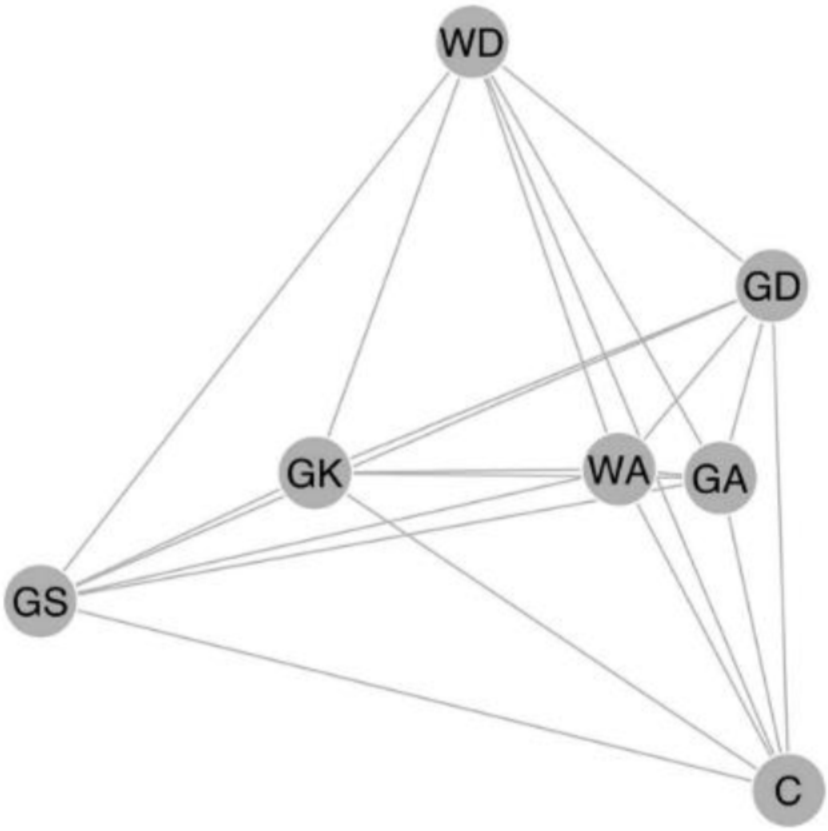


Figure 1.2 A network analysis of movement sequence similarity between playing positions (Sweeting et al., 2017)

role is focused on assisting with moving the ball into the shooting circle and providing passing options at the centre pass (Fox et al., 2014). The WA displayed a lower number of jumps per match, but a high match-to-match variation, suggesting requirements for each match can vary greatly for this position (Brooks et al., 2020a).

CENTRE

The Centre position has the least restrictions on available court space, acting as an all-round position. Being able to move through all three thirds, the C covers the most distance per game (4.7 – 5.5 km) (Brooks et al., 2020a, van Gogh et al., 2020) and compared with other positions spends more time jogging and running than standing (Bailey et al., 2017, Simpson et al., 2020a, van Gogh et al., 2020). As the centre is not allowed in the shooting circle, their role pertains to assisting passes to the shooters like the WA. Research has found the centre position is usually shorter in stature than that of the shooters (Graham et al., 2020) and must complete large amounts of multidirectional movement (Chandler et al., 2014a, Fox et al., 2014).

WING DEFENCE

The WD is part of the midcourt sub-group but plays a predominately defensive role, highlighted by large frequencies of guarding and the greatest load of off-ball guarding (Fox et al., 2013, Bailey et al., 2017). The WD plays an important role in defending entry to the oppositions shooting circle as well as providing movement and passing options during offensive transitions.

GOAL DEFENCE

The GD is one of two defensive positions that are allowed in the opposition's shooting circle and is usually tasked with guarding the opposition's GA. The GD's main priorities are to defend access to the shooting circle, block shots and rebounding missed shots. The GD position usually has a greater CMJ height capacity compared with midcourt and shooter positions, highlighting a higher vertical plane load for this position (Graham et al., 2020).

GOAL KEEPER

The other position that is allowed into the opposition shooting circle is the GK, with the main focus on preventing and influencing the opposition's GS shots. The GK is one of the two most restricted positions, but when adjusting for available court area, the GK displays a large amount of movement, comprised of the second-highest accelerations per 10 m covered (6.75 ± 0.37 m $\cdot$ s^{-2}) (Brooks et al., 2020a).

1.1.2 Performance analysis of netball

Netball research has progressed closely alongside the increase in the sports professionalism, mostly focusing on the movement profile of players during matches and training or on tactical notational analysis (Whitehead et al., 2021). Several studies have investigated the movement profile of the different positions and playing levels (Simpson et al., 2019, van Gogh et al., 2020, Graham et al., 2020, Simpson et al., 2020b, Young et al., 2016); these are important to understand as physical capacities can present different affordances influencing the tactical behaviours of players (Silva et al., 2014b). One of the main characteristics of netball is its high pace, a function of players being unable to hold onto the ball for more than three seconds, and subsequently resulting in players changing direction on average every 4.1 s (Fox et al., 2014). The constant change of direction is an integral component of team tactics as it allows for easier movement of the ball with easier passes potentially being available. Research investigating elite netball technical elements has shown elite level players to be under lower levels of pressure (defined as direct opponent was in a sag back position taking up space) when passing compared with development athletes (elite 63.0 ± 5.7%, development 47.6 ± 6.5%) (Bruce et al., 2009). This difference could be owning to the development athletes executing more passes when only one option was available (developmental 75.93 ± 5.58 %, elite 50.19 ± 5.86 %), compared with the elite group who displayed larger percentages of passes when there were >2 options available (Bruce et al., 2009). Being able to execute passes under low levels of pressure and with more passing options led elite level players to complete ~4.6 % more successful passes (Bruce et al., 2009), highlighting the importance of player positioning on attack and pressuring on defence.

Other notational analysis studies have focused on the centre pass tendencies of teams and players as this is a repeatable event within netball, occurring after every goal is scored.

The direction of a turn after receiving the ball from the centre pass appears to have little effect on the successfulness of the subsequent pass (Pulling et al., 2016). Furthermore, players who did not turn when receiving the pass had only a slight increase in the success of the following pass (95.3 %) compared with turning out and in before receiving (93.1 % - 93.2 %) (Pulling et al., 2016).

In more recent times, a number of studies have begun incorporating more advanced methods of analysis in netball research, with the use of machine learning tools such as clustering, self-organizing maps and data mining algorithms (Sweeting et al., 2017, Croft et al., 2018, Browne et al., 2019, Smith, 2021). Utilizing clustering algorithms, Sweeting et al. (2017) were able to characterise the movement sequences from spatio-temporal data, furthering previous attempts to describe a netball player's physical output. Movement sequences showed that the most prevalent features in a game were straight walking and neutral acceleration (Figure 1.3). Neutral acceleration is described as acceleration data that is contained in the cluster with a centroid of 0.0 $m \cdot s^{-2}$ (Sweeting et al., 2017). However, this could partially be a function of court restrictions and match activity, for some positions extended periods of inactivity can occur when the ball is at the opposite end of the court. Another study had provided insight into netball performance using machine learning, integrating self-organizing maps to identify elite netball styles of play (Croft et al., 2018). Their analysis revealed seven unique netball game styles, highlighting the variance of game plans that coaches can employ within a match. Finally, at a more player-based level, Browne et al. (2019) employed an *A priori* algorithm to identify common passing chains from the centre pass in netball, discovering the most frequent being "Centre→Goal Attack→Wing Attack→Goal Shooter" (Figure 1.4). This highlights that the most frequent passing sequence is located along the right-hand side of the court and fewer passes could be an indication of a direct style of play. These advanced methods

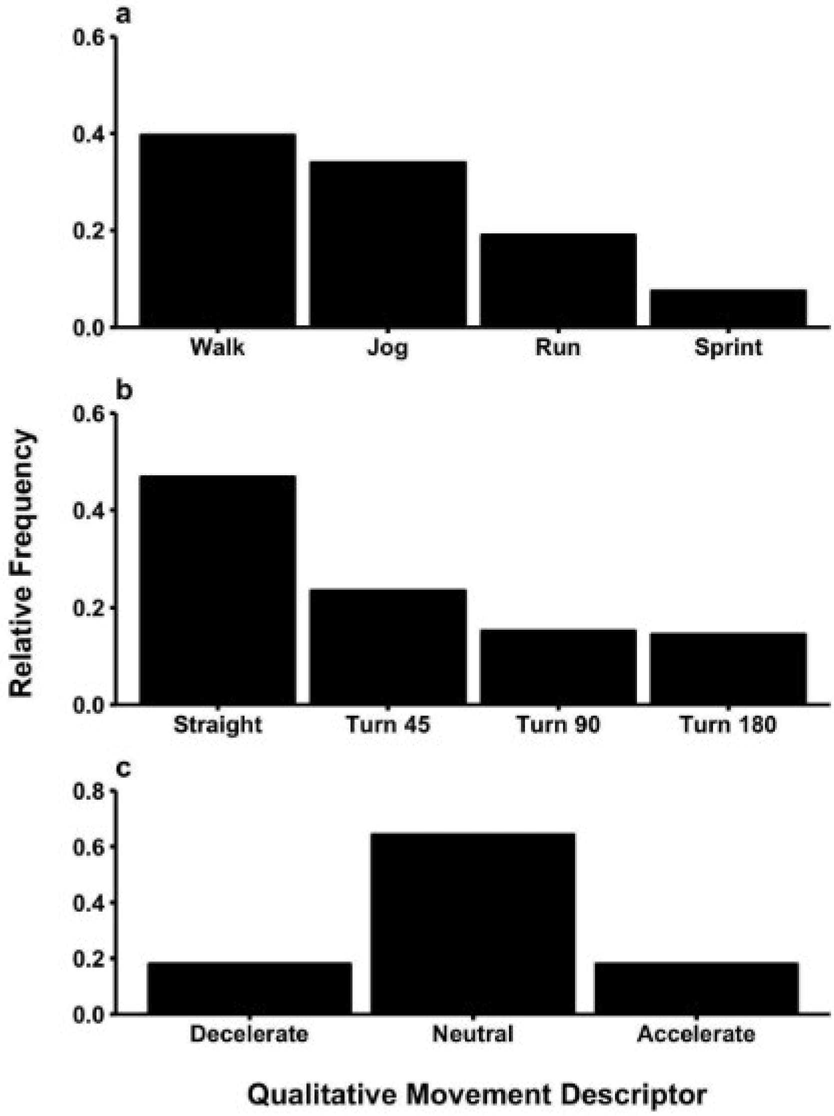


Figure 1.3 Frequently recurring movement features in elite netball. The relative frequency of cluster observations for (a) velocity, (b) angular velocity and (c) acceleration movement (Sweeting et al., 2017).

of performance analysis have begun to provide a baseline of knowledge and allow the integration of many variables, overcoming previous research limitations in netball.

Research pertaining to match outcome probability is also an important aspect of netball performance analysis (Whitehead et al., 2021). Investigations of match outcomes have shown elite netball is a very suitable sport for modelling probabilities owning to its high

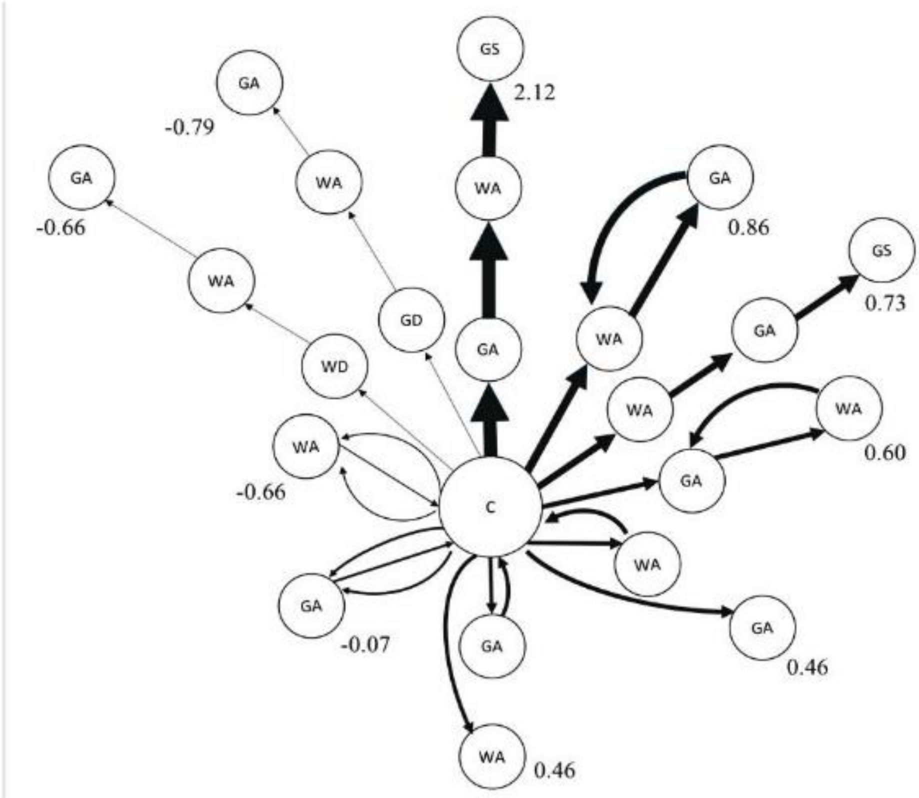


Figure 1.4 Ten most frequent passing motifs using playing position system generated from the first three passes of a centre pass. The value of the z-score is listed and displayed by the weighting of the line connecting the players, i.e., the thicker the line the greater the z-score

scoring rate with clear outcomes (Bake et al., 2021). However, research into this domain has been limited to only a few studies (Bake et al., 2021, Ofoghi et al., 2021). Both investigations of match outcomes in elite netball have advocated for the inclusion of contextual factors such as home and opposition strength, score state and match time. Findings from Ofoghi et al. (2021) indicate that technical match characteristics are consistent across the first half of the match and more variable in the second half, with the variables most associated with match outcome being time and feeds (a pass made into the shooting circle.). As such, it has been suggested that for teams to increase their chance of winning they should focus on minimizing negative actions over increasing positive actions especially in the second half of a match. For tactical associations with match outcome, Bake et al. (2021) highlighted that increasing the number of possessions for stronger teams does not actually increase their match win probability, but a lower number of possessions can decrease it. The results of both these studies suggest stronger teams should not only aim for more possession time but also focus on scoring as directly as possible to limit high scoring and turnovers that could help the opposition win with a lower number of possessions. Other match outcome results from Bake et al. (2021) show an advantage between 10-17% can be garnered by starting the final quarter in possession (in the case of the match finishing with one team having had one centre pass), however these results pertain to the Vitality Superleague so generalisability to other netball competitions may be limited. These match outcome studies provide a baseline understanding of important variables and team tendencies/tactics that can support coaches and analysts in their decisions.

Quantitative tactical research beyond this point is limited. However, studies have utilized netball experts and coaches as a qualitative medium to understand tactical dimensions of netball and the most important aspects contributing to performance (Coombe et al., 2020b, Coombe et al., 2020a, Croft et al., 2020). Across a number of studies, several main themes and behaviours have been identified by coaches and netball experts as important to netball performance (Figure 1.5). The most commented theme by coaches in one study was "movement spatial" followed by "attacking actions" and "player positioning" (Croft et al., 2020), aligning with the results of Coombe et al. (2020b) whereby the consensus of a panel of expert coaches identified four major tactical principles: "space and movement", "timing", "support" and "reading play". Furthermore, the same panel also suggested nine important attacking behaviours; "protect space", "court balance", "decisive movement", "draw or fake", "pace of ball", "getting free", "options to the ball", "option selection" and

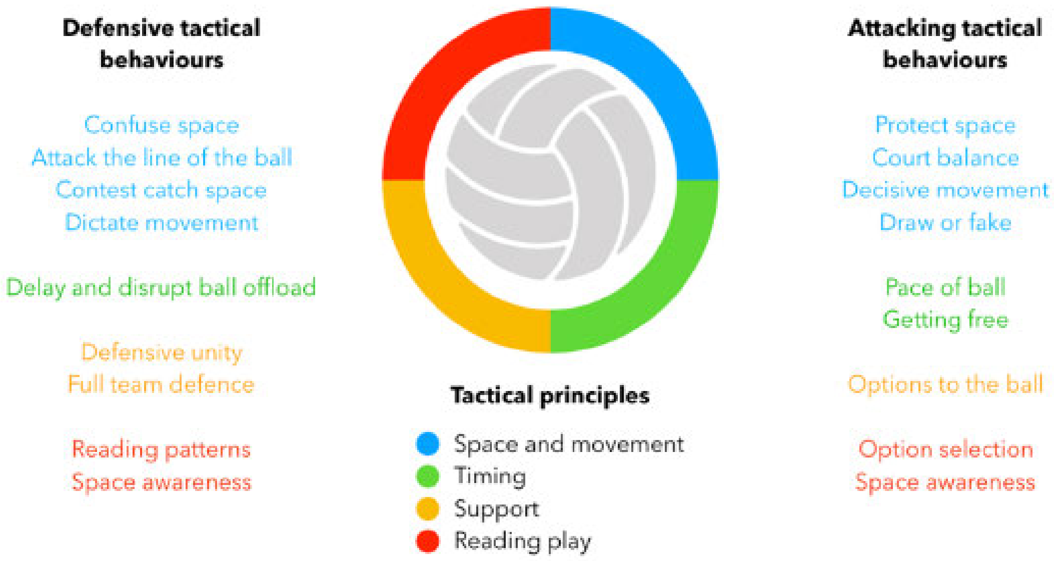


Figure 1.5 Tactical Principles Guideline (Coombe et al., 2020a)

"space awareness", with "options to ball", "getting free" and "movement" ranked as the most important. For defending behaviours: "confuse space", "attack the line of the ball", "contest catch space", "dictate movement", "delay and disrupt ball offload", "defensive unity", "full team defence", "reading patterns" and "space awareness" were identified as the most important behaviours" (Coombe et al., 2020a). Coaches' expert opinions suggest player movement and positioning is of the utmost importance for attacking possessions in elite netball, while for defending, the ability to be a cohesive defensive unit that can dictate the opposing attacker's movement is a priority (McLean et al., 2019). At the group level, collective behaviours have been found to be an important aspect in causing turnovers, with coaches identifying an average of five players involved in creating turnovers (Coombe et al., 2020b). Highlighting the importance of collective behaviour above individualist actions, this is especially important in attack as the player in possession of the ball is required to dispose of the ball within three seconds, thus teammates must provide passing options through continued movement, correct positioning and optimal spacing. Subsequently such, players must perform several maneuvers before the ball is ready to be passed to provide multiple passing options with the least amount of interference from defenders (Fox et al., 2014).

Although investigation into elite netball match outcomes, player behaviours and team tactics are important to successful performance, there have yet to been attempts to quantify how these variables can function together instead of looking at them individually, potentially due to the lack of player tracking technology previously available (Lord et al., 2020). While a number of studies have begun using local positioning systems to investigate movement sequences and match and training physical outputs (Sweeting et al., 2017, Simpson et al., 2020a, Brooks et al., 2021), the quantification of tactical variables utilizing player movement data is a novelty still yet explored in netball (Croft et al., 2020).

1.2 Electronic performance and tracking systems

To capture tactical player positioning and movement, spatio-temporal data is required. Several Electronic Performance and Tracking Systems are available for use, with various advantages and disadvantages and varying levels of validity (Mara et al., 2017, Goes et al., 2020, Rico-González et al., 2020b). There are three main types of tracking systems employed to track players movement and position: optical, GPS/GNSS and LPS (Leser et al., 2014). In a recent systematic review of EPTS, research studies included the use of optical tracking systems 60% of the time, followed by GPS/GNSS 33% of the time and finally LPS only 7% (Rico-González et al., 2020f). For use indoors, however, only optical and LPS tracking systems are applicable, as GPS/GNSS signals are unable to penetrate stadium roofs and ceilings.

1.2.1 Optical tracking systems

Optical player tracking systems that employ multiple cameras to capture the full coverage of a stadium are a popular choice in both research and applied settings (van der Kruk and Reijne, 2018, Lutz et al., 2020), as they offer a wide variety of use cases including; player trajectory extraction, highlight detection, visualizations and 3D reconstruction of sports matches (Manafifard et al., 2017, Mara et al., 2017). Optical systems are also less invasive compared with GNSS and LPS which require micro-sensors to be worn (van der Kruk and Reijne, 2018, Bastida-Castillo et al., 2019b), and can also capture home and opposition players for coverage of both teams (Mara et al., 2017). Additionally, optical systems have the ability to track the ball, opening up further research and applied use cases that are limited with the other tracking systems (Goes et al., 2020). Compared solely to GNSS, optical systems can also be used indoors. The accuracy of optical systems has been found to be acceptable when measuring distance (0.25% typical error between actual and estimated distance), while for change of direction movements of 90° displayed a coefficient of variation of 4.89% (Mara et al., 2017).

However, there are many limitations that must be overcome to use optical systems correctly; player occlusions, camera blur, lighting and illumination changes, player detection and classification, the requirement of multiple cameras, qualified personnel, complex interactions between players and umpires, dynamic environments, changing backgrounds and calibration inaccuracy (Castellano et al., 2014, Manafifard et al., 2017, van der Kruk and Reijne, 2018, Bastida-Castillo et al., 2019b). Of most importance for tactical analysis are player occlusions and incorrect classification and detection of players, which can cause the aggregate calculation of collective tactical variables to be widely inaccurate. The cost of optical systems can also be prohibitive for some users, as high-quality cameras and operators can see costs far exceeding that of GPS (van der Kruk and Reijne, 2018).

1.2.2 Local positioning systems

Local positioning systems have recently appeared more often in both research and in the applied setting as they offer a way to track players indoors. Different LPS utilise varied technology to track the position of objects, including Bluetooth, ultra-wideband, radio-frequency and Wi-Fi (Hoppe et al., 2018, Rico-González et al., 2020c). Unlike GNSS systems which use satellites to triangulate a player's position, LPS use antennas (or nodes) as their reference system (van der Kruk and Reijne, 2018, Rico-González et al., 2020c). Nodes are placed around the court or arena in specific locations which allow for the most optimal coverage of the playing dimensions, as well as limiting interference from metal surfaces (Alarifi et al., 2016, Luteberget et al., 2018, Lutz et al., 2020, Rico-González et al., 2020c).

Ultra-wideband LPS have become a popular system to use as they are able to reduce the interference of multipath signals via short pulses waveforms, larger data rates (up to 100 Megabits per second) and high bandwidth (Alarifi et al., 2016, Brooks et al., 2020b). More specifically, UWB systems determine player positioning by using time-of-flight and time difference of arrival algorithms on the electromagnetic waves that travel between nodes and the micro sensor receivers that are housed in players uniforms (Figure 1.6) (Stelzer et al., 2004). Compared with GNSS, LPS host several advantages that have garnered its increased use, specifically; the ability of LPS to function in a multipath environment, indoor use, its increased sampling rate, greater accuracy and potentially greater scalability (Bastida Castillo et al., 2018, van der Kruk and Reijne, 2018, Bastida-Castillo et al., 2019a). There are disadvantages with LPS, compared with optical and GNSS, mainly surrounding the cost of the system and the time required for installation (Hoppe et al., 2018). Fixed LPS systems also have the disadvantage of not being portable; while there are portable options (e.g. using Velcro), setup times are a lot longer than GPS

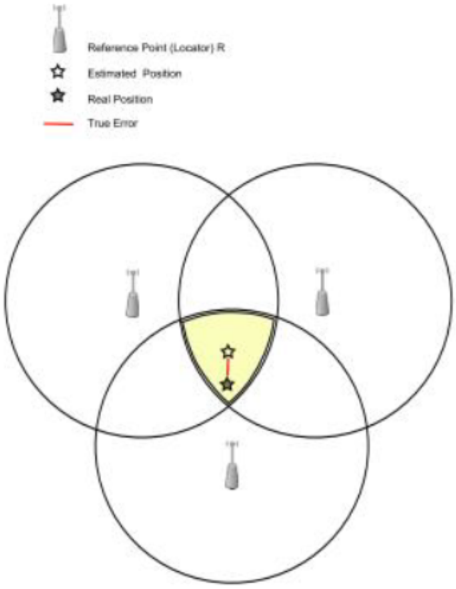


Figure 1.6 Positioning using reference point (Alarifi et al., 2016)

and require consistent placement and calibration of nodes (Bastida Castillo et al., 2018, Hoppe et al., 2018, Lutz et al., 2020). Additionally, metal interface can be a major problem when surveying and installing the LPS nodes, thus research has identified a number of optimal placement procedures that should be adhered to.

In order to obtain optimal coverage of the court, research suggests placing the nodes in a circumference shape (Luteberget et al., 2018, Rico-González et al., 2020c), not close to walls or corners (Luteberget et al., 2018) and in direct line of sight without metal interference. The height of nodes is also an important consideration, with Pino-Ortega et al. (2021) suggesting an optimal height of 1.30 m after an investigation of varying node heights on distance and tactical variables. A node height of 1.30 m resulted in a difference between -0.94 and 1.17 % compared to a height of 0.15 m which displayed a difference range from -1.05 to 3.28 % (Pino-Ortega et al., 2021).

The validity of UWB systems seems to be adequate for measuring frequent movements found in indoor sports (Leser et al., 2014, Serpiello et al., 2017). In a couple of studies comparing a UWB system against a reference system (e.g. Vicon), differences in distance, mean and peak speed and acceleration during linear drills were found to range between 0.2 and 12 % (Serpiello et al., 2017), while two other studies found the difference in position to be between 0.23 - 0.31 m (Ogris et al., 2012, Luteberget et al., 2018) in the optimal condition. For *x* and *y* coordinates separately, mean absolute errors of 0.57 and 7.15 m were found, respectively (Bastida Castillo et al., 2018). Differences between static and dynamic movements have also been researched, with static errors ranging from 0.19 to 0.32 m and multidirectional movements displaying relative errors <0.2% (Rhodes et al., 2014). Also, dynamic movements have been shown to have a distance error of 0.23 m (van der Kruk and Reijne, 2018).

With recent advances in player tracking systems, EPTS have been increasingly used to collect collective tactical variables (collective player positioning), and several studies have also begun validating LPS for use in collecting and measuring collective tactical variables. For the validity of UWB systems when measuring tactical variables, the inter-unit distance was found to have a 0.20 ± 0.05 m error compared to Vicon (Hodder et al., 2020), while for the aggregate measure of surface area (m^2 of the smallest convex hull of boundary players) GNSS displayed a systematic bias for underestimating surface area compared with LPS (Rico-González et al., 2020a). It has been suggested that differences between GNSS and LPS for measuring collective tactical variables could be owing to the fixed nature of the nodes for the LPS while satellites and lines of sight are constantly shifting for GNSS (Rico-González et al., 2020a).

Overall, LPS have been indicated as the most accurate of the three EPTS (Leser et al., 2014, Pino-Ortega et al., 2021) for measuring both physical and tactical variables and has also been successfully compared against a motion tracking standard protocol in Vicon (FIFA, 2020). This provides an avenue to collect player positioning and movement data for indoor sports, which are crucial in researching collective tactical variables.

CHAPTER 2 – A REVIEW OF THE COLLECTIVE TACTICAL VARIABLES LITERATURE

2.1 Collective behaviours

2.1.1 Introduction

With the ability to track players positioning on the field, tactical analysis using spatio-temporal data has become a popular research area of focus, especially in sport science research (Goes et al., 2020). Tactical analysis utilizing EPTS pertains to the quantification of collective behaviours of players and teams by aggregating player positioning and movements into variables known as collective tactical behaviours, representing player behaviours relating to team tactics.

2.1.2 Tactics

In team sports, tactics refer to the way players organize themselves on the playing field in relation to one another to form a strategic action that focuses on completing a shared goal, while also being able to adapt to the opposition and the environment (Moura et al., 2013, Rein and Memmert, 2016, Goes et al., 2020). Tactics can be formed for the team and also sub-groups that require different players to co-adapt (Rein and Memmert, 2016). Of interest for coaches is the ability to measure how well their players are abiding by and performing the tactics agreed upon (Bradley and Ade, 2018), as it has been suggested greater tactical organization by one team can better support that team winning (Bartlett et al., 2012). One such avenue to measure tactical performance is understanding the collective behaviours occurring between players and how well their resulting collective performance aligns with the predetermined team tactics (Memmert et al., 2017, Lord et al., 2020). Such behaviours can include the stretching and contraction of groups, player positioning, distance to one another and also the area certain groups of players are controlling (Araújo et al., 2015, Gudmundsson and Horton, 2016, Memmert et al., 2017).

2.1.3 Collective behaviours

Collective behaviours were initially studied in several biological organisms such as flocks of birds, shoals of fish and ant colonies, before being utilized in team sports (Gardner and Grafen, 2009, Duarte et al., 2012a). With an understanding of the emergent behaviours and interactions in animal systems, the transference of these concepts to team sports represents the culmination of individual player behaviours together, in a synergistic and cooperative manner that support self-organisation and team actions toward shared goals (Riley et al., 2011, Silva et al., 2013, Silva et al., 2014b, Folgado et al., 2018b). One of the main reasons studying collective behaviours in team sports has become popular is owing to uptake usage of ecological dynamics perspective that conceptualizes groups of players as cooperative interacting systems, whereby roles and behaviours emerge from the shared affordances available (Clemente et al., 2013c, Leite et al., 2014, Araújo et al., 2015). As such, sport scientists, coaches, analysts and researchers have focused on the self-organizing and emergent collective behaviours that have been suggested as essential for team cohesion, synchrony and overall performance (Clemente et al., 2014a, Araújo and Davids, 2016, Gonçalves et al., 2016). Of interest is how players adapt and interact with teammates, opposition players and environmental constraints and integrate their behaviours to support the team's systems and tactics (Duarte et al., 2012a, Gudmundsson and Horton, 2016). Supporting team tactics via collective behaviours, requires individuals to have dynamic positioning and movement that is malleable to the conditions presented, and integrates with nearby teammates, constituting their individual actions together (Passos et al., 2009, Folgado et al., 2018b, Goes et al., 2020).

2.1.4 Ecological dynamics

Collective behaviours and their relationship with tactical analysis in team sports can be conceptualized through the lens of ecological dynamics theory, which provides a perspective of the performer (player and team) and environment relationship (Araujo et al., 2006, Passos et al., 2009, Araújo and Davids, 2016). More specifically, ecological dynamics highlight the affordances and constraints that the environment provides to players, and how such information is processed by players into emergent behaviours that allow for actions to coordinate and self-organize as a collective, alongside their teammates (Araújo and Davids, 2016, Low et al., 2020, Passos et al., 2009). Constraints of the environment which can impact player behaviours can include; pitch restrictions, surfaces, temperature, rules, crowd support, number of players and equipment types (Araújo and Davids, 2016, Alexander et al., 2018, Baptista et al., 2020, Low et al., 2020). A number of these environmental constraints are unable to be controlled by players, thus presenting the dynamic and complex nature of team sports, whereby players are required to be malleable and adaptive.

2.1.5 Dynamic systems & affordances

Initially sports teams were theorized through dynamic systems, which could construct a perspective of how coordinated movements of players emerge, change and adapt (Araújo and Davids, 2016). Where opposing teams are the interacting parts of the system, with individual player actions regulating the behaviours and information available (Passos et al., 2011, Gonçalves et al., 2016, Browne et al., 2019, Coito et al., 2020, Lord et al., 2020). At the player level, they regulate their behaviours from the information they consume from other players and the environment (Silva et al., 2014b, Folgado et al., 2018b). For a group (or team), organisation and coordinated behaviours were linked to the division of labour, expressed as a key component where players individual actions feed the larger team tasks, allowing the team to exhibit its own unique behaviour as its own entity (Eccles, 2010, Duarte et al., 2012a, Low et al., 2020). Culminating in individual and collective behaviours combining to form a complex system where players behaviours and movements are coordinated towards the same goal (Duarte et al., 2012a). Where ecological dynamics forks from this is through the incorporation of affordances, which can be understood as the possibilities for action, emerging from the environment and interactions with players, as a construct of an athlete's capacity (Vilar et al., 2012, Silva et al., 2014b, Araújo and Davids, 2016). Furthering the notion of affordances is shared knowledge, occurring between several players when sharing the same task goal and task constraints (Araújo and Davids, 2016, Low et al., 2020). Shared knowledge pertains to the combined understanding of how to achieve a shared goal under the imposed conditions and environment (Eccles, 2010), and therefore lack of cohesion could be seen as a collective not completely attuned to similar information. Shared affordances guide how players collectively behave when they are working in cooperation with one another, as their perception of possible actions are based on the affordances provided to one another. (Passos et al., 2009, Araújo et al., 2015, Araújo and Davids, 2016). Overall, the actions performed are influenced by the tactics of the team and opposition and positioning and behaviours of other players, thus accrued information leads to behaviours formed by the information perceived, affordances of actions and previous experiences and learning (Fajen et al., 2009, Duarte et al., 2012a). Teams of players who can collectively understand the affordances provided to each team mate can further advance the collective behaviours they each display, helping with greater organization and team coordination.

2.1.6 Self-organisation

From the array of actions and decisions individual players can make emerge co-adaptive behaviours that are dependent upon team behaviours, the dynamically changing affordances encountered and the interactions with other components of the complex system (Passos et al., 2012, Silva et al., 2013, Folgado et al., 2018b). Creating a co-adaptive loop of shifting environmental constraints and interactions, that emerge from players decisions and behaviours (Passos et al., 2012, Santos et al., 2018). One concept of co-adaption is the behaviour of self-organisation, which explains the process of a player's tendencies and behaviours converging to a state of order within a system (Araujo et al., 2006, Passos et al., 2009, Passos et al., 2012, Vilar et al., 2012). Especially pertinent for players of close proximity to one another, as shared affordance and information are more clearly defined (Passos et al., 2009, Bourbousson et al., 2010a), and for certain agents within a system who can have larger influence (captain, coach, focal players) of how a systems self-organisation finds order for its components (Steele and Chad, 1991, Passos et al., 2009, Passos et al., 2012, Vilar et al., 2012).

2.1.7 Summary

Collective behaviours viewed through the theoretical concept of ecological dynamics with a focus on player and group affordances, environmental constraints and self-organization processes provide a clear definition to base tactical variable construction and measurement from. Combining collective behaviours with tactical analysis via compound variables called collective tactical variables, allows the measurement and analysis of player–player and player environment interactions under the scope of ecological dynamics (Araújo et al., 2015, Coito et al., 2020, Low et al., 2020). Collective tactical variables have been used to investigate team and sub-group behaviours pertaining to; spacing, coordination, transitions, spatial exploration and control, dispersion and positioning and finally overall system organisation and change (Passos et al., 2012, Vilar et al., 2012, Clemente et al., 2014a, Gonçalves et al., 2014, Leite et al., 2014, Clemente et al., 2018a, Folgado et al., 2018b, Olthof et al., 2019).

2.2 Collective tactical variables

As accessibility to player positioning and spatio-temporal data has increased, so has the ability to measure behaviours of players within a system that relate back to their team tactics (Lord et al., 2020). Measures of these behaviours are called collective tactical variables (or sometimes compound variables) and are created through the aggregation of multiple players positioning and subsequent movements on the field of play (Marcelino et al., 2020). Of previous studies exploring collective tactical variables, most are focused on the reduction of the raw positioning of players into variables that try and capture group and players positioning (84%), other use cases of these variables included mean positioning (57%), player dispersion (46%), lateral and longitudinal spread (30%) and spatial control (7%) (Goes et al., 2020), for a schematic illustration of several collective tactical variables see Figure 2.1.

The understanding of the behaviours and positioning between two players (dyad) relative to one another provides the simplest introduction of collective tactical variables. Inter-player distances (distance between two players) has been researched extensively for intra-coupling (two players from the same team) and inter-coupling (two players from opposing teams), and how players move in coordination with one another, or in opposition (Bourbousson et al., 2010a, Rico-González et al., 2020d). While only two players are included in this type of measure, inter-player distance is still characterized as a complex dynamical system as it contains features of nonlinearity and unpredictability in movement and behaviours, which also influence higher-order processes within the team system (Passos et al., 2009, Vilar et al., 2012). Expanding upon the distances between two players is considering the team and sub-groups dispersion on the playing field. The width and length variables have been used to describe team ranges and dispersion of a group of players both laterally and longitudinally (Duarte et al., 2013). The width of a group of

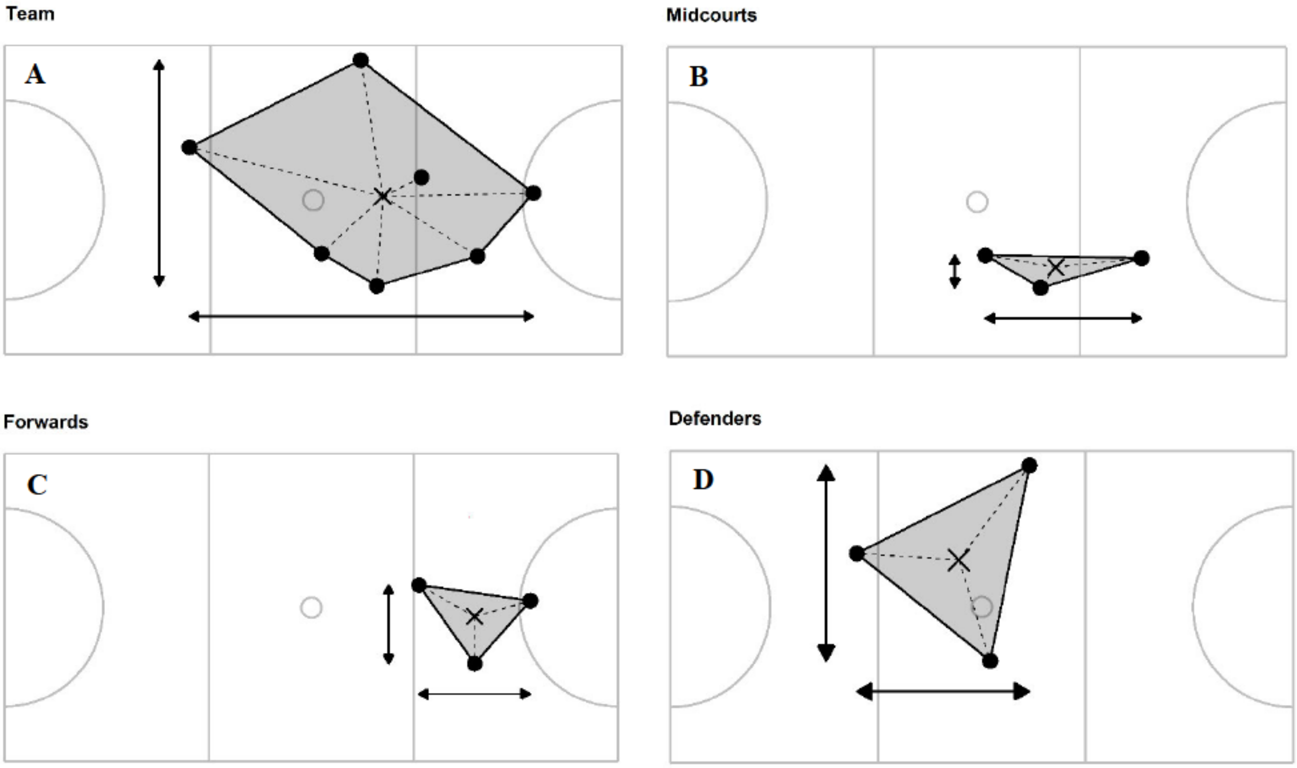


Figure 2.1. Illustration of five collective tactical variables in netball for the team (A), midcourts (B), forwards (C), and defenders (D). Players positions (●) are combined to provide the centroid (mean position, ×), length (horizontal arrow line), width (vertical arrow line), stretch index (mean length of dashed lines) and surface area (grey shading). Solid grey lines represent court markings and define, for example, the left- and right-hand thirds of the court area to which the goal keeper and goal shooter are restricted

players (or team) represents the distance between the two most lateral players of that group, while the length is the distance between the two most longitudinal players (Frencken et al., 2011, Olthof et al., 2019, Coito et al., 2020). These variables begin to provide information on the collective positioning of groups of players and how they are dispersed within the playing environment.

Accompanying the dispersion of groups of players, is their mean positioning, expressed through the calculation of a centroid. A centroid represents the geometrical centre (average position) of a group of players (Frencken et al., 2011, Rein and Memmert, 2016, Bradley and Ade, 2018, Low et al., 2020, Rico-González et al., 2020e). The centroid, from a global perspective aims to assess the behaviour of a whole team, as it aggregates all players positioning together (Goes et al., 2020, Rico-González et al., 2020e, Silva et al., 2014b), however it has more specific use cases in; comparing opposing teams mean position on the pitch relative to one another, and how their positioning flows throughout a match (Frencken et al., 2011, Clemente et al., 2013c, Memmert et al., 2017, Coito et al., 2020). The centroid can also be analysed in lateral and longitudinal axis's, creating separate variables measuring the collective positioning (displacement) of players forwards-backwards and side-side on the playing field (Frencken et al., 2011, Clemente et al., 2013b, Folgado et al., 2014b). Additionally, the centroids of a team have been combined with other focal points of the playing field to provide context to the teams or sub-groups positioning relative to important locations. Popular combinations include; the distance between the team centroid and team or opposing goals, the distance between sub-group centroids (midfield, forwards and defenders) and distance between centroid and ball position (if available) (Clemente et al., 2013a, Gonçalves et al., 2014, Aguiar et al., 2015).

Several collective tactical variables have also been created to measure the shape or surface coverage of players. The length-per-width ratio is one variable that aims to provide a representation of the team playing shape, being either elongated, balanced or laterally flattened (Duarte et al., 2013, Silva et al., 2014a, Olthof et al., 2015). The length-per-width ratio, calculates the ratio of a team's length and width variables, providing a ratio number summarizing the team's dispersion laterally and longitudinally (Silva et al., 2014a, Memmert et al., 2017). Interpretation of the length-per-width ratio values varies in research studies, a general consensus suggests values <1 indicates greater width values (laterally flattened shape), values ~1 highlight an even spread of width and length, and values >1 indicate superior length dispersion (elongated shape) compared with the width

(Folgado et al., 2014b, Silva et al., 2014a, Castellano et al., 2016, Gonçalves et al., 2019, Coito et al., 2020). A collective tactical variable that measures the coverage or surface covered by a team is the surface area (Araújo et al., 2015). The surface area is calculated by computing the m² the smallest convex hull of all outfield players of a team or sub-group (smallest polygonal area of the peripheral players) (Silva et al., 2014a, Araújo et al., 2015, Gonçalves et al., 2016). Some literature articles have used the surface area to describe the shape of a team (either contracted or expanded) however most studies focus on its use as a measure of spatial control or coverage (Frencken et al., 2011, Moura et al., 2013, Araújo and Davids, 2016, Barnabé et al., 2016).

Research relating to the use and applicability of different collective tactical variables has progressed, thus the variables have been adapted and iterated on, creating new variables that more specifically try and measure different collective behaviours. The stretch index of a team or group is one such variable, while very similar to the mean inter-player distance of a group of players, the stretch index presents the dispersion of players in relation to their spatial centre (centroid) (Bourbousson et al., 2010a, Silva et al., 2014b). Calculated as the mean distance of each player to their team centroid (Clemente et al., 2014b, Silva et al., 2014b, Barnabé et al., 2016), the stretch index advances basic inter-player distances by relating player dispersion to a focal point of the team, allowing research and applied practitioners to use it as a measure of contraction and expansion from this focal point (Bartlett et al., 2012, Sampaio et al., 2014a, Araújo et al., 2015, Olthof et al., 2015, Araújo and Davids, 2016, Canton et al., 2019). The stretch index can also be calculated for lateral and longitudinal axis' independently, representing the mean dispersion of players on each axis to that axis' centroid (Araújo et al., 2015).

Collective tactical variables can also be measured in several ways. The most common is the mean value of the variables, which is calculated usually per possession or over the entire match. The variability (standard deviation) has also been utilized to provide insight into the variance of the measures instead of just looking at one central tendency measure (Figueira et al., 2018b). Finally, the irregularity of variables is measured via approximate entropy, a measurement technique to assess the predictability within a time series of complex systems (Pincus, 1991, Passos et al., 2009, Fonseca et al., 2012a, Gonçalves et al., 2016). Low values (closer to 0) of ApEn represent more predictable or regular time series patterns, while values (closer to 2) represent less regularity (Fonseca et al., 2012a, Gonçalves et al., 2019). It has been suggested that low values of ApEn (indicating high regularity) can reveal information representing self-organisation and coordination, with higher values (indicating low regularity) potentially showing more chaotic and unpredictable collective behaviours (Aguiar et al., 2015, Gonçalves et al., 2019). With the development of collective tactical variables and accompanying measurement techniques, many studies have investigated how best these measures of collective behaviours can be utilized in applied environments and external factors that may influence them.

2.3 Uses of collective tactical variables

Research pertaining to collective tactical variables has become a focus of sport science research, with studies moving past investigating the use of these compound variables and now exploring their applicability and the effects of the contextual and environmental constraints that are imposed during matches and training. These variables include but are not limited to; attacking principles of games, phase of play (attack or defence), game style and strategies, the strength of the opposition, age, score status, time of the match, fatigue, sub-areas on the playing field, location of the match (home and away) and training compared with match outputs.

2.3.1 Attacking principles in matches (attack vs defence)

A primary focus of research has been how collective tactical variables can be used to measure players' compliance with attacking and defending principles outlined in their team's strategic system. A repeated trend has been found in the literature for attacking players to be positioned further apart than their opposing defenders (Fonseca et al., 2012b), linking back to the common tactical notion that attacking players must try to separate the defenders through chaotic and unpredictable behaviours (Castellano et al., 2013, Vilar et al., 2013, Clemente et al., 2014a, Gonçalves et al., 2019). By separating defenders, a disruption of the defending team's tactics pertaining to compactness and coordinated actions can take place, resulting in the defenders being unable to restrict the space (Castellano et al., 2013, Araújo and Davids, 2016, Alexander et al., 2018). As such, several studies have found greater width, length, surface area and stretch indices for teams during attacking phases (Castellano et al., 2013, Barnabé et al., 2016, Castellano et al., 2016, Alexander et al., 2018, Bueno et al., 2018, Gonçalves et al., 2019, Rico-González et al., 2020d). Generally, as teams try and execute these tactical principles of attack and defence, defenders adopt elongated playing shape to maintain stability and guard the most dangerous attacking space (usually middle channel of playing field), while attackers utilize the width of the playing field (Clemente et al., 2013b, Castellano and Casamichana, 2015, Castellano et al., 2016, Alexander et al., 2018, Gonçalves et al., 2018). Of note, increases to the surface area and distance variables for attacking teams can somewhat be an artefact of greater field dimensions longitudinally, thus contributions from this axis to dispersion and spacing variables are greater (Castellano et al., 2016).

2.3.2 Possession outcome & game style

Another primary use for collective tactical variables has been assessing their association with successful and unsuccessful possessions and moments in a match, and how behaviours (as measured by collective tactical variables) shift in relation to game styles. Research in rugby union found the outcome (successful/unsuccessful) of possessions (try/tackle) could be predicted from the velocity and inter-player distances of the attacking and defending player dyad (Passos et al., 2008). In soccer, when the defender can lead the movement directions of their opposing attacker, it can result in more predictable coordination tendencies of both players, thus favoring the defending player (Duarte et al., 2012b). For teams to also control their opposition's movement, game styles in soccer such as "high press" and "low block" are common strategies, and thus received research attention regarding the behaviours they elicit. It has been suggested that when a team utilizes a high-press defending strategy during matches, the two teams are closer in proximity (teams centroids closer together), and the defending team has a greater length, LPWratio and inter-player distances (Low et al., 2021). While for the opposing attacking team, greater team length and LPWratio were found in comparison to playing against a deep defending game style (Low et al., 2021). Playing formations in soccer have also been investigated alongside collective tactical variables, in 7v7 SSG's the 4:3:0 displayed greater width and surface area compared to a 0:4:3, while a 4:1:2 formation tended to have greater irregularity (ApEn) values of a players distance to own centroid compared to the 4:3:0 and 0:4:3 (Baptista et al., 2020). These findings display clear distinct behavioral shifts pertaining to dispersion and positioning based on the game styles and tactical formations coaches decide to play.

2.3.3 Effect of age

When comparing collective tactical variables, age-related behaviours are an important factor to consider, with older players usually presumed to have greater playing and training experience and thus greater cohesion and tactical ability then their younger counterparts (Folgado et al., 2014a). Several studies have investigated the differences in collective tactical variables between age groups, with a general consensus that older players display greater exploratory behaviours coupled with greater self-organisation coordination (Barnabé et al., 2016, Bueno et al., 2018, Clemente et al., 2020b). The distance between players and their team's centroid were greater in players from older age categories (U17>U15>U13) (Clemente et al., 2020b), highlighting greater dispersion from the focal mean of the group. Additionally, older players (U19 vs U17) utilized the width of the pitch more (Olthof et al., 2015), as well as displaying greater surface area (U19: 202.6 ± 68.5 compared to U16:176.6 ± 57.8) (Barnabé et al., 2016), and stretch indices (U19: 5.25 ± 0.08 vs U17: 5.03 ± 0.07) (Olthof et al., 2015). Older players displayed lower ApEn for several collective tactical variables, indicating greater stability of their collective behaviours (Barnabé et al., 2016, Castellano et al., 2017). One hypothesis regarding the differences in collective tactical variables between age groups is the shared information and affordances older players gain through training and match experience, compared to younger players who mostly try to solve match tasks individually. (Folgado et al., 2014a).

2.3.4 Strength of opposition

Similar to the differences in age, the strength of opposition and playing level (tier) have also been suggested as important contextual factors to adjust for when using collective tactical variables. Most studies investigating opposition strength have compared either national level players vs regional level players, top ladder position teams vs bottom ladder position teams or different tier leagues (league one vs league two). When comparing top position teams and bottom position teams, Castellano et al. (2013) found greater length and width frequencies when playing against weaker teams, indicating higher-ranked teams can fulfil the attacking principles of dispersion and width utilization. For teams defending against higher ranked teams, greater width, length and surface area frequencies were also found (Castellano et al., 2013), further supporting the attacking principles of the stronger team able to separate and disrupt the defending team's coordination (Gonçalves et al., 2019). When comparing national and regional level players, the national level players displayed greater LPWratio values during attacking phases, especially in the largest field condition (national players: 1.45 ± 0.24, regional players: 1.14 ± 0.22), suggestive of a collective goal of larger dispersion (Silva et al., 2014a). Finally, a comparison of league one and league two teams found larger width and length values for league one teams, depicting further the influence playing level and experience has on collective behaviours of teams. Furthermore, the bottom-ranked teams from league one also displayed greater width and length compared to the top teams of league two. The summary of all these results show a clear difference between playing level and opposition strength in terms of collective tactical behaviour (Gonçalves et al., 2019).

2.3.5 Score status and time in match

Other auxiliary factors that have been found to influence the output of collective tactical variables include the score status during a match and the time point in the match. When teams are placed in a losing scoreboard position, it is suggested their longitudinal centroid position increases, indicating a potential greater focus on scoring to even the scoreboard (Clemente et al., 2014b). Changes to lateral positioning were also found, with a soccer team shifting further to the left of the field when in a losing position compared with winning and drawing. For teams in a drawn scoreboard position, increases to stretch index and surface area were displayed, once again potentially indicating teams trying to separate the opposing defenders to be able to score (Clemente et al., 2014b). Match time has also been shown to have some influence over collective tactical variables, with differences between the first and second halves found. In one research study, soccer teams displayed a tendency to position themselves on the right-hand side of the field in the first half, while during the second half, a decrease in the teams dispersion and positioning were highlighted (Clemente et al., 2013c). Effects of match time have been previously linked to degradations in the physical capacity as a result of fatigue (Duarte et al., 2013, Clemente et al., 2018b), however studies investigating this effect are limited, and thus findings based on match time must be interpreted with caution. Nevertheless, the influence of scoreline and differences throughout the match have shown some changes in collective behaviours that would be of interest to coaches. (Folgado et al., 2018b).

2.3.6 Sub-areas and sub-groups

The final way collective tactical variables have been analysed is by segregating the playing field into sub-areas or comparing different positional groups' behaviours with one another. Sub-groups of players may share local information and constraints (Leite et al., 2014, Aguiar et al., 2015); this was found to be true when analysing player distances to centroids, with players displaying greater proximity and coordination with their positional sub-group (Gonçalves et al., 2014). Better coordination effects were however found for the midfield group compared with the forward group as the midfield group positional responsibilities are more stable compared with the forwards (Gonçalves et al., 2014). Players within sub-areas of the playing field have also been suggested to have differing collective behaviours, highlighted by the increased numerical superiority of defenders verse attackers usually found in defensive zones and also the greater irregularity found in the centre-middle sub-areas, as the middle of the field borders all other zones, thus, player movement through this zone is the largest (Vilar et al., 2013).

All the contextual effects and constraints that can impact collective tactical variables in matches, can be found mostly in training as well. To replicate the behaviours of matches in training, studies have also focused vastly on the ability to elicit these behaviours in SSG training drills and the effects different drill constraints can have.

2.4 Describing tactical behaviours in training

2.4.1 Small-sided games

Constrained-based games, also known as small-sided games are a common drill design in team sports to emulate the player interactions and the main tactical principles of full matches (Folgado et al., 2018c, Folgado et al., 2018a, Soltanzadeh and Mooney, 2018, Goes et al., 2020, Clemente et al., 2021). Small-sided games are popular as they also provide an avenue to train physical, technical and tactical components together, and can offer similar informational affordances as matches (Aguiar et al., 2012, Clemente et al., 2018b, Olthof et al., 2018, Clemente et al., 2020a, Fernández-Espínola et al., 2020). The main modifications that make SSGs different to matches include restrictions to playing field dimensions, changes to playing numbers, modified rules, environmental constraints and specific use of unbalanced age and expertise levels (Clemente et al., 2020a, Fernández-Espínola et al., 2020, Goes et al., 2020). These modifications have all been investigated in regard to their ability to elicit changes to collective behaviours as measured by collective tactical variables (Table 2.1) (Clemente et al., 2020a).

2.4.2 Pitch size and restrictions (SSG)

The main source of modification in SSG is the adjustment or restriction of playing space, with numerous studies investigating the influence of these different pitch/court dimensions on collective tactical variables. Increased length of soccer pitches was predominately associated with greater width, length, stretch index and surface area values (Silva et al., 2014a, Castellano et al., 2017, Clemente et al., 2018b, Folgado et al., 2018b), as well as greater distances between players and their centroid (Leite et al., 2014, Clemente et al., 2018b). Larger pitch sizes promoting greater exploratory behaviour and player dispersion is an obvious outcome of such drill modifications, for coaches though more interest lies in the changes in collective tactical behaviours with differing size pitch

Table 2.1. Small-sided games research, investigating collective tactical variables.

Study	Sport	Themes/Aims	Player Numbers	Collective Tactical Variables Used
Aguiar et al. (2015)	Soccer	Numerical differences	3v3 to 6v6	Centroid, inter-team distances, player distance to the centroid
Barnabé et al. (2016)	Soccer	Age	6v6	Length, width, surface area, stretch index
Castellano et al. (2017)	Soccer	Age, Field size restrictions	7v7	Length, width, surface area, stretch index, centroid
Castellano et al. (2016)	Soccer	Rule modification	5v5	Length, width, surface area, inter-team distance
Clemente et al. (2020b)	Soccer	Age	4v4	Surface area, stretch index, inter-team distances, player distance to the centroid
Clemente et al. (2018b)	Soccer	Field size restrictions	11v11	Centroid, stretch index
Clemente et al. (2020b)	Soccer	Age	4v4	Surface area, inter-team distance, player distance to the centroid, stretch index
Duarte et al. (2012c)	Soccer	Rule modification	3v3	Centroid, surface area
Folgado et al. (2018a)	Soccer	Field size restrictions	4v4	Length, width, inter-player distance
Folgado et al. (2014b)	Soccer	Age	3v3 to 4v4	Length-per-width ratio, inter-team distance
Frencken et al. (2011)	Soccer	Opposing team relationships	4v4	Length, width, surface area, centroid
Gonçalves et al. (2016)	Soccer	Numerical differences	4v3 to 4v7	Surface area, inter-player distance, player distance to the centroid
Gonçalves et al. (2017)	Soccer	Field size restrictions	10v9	Stretch index, inter-player distance,
Olthof et al. (2015)	Soccer	Age	4v4	Inter-team distance, stretch index, length-per-width ratio
Olthof et al. (2018)	Soccer	Age Field size restrictions	4v4	Inter-team distance, length-per-width ratio, surface area, stretch index, inter-player distance
Olthof et al. (2019)	Soccer	Field size restrictions Numerical differences	4v4 to 8v8	Length, width, inter-player distance, surface area
Ric et al. (2017)	Soccer	Rule modification Field size restrictions	10v9	Length, width, inter-player distance

Sampaio and Maçãs (2012)	Soccer	Training intervention	5v5	Centroid, stretch index
Sampaio et al. (2014a)	Basketball	Training intervention	5v5	Inter-player distance, stretch index, player distance to the centroid
Sampaio et al. (2014b)	Soccer	Numerical differences Score status Game pace	5v5	Centroid, player distance to the centroid
Silva et al. (2014a)	Soccer	Skill level Field size restrictions	4v4	Surface area, length-per-width ratio, inter-team distance
Silva et al. (2014b)	Soccer	Skill level Numerical differences	5v3 to 5v5	Stretch index, major ranges, distance to the centroid, distance to the goal, inter-team distances
Travassos et al. (2014)	Soccer	Rule modification	5v5	Inter-team distances, stretch index, relative stretch index
Vilar et al. (2014)	Soccer	Numerical differences	5v3 to 5v5	Inter-player distance, defender distance to the ball

conditions. Small-sized conditions have been suggested to elicit greater individual actions associated with attacking penetration as distances between attackers and defenders are a lot smaller (Ric et al., 2017, Olthof et al., 2018, Clemente et al., 2020a). For half-size soccer pitch conditions, greater proximity between players (compared with large conditions) and greater distances between teams (compared with small conditions) appears to promote greater coordination behaviours associated with compactness and team unity (Travassos et al., 2014, Clemente et al., 2018b). Conversely, full-size conditions were highlighted by greater overall distance and stability (reduced variability) of inter-team distances (centroids) (Olthof et al., 2018, Fernández-Espínola et al., 2020), potentially owning to affordances of greater relative space per player and thus increased decision time to process information (Fernández-Espínola et al., 2020).

2.4.3 Player numbers and numerical differences

The modification of player numbers in SSGs is another technique coaches can use to create numerical imbalances which players may face during matches. Research has found that by increasing the number of players in the same sized field dimension, the surface area of teams increases, with Gonçalves et al. (2018) finding increases of 442% when increasing from three to four players per team and 35% with nine to ten players per team. As more players are introduced to SSGs the changes in surface area can reach a plateau as the calculation is of only peripheral players (convex hull), thus some extra players do not increase surface area values. As highlighted by decreased variability of surface area when considering 8 or more players (Gonçalves et al., 2018), these players instead just decrease the relative space each player has on the pitch/court (Olthof et al., 2018, Olthof et al., 2019). Additionally, increased player distance and regularity to own and opposition centroid was also found to be associated with increased player numbers (Aguiar et al., 2015). For conditions with a lower number of players, the opposite is true, with decreased regularity (ApEn) values and increased relative playing space, meaning players are more isolated and less able to perform coordination behaviours associated with being closer together (Gonçalves et al., 2016, Olthof et al., 2018). During matches, numerical overload and underloads occur organically but also as a result of coaching tactics. Therefore, training under such conditions allow players to become more attuned to the constraints and information available in numerical unbalanced conditions. Conditions that contain a lower number of defenders, has been suggested to deemphasize the need of attackers to produce self-organizing behaviours and instead promote individual actions. (Silva et al., 2014b, Gonçalves et al., 2016).

2.4.4 Rules, age and experience

Beyond the popular SSG modifications of pitch sizes and player imbalances, other adjustments that have been investigated in relation to collective tactical variables include the effects of rule changes, age and experience level. Coaches have explored the inclusion of additional scoring targets in soccer SSGs, in an effort to promote more dynamic task information and subsequent behaviours from players (Travassos et al., 2014). Other rule changes pertain to restrictions on player movements based on zones of the playing field; it was found that players were more coordinated when positioned in free or semi-open restrictions compared with restricted spacing zones (Gonçalves et al., 2017). Comparing the different ages and experience levels has also been of focus in previous studies, with suggestions that less experienced and younger players are less tactical proficient in their behaviours (Silva et al., 2014a). One study found that more experienced players (professional vs semi-professional) displayed closer positioning with their opponents and higher positioning regularity when the SSG had an increase number of opponents. These results highlight how professional players may be able to better self-organize their behaviours with their teammates, as they are more aware of environmental constraints (Gonçalves et al., 2016).

2.4.5 Interventions of physical workloads

Match environments which SSGs are trying to replicate are complex and dynamically shifting systems with technical and physical constraints also imposed. In basketball, player positioning coordination with their team centroid increases post physical activity intervention, along with increases in dispersion variables of ~2 m (Sampaio et al., 2014a). Furthermore, player positioning regularity was found to be higher when players' speed were higher (=> 13Km.h^{-1}), which the authors suggested highlights fatigue may be preventing players from explosive movements which would contribute to greater unpredictability (Sampaio et al., 2014a). Fatigue during SSGs and matches is an easy assumption to explain changes in behaviours associated with increased physical activity. However currently, there are limited studies that have properly explored these effects. Of the literature available, it has been suggested that experimental metal fatigue imposed upon soccer players in a 6v6 SSG decreased the coordination between players (Coutinho et al., 2017), while muscular fatigue decreased the regularity of inter-player distances between pairs of players (Coutinho et al., 2018).

2.4.6 Summary

Research has shown SSGs can stimulate behaviours that follow the tactical principles of full games. Teams in different SSG conditions produced larger length, width and overall dispersion values on attack, while defenders collective positioning was more elongated (Castellano et al., 2016, Bueno et al., 2018), mirroring the collective behaviours found during matches (Olthof et al., 2019). Overall, larger field dimension conditions along with conditions with more players were found to increase the dispersion and surface area of players, also increasing the promotion of behaviour associated with defensive unity (Aguiar et al., 2015, Fernández-Espínola et al., 2020). While for the smaller formats and less number of players, one on one interactions and isolated behaviours are more frequent, creating different behaviours to be of focus (Clemente et al., 2020a). Player experience level and physical interventions also have been shown to influence the collective behaviours of teams with greater coordination and self-organizing behaviours found with professional players and teams post physical activity intervention (Almeida et al., 2012, Sampaio et al., 2014a, Silva et al., 2014a, Aguiar et al., 2015).

2.5 Limitations and suggestions for collective tactical variables

Throughout the investigation of collective tactical variables, several suggestions have been highlighted for analysing these variables, along with some limitations to consider. Most early studies analysed collective tactical variables at the team level. However, it has been suggested that by only measuring team level interactions, many behaviours and information could be overlooked (Bartlett et al., 2012, Memmert et al., 2017, Low et al., 2020). Specifically, sub-groups of players can have access to completely different local information and thus also different affordances that allow for coordination and behaviours to evolve differently at this level (Silva et al., 2014b, Santos et al., 2018). Furthermore, it has been suggested that players' behaviours are more closely linked with their positional centroid compared to their team centroid (Gonçalves et al., 2014), as this more closely relates to their shared affordances (Gonçalves et al., 2018, Low et al., 2020). Despite a possible loss of some team-level information, analysing collective tactical variables at the sub-group level allows more direct insight into specific interactions of players from the same sub-groups. When only looking at team level variables, these sub-group interactions may be missed as not all players are always present or active in the play (Frencken et al., 2012, Rico-González et al., 2020g).

The main aim of using collective tactical variables is to provide some measure of the collective behaviours players are displaying as a result of their tactical plans (Duarte et al., 2012c, Goes et al., 2020, Marcelino et al., 2020). A clear distinction must be made between tactics and strategies when referenced in this thesis; tactics pertain to how players react to the affordances they perceive and the environmental (and spatio-temporal) constraints that are imposed, with strategy displaying the global decision-making process players undertake in accordance with their coaches planning before a match (Harbourne and Stergiou, 2009). As such, strategy are pre-planned decisions while tactics are time-sensitive actions in response to stimulus during a match.

Collective tactical variables are aggregate variables, summing several player positions together; however, aggregate calculations can mean a loss of certain information. As previously mentioned, team values can overlook sub-group information, but they may also overlook each individual player's movement and positioning information that are components of the collective tactical variables (Goes et al., 2020). For instance, the team centroid can display the same value for numerous different tactical formations (Low et al., 2020, Rico-González et al., 2020e).

Collective tactical variables are also sensitive to the number of players included in their calculations. For team level variables that include a higher number of players, it has been suggested that each player in the calculation has less weighting or influence on the variable, compared with variables calculated with a smaller number of players (Coito et al., 2020). For instance, the length and width variables only include two players in the calculation regardless if they are measuring team or sub-group behaviors (Bartlett et al., 2012), while the surface area includes the peripheral players of the convex hull, thus having several players within the boundaries that are not contributing to the calculations (Gonçalves et al., 2018). Surface area has also been indicated to become more predictable as the number of players included in its calculation increases (Coito et al., 2020), and for all collective tactical variables increased player numbers were associated with lower variability but greater overall values (Olthof et al., 2019).

While several factors that influence collective tactical variables have been analysed, the positioning of the ball, an important component for contextually analysing player behaviours has been limited (Travassos et al., 2011, Clemente et al., 2013c). From one systematic review, only 18% of studies included ball tracking analysis (Goes et al., 2020); studies not including ball tracking have predominantly been restricted by technology limitations, especially for the limited ability of LPS and GPS to track the ball and the high costs associated with optical systems (Manafifard et al., 2017).

Other considerations must also be understood when analysing the different measures of collective tactical variables. Approximate entropy has a few limitations and considerations pertaining to the length of the time series used. It is suggested when using ApEn as a measure of regularity, that a time series of at least 50 data points is used (Stergiou et al., 2004), as shorter data lengths have been indicated as unreliable (Fonseca et al., 2012a, Gonçalves et al., 2019). Additionally, for team sports where possession lengths greatly differs, normalization methods are suggested, to allow for balanced comparison between outputs (Fonseca et al., 2012a).

Overall, the literature that has investigated collective tactical variables has grown over the past decade, with an increase in the number of studies focusing on collective tactical variables (Lord et al., 2020). Thus, future research about collective tactical variables has been recommended to include the following contextual information where possible; quality of the opposition, match status, attacking and defending phases of play, sub-group level analysis, physical capacity, match location, ball position (Bartlett et al., 2012, Moura et al., 2013, Bradley and Ade, 2018, Clemente et al., 2018a, Folgado et al., 2018b, Lord et al., 2020, Rico-González et al., 2020d).

2.6 Aim of the Thesis

It is clear tactical movement patters and collective positioning are important in elite netball, but collective tactical variables which capture these behaviours have not been explored. With substantial research about collective tactical variables now being conducted, it is expected that more studies will investigate team sports other than football. With the innovation of local positioning systems to accurately collect player positioning indoors, calculation of collective tactical variables for sports like netball is now possible. Therefore, the aim of this thesis is to explore the use and applicability of collective tactical variables previously investigated in other sports to netball. Beginning with an initial validation of a local positioning systems ability to accurately collect inter-unit distances, to ensure the EPTS used is appropriate. Then, as collective tactical variables are a novel performance analysis method in netball, investigation of a wide variety of collective tactical variables, measures and contextual factors will be explored. Contextual factors important to netball performance and to be included in the analysis are; length of possessions, score status, time of the match, opposition strength and time of the season.

Additionally, relating collective tactical variables to the performance of a match is of interest in most sports, thus an investigation into what influences changing collective tactical variables during matches can have on the probability of scoring and subsequently winning a match. Finally, as SSGs are a popular training modality to recreate tactical dimensions and tasks from matches, a comparison of several SSG conditions and their impact on the collective tactical variables that are elicited will be conducted.

CHAPTER 3. STUDY 1 – CRITERION VALIDITY OF CATAPULT CLEARSKY T6 LOCAL POSITIONING SYSTEM FOR MEASURING INTER-UNIT DISTANCE

3.1 ABSTRACT

The validity of a local positioning system to measure inter-unit distance was investigated during a team sport movement circuit. Eight recreationally-active, female indoor team-sport players completed a circuit, comprised of seven types of movements (walk, jog, jump, sprint, 45° change of direction and shuffle), on an indoor court. Participants wore a receiver tag (ClearSky T6, Catapult Sports) and seven reflective markers, to allow for a comparison with the reference system (©Vicon Motion Systems, Oxford Metrics, UK). The inter-unit distance was collected for each combination of participants. Validity was assessed via root mean square error, mean bias and percentage of variance accounted for, both as an overall dataset and split into distance bands. The results presented a mean root mean square error of 0.20 ± 0.05 m, and mean bias detected an overestimation for all distance bands. The LPS shows acceptable accuracy for measuring inter-unit distance, opening up opportunities to utilise player tracking for tactical variables indoors.

3.2 INTRODUCTION

3.1.1 Player Tracking Technology

Electronic performance and tracking systems have recently seen large developments, allowing it to facilitate tracking of players both indoors and outdoors with greater accuracy. Until recently, EPTS were limited to outdoor sports, whereby global positioning systems were used to track a player's locomotion, position and speed (Scott et al., 2016, Malone et al., 2017). With a large focus on GPS in outdoor sports, the accuracy of this type of technology has been extensively investigated, showing adequate accuracy for assessing players distance (Scott et al., 2016). However, during unstructured movements, high rates of change in velocity and at peak speeds, less favourable results were found. Overestimations of up to 19.3 % were found in changes in velocity during decelerations (Varley et al., 2012), while peak speeds were underestimated compared to the reference system by 14 - 29 % (Vickery et al., 2014). Even with the considerations of GPS accounted for, the use of GPS has been inaccessible for indoor sports, with stadium infrastructure preventing clear signals to satellites. As such, indoor sports including basketball, handball, futsal and netball have been restricted to expensive optical tracking systems, which are susceptible to player occlusion errors (Siegle et al., 2013). However, recent developments in LPS's, specifically Bluetooth-based and UWB technologies have opened up opportunities to integrate EPTS in indoor sports (Bourbousson et al., 2010a, Figueira et al., 2018a, Luteberget et al., 2018).

3.1.2 Ultra-Wideband

Local Positioning Systems operate indoors on usually short-range communication between radio wave generators and receivers. As such, they can run on varying bandwidths depending on the technology, UWB specifically occupies a large frequency bandwidth (>500 MHz) (Mautz, 2012). Operating at this bandwidth allows UWB systems penetration through objects such as wood, plastic, brick, and other building materials, excluding metal (Rovňáková et al., 2008). This provides the ability for the tracking of humans without occlusion errors occurring (Mautz, 2012). Additionally, unlike other radio frequency tracking technologies, UWB's high bandwidth combined with very low short pulses waveforms allows for reduced signal interference from other radio frequency devices and increased signal stability (Rovňáková et al., 2008, Alarifi et al., 2016).

Local Positioning Systems using UWB technology have been validated previously for analysing position, speed and distance (Serpiello et al., 2017, Luteberget et al., 2018, Bastida-Castillo et al., 2019a). During linear drills, mean and peak acceleration and speed displayed errors in the range of 0.5 to 7.5% (Serpiello et al., 2017), while total distance was found to have error ranges between 0.5 to 2.3% (Serpiello et al., 2017, Luteberget et al., 2018). Finally, position was found to have the least amount of error, with 0.19 to 0.58% error ranges (Bastida-Castillo et al., 2019a). However, this paper used known distance as a reference, which may underestimate the difference between systems. With the validation of UWB for locomotion and player position, research has now focused on describing the match and training demands of each sport (Luteberget and Spencer, 2017, Vázquez-Guerrero et al., 2019, Douglas and Kennedy, 2020, FIFA, 2020).

However, recent research using GPS positional data has focused on spatiotemporal tactical variables to analyse team collective behaviours and dynamics. Now with the same ability as GPS to track player positions on an indoor court, positional data from UWB systems can be used to provide contextual information to analyse players' tactical roles and how they impact other players' performance (Bradley and Ade, 2018).

1.3 Tactical Variables

Tactical variables are used to explain player, team and opposition dynamics on the field through their interactions, spacing, synchronisation and integration alongside technical and physical variables. Tactical variables can be understood as variables that occupy both space and time (i.e., spatiotemporal) and are derived from the field of geometry (Gudmundsson and Horton, 2016). The most basic tactical variable is inter-player distance; identifying the distance between players' positions on the field (Folgado et al., 2014a, Folgado et al., 2018b) and providing insight into their interactions and coordination tendencies. Team-based tactical variables include surface area and dominant region; explaining the effective playing space a team or group of players look at controlling (Frencken et al., 2011, Gonçalves et al., 2016), stretch index and length-per-width ratio; indicating the contraction and expansion of a team as they move through the transitional phases of a game (Bourbousson et al., 2010b, Bartlett et al., 2012, Memmert et al., 2017). Finally, the collective behaviour and synchronisation of a team have previously been analysed using the team centroid and approximate entropy; describing the behaviour and centre position of a team of players and their inter-player coordination respectively (Gonçalves et al., 2016, Rein and Memmert, 2016).

These tactical variables have previously been analysed for outfield sports using GPS (Memmert et al., 2017, Alexander et al., 2018). While research is beginning to utilise LPS and optical EPTS, for tactical analysis indoors (Bourbousson et al., 2010a, Bourbousson et al., 2010b, Figueira et al., 2018a), these systems have yet to be validated for their accuracy in measuring inter-unit distance. This is of importance for tactical analysis, as most tactical variables are primarily made up of inter-unit distances which are then combined to create team level variables. If inter-unit distance accuracy is poor, this may compound when calculating multiple inter-unit distances for larger spatiotemporal variables. As such, this study aims to assess the criterion validity of Catapult ClearSky T6 Local Positioning System for measuring inter-unit distance, applicable to all indoor sports for tactical analysis.

3.3 METHODS and MATERIALS

3.3.1 Participants and Experimental Overview

Eight recreationally-active female indoor team sport players (26.9 ± 3.7 years old, 174.0 ± 8.2 cm, 67.5 ± 8.4 kg) were recruited to participate in this study. All participants received verbal and written information regarding the procedures of the study and provided written consent to participate in the study. The investigators' institutional Human Research Ethics Committee approved the study. The study was conducted at Melbourne Arena (Melbourne, Australia), a commonly used arena for team sports competitions. Melbourne Arena had previously been fitted with the UWB tracking system and surveyed for calibration of court dimensions. The testing session comprised of a team sport movement circuit measuring 15 x 20 m on an indoor parqueted surface. Participants completed the circuit while wearing a receiver tag (ClearSky T6, Catapult Sports, Australia) which was placed in a wearable vest, positioned between the participant's scapulae. Participants also had attached seven reflective markers, placed on the receiver tag and other prominent landmarks of the participants, these were used for the reference system to capture participant position and for future reference system analysis. The reference system was set up around the circuit area, with a larger capture area of 19 – 24 m to ensure no black spots occurred. All participants completed a self-paced warm-up, before the start of the circuit.

3.3.2 Data Collection

Circuit

The indoor sports movement circuit comprised locomotion activities commonly occurring in indoor sports, as presented in Figure 3.1. Participants performed eight movement sequences in the following order:

1. Self-paced Walk (9 m).
2. Self-paced Jog (9 m).
3. Jump.
4. Self-paced run (13 m).
5. Maximal Acceleration (9 m).
6. Three self-paced 45° Change of Directions (13 m).

7. Self-Paced Side Shuffle (15.4 m).
8. Self-Paced Walk (13m)

Catapult ClearSky T6 Setup

The LPS (Catapult ClearSky T6, Catapult Sports, Australia) was previously installed for the area comprised of 20 fixed anchor nodes. Nodes were fixed at varying heights ranging between 19.7 – 20.9 m and proximity from the court boundaries ranging between 12 – 32 m, as presented in Figure 3.1; this ensured full-court coverage and minimised metal interference. The master anchor was connected via Ethernet cabling to the data processing laptop, which captured data at a reported frequency of 10 Hz. Data were processed using Openfield™ console software version 1.22.2 (Catapult Sports, Melbourne, Australia), with receiver tags worn by participants seen by the system at all times. The system utilizes a narrow UWB frequency of range 3.1 to 10.6 GHz to locate receiver tags in the surveyed area. A minimum of three anchor nodes were required to have a clear lock on a receiver tag, with the location of the tags being calculated through a multi-process algorithm using Two-Way Ranging (TWR), Angle of Arrival (AoA) and Time Difference of Arrival (TDOA).

Vicon Setup

The reference system used was a Vicon motion analysis system (©Vicon Motion Systems, Oxford Metrics, UK), set up using 20 cameras (T40 and Vantage) as presented in Figure 3.1. The system captured at a frequency of 100 Hz, with the cameras mounted on tripods offset 2 m from the perimeter of the circuit area, for a capture area of 19 x 24 m. Seven, 40-mm reflective markers were attached to the receiver tag and other prominent landmarks on the participants;

1. Catapult Unit (receiver tag).
2. Right Shoulder.

3. Left Shoulder.
4. Left Front Hip.
5. Right Front Hip.
6. Right Back Hip.
7. Left Back Hip.

The reflective marker attached to the outside of the pouch containing the receiver tag was used as the reference systems comparative position, while the other six reflective markers were used for future analysis. All 20 cameras were connected via two Gigabit switches that were attached to the data processing laptop (separate from the LPS laptop) via Ethernet cabling. The reference system was calibrated to the capture area, with Vicon calibration Image and World errors of 0.094 mm and 0.525 mm respectively. Additionally, the refinement frames were set at 3000 frames with the origin of the calibration set using Active Wand v2. Reference system marker dropout was accounted for using Vicon Nexus software version 2.8.2 (©Vicon Motion Systems, Oxford Metrics, UK), by gap-filling through automatic pattern detection (maximum 10 frame gaps only filled). This automatically used other marker locations to determine the trajectory of the dropped marker. If these markers were unavailable, the spline fill option was used, which calculates the position based on 10 frames on either side of the dropped marker. Finally, when marker dropout was for a substantial length, the data were excluded from the analysis.

3.3.3 Data Processing

Data was exported from the LPS and reference system software and analysed in R statistical software (R: A language and environment for statistical computing, Vienna, Austria). Raw Vicon data were smoothed and filtered using proprietary Butterworth and

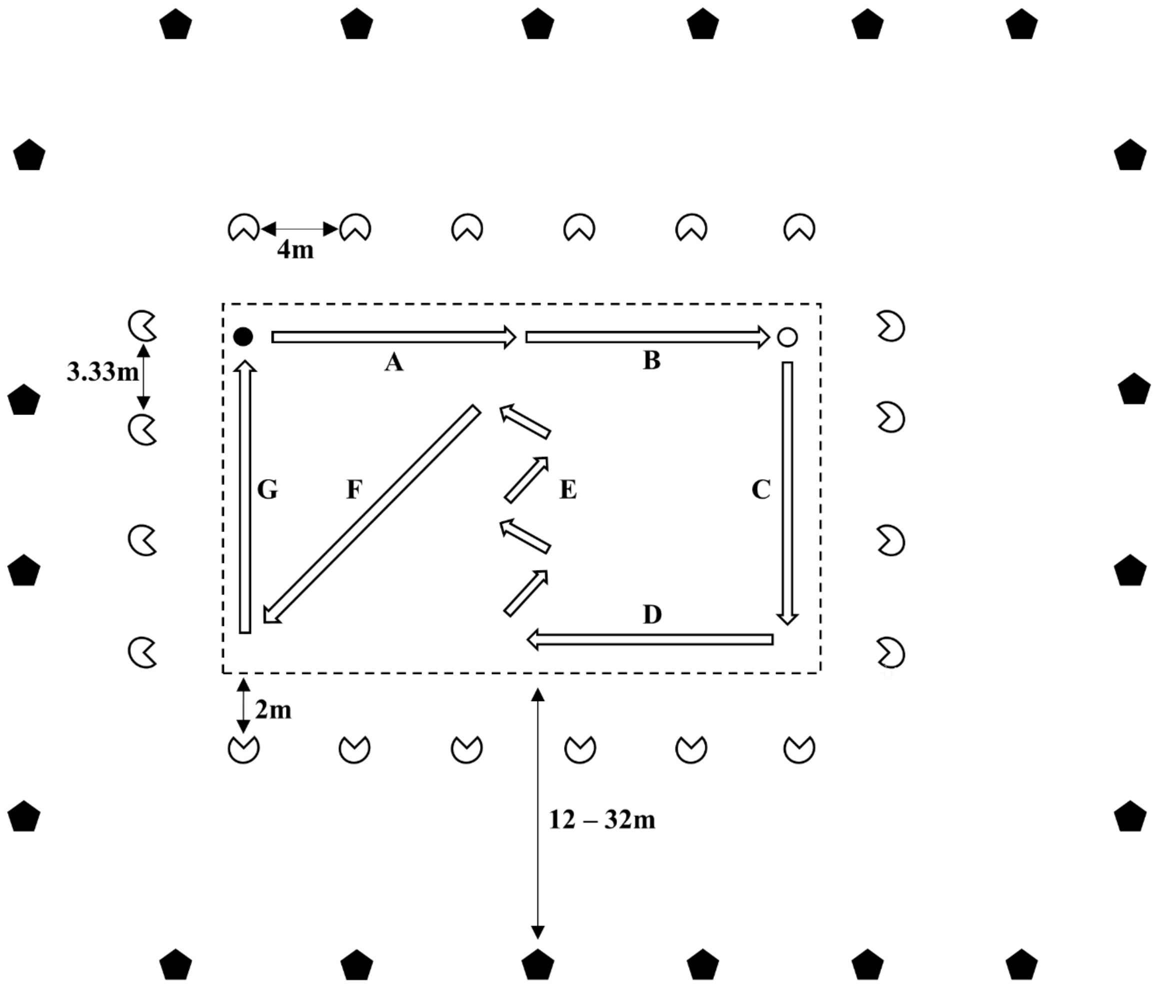


Figure 3.1. Schematic representation of Vicon setup (white indented circles), ClearSky setup (black pentagons) and circuit boundaries (dashed line), with illustration of circuit movements: start (black circle), walk (A and G), jog (B), jump (white circle), run (C), maximum acceleration (D), change of direction 45° (E) and shuffle (F).

moving average filters, to mimic the same processing that is applied to the ClearSky data (further details of smoothing and filtering processes are protected by a nondisclosure agreement). As Vicon data was captured at 100 Hz, compared to Catapult captured at 10 Hz, raw Vicon data were down-sampled from 100 to 10 Hz by sub-setting every 10th frame. Each subset of data was inspected for best fit to the Catapult data. Additionally, the Y component of Vicon data required translation, as it had been captured as the Z-axis. Therefore, by finding the mean between the Vicon data and Catapult dataset, Vicon data was translated down to the same scale

3.3.4 Statistical Analysis

Inter-unit distance was calculated for each combination of participants as the distance between each players x, y coordinates. Each participant combination was used once only, resulting in 21 individual combinations (one participant was not used due to Vicon poor data quality). This was calculated for both ClearSky and Vicon datasets using the below formula;

$$D = \sqrt{(a_x - b_x)^2 + (a_y - b_y)^2}$$

Where D is the distance between the two participants, a is participant one and b is participant two and x and y are the coordinates. The two datasets, ClearSky and Vicon were visually inspected to ensure they lined up at a common starting point (Figure 3.2). Criterion validity was measured using Root Mean Square Error (RMSE), reported in metres using the following equation:

$$RMSE = \sqrt{\frac{\Sigma_{i=1}^{n}(P_i - O_i)^2}{n}}$$

Where P is ClearSky data; O is Vicon data and n is the length of the time series. Mean Bias was used to measure the bias of the ClearSky LPS, it was calculated using the following formula:

$$MB = \frac{1}{n}\sum_{i=1}^{n} (P_i - O_i)$$

Where P is ClearSky data, O is Vicon data and n is the length of time series. Finally, the Percentage of Variance Accounted For (%VAF) was used to measure the portion of the variance for Vicon, accounted for by ClearSky. This was calculated for each combination and distance band using the below formula:

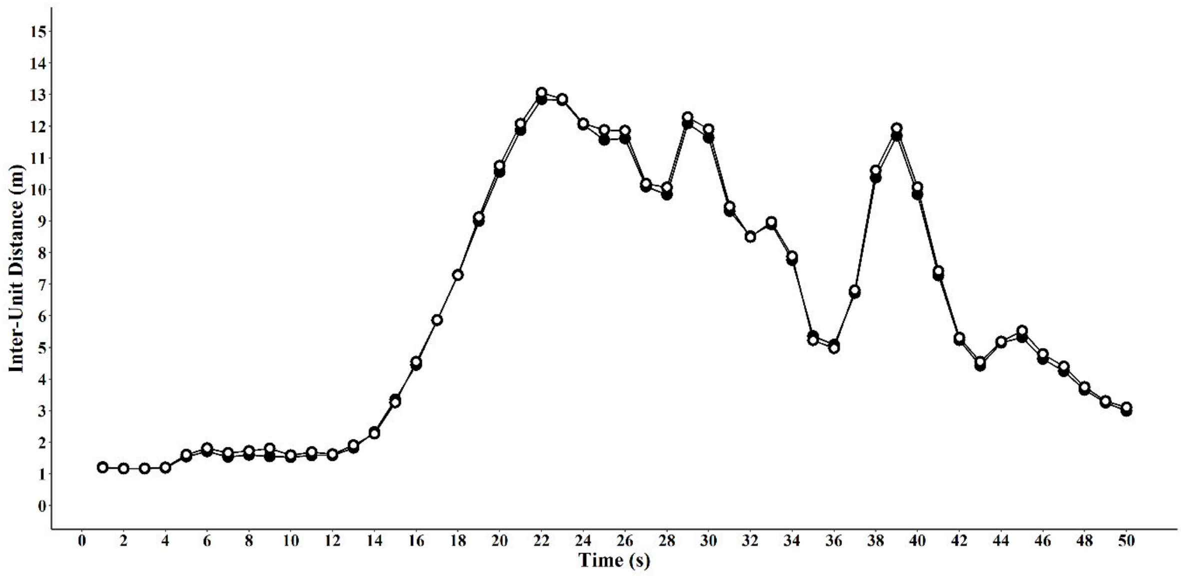


Figure 3.2. Example comparison of ClearSky (white circles) and Vicon (black circles) inter-unit distance. Vicon data was smoothed and filtered to match Catapult using a proprietary combination of filtering techniques.

$$\% \, VAF = 100 \times \left(1 - \frac{\sum_{t=1}^{n} \, (O_{\mathrm{t}} - P_{\mathrm{t}})^2}{\sum_{t=1}^{n} \, (O_{\mathrm{t}})^2} \right)$$

Where P is Catapult data, O is Vicon data, n is the length of time series and t is the time.

Additionally, a rolling RMSE function was used on all combinations, providing a matrix of RMSE as a function of cumulative time. This was used to compute RMSE stabilisation at a threshold of 1/500 of the final rolling cumulative RMSE (Figure 3.3), to ensure enough data was analysed, whereby the error rates stabilized. Through this stabilisation analysis, data lengths between 43 and 50 seconds were found to be sufficient for stabilisation of error. All combination datasets were cut at 50 s to ensure consistent results. Finally, analysis was conducted on the association between the distance of units and its function on the accuracy of inter-unit distance. Distances were discretised into five interval bands to highlight differences between smaller and larger inter-unit distances on

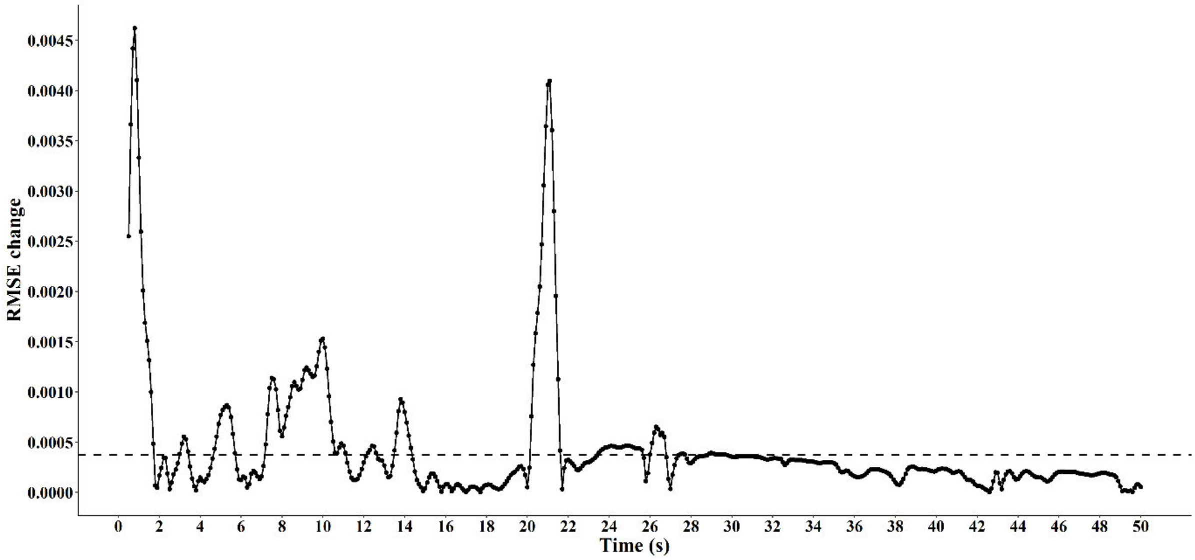


Figure 3.3 Root mean square error stabilisation. Threshold of 1/500; under threshold change (below dashed line), over threshold change (above dashed line).

the RMSE, mean bias and %VAF between the LPS and reference system. The accuracy measures were calculated for each distance band, by analysing the values that resided within each band. The five bands were;

1. 0 – 5 m
2. 5 – 10 m
3. 10 – 15 m
4. 15 – 20 m
5. > 20 m

The study methodology was written following a recently published protocol (Rico-González et al., 2020c) to warrant the strict description of the use of technology, scoring 16 points out of 21 (76%).

3.4 RESULTS

The overall RMSE between the Catapult LPS and Vicon system for inter-unit distance was 0.20 ± 0.05 m, while the mean bias was 0.10 ± 0.06 m. Comparisons between

ClearSky and Vicon inter-unit distance at different distance bands are presented in Table 3.1. Inter-unit distance based on distance bands resulted in larger RMSE values at larger distances. Bands of 5-10 m, 10-15 m, 15-20 m and >20 m had RMSE values in the range of 0.20 to 0.22 m, compared to the 0-5 m band with a RMSE of 0.18 m.

3.5 DISCUSSION

The objective of this investigation was to assess the criterion validity of Catapult ClearSky T6 Local Positioning System for assessing inter-unit distance. The overall results of the study returned a mean RMSE of 0.20 ± 0.05 m, which was more favourable compared to a previous investigation of a Bluetooth Low Energy Channel tracking system, presenting a mean error of 0.30 ± 0.13 m (Figueira et al., 2018a). The current study also found a mean bias of 0.10 ± 0.06 m, including all distance bands displaying bias overestimates of the true values, especially at distances below 10 m. Finally, %VAF analysis was stable across all distance bands, excluding distances above 20 m. These findings are important for use of the LPS to accurately measure spatiotemporal variables, as these variables base function is centered on inter-unit distances.

These results align with similar research which found the ClearSky T6 LPS to have a mean error of 0.21 ± 0.13 m for measuring position (Luteberget et al., 2018) in the optimal setup. Previous investigations into the errors associated with anchor placement on the validity of the ClearSky system have found increased error in-sub optimal setups (1.79 ± 7.61 m) compared to optimal setups (0.21 ± 0.13 m) for position estimates (Luteberget et al., 2018). This was attributed to node positions, near corners and proximity between nodes and court boundaries which could reduce accuracy due to increased multipath propagation (Muthukrishnan, 2009). Errors of this nature were mitigated as the setup was

Table 3.1. Difference between distance bands inter-unit distance accuracy; root mean square error, mean bias and percentage of variance accounted for.

Distance Band	n. frames	RMSE (m)	Mean Bias (m)	Percentage of Variance Accounted for (%)
0 – 5 m	2731	0.18 ± 0.08	0.14 ± 0.10	94.34 ± 0.09
5 – 10 m	3232	0.20 ± 0.07	0.14 ± 0.10	98.64 ± 0.01
10 – 15 m	2643	0.20 ± 0.07	0.07 ± 0.06	98.32 ± 0.01
15 – 20 m	1684	0.21 ± 0.06	0.03 ± 0.05	97.88 ± 0.03
>20 m	210	0.22 ± 0.05	0.06 ± 0.08	74.37 ± 0.28

optimized within the stadium, as seen in Figure 3.1, which represents varying anchor eights to mitigate metal infrastructure interference and adequate proximity of node to the edge of the field.

Analysis of the associations between different distance bands and inter-unit distance accuracy indicates an increased error at larger distances. These findings suggest that as distances between units increase so does the error of observed values, as seen with a linear increase in RMSE results from 0.18 ± 0.08 at distances between 0 – 5 m to 0.22 ± 0.05 m above 20 m. It is difficult to compare these results with previous studies, as to our knowledge this study is the first to analyse inter-unit distance accuracy at distances above 20 m. The previous investigation found higher accuracy for larger distances, however, the studies distances only ranged from 0.5 - 1.8 m (Figueira et al., 2018a). While the setup of this study was optimal for the stadium used, each stadium requires correct surveying and optimal positioning of anchors to mitigate black spots and interference. Additionally, further validation of tactical variables is required, as only one study thus far has investigated EPTS for measuring tactical variables (Bastida-Castillo et al., 2019a).

Therefore, future research should look at the validation of the inter-stadium reliability of EPTS to allow accurate comparison of tactical variables during matches and training.

3.5.1 Conclusion

With acceptable inter-unit distance accuracy found in this study, as well as adequate ability to measure distance, speed and position (Serpiello et al., 2017, Luteberget et al., 2018), the ClearSky LPS can be confidently used to capture spatiotemporal tactical variables. Which can be used, to assess team tactical synchronisation, inter-player interactions and coordination tendencies. The RMSE for inter-unit distance ranged between 0.18 – 0.22 m for all distance bands, representing acceptable validity at all distances investigated. This opens up opportunities for increased investigation using spatiotemporal tactical variables in indoor sports.

CHAPTER 4. STUDY 2 – EXPLORATION OF COLLECTIVE TACTICAL VARIABLES IN ELITE NETBALL: AN ANALYSIS OF TEAM AND SUB-GROUP POSITIONING BEHAVIOURS.

4.1 ABSTRACT

Collective tactical behaviours are aspects of player interactions that are particularly important in netball, due to its unique restrictions on player movement (players unable to move when in possession of the ball). The aim of this study was to explore variables representing collective tactical behaviours in netball. A local positioning system provided player positions of one team throughout seven national-level netball matches. The positions were analysed to provide mean, variability (standard deviation) and irregularity (normalised approximate entropy) for each attack and defence possession (470 and 423, respectively) for the team and positional subgroups (forwards, midcourts and defenders) for 10 position-related variables. Variability provides a linear measure perspective of collective tactical variables, while non-linearity is handled by irregularity (ApEn) as presented in Harbourne and Stergiou (2009). Correlational analyses showed collective tactical variables could be grouped as lateral and longitudinal dispersion variables. The variables were each analysed after log transformation with a linear mixed model to compare attack and defence and to estimate standardised effects on attack and defence of possession outcome, possession duration, score difference, match time, opposition strength and season time. During attack, the team and all sub-groups adopted greater lateral dispersion between players, while on defence there was generally greater longitudinal dispersion. The team also showed increased longitudinal dispersion when home and opposition possessions ended in a score. Additionally, greater irregularity was observed in active sub-groups (forwards on attack, defenders on defence). Score

difference and opposition strength had trivial-small but generally unclear effects. In conclusion, these effects show that analysis of player positions on attack and defence is a promising avenue for coaches and analysts to modify collective tactical behaviours in netball.

4.2 INTRODUCTION

The analysis of collective team behaviours has become more prominent over the past decade (McGarry et al., 2002, Sampaio and Maçãs, 2012, Memmert et al., 2017, Goes et al., 2020, Low et al., 2020). The focus of collective behaviour research on soccer has been afforded by the early ability to track a player's location using vision-based tracking systems and Global Positioning System (GPS) devices in outdoor environments (Aughey, 2011, Buchheit et al., 2014). Conversely, indoor-court sports have been limited due to the inability of GPS devices to penetrate indoor stadium roofs and ceilings and due to the occlusion errors, which are common with vision-based tracking systems (Siegle et al., 2013). However, recent advancements in Local Positioning Systems (LPS) now provide an avenue to collect player tracking data indoors.

Tactical behaviour in sport can be defined as how individual players and teams as a whole, utilise shared affordances and environmental constraints to achieve a shared goal (e.g., scoring a goal) (Araújo and Davids, 2016, Goes et al., 2020, Low et al., 2020, Rico-González et al., 2020e). An ecological dynamics approach provides a theoretical framework, suggesting the importance of measuring tactical behaviour, to properly capture the complex and dynamic nature of a team's performance, which encompass' individual player actions and affordances that allow adaption of collective behaviours with teammates (Passos et al., 2009, Araújo and Davids, 2016). To capture such behaviour, the introduction of variables providing an aggregated view of the collective and tactical behaviours of teams and sub-groups have arisen (Duarte et al., 2012a, Duarte et al., 2012c, Goes et al., 2020).

Inter-player distance, due to its simplicity and ease of computation, is a commonly assessed collective tactical variable, used to measure the distance between two players. (Rico-González et al., 2020d). Literature suggests that, on average, players of the attacking team are further apart than those of the defending team (Fonseca et al., 2012b). The team centroid, another commonly used collective tactical variable (Low et al., 2020, Rico-González et al., 2020e), is an aggregate measure that is used to understand the positioning of a team or group of players (Frencken et al., 2011, Rein and Memmert, 2016). Research suggests that players are more coordinated with their position-specific centroid as they are adjusted to positional affordances and constraints which helps with sub-group behaviours (Gonçalves et al., 2014). Additionally, the width, length and length-per-width ratio explain how spread laterally and longitudinally a group of players are (Frencken et al., 2011, Duarte et al., 2013). Research has previously found that the team's dispersion was longer and wider during the offensive phases of a match compared to defensive phases in soccer against weaker teams and in Australian rules football (Castellano et al., 2013, Alexander et al., 2018). The length-per-width ratio has been used to explain the playing shape of a team or sub-group (Silva et al., 2014a), with greater values of length-per-width ratio representing an elongated playing shape (Silva et al., 2014a, Castellano et al., 2016). Finally, the surface area, which explains the playing shape and space of a group of players and the stretch index, measuring the dispersion of a group of players, have also been used to analyse collective tactical behaviours (Araújo and Davids, 2016, Barnabé et al., 2016, Silva et al., 2014b).

Team-level behaviours provide a global marker of performance, it has however been suggested that collective behaviours should also be analysed at sub-group levels. Allowing capture of different dynamics associated with individuals of sub-groups sharing similar tendencies and goals, which are separated from the global team structure (Bartlett et al., 2012, Gonçalves et al., 2017, Benito Santos et al., 2018, Gonçalves et al., 2018, Low et al., 2020). Team-level aggregate measures provide useful information at a global level, yet they may fail to capture smaller groups movements and behaviours, as well as include certain players or positions that are not always active in the play (Bartlett et al., 2012, Goes et al., 2020, Rico-González et al., 2020e).

Furthermore, additional measures of collective tactical variables including, mean, variability (standard deviation) and irregularity (approximate entropy) are also of importance when using collective team variables. Most research has represented collective tactical variables using the mean, providing values on the same scale as the collected variables, allowing for ease of interpretation (Barnabé et al., 2016, Figueira et al., 2018b, Goes et al., 2020). Several studies have also explored the use of the variability and irregularity when measuring collective tactical variables; both these types of measurements provide further insight, specifically the evolution and regularity of these variables during a possession or match (Aguiar et al., 2015, Memmert et al., 2017, Gonçalves et al., 2016).

One sport that has yet to explore collective tactical variables is netball. Netball research has previously investigated match and training physical profiles (Cormack et al., 2014, King et al., 2018, Simpson et al., 2019, Brooks et al., 2020b, Brooks et al., 2021), technical aspects utilising notational methods (Bruce et al., 2009, Pulling et al., 2016) and more recently non-linear analysis and machine learning techniques to account for the dynamic nature of the sport (Sweeting et al., 2017, Croft et al., 2018, Browne et al., 2019, Coombe et al., 2020b, Croft et al., 2020, Ofoghi et al., 2021, Bake et al., 2021). However, one area of research which is yet to be studied is collective team behaviours, with a recent systematic review highlighting no such research articles having been published on netball, (Lord et al., 2020) with several of additional studies suggesting future research is required in team and player positioning (McLean et al., 2019, Croft et al., 2020, Whitehead et al., 2021). This is pertinent to netball, as the court restrictions and inability of the player in possession of the ball to move, requires a collective team performance, with previous literature stating key aspects of netball performance being off-ball space creation, maintaining unit structure, timing and support (McLean et al., 2019, Coombe et al., 2020b)

Additionally, previous research has accounted for numerous contextual factors, such as possession outcome, score status, the strength of opposition, possession duration, match time and season time, which may be influencing collective behaviours (Castellano et al., 2013, Clemente et al., 2013b, Clemente et al., 2014b, Folgado et al., 2018b, Gonçalves et al., 2019, Marcelino et al., 2020). When teams are losing in the score, research has shown they display lower intra-team synchronisation (Folgado et al., 2018b). Decreased values of dispersion and average field position during the second half of a soccer match highlight the effect of match time (Clemente et al., 2013c). Additionally, longer possessions have been associated with more regular patterns as players have more time to perceive information (Aguiar et al., 2015). Finally, the inter-player distance between a dyad is predictive of try outcomes in rugby union (Passos et al., 2009), emphasising the importance of accounting for such contextual factors when measuring collective tactical variables.

As such, this research study is to explore collective tactical variables in netball, at the team and sub-group levels, accounting for contextual effects, to provide a broad initial insight into the potential uses and applicability of chosen variables to measure collective behaviours in elite netball.

4.3 METHODS

4.3.1 Experimental overview and participants

Spatiotemporal data were collected from seven competitive national-level netball matches, from a professional team participating in the Suncorp Super Netball League. All participants received verbal and written information regarding the procedures of the study and provided written consent to participate in the study. The study was approved by the researchers' institutional ethics committee. All seven matches were played at an arena fitted with the ClearSky T6 Local Positioning System (Catapult, Australia) and calibrated to avoid metal interference and to ensure optimal placement for coverage of netball court dimensions. All matches were played on a parqueted surface with dimensions 30.5 x 15.25 m following International Netball Federation Rules of Netball 2016 (International-Netball-Federation, 2016). The matches consisted of 4 x 15-min quarters with 5-min breaks between quarters and a 15-min break between halves.

4.3.2 Data collection

Positional data

Positional data for all participants were collected using the Catapult ClearSky T6 Local Positioning System. This system has previously been validated against the Vicon motion capture system (©Vicon Motion Systems, Oxford Metrics, UK), with a mean positional estimate difference of 0.21 ± 0.13 m in an optimal setup (Luteberget et al., 2018) and mean bias between 0.2-12% for measurement of total distance, mean and peak speed, and mean and peak accelerations during linear drills (Serpiello et al., 2017). Additionally for tactical use, inter-unit distance measurement was found to have a root mean square error of 0.20 ± 0.05 m (Hodder et al., 2020). The same calibration and setup were used for the LPS as in the validation study by (Hodder et al., 2020), as it is a fixed system in the stadium. Each participant match uniforms were fitted with an internal stitched pouch, which housed the LPS receiver tag positioned between the shoulder blades. Positional data was captured at 10 Hz and downloaded in the software-derived format as .csv files to the LPS data processing laptop immediately after each match.

Event data

Match event data were collected post-event using video analysis software Sportscode version 11.3.0 (Hudl Sportscode, Nebraska, United States of America). Event data was recorded post-match for all seven matches, including the team in possession and score difference (numeric difference between attacking team score and opposition team score). Possession was defined as the team who had possession of the ball, either the attacking team (team participating in the study) or the opposition team. Possessions began with the umpire's signal, indicating the commencement of a centre pass or restart after a penalty. Additionally, possessions also began in open play through a turnover, in which possession started as the closest 10th of a second to which an attacking or opposition team player gained possession of the ball. During timeouts, pauses in play or when neither team had clear possession of the ball, the time phase was coded as "No Possession" (Vilar et al., 2013, Olthof et al., 2019). Possession outcome was recorded as either a score or turnover for the home team or opposition team, with any possession not ending in a score or turnover recorded as "other". Score difference was also recorded for each possession, as a numeric value indicating the difference between the attacking team score and opposition score. Finally, two additional variables were added to the data set; possession duration and ladder-points difference (difference between team and oppositions end of season ladder points), to account for possession duration and opposition strength differences respectively. Ladder-points at the end of a season has previously been used as a measure of opposition strength (Castellano et al., 2013, Gonçalves et al., 2019), in the current study ladder-points is modelled as a difference between the ladder points of the team in the study and their opposition.

4.3.3 Data processing

Positional data were processed first in R statistical software (R, Vienna, Austria), version 4.0.2. The origin for player position was set to one corner of the netball court. Attacking direction was reset each quarter as teams change the direction after each break. Upon completion of initial processing, player position data and event data were synchronised using a two-step procedure. First, event data were converted to milliseconds and aligned with positional data. Secondly, datasets were synced using a common synchronisation point; when the centre position player first made contact with the centre circle at the start of each quarter and restart after time-outs. This step was adjusted to a tenth of a second precision based on the plotting animations of player positional data (Aguiar et al., 2017). Additionally, when a player was substituted, the new player's positional data were added to the previous player's data at the point of substitution. (Duarte et al., 2013). Furthermore, the study methodology was written following a recently published protocol (Rico-González et al., 2020c) to warrant the strict description of the use of technology, scoring 16 out of 21 points (76%). This score represents the number of methodologic considerations accounted for when using player tracking technology.

A value for each of ten collective tactical variables was calculated every 0.1 s for the whole team and for each sub-group: forwards (goal shooter, goal attack, wing attack),

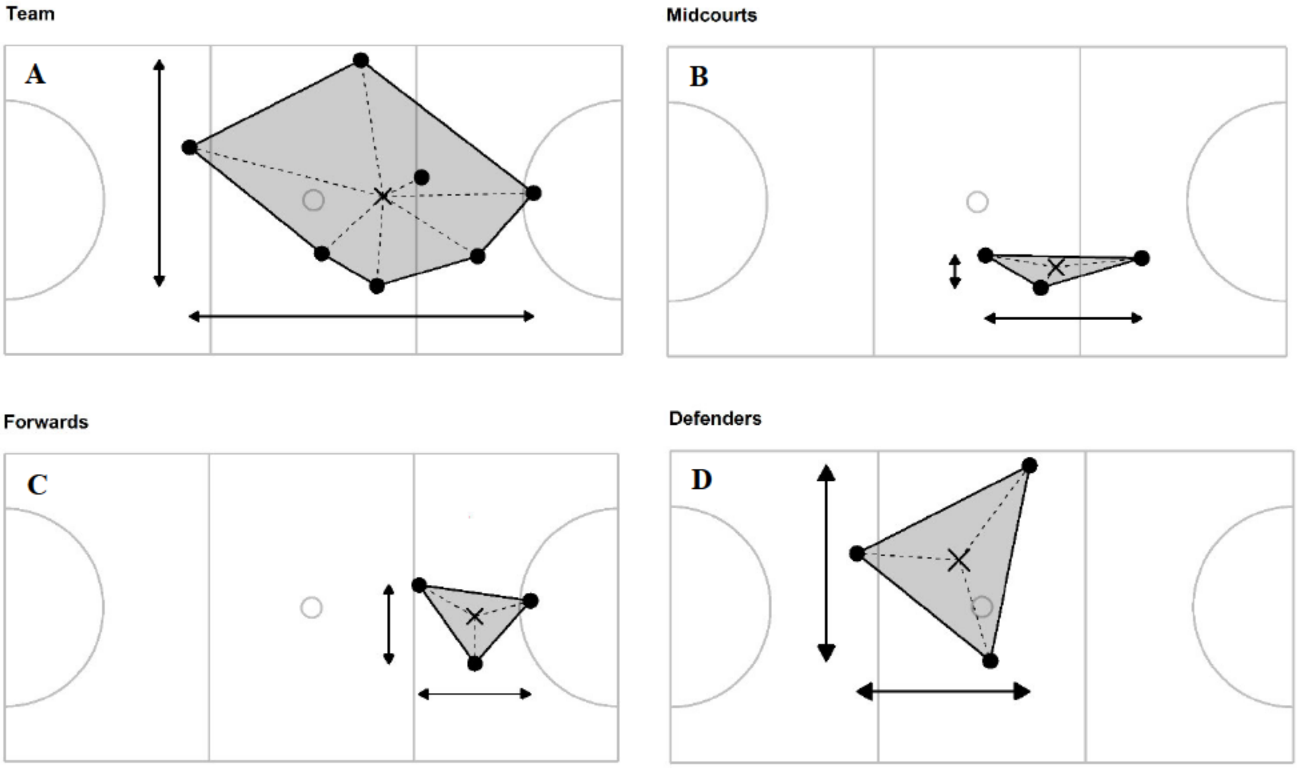


Figure 4.3. Illustration of five collective tactical variables for the team (A), midcourts (B), forwards (C), and defenders (D). Players positions (●) are combined to provide the centroid (mean position, ×), length (horizontal arrow line), width (vertical arrow line), stretch index (mean length of dashed lines) and surface area (grey shading). Solid grey lines represent court markings and define, for example, the left- and right-hand thirds of the court area to which the goal keeper and goal shooter are restricted.

midcourts (wing attack, centre, wing defence), and defenders (wing defence, goal defence, goal keeper). These positional sub-groups were selected to mirror previous research (Bailey et al., 2017). The collective tactical variables were defined as follows (see Figure 1 for an additional illustration of the first five):

Mean inter-player distance

Mean distance of each player to all other players in the team or sub-group, including each player-player dyad only once in the calculation (Bourbousson et al., 2010a). Distance between players is the most basic of collective tactical variables but holds information pertaining to expansion and contraction

Centroid

Average position of the team or sub-group of players (Frencken et al., 2011, Memmert et al., 2017). The centroid's longitudinal and lateral components were also calculated to provide further information regarding average positioning on the court. Position on the netball court provides insight into team strategies.

Length

Distance between the most backward and forward players at each end of the court (Frencken et al., 2011). Both length and width are important variables that can highlight a teams strategies of possession or high tempo play

Width

Distance between the two most lateral players on each side of the court (Frencken et al., 2011, Olthof et al., 2019).

Width per length ratio

Dividing width by length, with values >1 indicating a wider playing shape and <1 a more elongated shape. Combining two variables, wplratio along with surface area allows a summary of the type of shape and position teams decide to play.

Surface area

Area (m^2) of the smallest convex hull of boundary players (Frencken et al., 2011, Moura et al., 2013, Araújo et al., 2015).

Stretch index

Distance of each player to the teams or sub-groups centroid (Silva et al., 2014b, Araújo et al., 2015, Araújo and Davids, 2016). Similar to the centroid, the stretch index was also separated into longitudinal and lateral values, representing the amount of dispersion in either direction.

The mean, standard deviation and normalised approximate entropy of each collective tactical variable were calculated for each possession. Approximate entropy is a measure used on time-series data to assess the randomness and regularity of complex systems (Pincus, 1991). Approximate Entropy (m, r, N) can be used to assess the probability that a pattern of segmented data in a time series (N) can to predict the pattern of segmented data of the same time series a certain distance apart. Two fixed parameters m (length of the segment to be compared) and r (tolerance factor) were set at 2 and 0.2 respectively, following suggestions from Stergiou et al. (2004) in which further explanation of input calculations can be found. Due to each possession in this data set varying in length, normalised values of ApEn were computed, to allow for comparison of ApEn values between all possessions of different lengths. Normalised ApEn was calculated using the ApEn ratio-random method, whereby the original ApEn value is divided by the mean ApEn value of 100 randomly scrambled values of the time series (Fonseca et al., 2012a). In this ratio, values close to 0 represent high regularity while values close to 1.0 represent low regularity (Fonseca et al., 2012a). A total of 898 attack and defence possessions was used in the analysis, with an average duration during attacking possessions of 18.9 ± 7.8 s (mean ± SD) and during defence possession of 17.4 ± 8.3 s. From this point forward, the mean, standard deviation and approximate entropy will be referred to as "measures" when referenced collectively.

4.3.4 Statistical Analysis

Analyses were conducted with the Statistical Analysis System (Studio On Demand for Academics, version 9.4, SAS Institute, Cary NC). The mean, standard deviation and ApEn for each collective tactical variable were log-transformed for further analysis (with the exception of the mean for centroid longitudinal and lateral, for which log-transformation would not be appropriate, both variables pertain to the mean position of multiple players, therefore log-transforming these two variables would remove their scale (position on court). Conversely, other variables were log-transformed for normality purposes, while these other variables use the positioning of the players in their calculations, they don't pertain to position on court and instead distances and area of players, making their scales different to that of the centroid variables. Pearson correlations between all the collective tactical variables were first derived to assess the similarity of the variables. For presentation purposes, the set of three correlations (for the mean, standard deviation and approximate entropy) are shown for each pair of collective tactical variables in a correlation matrix for the team and each positional subgroup. The order of the variables in each correlation matrix was changed to reveal clusters of similar variables (higher correlations within clusters than between clusters). Regardless of the correlations, each variable was subsequently analysed as the dependent in a general linear mixed model (Proc Mixed in SAS). There was a total of four zero or negative ApEn values; these were set to half the minimum positive value, before log transformation. Each analysis aimed to estimate factors modifying the collective tactical variable separately for attack and for defence but to include the factors that interacted with possession type so that the differences between attack and defence and the uncertainty of the differences could be estimated.

The fixed effects in the model were possession type (to estimate mean values of the collective tactical variable in attack and defence) and possession type interacting with each of the following variables (to estimate their modifying effect in attack and defence): possession outcome (home team score or turnover on attack and opposition team score or turnover on defence), possession duration (linear numeric, log-transformed), score difference (linear numeric), match time (linear numeric), ladder-points difference (linear numeric), and finally match number (linear numeric). Visual inspection of plots of residuals vs predicted and residuals vs predictors showed no obvious evidence of non-uniformity and non-linearity of effects.

The magnitudes of the effects of the nominal predictors (possession type, possession outcome) were evaluated for the mean possession duration (17 s for attack, 16 s for defence), zero score difference (representing equally matched teams during the match), the middle of a 60-min match, zero ladder-points difference (representing equally matched teams across the season), and the middle match of the season. The magnitudes of the linear numeric modifying effects were evaluated as follows: for possession duration the effect of two SDs (factor increases of 2.4 on attack and 2.7 on defence), for score difference 10 points (representing approximately two SDs of the score-difference distribution), for match time 60 min (representing the match trend), for ladder-points difference 55 (for the effect of the strongest opposition minus the weakest opposition), and for match number 13 (representing the season trend between the first and fourteenth match). Only the seven home matches were analysed.

The random effects were match identity (to adjust for changes in means of the collective tactical variable between matches) and the residual (representing changes between possessions not explained by all the other effects in the model). Separate variances were specified for the random effects on attack and on defence; for the residual, separate variances were also specified for each quintile of possession duration within possession type (to allow for the possibility of substantial differences in error with different possession durations, given the strong fixed effects of possession duration that were observed for ApEn). Outliers identified by standardised residuals >4.5 (up to five of the 898 possessions) were deleted, then the data were reanalysed (Hopkins et al., 2009).

Means and SDs of the collective tactical variables were derived from the mixed model: the means are back-transformed least-squares means; the SDs are the residuals for the middle quintile for possession duration, back-transformed to percent units. Effects are presented in percent units with uncertainty expressed as ±90% compatibility limits.

Magnitudes of effects were assessed using standardisation, where the standardising SD was the square root of the mean of all the residual variances. For those who prefer a frequentist interpretation of sampling uncertainty, decisions about magnitudes accounting for the uncertainty were based on one-sided interval hypothesis tests, according to which a hypothesis of a given magnitude (substantial, non-substantial) is rejected if the 90% compatibility interval falls outside that magnitude (Hopkins, 2020), P values for the tests were therefore the areas of the sampling t distribution of the effect falling in the hypothesized magnitude, with the distribution centered on the observed effect. Hypotheses of inferiority (substantial negative) and superiority (substantial positive) were rejected if their respective p values ($p_{–}$ and p_{+}) were <0.05; rejection of both hypotheses represents a decisively trivial effect in equivalence testing. The hypothesis of non-inferiority (non-substantial-negative) or non-superiority (non-substantial-positive) was rejected if its p-value ($p_{N–}=1–p_{–}$ or $p_{N+}=1–p_{+}$) was <0.05, representing a decisively substantial effect in minimal-effects testing. A complementary Bayesian interpretation of sampling uncertainty is also provided when at least one substantial hypothesis were rejected: the p-value for the other hypothesis is the posterior probability of a substantial true magnitude of the effect in a reference-Bayesian analysis with a minimally informative prior (Hopkins, 2019), and it was interpreted qualitatively using the following scale: >0.25, possibly; >0.75, likely; >0.95, very likely; >0.995, most likely (Hopkins et al., 2009). The probability of a trivial true magnitude ($1–p_{–}–p_{+}$) was also interpreted with the same scale. Probabilities were not interpreted for unclear effects: those with inadequate precision at the 90% level, defined by failure to reject both substantial hypotheses ($p_{–}$>0.05 and p_{+}>0.05). Effects on magnitudes and probabilities of a weakly informative normally distributed prior centered on the zero effect and excluding extremely large effects at the 90% level were also investigated (Greenland, 2006, Hopkins, 2019). Effects with adequate precision at the 99% level ($p_{–}$<0.005 or p_{+}<0.005) are highlighted in bold in tables since these represent stronger evidence against substantial hypotheses than the 90% level and therefore incur lower inflation of error with multiple hypothesis tests.

4.4 RESULTS

4.4.1 Correlations between collective tactical variables

Tables 4.1 and 4.2 show the pairwise correlations between all the variables, ordered to reveal two clusters of variables with generally higher correlations within the clusters than between the clusters. The clustering is the same and the correlations have similar values for attack and defence. The first cluster can be interpreted as dispersion of the players in the longitudinal direction, the second as dispersion in the lateral direction, and the two centroids as the mean position in the longitudinal and lateral directions. Variables showing pairwise correlations of greater than 0.82 in the first cluster are stretch index, inter-player distance and stretch index longitudinal, while those in the second cluster are width and stretch index lateral. For positional sub-groups (see supplementary tables), the clusters were less well defined, owing to somewhat higher correlations between some variables between clusters. When considering correlations of at least ~0.8 within clusters, the clusters were the same as those for the team, although two of the three correlations were <0.5 for defenders on defence.

Table 4.1. Correlations between all collective tactical variables for the **team** on attack. Each set of three values are correlations for the mean, variability and irregularity respectively. The variables have been ordered and outlined to show clusters with generally higher correlations between variables within the clusters than between the clusters.

Variable	1	2	3	4	5	6	7	8	9	10
1. Stretch index		.97, .95, .93	.94, .90, .89	.72, .52, .60	.06, .18, .48	.05, .14, .47	-.24, .33, .43	.43, .19, .49	-.01, .23, .24	.01, .13, .36
2. Inter-player distance	.97, .95, .93		.89, .82, .82	.81, .61, .67	.11, .18, .46	.10, .13, .44	-.23, .31, .42	.51, .23, .50	-.01, .25, .28	.00, .14, .33
3. Stretch index longitudinal	.94, .90, .89	.89, .82, .82		.73, .55, .62	-.24, .26, .50	-.26, .23, .50	-.47, .42, .49	.14, .14, .42	-.02, .20, .26	.00, .12, .42
4. Length	.72, .52, .60	.81, .61, .67	.73, .55, .62		-.19, .13, .47	-.17, .11, .46	-.53, .36, .52	.27, .07, .45	.05, .30, .27	.00, .20, .39
5. Width	.06, .18, .48	.11, .18, .46	-.24, .26, .50	-.19, .13, .47		.89, .75, .82	.88, .62, .78	.83, .69, .77	.00, .17, .25	.03, .19, .48
6. Stretch index lateral	.05, .14, .47	.10, .13, .44	-.26, .23, .50	-.17, .11, .46	.89, .75, .82		.79, .50, .73	.80, .62, .76	.04, .21, .27	-.07, .21, .44
7. Width per length ratio	-.24, .33, .43	-.23, .31, .42	-.47, .42, .49	-.53, .36, .52	.88, .62, .78	.79, .50, .73		.58, .32, .63	-.02, .14, .24	.02, .03, .40
8. Surface area	.43, .19, .49	.51, .23, .50	.14, .14, .42	.27, .07, .45	.83, .69, .77	.80, .62, .76	.58, .32, .63		.03, .15, .28	.01, .19, .40
9. Centroid longitudinal	-.01, .23, .24	-.01, .25, .28	-.02, .20, .26	.05, .30, .27	.00, .17, .25	.04, .21, .27	-.02, .14, .24	.03, .15, .28		-.02, .25, .22
10. Centroid lateral	.01, .13, .36	.00, .14, .33	.00, .12, .42	.00, .20, .39	.03, .19, .48	-.07, .21, .44	.02, .03, .40	.01, .19, .40	-.02, .25, .22	

Uncertainty (90% compatibility limits): ~±0.1 to ~±0.01 for correlations of 0.00 to 0.95 respectively assuming a sample size of ~300.

Table 4.2. Correlations between all collective tactical variables for the team on defence. Each set of three values are correlations for the mean, variability and irregularity respectively. The variables have been ordered and outlined to show clusters with generally higher correlations between variables within the clusters than between the clusters.

Variable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1. Stretch index		.99, .95, .92	.98, .96, .93	.79, .65, .74	.03, .12, .32	-.02, .13, .32	-.30, .27, .41	.45, .24, .40	.08, .15, .14	.10, .12, .35
2. Inter-player distance	.99, .95, .92		.95, .89, .86	.85, .75, .80	.08, .16, .35	.04, .18, .33	-.28, .26, .44	.52, .32, .44	.07, .20, .18	.09, .15, .33
3. Stretch index longitudinal	.98, .96, .93	.95, .89, .86		.79, .64, .71	-.16, .13, .30	-.20, .14, .32	-.46, .31, .42	.28, .18, .36	.02, .1 5, .17	.08, .15, .37
4. Length	.79, .65, .74	.85, .75, .80	.79, .64, .71		-.13, .17, .33	-.12, .19, .29	-.49, .27, .43	.36, .29, .43	-.09, .21, .20	.05, .20, .32
5. Width	.03, .12, .32	.08, .16, .35	-.16, .13, .30	-.13, .17, .33		.91, .77, .76	.88, .57, .74	.82, .69, .73	.16, .24, .25	.06, .26, .42
6. Stretch index lateral	-.02, .13, .32	.04, .18, .33	-.20, .14, .32	-.12, .19, .29	.91, .77, .76		.83, .46, .66	.78, .66, .68	.11, .32, .34	.04, .31, .40
7. Width per width ratio	-.30, .27, .41	-.28, .26, .44	-.46, .31, .42	-.49, .27, .43	.88, .57, .74	.83, .46, .66		.55, .28, .56	.14, .09, .32	.01, .04, .41
8. Surface area	.45, .24, .40	.52, .32, .44	.28, .18, .36	.36, .29, .43	.82, .69, .73	.78, .66, .68	.55, .28, .56		.07, .25, .29	.12, .20, .38
9. Centroid longitudinal	.08, .15, .14	.07, .20, .18	.02, .15, .17	-.09, .21, .20	.16, .24, .25	.11, .32, .34	.14, .09, .32	.07, .25, .29		-.05, .35, .32
10. Centroid lateral	.10, .12, .35	.09, .15, .33	.08, .15, .37	.05, .20, .32	.06, .26, .42	.04, .31, .40	.01, .04, .41	.12, .20, .38	-.05, .35, .32	

Uncertainty (90% compatibility limits): ~±0.1 to ~±0.01 for correlations of 0.00 to 0.95 respectively assuming a sample size of ~300.

4.4.2 Effect of attack vs defence

The means and variability of the collective tactical variables for attack and defence, and the differences between the means, are shown in Table 4.3. For variables within the same cluster, the means in raw units for attack (and defence) sometimes differ widely between variables (exception: means for irregularity, which are all in the same dimensionless units), but the variability in percent units, the effects in percent units, and the qualitative magnitudes of the effects are generally similar (e.g., width and stretch index lateral). Except for the extremely large effect on the mean for centroid longitudinal (representing the team being closer to the scoring goal on attack), the biggest effects occur in the second cluster, especially for mean and variability of width and stretch index lateral (representing a more expanded dispersion of the players on attack).Similar to those for the team, in that highly correlated variables within clusters had similar magnitudes for the differences between attack and defence.

Similar to the team, the midcourt sub-group showed its largest effects in its second cluster of variables. In contrast, the forward and defender sub-groups showed the largest differences between attack and defence in their first cluster, with the forwards having a lower value on attack and the defenders having a lower value on defence. Both sub-groups also displayed noticeable differences in irregularity for most variables, presenting opposite sign but similar magnitude to that of the mean.

4.4.3 Effect of possession outcome

Table 4.4 shows the difference between possessions resulting in a score vs a turnover for each of the derived measures of each collective tactical variable for the team. The first cluster of variables (representing longitudinal dispersion) for the mean and variability displayed the largest effects during attack and defence, but they were at most small. Specifically, when the home team scored, the stretch index and stretch index longitudinal

Table 4.3. Collective tactical variables for the **team's** attack and defence possessions adjusted for possession duration, score difference, ladder point's difference, match trend and season trend. Dashed lines separate the variables into the clusters defined by the correlations in Table 4.1. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent. Data for attack and defence are predicted means (raw units) from the mixed model, and SDs are an appropriate residual representing differences between possessions. Data for attack minus defence are predicted mean differences (% units) with 90% compatibility limits (% units) and decisions about the magnitude of the differences.

Variables	Attack	Defence	Attack minus Defence	Magnitude
Mean				
Stretch Index (m)	6.78 ± 8%	6.64 ± 10%	2.0, ±3.8 %	small↑*^{0}
Inter-player distance (m)	10.25 ± 7%	9.98 ± 9%	2.7, ±3.0 %	small↑**
Stretch index longitudinal (m)	6.03 ± 10%	6.10 ± 13%	-1.2, ±4.6 %	trivial
Length (m)	22.0 ± 7%	21.7 ± 8%	1.1, ±2.8 %	trivial
Width (m)	7.3 ± 16%	6.1 ± 18%	17.6, ±3.1 %	**moderate↑******
Stretch index lateral (m)	2.02 ± 16%	1.67 ± 16%	20.8, ±3.6 %	**moderate↑******
Width per length ratio (m)	0.30 ± 23%	0.26 ± 22%	15.4, ±6.7 %	**moderate↑*****
Surface area (m²)	86 ± 17%	73 ± 17%	17.4, ±3.4 %	**moderate↑******
Centroid longitudinal (m)	18.3 ± 1.3	11.7 ± 1.7	6.84, ±0.69	**extremely large↑******
Centroid lateral (m)	7.5 ± 1.1	7.5 ± 1.1	0.04, ±0.26	trivial
Variability				
Stretch index (m)	0.82 ± 42%	0.88 ± 46%	-6.8, ±9.2 %	trivial↓^{0}*
Inter-player distance (m)	1.00 ± 44%	1.09 ± 45%	-8.1, ±9.0 %	trivial↓^{0}*
Stretch index longitudinal (m)	0.99 ± 50%	0.97 ± 46%	1, ±13 %	trivial
Length (m)	2.09 ± 43%	2.19 ± 48%	-4.4, ±9.3 %	trivial↓^{0}*
Width (m)	1.70 ± 33%	1.34 ± 43%	23.4, ±6.2 %	**moderate↑******
Stretch index lateral (m)	0.50 ± 36%	0.38 ± 41%	28.1, ±6.7 %	**moderate↑******
Width per length ratio (m)	0.97 ± 69%	1.00 ± 50%	-3, ±12 %	trivial^{00}
Surface area (m²)	19.6 ± 41%	17.4 ± 48%	10.8, ±6.0 %	**small↑****
Centroid longitudinal (m)	1.95 ± 49%	1.50 ± 60%	30, ±14 %	**moderate↑*****
Centroid lateral (m)	0.82 ± 55%	0.68 ± 61%	18.2, ±9.7 %	**small↑****
Irregularity				
Stretch index	0.19 ± 56%	0.16 ± 70%	16.1, ±8.3 %	**small↑****
Inter-player distance	0.20 ± 56%	0.17 ± 62%	14.7, ±9.0 %	**small↑****
Stretch index longitudinal	0.17 ± 57%	0.15 ± 75%	8, ±12 %	small↑^{0}
Length	0.20 ± 54%	0.18 ± 72%	7, ±14 %	trivial^{0}
Width	0.34 ± 44%	0.38 ± 44%	-12.0, ±4.8 %	**small↓****
Stretch index lateral	0.31 ± 36%	0.38 ± 31%	-19.7, ±4.5 %	**small↓******
Width per length ratio (m)	0.33 ± 66%	0.27 ± 46%	32, ±12 %	**moderate↑******
Surface area	0.35 ± 43%	0.34 ± 46%	1.9, ±6.5 %	trivial^{00}
Centroid longitudinal	0.08 ± 86%	0.10 ± 98%	-18, ±20 %	small↓*^{0}
Centroid lateral	0.20 ± 47%	0.23 ± 61%	-16, ±12 %	**small↓****

90%CL, 90% compatibility limits; ↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardised changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

Table 4.4 Difference between home score and home turnover (on attack) and between opposition score and opposition turnover (on defence) for each of the derived measures of each collective tactical variable for the **team**. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Home (attack) Score – Turnover	Home (attack) Decision	Opposition (defence) Score – Turnover	Opposition (defence) Decision
Mean				
Stretch index (m)	2.0, ±1.3 %	**small↑^{*0}**	2.9, ±1.8 %	**small↑****
Inter-player distance (m)	1.4, ±1.1 %	**trivial↑^{0*}**	1.9, ±1.5 %	**small↑^{*0}**
Stretch index longitudinal (m)	3.6, ±1.6 %	**small↑****	4.4, ±2.2 %	**small↑*****
Length (m)	1.6, ±1.2 %	**trivial↑^{0*}**	2.6, ±1.4 %	**small↑****
Width (m)	-4.8, ±2.5 %	**small↓****	-5.3, ±2.6 %	**small↓****
Stretch index lateral (m)	-4.1, ±2.6 %	**small↓^{*0}**	-4.9, ±2.7 %	**small↓****
Width per length ratio (m)	-6.2, ±3.3 %	**small↓****	-7.5, ±3.2 %	**small↓*****
Surface area (m^2)	-2.3, ±2.6 %	**trivial^{00}**	-2.4, ±2.8 %	**trivial↓^{0*}**
Centroid longitudinal (m)	0.62, ±0.24	**small↑****	-0.59, ±0.28	**small↓*****
Centroid lateral (m)	0.09, ±0.19	trivial^{00}	-0.05, ±0.17	trivial^{00}
Variability				
Stretch index (m)	12, ±7.2 %	**small↑****	17, ±8.5 %	**small↑*****
Inter-player distance (m)	11, ±6.7 %	**small↑^{*0}**	18, ±8.8 %	**small↑*****
Stretch index longitudinal (m)	14, ±7.3 %	**small↑****	18, ±8.3 %	**small↑*****
Length (m)	11, ±6.8 %	**small↑****	18, ±8.4 %	**small↑*****
Width (m)	-3.4, ±5.1 %	**trivial^{00}**	-5.0, ±5.9 %	**trivial↓^{0*}**
Stretch index lateral (m)	-4.7, ±5.2 %	**trivial^{00}**	-3.2, ±5.7 %	**trivial^{00}**
Width per length ratio (m)	-9.1, ±7.7 %	**trivial↓^{0*}**	-10.1, ±7.6 %	**small↓^{*0}**
Surface area (m^2)	-3.4, ±5.3 %	**trivial^{00}**	-2.9, ±6.0 %	**trivial^{00}**
Centroid longitudinal (m)	3.4, ±6.9 %	**trivial^{00}**	13, ±8.8 %	**small↑****
Centroid lateral (m)	-8.1, ±6.6 %	**trivial↓^{0*}**	-0.4, ±8.6 %	trivial^{00}
Irregularity				
Stretch index	-16, ±6.9 %	**small↓****	-13, ±8.6 %	**small↓^{*0}**
Inter-player distance	-15, ±6.8 %	**small↓****	-9, ±8.5 %	**trivial↓^{0*}**
Stretch index longitudinal	-17, ±6.8 %	**small↓****	-12, ±8.5 %	small↓^{*0}
Length	-13, ±6.8 %	**small↓^{*0}**	-11, ±8.7 %	**small↓^{*0}**
Width	-7, ±5.3 %	**trivial↓^{0*}**	-2.2, ±5.8 %	**trivial^{00}**
Stretch index lateral	-2.9, ±5.5 %	**trivial^{00}**	-1.4, ±5.4 %	trivial^{00}
Width per length ratio	13, ±9.0 %	**small↑****	6.6, ±7.6 %	**trivial↑^{0*}**
Surface area	-3.9, ±5.4 %	**trivial^{00}**	0.00, ±6.5 %	trivial^{00}
Centroid longitudinal	-3.8, ±10 %	**trivial^{00}**	-18, ±10 %	**small↓****
Centroid lateral	-1.9, ±7.0 %	**trivial^{00}**	2.9, ±8.3 %	trivial^{00}

↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely.
*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).
Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

showed small positive effects compared with when the possessions ended in a turnover. For possessions when the opposition scored, all the variables in the first cluster showed small positive effects. Effects on irregularity were similar on attack and defence: small and possibly or likely substantial reductions in irregularity for variables in the first cluster, but reasonable evidence of trivial effects otherwise.

Positional sub-groups displayed varied effects of possession outcome. The defender sub-group displayed the most dissimilar effects to that of the team, with its largest effects in the second cluster for mean, variability and irregularity. The forward sub-group showed the largest effects for the first-cluster variables; however, these were opposite in sign to the team. The only positional sub-group showing effects on scoring vs turnover similar to those of the whole team was the midcourt, for irregularity of variables in the first cluster on attack.

4.4.4 Effect of possession duration

The team (Figure 4.2) and sub-groups (supplementary tables) showed similar effects for variability and irregularity of all variables in the magnitude of the linear effect of two standard deviations of possession duration. There were large decreases for irregularity during attack and defence, while for variability there were moderate increases. For the mean of the first cluster variables, the team and midcourt displayed small to moderate positive effects over the possession. For the defender and forwards sub-groups, small to moderate effects were also displayed during defence, be that a reduction for defenders and an increase for forwards.

4.4.5 Effect of score difference

The majority of the observed effects of 10 points of score difference were trivial (supplementary tables), but only a few variables were decisively trivial and none was

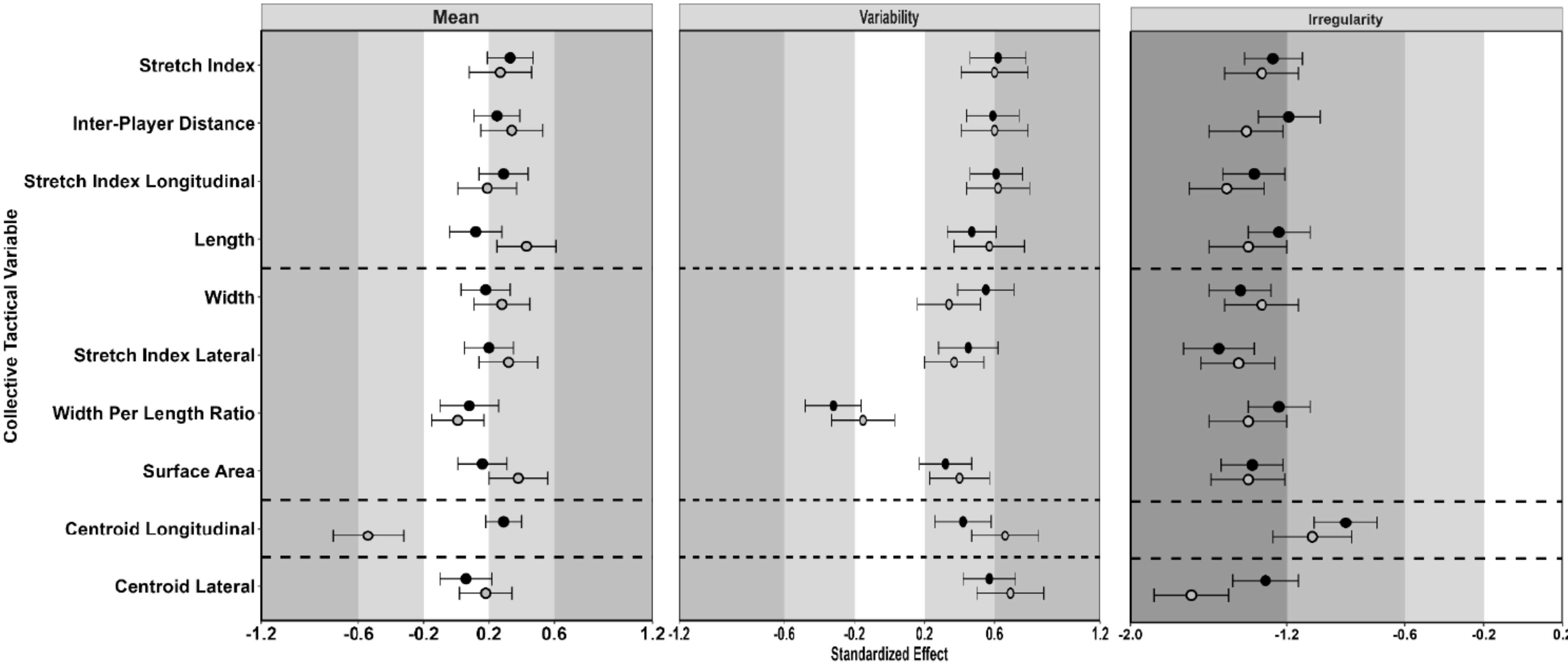


Figure 4.4. Standardised effect of two SDs of possession duration for the mean, variability and irregularity on collective tactical variables for the team on attack (filled circles) and defence (open circles). . With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation. Values on the left side of zero on each plot represent negative standardised effects while on the right positive standardised effects.

decisively substantial. In contrast, for all positional sub-groups, the mean and variability of variables in the first cluster displayed small to moderate effects during defence, with the forward sub-group displaying the opposite sign to that of the midcourt and defender sub-groups.

4.4.6 Effect of match time

Substantial changes over the match in attack for the mean of variables in the first cluster occurred for the team and the forward and midcourt sub-groups (supplementary tables). During defence, similar small to moderate effects were shown by the team and midcourt sub-group, but not the forward subgroup, as the defender sub-group displayed similar effects instead. The variability of first cluster variables also displayed small to moderate effects for the midcourt and defender sub-groups (implying reduced variability of longitudinal dispersion over the match). Lastly, the midcourt sub-group displayed moderate effects for the second cluster of variables in defence.

4.4.7 Effect of ladder-points difference

Mainly unclear trivial to small observed values (supplementary tables), only the variability in the second cluster variables had good evidence for a small reduction in lateral dispersion of the players when matched against a weaker team. Positional sub-groups displayed similar trivial to small effects to that of the team, although there was reasonable evidence for the defenders' small substantial reduction in longitudinal regularity when playing a weaker team.

4.4.8 Effects of match identity

The standard deviation representing differences between match means (after adjustment for all other effects in the model) had inadequate precision for every measure and every collective tactical variable. The observed magnitudes for the standard deviations were generally small for the team but ranged from trivial too large for the sub-groups.

4.4.9 Weakly informative priors

The effect which showed the greatest shrinkage was the difference of the teams' centroid longitudinal between attack and defence possessions, with a minimally informative prior the effect was 4.29, ±0.46 (mean, ±90% compatibility limits), after shrinkage with a weakly informative prior the effect became 4.24, ±0.46, which is obviously a negligible shrinkage.

4.5 DISCUSSION

The correlation analyses showed that the collective tactical variables could be grouped into clusters, with higher correlations between variables within the clusters than between the clusters, and usually with the same clustering for the team, the sub-groups and the three measures (mean, SD and ApEn). The clusters represent four largely independent dimensions: longitudinal and lateral dispersion and positioning. For the sub-groups, the variables surface area and width per length ratio represent intersections between longitudinal and lateral dispersion clusters, containing elements of both.

The reason for the high correlations between some variables is obvious from the way they are calculated, as noted by Bartlett et al. (2012) for inter-player distance and stretch index, which had the highest correlation in the present study. The correlations between some variables reduced in the player positional subgroups, potentially because of the effect on dispersion when the goal keeper or goal shooter are included or excluded in the subgroups. The effect of these two players on the calculations of the variables also explains why surface area and length-per-width ratio displayed lower correlations with variables within the lateral dispersion cluster for sub-groups than for the team. At the team level, longitudinal dispersion is constrained by the court restrictions imposed upon the goal keeper and goal shooter positions (see Figure 1); thus, high correlations were found for the variables surface area and width per length ratio with other variables in the lateral dispersion cluster. At the sub-group level, one or both of the goal keeper and goal shooter is removed from the calculations, resulting in a greater contribution of longitudinal dispersion to these two variables.

The effects on variables within each cluster were generally similar, which is an obvious consequence of the high correlations between the variables within each cluster. For the purposes of this discussion, the focus will therefore be on one variable with the highest correlations in each cluster. Inter-player distance rather than stretch index was chosen as the representative measure of longitudinal dispersion because it is more practical for coaches and players. Width was chosen as the representative measure for lateral dispersion, along with the two centroids for longitudinal and lateral positioning.

Of all the factors modifying the positional tactical variables, possession type (representing the difference between attacking and defending possessions) had generally the largest observed effects for the team and all subgroups. The largest effects of possession type were on centroid longitudinal, a result of moving closer to the attacking goal on attack and defending goal on defence. The mostly moderate differences between attacking and defending possessions for the width of the team and of midcourt and defender sub-groups represent increased lateral dispersion during attacking possessions, which aligns with previous findings in soccer and common coaching principles surrounding the strategies of attack and defence in team sports (Barnabé et al., 2016, Coombe et al., 2020b, Clemente et al., 2014a, Alexander et al., 2018, Castellano et al., 2016). The attacking team players apparently focus on destabilising the defending opposition through increased lateral dispersion (Castellano et al., 2016, Alexander et al., 2018). The midcourt sub-group most epitomizes the use of lateral dispersion on attack, an affordance of court structure and positional restrictions, whereby midcourt players are not permitted in the shooting circle.

Positional sub-groups displayed several differing tactical behaviours influenced by possession type. Forward and defender sub-groups showed moderate to large greater inter-player distance irregularity during their active phases of a match (attacking possessions for forwards and defensive possessions for defenders). Defenders also showed moderately greater width irregularity during defence, possibly because the activities of off-ball guarding and defending result in more irregularity as the defending sub-group players jostle for position and react to their direct opponents' movements (Bailey et al., 2017). Additionally, Australian netball teams have a preference to play one-on-one defence over zone defence, further emphasizing the dyadic and reactive nature of netball defending (Bruce et al., 2018). During non-active phases, both the forward and defender sub-groups exhibited less irregularity of collective tactical variables and large to very large mean differences in inter-player distances as they spread out to provide mostly stationary assistance to their active teammates. This is influenced by court restrictions imposed upon players, as well as the distinctive movement features most common in netball, whereby walking with straight movement and neutral acceleration are most prevalent (Sweeting et al., 2017).

Several small effects were found for the differences between possession outcomes (scoring and turnover). When the home team and opposition team possessions resulted in a score, the home team displayed increased mean values and increased variability of longitudinal dispersion, suggesting that expansion and variability through the length of the court is also an important attacking principle to stretch defenders apart. This principle is further supported by the forward sub-group displaying small observed decreases in inter-player distances and the midcourt sub-group reducing inter-player distance irregularity when the home team scored. Thus, successful possessions may tend to be those with a more direct path to the goal, where opposition defenders are destabilised and separated (McLean et al., 2019). When the opposition scored, the defender sub-group presented small reductions in inter-player distances, width and surface area, representing compactness of positioning, previously highlighted as a critical defensive strategy in netball (McLean et al., 2019). It must be noted that results like these are somewhat limited by the sample size and considered most pertainiet for the team analysed in this thesis.

The evolution of some collective tactical variables throughout a match was apparent in this study. A reduction in the longitudinal dispersion of the team, midcourt and forward sub-groups during attack and of the team, midcourt and defender sub-groups during defence aligns with previous findings in soccer, where team dispersion and field positioning decreased in the second half (Clemente et al., 2013c). The effect on the midcourt sub-group showed that these players adopt closer positioning to one another as the match progresses. Fatigue may at least partly explain these changes during a match, as previous research found reductions in intensity (significant decreases of heart rate max >85%) between the first and second halves (van Gogh et al., 2020).

As matches progressed, the forward sub-group displayed increased mean surface area and increased variability of inter-player distance during defence, highlighting the warning of Santos et al., 2018 that analysis of only team-level behaviours can fail to capture important sub-group behaviours. Limitations of team-level analysis only is further exacerbated in netball owing to the positional restrictions, causing collective tactical variables to be sometimes anchored with the GS or GK (positions with most restricted movement)

The small to moderate increases of variability with increasing possession time for most collective tactical variables for the team and all sub-groups simply reflect more opportunity for players to disperse longitudinally and laterally as the possession progresses (Silva et al., 2014a). The moderate to large reductions in the irregularity of all collective tactical variables for the team and all sub-groups are also an expected outcome, as longer possessions allow the time series to cancel out noise and chaotic patterns that are prevalent in shorter sequences (Stergiou et al., 2004, Gonçalves et al., 2019).

The strength of opposition has previously been shown in soccer to influence collective tactical variables, with greater surface area against stronger opponents (Castellano et al., 2013). In the current study of only seven matches, opposition strength (ladder-points difference) had a limited number of clear effects, but they were generally consistent with the findings of (Castellano et al., 2013). The clearest effect of ladder-points difference occurred in the defender sub-group on attack, where the small reductions in irregularity of longitudinal dispersion (in particular, stretch index) when playing a weaker team is consistent with the weaker team's inability to disrupt opposition defenders.

Changes in collective tactical variables over the season also had limited clear effects, owing to the small number of matches: only the team showed clear small increases of width. Season trends are still of potential importance for future research, as previous literature in soccer has suggested that tactics and group behaviours throughout a season change, as players adjust to the team strategy and further coordinate their behaviours with teammates (Araújo and Davids, 2016).

Score state had the most evidence for trivial effects for the team but there were clear substantial effects for some of the measures in some of the sub-groups. The increased longitudinal dispersion displayed by the mid-court sub-group on attack and defence suggests affordances of increased space lengthwise down the court may be apparent when leading on the scoreboard. The forward sub-groups reduction in longitudinal dispersion when leading during defence is potentially an adaptive behaviour in response to the midcourt sub-group utilizing more space closer to the attacking goal. The trivial effects for the variability of lateral dispersion for the midcourt and defender sub-groups when leading suggest these sub-groups retain the same defensive positioning that had successfully placed them in a winning situation.

Finally, the random effect of match ID had inadequate precision for all collective tactical variables, a consequence of the small number of matches. The observed substantial effects are consistent with factors affecting match means that were not accounted for in the model.

4.5.1 Limitations and future research directions

High correlations of collective tactical variables in elite netball have been identified in this research, presenting several variables that can be a focus for future study. However, several other considerations must be accounted for when using these variables. Collective tactical variables are a reduction analysis technique, whereby large amounts of information are reduced to one dimension (Rico-González et al., 2020e). As such, future research should consider other dimensions such as the behaviours of the opposing team, inter-team coordination and line forces; which provides a measure of inter-team sub-group cohesion (Silva et al., 2014b). To better assess the effects of ladder-points difference and season time, many more matches than seven would be required, as well as data from multiple teams with differing tactical styles. More matches would also improve the precision of the effect of match identity and thereby reveal whether factors affecting the overall tactics in each match other than those assessed in the present study (e.g.

coaches changing strategy for specific opponents). The findings of the present study could be implemented in the training environment and matches.

4.5.2 Conclusion

Team and sub-group results have identified how collective tactical variables dynamically shift over the throughout a match and during different phases. Additionally, the contribution of correlation analysis further enhances the understanding of how collective tactical variables can be implemented into elite netball and highlights those variables which may be most suited or redundant for future analysis. Finally, exploration at the team and sub-group level has displayed interactions among each of their components and how specific positions can influence organisation levels of higher-order. Through the exploration of collective tactical variables, an initial base of knowledge has been provided to support the implementation of this type of analysis in elite netball.

4.5.3 Practical applications

- Base of knowledge pertaining to collective tactical variables in elite netball.
- Elite netball displays tactical behaviours of expansion and contraction on attack and defence respectively.
- Team showed increased longitudinal dispersion when attacking possession ended in a score.
- Active phases of play for sub-groups invites more irregular behaviours.
- Team level behaviours fail to capture smaller sub-group behaviours.
- Match time effect align with physical intensity changes during a match.

CHAPTER 5. STUDY 3 – EFFECTS OF COLLECTIVE TACTICAL VARIABLES AND PREDICTORS ON THE PROBABILITY OF SCORING IN ELITE NETBALL.

5.1 ABSTRACT

In netball, understanding the group behaviours and constraints that can influence the probability of scoring can provide information that impacts the outcome of a match. The aim of this study was to model the effects of collective tactical variables and contextual predictors on scoring probability in elite netball. A local positioning system provided player positions of one team throughout seven national-level netball matches. The positions were analysed to provide mean, variability (standard deviation) and irregularity (normalised approximate entropy) for each attack and defence possession (470 and 423, respectively) for the team and positional subgroups (forwards, midcourts and defenders) for 10 collective tactical variables. The effects of collective tactical variables on the probability of scoring were estimated with a logistic-regression version of the generalized linear mixed model, with adjustment for predictor variables; possession duration, score difference, match time, ladder-points difference and match number. The home team and opposition team displayed a greater probability of scoring when they were able to maintain possession and extremely short possessions were associated with decreased scoring probability. The team also showed an increase in score probability over the course of a match (Data are the changes in the probability: 18± 16% (%, ±90% compatibility limits)), but a decrease in scoring probability was associated with a leading score state (-23± 10%). Increased mean and variability of collective tactical variables of longitudinal dispersion showed large increases to the probability of scoring for the team and opposition, as it reflects player proximity to the goals and direct movement in the middle channel of the

court. Lateral dispersion negatively affected the probability of scoring for both teams, indicating it is more favourable to maintain positioning and ball movement in the middle of the court.

5.2 INTRODUCTION

Collective tactical variables have been used to capture the complex nature of player interactions and behaviours in sport (Duarte et al., 2013, Silva et al., 2014b), by aggregating players positions into variables that provide insight into group behaviours such as dispersion, contraction and synchronisation (Goes et al., 2020, Gonçalves et al., 2014). These variables have been suggested as important tools to understand the behaviours that reflect strategic actions in the field of play (Folgado et al., 2018b, Vilar et al., 2013), and their relevance in gaining success at different contest levels (Ofoghi et al., 2013). Thus far research in soccer has provided insight into the dispersion of players (Bourbousson et al., 2010a), the attacking and defending flow of opposing teams (Rein and Memmert, 2016) and the playing shape and ranges of groups of players (Silva et al., 2014a, Duarte et al., 2013). Additionally, findings of increased width and spacing by older teams (Olthof et al., 2015), tactical shifts of increased frequency of width against weaker teams (Castellano et al., 2013) and behaviours of greater lateral dispersion during attacking phases (Barnabé et al., 2016), have provided a descriptive understanding of how collective tactical variables can change under constraints and affordances offered by teammates and opposition (Low et al., 2020, Araújo et al., 2015).

Further research has highlighted the use of collective tactical variables as measures of tactical performance and use as performance indicators. Collective tactical variables can vary as a result of environmental and physiological constraints, with decrements over the course of a match (Clemente et al., 2013c) and changes associated with interventions of increased activity(Sampaio et al., 2014a). The remaining literature has focused on the predictive nature of collective tactical variables on performance, especially during critical key moments of a match. Research in rugby union has found that inter-player distance between pairs of attacking and defender players has predictive power of successful try attempts (Simpson et al., 2020b). Additionally, a key moment in soccer small-sided games where the attacking team's longitudinal centroid crosses over the defending team's longitudinal centroid was thought to be able to identify scoring opportunities (Frencken et al., 2011). However, further investigation found divergent views, with the critical match periods based on variability thresholds not strongly related to goals and goal scoring opportunities (Frencken et al., 2012). Due to the limited number of goals and scoring opportunities in soccer, data of successful scoring outcomes is limited, one sport however that lends itself to investigating the effects of collective tactical variables on scoring probability is netball.

Owing to the high number of possessions per netball match (similar to that of basketball), and the clear outcomes of each possession, netball provides a rich dataset to model the possession-to-possession effects on scoring probability (Bake et al., 2021). Additionally, findings from elite netball coaches match discussions have also stated possession outcome as one of five main dimensions of netball performance (Croft et al., 2020). Research in netball has provided an insight into the tactical principles that underpin turnovers; space, movement, timing, support and reading play, as well as suggestions that team dynamics instead of individual player behaviours are of higher order in causing turnovers (Coombe et al., 2020b, Coombe et al., 2020a). Furthermore, recent research has suggested to increase the chances of winning, teams should focus on reducing negative technical actions, before trying to increase positive technical actions, as teams have more chances to lose the ball than gain it (Ofoghi et al., 2021). The coupling of a high number of possessions with clear outcomes and relevance of collective team behaviours to netball performance supports the integration of collective tactical variables and their potential use as performance indicators. Tactical performance analysis research has been limited in netball as it is a newly professional women's sport (McLean et al., 2019, Croft et al., 2020, Lord et al., 2020, Whitehead et al., 2021). However advances in local positioning systems ability to measure collective tactical variables (Hodder et al., 2020), now provides an avenue to investigate tactical behaviours. Therefore, the primary aim of this study was to investigate what magnitudes of effect increasing collective tactical variables and other contextual predictors can have on the probability of scoring in elite netball. The results provide an advanced view of the use of collective tactical variables beyond just describing their outputs in matches and training.

5.3 METHODS

5.3.1 Data collection and processing

Player positioning data was collected from seven competitive national-level netball matches, from a professional team participating in the Suncorp Super Netball League. A local positioning system was used to collect the data at 10 Hz; participants' uniforms were fitted with an internal stitched pouch that housed the local positioning system receiver tag, positioned between the shoulder blades. The following match event data were collected post-event using video analysis software (Sportscode, Hudl): team in possession, possession outcome, possession duration, ladder-points difference (difference between team and oppositions ladder points at the end of the season) and score difference (numeric difference between attacking team score and opposition team score). Positional data were processed in R statistical software (R, Vienna, Austria), version 4.0.2. The coordinate's origin point was set to one corner of the netball court and the attacking direction was reset each quarter as teams change the direction after each break. Player position data and event data were then synchronised to a common starting point. Ten collective tactical variables were calculated every 0.1 s for the whole team and each sub-group: forwards (goal shooter, goal attack, wing attack), midcourts (wing attack, centre, wing defence), and defenders (wing defence, goal defence, goal keeper). Variables included: mean inter-player distance, centroids, length, width, width per length ratio, surface area and stretch indices. A total of 903 possessions were collected: 311 on attack resulted in a score, 160 in a turnover and three in end-of-quarter or injury; on defence 256 resulted in an opposition score, 166 in an opposition turnover and seven were end-of-quarter or injury. The possessions that did not end in a score or turnover were excluded from further analysis.

5.3.2 Statistical analysis

The analysis aimed to estimate the effects of collective tactical variables for the three measures (mean, SD, ApEn) and contextual predictors on scoring probability in elite netball for the team and three sub-groups. In Chapter 4, Pearson correlations between all the collective tactical variables were first derived to assess the similarity of the variables and thereby group them into clusters of similar variables (higher correlations within clusters than between clusters). The effects of the variables on possession outcome are presented in tables with these clusters delineated since the effects of variables within each cluster were expected to be similar.

The effects of collective tactical variables on the probability of scoring were estimated with the logistic-regression version of the generalized linear mixed model, realized with Proc Glimmix in the Statistical Analysis System (Studio On Demand for Academics, version 9.4, SAS Institute, Cary NC). A separate analysis was performed for each measure (mean, variability and irregularity) for each variable, for the team and for each positional sub-group. The dependent variable was the possession outcome (1 for scoring, 0 for turnover), and the collective tactical variable was included as a linear numeric predictor. The variable was rescaled to give match means of zero to ensure estimation of a pure within-match effect. The between-match effect of the variable was also estimated by including the match mean as an additional predictor; this effect was generally unclear, owing to the small number of matches, and its inclusion did not modify the within-match effect, therefore the between-match effects are not presented in this study.

Several other predictor variables were used for adjustment in each analysis: possession duration (nominal, parsed into quintiles, adjusted to the mean), score difference (linear numeric, adjusted to zero, representing equally matched teams during the match), match time (linear numeric, representing the match trend, adjusted to the mean), ladder-points difference (linear numeric, adjusted to the mean) and match number (linear numeric, representing the season trend, adjusted to mid-season). Quintiles were used for possession duration because it was evident from inspection of the plot of residuals versus possession duration that the effect of this predictor was non-linear. To investigate the extent of non-linear effects of the collective tactical variables, additional analyses were performed with each variable parsed into quintiles. Outcomes from these analyses are reported only when any appreciable non-linearity was apparent and would impact the practical application of changing the value of the collective tactical variable. A random effect for match identity was included to account for easy or difficult matches (differences between matches in the mean probability of scoring), and the residual was specified to allow for an over-dispersed binomial distribution. An analysis using the adjustment fixed effects and the random effects was first performed to estimate their magnitudes, as described in the footnote to

Table 5.1. These estimates changed to some extent when each collective tactical variable was included in the model, but are not shown in the Results.

Each collective tactical variable was log-transformed for further analysis (with the exception of the mean for centroid longitudinal and lateral, for which log-transformation would not be appropriate); the standard deviations for these variables were often comparable to their means and are therefore shown as factors. The effects of these variables were evaluated for 2 SD of the log-transformed values (the square of the factor SD: the predicted probability for the mean times 1 SD minus the predicted probability for the mean divided by 1 SD). The mean and SD were derived as the mean of the match means and the overall within-match SD (the SD of all possessions with match means rescaled to zero).

To assess the magnitude of each effect on the probability of scoring, it was assumed that the effect would be applied to every possession in a match and thereby increase the chances of the team winning. A smallest important effect would result in the team winning one extra match every 10 matches; thresholds for moderate, large, very large and extremely large effects would result in three, five, seven and nine extra matches every 10 matches (Hopkins et al., 2009). The effects are odds ratios provided by the logistic regression. To determine the odds ratios corresponding to these magnitudes, the probabilities of winning an average match before and after the effect was applied to every possession were calculated using the binomial distribution via the COMBIN function in an Excel spreadsheet (available from the authors on request). The average match was that of the Suncorp Super Netball League season of 2019, consisting of 83 possessions with a probability of scoring 69%. The resulting odds-ratio thresholds were 1.09, 1.30, 1.58, 2.02 and 3.10 for the fixed effects and the square root of these values for the random effects (Smith and Hopkins, 2011). For ease of understanding, the effects are shown as changes in the percent chances of scoring in a possession; therefore, the odds-ratio effects are shown as percent effects calculated by assuming a probability of scoring of 63% (the average of the predicted probabilities on attack and defence for the team in the current study); the magnitude thresholds for the percent effects corresponding to the odds-ratio thresholds were 2.0%, 6.1%, 11%, 16% and 26% for the fixed effects and half these values for the random effects.

Uncertainty in the effects was expressed as 90% compatibility limits. For those who prefer a frequentist interpretation of sampling uncertainty, decisions about magnitudes accounting for the uncertainty were based on one-sided interval hypothesis tests, according to which a hypothesis of a given magnitude (substantial, non-substantial) is rejected if the 90% compatibility interval falls outside that magnitude (Hopkins, 2020). P values for the tests were therefore the areas of the sampling t distribution of the effect falling in the hypothesized magnitude, with the distribution centered on the observed effect. Hypotheses of inferiority (substantial negative) and superiority (substantial positive) were rejected if their respective p-values ($p_{–}$ and p_{+}) were <0.05; rejection of both hypotheses represents a decisively trivial effect in equivalence testing. The hypothesis of non-inferiority (non-substantial-negative) or non-superiority (non-substantial-positive) was rejected if its p value ($p_{N–}$=1–$p_{–}$ or p_{N+}=1–p_{+}) was <0.05, representing a decisively substantial effect in minimal-effects testing. A complementary Bayesian interpretation of sampling uncertainty is also provided when at least one substantial hypothesis were rejected: the p-value for the other hypothesis is the posterior probability of a substantial true magnitude of the effect in a reference-Bayesian analysis with a minimally informative prior (Hopkins, 2019), and it was interpreted qualitatively using the following scale: >0.25, possibly; >0.75, likely; >0.95, very likely; >0.995, most likely (Hopkins et al., 2009). The probability of a trivial true magnitude (1–$p_{–}$–p_{+}) was also interpreted with the same scale. Probabilities were not interpreted for unclear effects: those with inadequate precision at the 90% level, defined by failure to reject both substantial hypotheses ($p_{–}>0.05$ and $p_{+}>0.05$). Effects on magnitudes and probabilities of a weakly informative normally distributed prior centered on the nil effect and excluding extremely large change in probability of scoring (±26%) at the 90% level were also investigated (Greenland, 2006, Hopkins, 2019).

Effects with adequate precision at the 99% level ($p_{–}<0.005$ or $p_{+}<0.005$) are highlighted in bold in tables since these represent stronger evidence against substantial hypotheses than the 90% level and therefore incur lower inflation of error with multiple hypothesis tests. For practitioners considering implementation of a change in a collective tactical variable based on an effect in this study (e.g., reducing mean lateral dispersion by 2SD, which was associated with very large increased scoring probability), the effect needs only a modest chance of benefit (at least possibly increased scoring probability, $p_{+}>0.25$) but a low risk of harm (most unlikely decreased scoring probability, $p_{–}<0.005$). Substantial effects highlighted in bold therefore represent potentially implementable effects.

Where there were well defined clear large effects, the videos of possessions with low and high values of the predictor were inspected in an attempt to understand the underlying mechanism of the association. The insights gained thereby are reported in the Discussion section (Chapter 6.5).

5.4 RESULTS

The effects of predictors that were used for adjustment in the analysis of the collective tactical variables are shown in Table 5.1. The characteristics of these variables that were used for the adjustment were as follows: duration of possession (attack 19.1 ± 8.0, defence

Table 5.1. Effects of predictors of possession outcome (other than the collective tactical variables after adjustment for all the other predictors). Data are the changes in probability of scoring (%, ±90% compatibility limits) due to each predictor, with a decision about the magnitude of the change.

Predictor	Attack	Magnitude	Defence	Magnitude
Possession duration[a]				
Quintile 1 minus 3	-20, ±11%	**very large↓******	-31, ±13%	**extremely large↓******
Quintile 2 minus 3	-3, ±12%	small↓	-12, ±13%	large↓**
Quintile 4 minus 3	7, ±12%	moderate↑	-2, ±13%	trivial
Quintile 5 minus 3	7, ±12%	moderate↑	6, ±14%	small↑
Score difference (8 points[b])	-23, ±10%	**very large↓******	2, ±10%	trivial
Match trend[c]	18, ±16%	very large↑***	-13, ±17%	large↓
Team-strength difference[d]	7, ±21%	moderate↑	12, ±23%	large↑
Season trend[e]	2, ±20%	small↑	8, ±21%	moderate↑
Match identity[f]	8.5, ±15%	very large↑	8.9, ±15%	very large↑

[a] Possession durations were parsed into quintiles; the effects shown are for comparisons with the third (middle) quintile.
[b] Approximately 2 SD of the score differences at the start of each possession in a match.
[c] The end minus the start of a 60-min match.
[d] The strength of the opponent team minus that of the study team in each match, where strength was the ladder points at the end of the season.
[e] The match number at the end of season minus the start of the season.
[f] SD representing differences in the mean probability of scoring in each match not explained by the other predictors.
↑, increase; ↓, decrease.
Magnitudes for all predictors except match identity are based on the following thresholds for changes in the probability of scoring: <2.0, trivial; 2.0-6.1, small; 6.1-11, moderate; 11-16, large; 16-26, very large; >26 extremely large. Thresholds for match identity are half these values.
Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.
*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

17.35 ± 8.1 s), score difference (attack 2.8 ± 6.0 and defence 3.0 ± 6.1 goals), match trend (evaluated with a linear effect of match time, range 0-74.4 min), team-strength difference (evaluated with a linear effect of the end-of-season ladder points, mean 16.49 and range 55), season trend (evaluated with a linear effect of match number, range 1-14) and match identity (a SD shown in the table). Each of the effects in the table is adjusted for all of the other predictors but not for any of the collective tactical variables. The effects are the changes in the probability of scoring relative to predicted mean probabilities on attack and defence of 66% (90% compatibility limits ±7%) and 60% (±8%) respectively.

The comparisons of the quintiles of possession duration show that the shortest possessions (first quintile) had the lowest probability of scoring for attack and defence. Although the comparisons of the other quintiles were generally unclear, the effects are consistent with increases in the probability of scoring with longer durations, reaching a plateau by the fourth quintile for attack and no appreciable increase in the probability of scoring by increasing possession durations beyond the middle values.

A score difference of approximately two SDs displayed a very large negative effect on home team score probability, whereas the opposition team displayed a trivial but unclear effect. Match trend, team-strength difference, season trend and match identity displayed mainly substantial but unclear effects, with the exception of a very likely positive effect of match trend on attack.

Effects of collective tactical variables on the probability of scoring were evaluated for 2 SDs of each variable (the supplementary tables show the means and SD). The effects are shown for the team in Table 5.2 and the sub-groups in Tables 5.3-5.5. The variables in each table are grouped according to the correlations between variables within and between groups described in the Methods: longitudinal dispersion, lateral dispersion, longitudinal positioning and lateral positioning. Two variables in the positional sub-groups could not be assigned uniquely to one of these four groups: surface area had some correlations similar to those with the variables within the longitudinal and lateral dispersion clusters, while width per length ratio had some correlations similar to those with variables within the lateral dispersion cluster. In general, the effects of variables within each cluster are similar.

5.4.1 Effects of longitudinal dispersion

Table 5.2 shows that the effects of a 2-SD increase in longitudinal dispersion of the team mean and variability had large to very large increases on the probability of scoring at the end of a home-team possession (attack). The effects in the positional sub-groups (Tables 5.3-5.5) were smaller and unclear, with the exceptions of mean of the forwards sub-group

Table 5.2. Effects of collective tactical variables of the **team** on the probability of scoring at the end of a possession after adjustment for the predictors shown in Table 5.1 and centroid longitudinal. Data are the changes in the probability (%, ±90% compatibility limits) predicted for a 2-SD possession-to-possession change of the variable, with decisions about the magnitude of the change. Clusters of variables representing consecutively longitudinal dispersion, lateral dispersion, longitudinal position and lateral position are outlined.

Variable	Attack	Magnitude	Defence	Magnitude
Mean				
Stretch index	13, ±8	**large↑*** **	15, ±9	**large↑*** **
Inter-player distance	11, ±8	**large↑*** **	12, ±9	large↑***
Stretch indexlongitudinal	17, ±8	**very large↑**** **	18, ±9	**very large↑**** **
Length	11, ±8	**large↑*** **	17, ±9	**large↑*** **
Width	-14, ±8	**large↓*** **	-15, ±8	**large↓**** **
Stretch indexlateral	-12, ±8	**large↓*** **	-12, ±8	**large↓*** **
Width per length ratio	-14, ±8	**large↓*** **	-18, ±9	**very large↓**** **
Surface area	-6, ±8	moderate↓**	-4, ±8	small↓
Centroid longitudinal	21, ±8	**very large↑**** **	-23, ±9	**very large↓**** **
Centroid lateral	4, ±8	small↑	-1, ±9	trivial
Variability				
Stretch index	14 ±8	**large↑*** **	20, ±9	**very large↑**** **
Inter-player distance	15, ±8	**large↑**** **	21, ±9	**very large↑**** **
Stretch indexlongitudinal	16, ±8	**large↑**** **	20, ±9	**very large↑**** **
Length	15, ±8	**large↑**** **	22, ±9	**very large↑**** **
Width	-6, ±8	moderate↓**	-6, ±9	moderate↓**
Stretch indexlateral	-8, ±1	moderate↓***	-1, ±8	trivial
Width per length ratio	-9, ±8	moderate↓**	-11, ±9	large↓***
Surface area	-4, ±8	small↓	-2, ±8	small↓
Centroid longitudinal	4, ±8	small↑	16, ±9	**large↑*** **
Centroid lateral	-8, ±8	moderate↓**	0, ±9	trivial
Irregularity				
Stretch index	-23, ±10	**very large↓**** **	-16 ±10	large↓***
Inter-player distance	-23, ±9	**very large↓**** **	-17 ±10	very large↓***
Stretch indexlongitudinal	-24, ±10	**very large↓**** **	-17, ±10	large↓***
Length	-19, ±9	**very large↓**** **	-15, ±10	large↓**
Width	-12, ±10	large↓***	-2, ±10	trivial
Stretch indexlateral	-5, ±9	small↓	-2, ±10	small↓
Width per length ratio	14, ±9	**large↑*** **	11, ±10	large↑**
Surface area	-8, ±9	moderate↓**	-4, ±10	small↓
Centroid longitudinal	-5, ±8	small↓	-17, ±10	**large↓*** **
Centroid lateral	-4, ±9	small↓	1, ±11	trivial

↑, increase; ↓, decrease.
Magnitudes for all predictors except match identity are based on the following thresholds for changes in the probability of scoring: <2.0, trivial; 2.0-6.1, small; 6.1-11, moderate; 11-16, large; 16-26, very large; >26 extremely large. Thresholds for match identity are half these values.
Reference-Bayesian likelihoods of substantial change: *possibly; **likely, ***very likely, ****most likely.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

Table 5.3. Effects of collective tactical variables of the **forwards** sub-group on the probability of scoring at the end of a possession after adjustment for the predictors shown in Table 5.1. Data are the change in the probability (%, ±90% compatibility limits) predicted for a 2-SD possession-to-possession change of the variable, with decisions about the magnitude of the change. Clusters of variables representing consecutively longitudinal dispersion, lateral dispersion, longitudinal position and lateral position are outlined.

Variables	Attack	Magnitude	Defence	Magnitude
Mean				
Stretch index (m)	-13, ±7	**large↓*****	18, ±10	**very large↑******
Inter-player distance (m)	-13, ±7	**large↓*****	19, ±10	**very large↑******
Stretch index longitudinal (m)	-12, ±7	**large↓*****	19, ±10	**very large↑******
Length (m)	-12, ±7	**large↓*****	19, ±10	**very large↑******
Surface area (m^2)	-6, ±7	moderate↓**	15, ±9	**large↑*****
Width (m)	0, ±7	trivial	-2, ±9	trivial
Stretch index lateral (m)	-1, ±7	trivial	-2, ±9	trivial
Width per length ratio	8, ±7	moderate↑**	-10, ±9	moderate↓**
Centroid longitudinal (m)	17, ±8	**very large↑******	-11, ±9	**large↓******
Centroid lateral (m)	2, ±8	small↑	-5, ±9	small↓
Variability				
Stretch index (m)	-3 ±7	small↓	10, ±9	moderate↑**
Inter-player distance (m)	-5, ±7	small↓	10, ±9	moderate↑**
Stretch index longitudinal (m)	-2, ±7	small↓	11, ±9	large↑**
Length (m)	-5, ±8	small↓	16, ±8	**large↑******
Surface area (m^2)	-5, ±7	small↓	7, ±9	moderate↑**
Width (m)	-9, ±7	large↓***	-5, ±9	small↓
Stretch index lateral (m)	-10, ±7	**large↓*****	-7, ± 9	moderate↓**
Width per length ratio	3, ±7	small↑	3, ±9	small↑
Centroid longitudinal (m)	10, ±7	**large↑*****	9, ±9	moderate↑**
Centroid lateral (m)	-10, ±7	**large↓*****	-4, ±9	small↓
Irregularity				
Stretch index	-5 ±9	small↓	-7, ±9	moderate↓
Inter-player distance	-2, ±9	small↓	-9 ±10	moderate↓**
Stretch index longitudinal	-4, ±9	small↓	-9, ±10	moderate↓**
Length	-8, ±9	moderate↓**	-10, ±9	moderate↓**
Surface area	-12, ±9	large↓***	-7, ±10	moderate↓
Width	-3, ±8	small↓	-11, ±10	moderate↓**
Stretch index lateral	-4, ±8	small↓	-13, ±10	large↓***
Width per length ratio	9, ±8	moderate↑**	-5, ±10	small↓
Centroid longitudinal	-21, ±8	**very large↓******	-2, ±10	trivial
Centroid lateral	6, ±8	moderate↑	-8, ±11	moderate↓

↑, increase; ↓, decrease.

Magnitudes for all predictors except match identity are based on the following thresholds for changes in the probability of scoring: <2.0, trivial; 2.0-6.1, small; 6.1-11, moderate; 11-16, large; 16-26, very large; >26 extremely large. Thresholds for match identity are half these values.

Reference-Bayesian likelihoods of substantial change: *possibly; **likely, ***very likely, ****most likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

Table 5.4. Effects of collective tactical variables of the **midcourts** sub-group on the probability of scoring at the end of a possession after adjustment for the predictors shown in Table 5.1. Data are the change in the probability (%, ±90% compatibility limits) predicted for a 2-SD possession-to-possession change of the variable, with decisions about the magnitude of the change. Clusters of variables representing consecutively longitudinal dispersion, lateral dispersion, longitudinal position and lateral position are outlined.

Variables	Attack	Magnitude	Defence	Magnitude
Mean				
Stretch index (m)	2, ±7	small↑	9, ±9	moderate↑**
Inter-player distance (m)	1, ±7	trivial	8, ±9	moderate↑**
Stretch index longitudinal (m)	4, ±7	small↑	15, ±9	**large↑*** **
Length (m)	2, ±7	small↑	11, ±9	large↑***
Surface area (m²)	1, ±7	trivial	6, ±9	moderate
Width (m)	-3, ±7	small↓	-6, ±9	moderate↓
Stretch index lateral (m)	-4 ±7	small↓	-5, ±9	small↓
Width per length ratio	-1, ±7	trivial	-12, ±9	**large↓*** **
Centroid longitudinal (m)	17, ±8	**very large↑**** **	-24, ±9	**very large↓**** **
Centroid lateral (m)	5, ±7	small↑	-4, ±9	small↓
Variability				
Stretch index (m)	5, ±7	small↑	4, ±9	small↑
Inter-player distance (m)	4, ±7	small↑	3, ±9	small↑
Stretch index longitudinal (m)	7, ±7	moderate↑**	7, ±9	moderate↑
Length (m)	3, ±7	small↑	4, ±9	small↑
Surface area (m²)	0, ±7	trivial	2, ±9	trivial
Width (m)	-8, ±7	moderate↓**	-3, ±9	small↓
Stretch index lateral (m)	-9 ±7	moderate↓**	-3, 9	small↓
Width per length ratio	2, ±7	small↑	-12, ±9	large↓***
Centroid longitudinal (m)	1, ±7	trivial	-11, ±10	large↓**
Centroid lateral (m)	-8, ±7	moderate↓**	-9, ±9	moderate↓**
Irregularity				
Stretch index	-18, ±8	**very large↓**** **	-7, ±10	moderate↓
Inter-player distance	-17, ±8	**very large↓**** **	-6, ±11	moderate↓
Stretch index longitudinal	-22, ±9	**very large↓**** **	-13, ±10	large↓***
Length	-18, ±9	**very large↓**** **	-6, ±10	small↓
Surface area	-14, ±8	**large↓*** **	-4, ±10	small↓
Width	-9, ±8	moderate↓**	-13, ±10	large↓***
Stretch index lateral	-8, ±8	moderate↓**	-12, ±10	large↓***
Width per length ratio	9, ±8	large↑***	20, ±11	**very large↑**** **
Centroid longitudinal	-1, ±8	trivial	-17, ±10	**very large↓*** **
Centroid lateral	-5, ±8	moderate↓	2, ±11	small↑

↑, increase; ↓, decrease.

Magnitudes for all predictors except match identity are based on the following thresholds for changes in the probability of scoring: <2.0, trivial; 2.0-6.1, small; 6.1-11, moderate; 11-16, large; 16-26, very large; >26 extremely large. Thresholds for match identity are half these values.

Reference-Bayesian likelihoods of substantial change: *possibly; **likely, ***very likely, ****most likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

Table 5.5. Effects of collective tactical variables of the **defenders** sub-group on the probability of scoring at the end of a possession after adjustment for the predictors shown in Table 5.1. Data are the change in the probability (%, ±90% compatibility limits) predicted for a 2-SD possession-to-possession change of the variable, with decisions about the magnitude of the change. Clusters of variables representing consecutively longitudinal dispersion, lateral dispersion, longitudinal position and lateral position are outlined.

Variables	Attack	Magnitude	Defence	Magnitude
Mean				
Stretch index (m)	5, ±7	small↑**	-22, ±9	**very large↓********
Inter-player distance (m)	5, ±7	small↑**	-23, ±9	**very large↓********
Stretch index longitudinal (m)	11, ±7	large↑***	-18, ±9	**very large↓********
Length (m)	11, ±7	**large↑******	-18, ±9	**very large↓********
Surface area (m²)	1, ±7	trivial	-18, ±9	**very large↓********
Width (m)	-13, ±7	**large↓********	-10, ±8	moderate↓**
Stretch index lateral (m)	-13, ±7	**large↓********	-11, ±9	moderate↓***
Width per length ratio	-12, ±7	**large↓******	7, ±9	moderate↑
Centroid longitudinal (m)	10, ±8	moderate↑**	-29, ±10	**extremely large↓********
Centroid lateral (m)	1, ±8	trivial	-5, ±9	small↓
Variability				
Stretch index (m)	1, ±7	trivial	6, ±9	small↑
Inter-player distance (m)	2, ±7	small↑	5, ±9	small↑
Stretch index longitudinal (m)	-1, ±7	trivial	12, ±9	large↑***
Length (m)	2, ±7	trivial	9, ±9	moderate↑**
Surface area (m²)	-1, ±7	trivial	-11, ±9	large↓***
Width (m)	-11, ±7	**large↓******	-11, ±9	large↓***
Stretch index lateral (m)	-10, ±7	**large↓******	-12, ±9	**large↓******
Width per length ratio	-2 ±7	small↓	-1, ±9	trivial
Centroid longitudinal (m)	-6, ±7	moderate↓**	31, ±11	**extremely large↑********
Centroid lateral (m)	-4, ±7	small↓	-9, ±9	moderate↓**
Irregularity				
Stretch index	-5, ±8	small↓	-2, ±11	small↓
Inter-player distance	-6, ±8	moderate↓	-2, ±11	trivial
Stretch index longitudinal	4, ±8	small↑	-6, ±11	small↓
Length	-1, ±8	trivial	-4, ±11	small↓
Surface area	-6, ±8	moderate↓	10, ±10	moderate↑**
Width	-9, ±9	moderate↓**	15, ±11	**large↑******
Stretch index lateral	-9, ±9	moderate↓**	16, ±11	moderate↑**
Width per length ratio	-2, ±8	small↓	0, ±10	trivial
Centroid longitudinal	-11, ±8	**large↓******	14, ±10	**large↑******
Centroid lateral	11, ±8	**large↑******	37, ±12	**extremely large↓********

↑, increase; ↓, decrease.

Magnitudes for all predictors except match identity are based on the following thresholds for changes in the probability of scoring: <2.0, trivial; 2.0-6.1, small; 6.1-11, moderate; 11-16, large; 16-26, very large; >26 extremely large. Thresholds for match identity are half these values.

Reference-Bayesian likelihoods of substantial change: *possibly; **likely, ***very likely, ****most likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

(large very likely decreases) and of means of the defenders sub-group (likely or very likely small to large increases). Increases in score probability for the opposition team (defence) were displayed by the team, forwards sub-group, and midcourts sub-group when the mean of longitudinal dispersion variables increased by 2 SD. The team and forwards sub-group also displayed similar effects for increases to the variability of the variables.

Effects of increasing the irregularity of longitudinal dispersion of the team on home-team and opposition-team possessions were large to very large decreases in the probability of scoring. The midcourts sub-group also displayed a very large decrease in the probability of scoring at the end of home-team possessions.

5.4.3 Effects of lateral dispersion

Effects of increasing the team and defenders sub-groups mean lateral dispersion on home-team and opposition possessions were associated with small to very large decreases in the probability of scoring. The team also displayed large decreases in scoring probability, associated with increases in the width per length ratio. Inspection of the predicted means of the quintiles showed that the negative effect of variability was due mainly to low probability of scoring for larger and largest values (fourth and fifth quintiles) of variability. The forwards and midcourts sub-group displayed similar effects for the variability of large decreases on attacking possessions.

Effects on scoring probability of increasing the irregularity of lateral dispersion of home-team and opposition possessions were mostly unclear for the team. The team did display for increases of the width per length ratio irregularity large increases of score probability on home-team and opposition team possessions. For sub-groups, the defenders displayed large increases of score probability for opposition possessions and the forwards and midcourts sub-groups displayed moderate to large decreases. On home team possessions less precise moderate effects were found for the defenders and midcourts sub-groups.

5.4.4 Effects of longitudinal positioning

Effects of increasing the team and all sub-groups mean longitudinal positioning on home-team possessions were associated with moderate to very large increases in the probability of scoring. For increases of variability of home-team possessions, the forwards sub-group displayed large increases in score probability.

Increases in the team and all sub-groups' mean longitudinal positioning for opposition possessions were associated with large to extremely large decreases in the opposition's probability of scoring. Increases in variability for the team and defenders sub-group displayed large to extremely large increases in the probability of scoring.

Effects on scoring probability of increasing the irregularity of longitudinal positioning of home-team possessions were large to very large decreases for the forwards and defenders sub-groups. For opposition possessions, the team and midcourts sub-group displayed large to very large decrease in score probability, and the defenders sub-group a large increase.

5.4.5 Effects of lateral positioning

For lateral court positioning on home-team possessions, mainly trivial to moderate unclear effects were found for the mean, variability and irregularity, with the exception of forwards sub-group displaying large decreases in score probability with increases of variability, and defenders sub-group displaying large increases with increases in irregularity. Inspection of quintiles revealed only one important non-linear effect: an inverted U representing lowest probabilities of scoring for lowest and highest mean values of lateral positioning.

On opposition possessions, mostly small unclear effects for lateral positioning were found; the only clear effect was the defenders sub-group displaying extremely large decreases of score probability when irregularity was increased.

5.4.6 Effects of weakly informative priors

The effect that showed the greatest weakly informative prior shrinkage was the mean of the team inter-player distance: with a minimally informative prior, the change in scoring probability was 11.0 ±8.1 % (mean ±90% compatibility limits; Table 5.2); after shrinkage with a weakly informative prior, the effect became 10.1 ±7.6 %, which obviously represents negligible shrinkage. A few effects with adequate precision at the 99% level were reduced to the 90% level with the weakly informative prior.

5.5 DISCUSSION

On defence, the effects are also averaged across all the other teams when they played the case-study team. The effects will be discussed in terms of the practical application of changes in the collective tactical variables that are associated with an increased probability of scoring at the end of each possession. However, the effects are only associations, and their efficacy needs to be supported by an experimental study.

For the predictors included and adjusted for in the model, the negative effects for possession duration imply that prolonging possession on attack, especially at the beginning of the possession is an important focus for attacking teams, whereas on defence the team should aim for a turnover as soon as possible. These strategies are consistent with coach sentiments about tactical features underpinning group behaviours in netball (Coombe et al., 2020b) and align with the findings, ranking possession time as having the highest association with match outcome (Ofoghi et al., 2021).

The decline in scoring probability associated with a leading score state on home-team possessions suggests the home team unfavourably shifted their behaviour when they were in a leading position. However this effect should not be interpreted in isolation: there was an equally large positive effect of scoring probability associated with elapsed match time, implying that the home-team counteracted the effect of score state towards the end of the match, potentially as netball matches tend to evolve from uniformity between teams during first halves to larger discrepancies in significant variables between teams in the second half (Ofoghi et al., 2021). Additionally, shifts in tactical behaviours and intensity associated with score state are known to affect the pace of soccer matches and thereby affect player coordination (Sampaio et al., 2014b, Gonçalves et al., 2018).

Increased score probability was also associated with elapsed match time for the home team on attack, indicating either that the opposition defence faltered or that the tactics employed by the home team eventually "compounded" as the match progressed. Effects were unclear for team-strength difference and season trend; these effects had the greatest uncertainty (width of the compatibility intervals) due to the limited number of matches, so only very- or extremely-large effects would have been clear. The limited number of matches also explains why the effects for match identity (differences between match means) were unclear, but the very large observed values imply that there are important factors differing from match to match that have not been included in this study; for example, teams can deploy differing game styles depending on their opposition (Croft et al., 2018).

The remainder of this discussion concerns the effects of the collective tactical variables on scoring. In Chapter 4, the three correlations between the measures (mean, variability and irregularity) of each variable within a cluster (longitudinal dispersion, lateral dispersion, longitudinal positioning and lateral positioning) were at best modest (less than

±0.4), with the exception of the correlations between variability and irregularity (approximately -0.6). It follows that only the large and opposite effects for variability and irregularity have a simple explanation in terms of the large negative correlations between these measures. All the other effects of the mean, variability and irregularity are presumably to some extent independent of each other and require independent explanations.

5.5.1 Longitudinal Dispersion

The increase in score probability for the home team associated with an increase in the mean longitudinal dispersion has a simple explanation: as the team expands lengthwise, some of the attacking players move closer to the goal, increasing the chances of scoring. There is a similar effect of the home team dispersion on opposition scoring, presumably because the home team on defence disperses longitudinally as the opposition progresses the ball towards their goal. Clemente et al. (2018b) have described a similar phenomenon in soccer. Videos (Figure 5.1) were inspected to understand the increases in score probability associated with greater variability of longitudinal dispersion of the home-team and opposition team; players were observed to make driving runs longitudinally, resulting in quicker and more direct avenues to goal. Direct and quick possessions have been suggested as a preferred style of play, allowing stronger teams more chances to insert their dominance, whereas fewer possessions can contribute to a reduction in match win probability for stronger teams (Bake et al., 2021).

Figure 5.1. Video capture of attacking players making longitudinal drives directly to circle edge. Left capture displays starting positions, red arrows represent driving (movement) direction, right capture displays final position of players.

Longitudinal dispersion resulting in proximity to the attacking goal is also an important determinant for positional sub-groups, as shown by decreases in score probability for the forwards sub-group and increases for the defenders sub-group associated with increased longitudinal dispersion; these effects make sense when considering how the positions of players evolve during possessions that result in scoring. On opposition possessions, video (Figure 5.2) analysis revealed behaviours for the forward sub-group are similar to those for the team: with increased mean longitudinal dispersion, players were dispersed towards the opposition's goal.

It was apparent in videos (Figure 5.3) that the decreased scoring probability associated with more irregular behaviours of the team and midcourts sub-group during home-team possessions was due to the defence impeding the movement of the attacking players; in coaching terms, a direct style of attack is desirable. Previous netball research has

Figure 5.2. Video capture of forward sub-group longitudinally dispersed during defence possession. Red arrow represents the distance between forward players in the longitudinal axis.

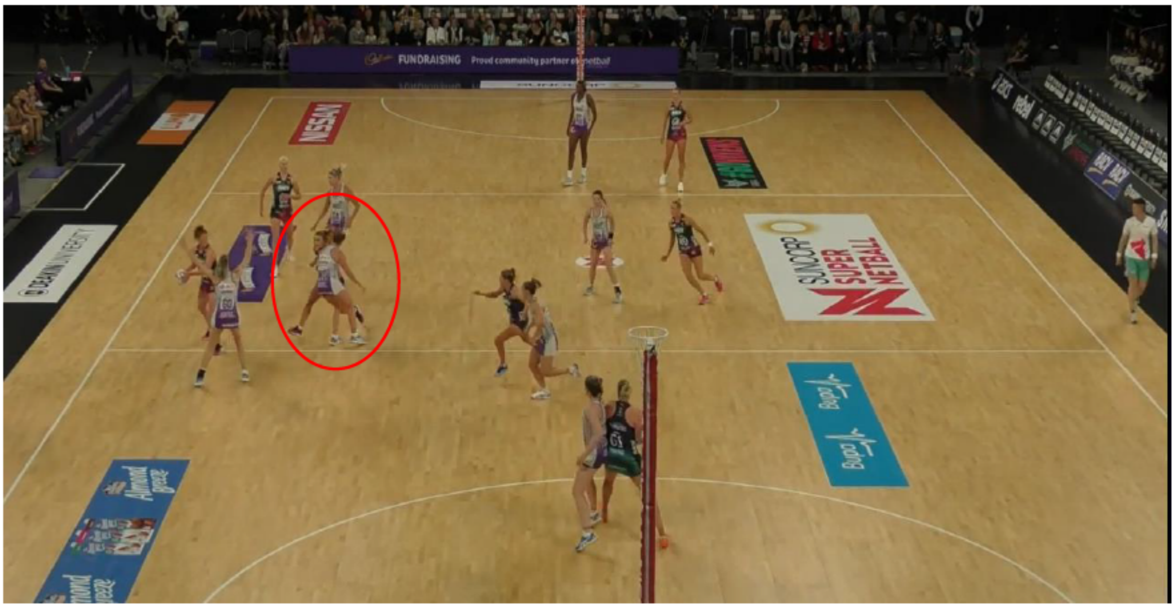


Figure 5.3. Video capture of a defender impeding an attackers direct run down the court, highlighted by the red circle.

highlighted that fewer passes from the start of a possession in the centre of the court are characteristic of structured and preplanned passing chains (Browne et al., 2019), in which the attacking team is in control of the movement sequences. For defending players aiming to gain control, attention on disrupting the attacker's positioning and thereby increasing their movement irregularity would limit direct possessions to the shooting circle (Coombe et al., 2020b, Croft et al., 2020). For opposition possessions, assuming that home-team irregularity would be mirrored by opposition irregularity, the decreases in the opposition's probability of scoring associated with more home team irregularity supports the argument that defenders need to focus on preventing direct access to the opposition's goal.

5.5.2 Lateral Dispersion

The negative effects of means of lateral dispersion on scoring probability in home-team and opposition team possessions are readily explained by closer lateral distances between attacking players allowing for shorter and safer passes. Increased lateral dispersion when the attacking team is closer to the goal could also reduce scoring probability by limiting passing options and increasing court imbalances (Coombe et al., 2020b); the increased dispersion could be due to the defenders dictating the movement of the ball (Browne et al., 2019) and unsettling the attackers (Leite et al., 2014).

The effects for the team's width-per-length ratio variability on attack shows that it is favourable to avoid the largest values for lateral dispersion (avoid edges of the court), as they were associated with the lowest probability of scoring. On defence, the increases in lateral dispersion irregularity associated with increased opposition scoring support the finding of Coombe et al. (2020b), that it is important for the defenders sub-group to remain compact and guard the middle channel of the court. Analysis of the videos (Figure 5.4) showed that increases in the lateral irregularity of the defenders sub-group reflected

Figure 5.4. Video capture of defender detached from their direct opponent. Red arrow represents opposing attacker the defending player is directly guarding.

more risky tactical behaviours of playing, in which some defenders detached from their direct opponent to confuse the space. However, for the forwards and midcourts sub-groups on defence, increased lateral irregularity was associated with decreased scoring probability, and video analysis indicated that these sub-groups should focus on increasing their irregularity through "actively defending". The large negative effects of increased team width-per-length ratio irregularity, was not revealed the in the inspection of the videos, unfortunately, the existing publications with the effects of irregularity do not explain the practical interpretation of this measure in netball.

5.5.3 Centroid Longitudinal

All mean longitudinal positioning effects for the home and opposition teams were simply related to being closer to the attacking goal on attack and defending goal on defence. The positive effects of increased variability of longitudinal positioning displayed by the forwards sub-group on attack could possibly be from repeated quick and direct ball movements between the middle of the court to the shooting circle. On defence, videos showed that the increased score probability associated with the team's and defenders sub-groups greater longitudinal positioning variability reflected movement that mirrored the opposition team's movement and highlighted an inability to prevent the opposition from gaining direct access to the shooting circle.

For the forwards and defenders sub-groups on attack, the negative effects of irregularity of longitudinal positioning were apparent in videos as possessions in which players from both sub-groups were required to make multiple drives when they were restricted from linear movement towards the scoring circle. On defence, the negative effects for the irregularity of the midcourts sub-group were due (in videos) to these players dictating opposition movement longitudinally as seen in Figure 5.3; being able to dictate movement has been rated as an "important" defensive tactical behaviour by elite coaches (Coombe et al., 2020b). The positive effect for the defenders sub-group on defence was due to them being unable to guard space as a unit, instead of reacting and trailing their opponents' movements. These differences between midcourts and defenders sub-groups are consistent with players of a sub-group being more attuned with affordances and goals of their specific sub-group (Gonçalves et al., 2014, Santos et al., 2018).

5.5.4 Centroid Lateral

The inverted-U pattern for the mean lateral positioning of the team on attack indicates that staying in the middle of the court may be more favourable for scoring, as it can minimize undesirable technical actions (bad hands, bad pass, turnover) which are associated with match outcome (Ofoghi et al., 2021). The positive effect of irregularity of the defenders sub-group on attack was apparent in videos (Figure 5.5) as continual hectic shifts in positioning on the attacking transverse line, to provide passing options.

Figure 5.5. Video capture of defenders during attacking providing passing options on the transverse line.

On defence, the extremely large negative effect of irregularity for the defenders sub-group was apparent in videos (Figure 5.6) as the opposition attackers had increased passing difficulty when they were pushed to the edges of the court; this defensive strategy has been highlighted by Coombe et al. (2020b).

5.5.5 Limitations and Future Research Directions

All of the trivial effects and many of the small effects in this study were unclear, especially for the effects derived from between-match predictors, owing to a limited sample of only seven matches. Many more matches and possessions are needed to estimate the effects of these variables on possession outcome. Further research with more matches is also required to get adequate precision for the effects of match mean values of the collective tactical variables on possession outcome and to identify any other factors, such as game styles not represented by the collective tactical variables that could account for the very large unexplained variance in scoring probability between matches.

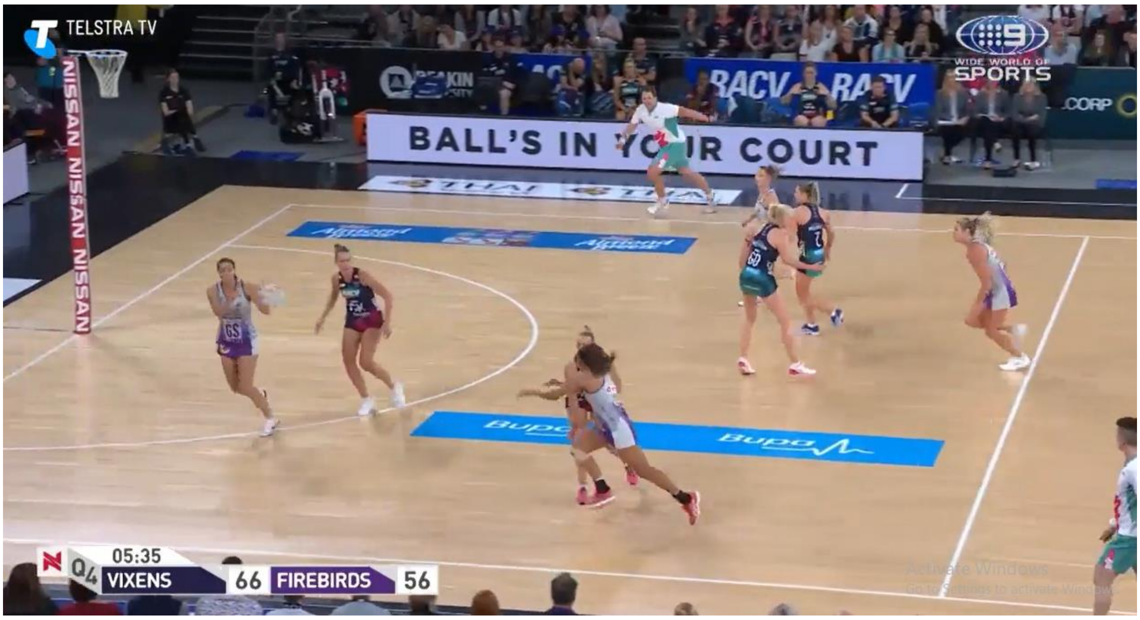


Figure 5.6. *Video Capture of opposition attackers playing close to the edges of the court.*

The approach taken here was to identify the effects of collective tactical variables with good evidence of benefit or harm about point-scoring, then to examine videos to determine the practical interpretation and application of the effects. The reader should consider that the following discussion refers to a case study for a particular netball team, with the ensuing interpretation of the effects on attack representing outcomes averaged across all the other teams in the league. However, the effects in this observational study are only associations, so further research of an experimental nature is required to determine if the effects do provide valuable strategies for a netball team. It would be unrealistic to expect that a 2-SD change could be achieved for every possession, and in any case, attempting to change the measure in every possession would almost certainly prompt the opposition to implement some type of countermeasure. Instead, the coach could implement a strategy whereby the team attempts to modify different measures at different stages of the match. The researcher or performance analyst could then determine the extent to which the measures change, and with enough data before and after the implementation of the strategy during a season, the effect of the strategy on scoring probability and on match outcomes could be determined. It is not known the extent to which these collective tactical variables can be changed in matches, it is not known, and needs further investigation, those variables showing moderate or larger effects would still be potentially beneficial if only a change of 1SD or only half a SD can be implemented.

5.5.6 Conclusion

By modelling the scoring probability associated with contextual factors and changes in collective tactical variables, insights into potentially favourable behaviours and styles of play have been revealed. Large effects of possession duration, score difference and elapsed match time highlight the importance of accounting for contextual factors and provide specific insight about the benefits of maintaining possessions at the beginning of possessions. Amongst the behaviours related to increased scoring were proximity of attacking players to the goal, longitudinal dispersion and avoidance of the wide edges of the court.

5.5.7 Practical Applications

- Extremely short possession durations are associated with a decreased score probability
- Proximity to goal is highly associated with an increased score probability.
- Direct styles of play are associated with reduced irregularity of collective tactical behaviours associated with increased score probability.
- Lateral dispersion and lateral movements are associated with a decreased score probability.

CHAPTER 6. STUDY 4 – COLLECTIVE TACTICAL VARIABLES IN ELITE NETBALL TRAINING. DIFFERENCE BETWEEN SMALL-SIDED GAME CONDITIONS 6V6, 5V5 AND 4V4.

6.1 ABSTRACT

Small-sided games (SSG) are a training modality in many team sports, and their utility can be investigated via collective tactical variables derived from positions of players. The aim of this study was to investigate differences in collective tactical variables of the four attacking and the four defending elite netball players in three SSG conditions: 4v4, 5v5 (one extra player) and 6v6 (two extra players, one less than in competitions). A local positioning system provided positional data of the original eight players, which were used to estimate possession mean, variability (standard deviation) and irregularity (normalised approximate entropy) of seven collective tactical variables of the attacking and defending teams. Two, 20-min SSGs for each condition were analysed using a linear mixed model to compare standardised effects of the SSG condition and to adjust for and estimate the effects of possession duration, SSG time and possession outcome. The irregularity of width per length ratio of the four attacking and four defending players was greatest in 4v4, the attackers' variability was greatest for inter-player distance and length in 5v5, while the four attacking players had the smallest mean surface area in 6v6; differences in restriction of players' movements in the three conditions can explain these findings. Adjustment effects were generally substantial in 5v5, where increased attacking team elongation throughout a game and increased defending team dispersion variability during scoring possessions highlight the dynamic collective behaviours that can be elicited in the 5v5 condition. These findings can support coaches when planning the periodization of tactical training.

6.2 INTRODUCTION

Small-sided games (SSGs) are a popular training modality in team invasion sports, due to their ability to elicit physical, technical and tactical outputs similar to that of full match conditions (Davids et al., 2013, Fernández-Espínola et al., 2020, Clemente et al., 2021). Small-sided games are usually restricted or modified in several ways, such as; spatial restriction, player imbalances, player expertise levels and rule modifications to provide players with dynamic affordances that mirror the complex nature of full-match conditions (Clemente et al., 2020a). The complexity that SSGs can provide is especially pertinent for training tactical behaviours of players, as replication of match behaviours in isolated drills can fail to capture the interactions between players and the emergence of collective player behaviours (Aguiar et al., 2012, Olthof et al., 2018). From a theoretical perspective, SSGs provide an introduction to changing affordances and the ability to auto-organize with team mates in an acute scale. Also providing the ability to build global team behaviours by combining isolated sub-groups collective behaviours into team collective behaviours. The theoretical basis therefore contains several links between each theories, feeding into one another. Affordances based theories explaining player's opportunities for actions are linked to the subsequent behaviours of their team mates from coordination at a global level (all players). Additionally auto-organization behaviours cross both sub-group and team domains with intricacies within both.

To capture and analyse the collective behaviours of players in SSGs, research has used collective tactical variables to measure the spatio-temporal relationships of players and teams (Duarte et al., 2013, Aguiar et al., 2015, Clemente et al., 2018b). Collective tactical variables such as width, length, surface area and inter-player distance provide insight into the dispersion of players in relation to one another and in reference to environmental constraints (Coito et al., 2020, Goes et al., 2020, Lord et al., 2020). At the group and team levels, the centroids and length-per-width ratio have been used to investigate the organisation of players, their positioning, and how they contract and expand to the affordances they encounter in different SSG conditions (Frencken et al., 2011, Folgado et al., 2014b, Olthof et al., 2015). Research has found increasing the number of player may increase collective tactical variable regularity (Ric et al., 2016), suggested previously to be an indication of better positional organization (Aguiar et al., 2015). However, this may be an artefact of the aggregate calculations whereby individual player influences on team collective tactical variables diminish as more players are included in the calculations, owing to the less relative space and higher player density (Goes et al., 2020, Olthof et al., 2018). In SSGs where pitch dimensions are restricted, several studies have found these smaller formats to decrease inter-player distances, relative space (Clemente et al., 2018b, Olthof et al., 2018) and the collective tactical variables associated with defensive delays (Travassos et al., 2014, Clemente et al., 2020a). Conversely, larger pitch dimensions provided players greater relative space (Silva et al., 2014a, Olthof et al., 2018) and also lead to increased variability of movements (Clemente et al., 2020a). Additionally, factors such as fatigue, game length and game status have also been suggested to influence collective tactical variables in SSGs (Clemente et al., 2013b).

One sport that collective tactical variables have yet to be investigated in is netball. For more than a decade, netball has been played professionally in a number of countries and is one of the most popular women's sport in the world (McLean et al., 2019, Whitehead et al., 2021). Netball is a fast-paced team sport (due to players only being allowed to hold the ball for three seconds) played by two teams of seven players, with players changing direction on average every 4.1s (van Gogh et al., 2020). Court restrictions placed on each position further enhance the dynamics and complexity of the sport (King et al., 2018, van Gogh et al., 2020), whereby each position has mostly predefined roles but must also work collectively to create movement positive affordances for their teammates (Coombe et al., 2020b). Due to the unique positional restrictions inhibiting player movement in netball (van Gogh et al., 2020), research has predominately focused on injuries (Smyth et al., 2020, Whitehead et al., 2021) and compared the physical match and training characteristics between positions (Fox et al., 2013, Chandler et al., 2014b, Graham et al., 2020, Simpson et al., 2020a, Brooks et al., 2021). Thus, research is still limited on collective behaviours of netball players, especially in reference to team and player positioning (Croft et al., 2020), which is highlighted by a recent team sport systematic review showing no collective team behaviour literature in netball (Lord et al., 2020), and a netball sport science systematic review displaying only 4.7% of studies included technical or tactical aspects (Whitehead et al., 2021). Of the existing research on tactical aspects in netball, transcribed recordings of coach conversations during matches showed they discussed tactical and technical elements in a game 695 times (Croft et al., 2020), while a survey of netball "experts" revealed tactical behaviours as an "important" category relating to netball performance (Coombe et al., 2020b). These studies show tactical behaviours are an important component in netball performance and match outcome (McLean et al., 2019, Coombe et al., 2020b).

Similarly to other team sports, netball coaches also utilise SSGs to replicate the demands of competition (Simpson et al., 2020a, Brooks et al., 2021). Research has identified workloads in SSGs as being lower than during games, suggesting coaches may use SSG's to develop technical and tactical skills instead of employing them as a conditioning tool (Simpson et al., 2020a). Due to court restrictions of netball positioning, SSGs in netball are generally focused on the four attacking players of the attacking team (Goal Shooter, Goal Attack, Wing Attack and Centre) and four defending players of the defending team (Goal Keeper, Goal Defender, Wing Defence and Centre), with any additional players who cannot enter the attacking third used as axillary support along the attacking transverse line. Manipulating the number of supporting players can provide stimulus pertaining to passing options, movement options and collective affordances relating to team tactics. However, until now no research has investigated the tactical behaviours present in different netball SSG conditions. Therefore, this study aimed to compare collective tactical variables in three different SSG conditions for four attackers (Goal Shooter, Goal Attack, Wing Attack and Centre) and four defenders' (Goal Keeper, Goal Defender, Wing Defence and Centre). Modification of SSG conditions will pertain to attacking possessions only (beginning at the centre pass) and either the base number of players (4v4), one additional player per team (5v5) or two additional players per team (6v6), with the 6v6 being most representative of a full match condition (as the missing seventh player for each team can have little influence on the SSG).

6.3 METHODS

6.3.1 Experimental overview and participants

Positional data during three SSG conditions (4v4, 5v5 and 6v6) were collected for an elite netball team participating in the Suncorp Super Netball League. In total, six 20-min SSGs (two for each of the three conditions) were played, consisting of two teams; four attacking players (Goal Shooter, Goal Attack, Wing Attack and Centre) and four defending players (Goal Keeper, Goal Defence, Wing Defence and Centre). The three conditions (Figure 6.1) contained either two additional players per team (6v6), one additional player per team (5v5) or no additional players per team (4v4); positional data for additional players was not used in the analysis, instead included in the study as SSG manipulation conditions. Teams were divided by coaches to represent the strongest quality players per position to balance the teams, players also followed official netball match rules (International-

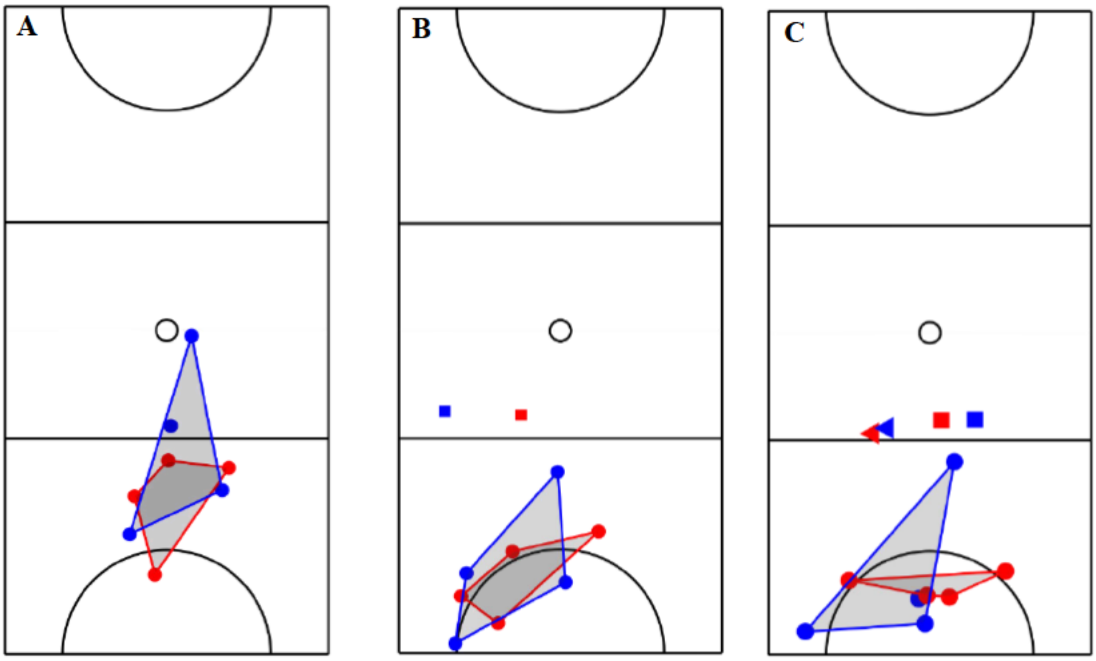


Figure 6.1. Illustration of player positioning in the three small-sided game conditions; 4v4 (A), 5v5 (B) and 6v6 (C). Attacking team players (red) and defending team players (blue) positions are shown for the original four attackers' and original four defenders' (●), one additional player per team (■) and two additional players per team (◀). Grey shading represents each team's surface area. Solid grey lines represent court markings.

Netball-Federation, 2020). Small-sided games were played in the attacking and midcourt thirds of a netball court with dimensions 20.33 x 15.25 m, in an arena fitted with the ClearSky T6 Local Positioning System (LPS) (Catapult, Australia). The LPS was calibrated to the specifications of the court and arena, ensuring optimal coverage of the court and placement of the nodes to avoid metal interference. All participants received verbal and written information regarding the procedures of the study and provided written consent to participate in the study. The study was approved by the researchers' institutional ethics committee.

6.3.2 Data Collection

Positional data were collected for all participants using the LPS, captured at 10 Hz via a receiver tag housed in an internal stitched pouch that was positioned between the participants' shoulder blades. The LPS used in the current study has previously been shown to have acceptable validity for capturing the distance between players, with Hodder et al. (2020) reporting a root mean square error of 0.20 ± 0.05 m for inter-unit distance. Small-sided game event data was collected post-event using video analysis software Sportscode version 11.3.0 (Hudl Sportscode, Nebraska, United States of America), by the first author. Small-sided game event data consisted of attacking possessions, beginning with the attacking team starting from a centre pass and ending in either an attacking goal or turnover. Possessions, where the four original defending players had possession, were not collected in this study as the aim pertained to the analysis of centre passes instead of transitions. Game time was also collected for the start of each possession, the possession duration and the possession outcome, either a score or turnover for the attacking team, with any possession not ending in a score or turnover, recorded as "other".

6.3.3 Data Processing

Initial data processing began with syncing and merging of player position and event data using R statistical software (R, Vienna, Austria), version 4.0.3. First, event data was converted to milliseconds to place them on the same time scale as position data and then synced to a common starting point. The starting point was adjusted to a tenth of a second precision via plotting animations of player positioning (Aguiar et al., 2017). Seven collective tactical variables for the four attackers and four defenders were calculated every 0.1 s for each possession. The additional players in the 6v6 and 5v5 were not included in the calculation of collective tactical variables. The 5th and 6th additional players are constrained to the attacking transverse, thus are unable to enter the attacking third, therefore these players roles are to act as axillary support for additional passing options and spacing constraints. For this reason, these players are excluded from collective tactical variables calculations, to avoid skewing variables output owing to their minimal movements and influence on the SSG. The collective tactical variables used and their definitions are as follows: inter-player distance, mean distance between players on the same team; length, distance between the two most longitudinal players on the team (Frencken et al., 2011); surface area, covered space by the players of one team (m^2) (Barnabé et al., 2016); width, distance between the two most lateral players on the team (Frencken et al., 2011); width per length ratio, the ratio between the width and length values, values between 0-1 indicate greater width, while values >1 indicate greater length; centroids, average position of a team longitudinally or laterally (Frencken et al., 2011). A total of 251 possessions was used in the analysis, with an average duration of 21.6 ± 11.3 s (mean ± SD).

Additionally, three measures were calculated for each collective tactical variable, per possession: mean, standard deviation (SD) and normalised approximate entropy (ApEn). Approximate entropy is a measure used to assess the regularity in nonlinear and complex systems (Pincus, 1991, Fonseca et al., 2012a). It is a popular measure in sports analysis, as it can display the repeatability or predictability within a data series, and has been suggested to reveal information about collective behaviours associated with coordination and self-organisation (Gonçalves et al., 2019, Pincus, 1991). Approximate entropy has three input parameters (m, r and N), which are used to set the length of the sequence (m), the tolerance factor (r) and the time series (N). Following recommendations from Stergiou et al. (2004) where an explanation of input parameters can be found, parameter m (length of segment) was set to 2, parameter r (tolerance factor) was set to 0.2 and parameter N was the length of the time series. Normalisation of approximate entropy was used to account for the differing possession lengths in the data, calculated by dividing the ApEn value by the mean ApEn of 100 scrambled time series, known as the ratio-random method (Fonseca et al., 2012a).

6.3.4 Statistical Analysis

The analysis aimed to estimate changes in the mean of each of the three measures (mean, SD, ApEn) for each of the collective tactical variables between SSG conditions for the attacking and defending teams separately. Analyses were conducted with the Statistical Analysis System (Studio On Demand for Academics, version 9.4, SAS Institute, Cary NC). Each of the seven collective tactical variables was log-transformed for further analysis (with the exception of the mean for centroid longitudinal and lateral, for which log-transformation would not be appropriate). Pearson correlations between all the collective tactical variables were first derived to assess the similarity of variables in the three SSG conditions. For presentation purposes, the set of three correlations (for the mean, standard deviation and approximate entropy) are shown for each pair of collective tactical variables in a correlation matrix for the attacking and defending teams. The order of the variables in each correlation matrix was changed to reveal clusters of similar variables (higher correlations within clusters than between clusters). Regardless of the correlations, each variable was subsequently analysed as the dependent in a general linear mixed model (Proc Mixed in SAS).

The fixed effects in the model were game type (to estimate mean values of the collective tactical variables in the three SSG conditions) and game type interacted with each of the following variables (to estimate their modifying effect in each SSG condition): possession duration (linear numeric, log-transformed), possession outcome (attacking team score or turnover) and game time (linear numeric). Visual inspection of plots of residuals vs predicted and residuals vs predictors showed no obvious evidence of non-uniformity and non-linearity of effects. Possession duration, possession outcome and game time were included in the models mainly for adjustment, so comparisons of the adjustment effects between the SSGs are not presented. The magnitudes of the effects of the nominal predictors (game type, possession outcome) were evaluated for the mean possession duration (back-transformed means of 24 s, 18 s and 23 s for 4v4, 5v5 and 6v6 respectively) and the middle of a 20-min SSG. The effect of possession duration was evaluated for two SDs (factor increases of 2.2, 2.7 and 2.4 for 4v4, 5v5 and 6v6 respectively), and the effect of game time was evaluated for 20 mins (representing the game trend). The random effects were game ID (to adjust for changes in means of the collective tactical variable between SSG games) and six residuals (to allow for different residual variability for each of the three SSG types for the attacking and defending teams). Data points identified by standardised residuals >4.5 (up to three of the 251 possessions) were identified as outliers and deleted before reanalysis (Hopkins et al., 2009).

Means and SDs of the collective tactical variables were derived from the mixed model: the means are back-transformed least-squares means, with SDs (the residuals) in back-transformed ± percent units (when <30%) or ×/÷ factor units (when >30%). Effects are presented in percent units with uncertainty expressed as ±90% compatibility limits (CL) when the effect and the ±90% CL were <30%; otherwise, factor effects with ×/÷90% CL are reported.

Magnitudes of effects were assessed using standardisation, where the standardising SD was the square root of the mean of all the residual variances. For those who prefer a frequentist interpretation of sampling uncertainty, decisions about magnitudes accounting for the uncertainty were based on one-sided interval hypothesis tests, according to which a hypothesis of a given magnitude (substantial, non-substantial) is rejected if the 90% compatibility interval falls outside that magnitude (Hopkins, 2020). P-values for the tests were therefore the areas of the sampling t distribution of the effect falling in the hypothesized magnitude, with the distribution centred on the observed effect. Hypotheses of inferiority (substantial negative) and superiority (substantial positive) were rejected if their respective p values ($p_{–}$ and p_{+}) were <0.05; rejection of both hypotheses represents a decisively trivial effect in equivalence testing. The hypothesis of non-inferiority (non-substantial-negative) or non-superiority (non-substantial-positive) was rejected if its p-value ($p_{N–}=1–p_{–}$ or $p_{N+}=1–p_{+}$) was <0.05, representing a decisively substantial effect in minimal-effects testing. A complementary Bayesian interpretation of sampling uncertainty is also provided when at least one substantial hypothesis were rejected: the p-value for the other hypothesis is the posterior probability of a substantial true magnitude of the effect in a reference-Bayesian analysis with a minimally informative prior (Hopkins, 2019), and it was interpreted qualitatively using the following scale: >0.25, possibly; >0.75, likely; >0.95, very likely; >0.995, most likely (Hopkins et al., 2009). The probability of a trivial true magnitude ($1–p_{–}–p_{+}$) was also interpreted with the same scale. Probabilities were not interpreted for unclear effects: those with inadequate precision at the 90% level, defined by failure to reject both substantial hypotheses ($p_{–}$>0.05 and p_{+}>0.05). Effects on magnitudes and probabilities of a weakly informative normally distributed prior centred on the nil effect and excluding extremely large effects at the 90% level were also investigated (Greenland, 2006, Hopkins, 2019). Effects with adequate precision at the 99% level ($p_{–}$<0.005 or p_{+}<0.005) are highlighted in bold in tables since these represent stronger evidence against substantial hypotheses than the 90% level and therefore incur lower inflation of error with multiple hypothesis tests.

6.4 RESULTS

6.4.1 Correlations between collective tactical variables

Correlation analysis highlighted two broad clusters of results with medium to large R-values within each cluster (see supplementary tables), and reveal two clusters of variables with generally higher correlations within clusters than between the clusters. Where there is dissimilarity of the effects in some SSG (e.g. effects of possession duration on inter-player distance, length and surface area on attack for the 5v5) the correlations between those variables are lower. For variability and entropy measures, clusters of correlations were less well defined, owing somewhat to the inverse correlations between width and WPLratio.

6.4.2 Small-sided game conditions: 4v4 vs 5v5 vs 6v6

The four original attacking players showed mostly trivial to small unclear differences in means of collective tactical variables between SSG conditions (Table 6.1), while similar differences were found for the four original defenders. The only differences in means with adequate precision at the 99% level represented the lowest value of surface area for 6v6 (possibly and likely small decreases relative to 5v5 and 4v4 respectively) (Tables 6.1-6.4). The defenders also displayed the largest mean inter-player distance and length values in the 6v6.

The differences in variability of collective tactical variables between the different SSGs were also predominantly unclear at the 99% level. There was a tendency for 6v6 to have the lowest values on attack (but only one effect was clear only at the 90% level, likely smaller than 4v4 for width) and for 5v5 to have the lowest values on defence (generally clear the 90% level and ranging from possibly to very likely smaller than 4v4 or 6v6, for inter-player distance, length, surface area and centroid longitudinal).

Table 6.1. Simple statistics provided by the mixed model (predicted mean for the middle of a game and mean possession duration; residual within-game standard deviation) for each small-sided game condition (4v4, 5v5 and 6v6) and for the attacking and defending teams. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as ×/÷ factors.

Variable	Attacking team 6v6	Attacking team 5v5	Attacking team 4v4	Defending team 6v6	Defending team 5v5	Defending team 4v4
Mean						
Inter-player distance (m)	7.7 ×/÷ 1.18	8.2 ×/÷ 1.16	7.8 ×/÷ 1.16	7.1 ×/÷ 1.22	6.1 ×/÷ 1.12	6.2 ×/÷ 1.20
Length (m)	8.7 ×/÷ 1.37	8.9 ×/÷ 1.29	8.0 ×/÷ 1.28	8.0 ×/÷ 1.35	6.6 ×/÷ 1.25	6.6 ×/÷ 1.30
Surface area (m^2)	21 ×/÷ 1.39	23 ×/÷ 1.38	23 ×/÷ 1.46	17 ×/÷ 1.41	14 ×/÷ 1.30	15 ×/÷ 1.46
Width (m)	5.3 ×/÷ 1.26	5.7 ×/÷ 1.30	6.2 ×/÷ 1.25	4.7 ×/÷ 1.35	4.6 ×/÷ 1.23	4.8 ×/÷ 1.27
Width per length ratio	0.59 ×/÷ 1.77	0.63 ×/÷ 1.77	0.69 ×/÷ 1.62	0.58 ×/÷ 1.72	0.69 ×/÷ 1.52	0.72 ×/÷ 1.48
Centroid longitudinal (m)	24 ± 1.5	23 ± 1.4	23 ± 2.2	24 ± 1.3	24 ± 1.1	23 ± 2.1
Centroid lateral (m)	7.5 ± 1.2	7.4 ± 1.1	7.5 ± 1.0	7.5 ± 1.1	7.4 ± 1.0	7.6 ± 0.91
Variability						
Inter-player distance (m)	1.2 ×/÷ 1.56	1.3 ×/÷ 1.58	1.3 ×/÷ 1.51	1.0 ×/÷ 1.68	0.74 ×/÷ 1.59	1.0 ×/÷ 1.56
Length (m)	2.3 ×/÷ 1.67	2.6 ×/÷ 1.44	2.6 ×/÷ 1.31	1.7 ×/÷ 1.67	1.4 ×/÷ 1.48	2.0 ×/÷ 1.48
Surface area (m^2)	7.6 ×/÷ 1.49	9.0 ×/÷ 1.64	9.2 ×/÷ 1.64	5.8 ×/÷ 1.83	4.0 ×/÷ 1.75	5.5 ×/÷ 1.70
Width (m)	1.4 ×/÷ 1.62	1.4 ×/÷ 1.66	1.8 ×/÷ 1.41	1.2 ×/÷ 1.60	1.1 ×/÷ 1.59	1.2 ×/÷ 1.49
Width per length ratio	0.99 ×/÷ 2.81	0.97 ×/÷ 2.51	0.95 ×/÷ 2.55	1.4 ×/÷ 2.40	1.5 ×/÷ 2.04	1.3 ×/÷ 2.08
Centroid longitudinal (m)	1.6 ×/÷ 1.66	1.5 ×/÷ 1.55	1.9 ×/÷ 1.46	1.5 ×/÷ 1.51	0.98 ×/÷ 1.74	1.7 ×/÷ 1.40
Centroid lateral (m)	0.74 ×/÷ 1.74	0.75 ×/÷ 1.60	0.75 ×/÷ 1.57	0.68 ×/÷ 1.67	0.57 ×/÷ 1.79	0.68 ×/÷ 1.46
Irregularity						
Inter-player distance (m)	0.18 ×/÷ 1.69	0.17 ×/÷ 1.63	0.17 ×/÷ 1.58	0.20 ×/÷ 1.53	0.19 ×/÷ 1.55	0.16 ×/÷ 1.76
Length (m)	0.16 ×/÷ 1.62	0.15 ×/÷ 1.63	0.12 ×/÷ 1.52	0.15 ×/÷ 1.57	0.14 ×/÷ 1.56	0.12 ×/÷ 1.62
Surface area (m^2)	0.23 ×/÷ 1.57	0.23 ×/÷ 1.53	0.22 ×/÷ 1.45	0.25 ×/÷ 1.56	0.25 ×/÷ 1.52	0.19 ×/÷ 1.71
Width (m)	0.19 ×/÷ 1.54	0.19 ×/÷ 1.61	0.18 ×/÷ 1.51	0.20 ×/÷ 1.63	0.22 ×/÷ 1.50	0.19 ×/÷ 1.64
Width per length ratio	0.12 ×/÷ 1.58	0.13 ×/÷ 1.76	0.17 ×/÷ 1.78	0.14 ×/÷ 1.67	0.15×/÷ 1.69	0.18 ×/÷ 1.74
Centroid longitudinal (m)	0.15 ×/÷ 1.72	0.13 ×/÷ 1.72	0.15 ×/÷ 1.76	0.13 ×/÷ 1.84	0.14 ×/÷ 1.64	0.15 ×/÷ 1.72
Centroid lateral (m)	0.07 ×/÷ 2.02	0.08 ×/÷ 1.79	0.06 ×/÷ 1.54	0.07 ×/÷ 1.78	0.07 ×/÷ 1.64	0.08 ×/÷ 2.03

Table 6.2. Difference between small-sided game conditions **6v6 and 5v5** for each of the derived measures of each collective tactical variable for attacking and defending teams, adjusted for possession duration and game trend. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent's. Data are effects (% units) and with 90% compatibility limits (% units) when both values are <30%; otherwise values are shown as factors. Decisions about the magnitude of the differences are also shown.

	Attacking team		Defending team	
Variables	**6v6 – 5v5**	**Decision**	**6v6 – 5v5**	**Decision**
Mean				
Inter-player distance(m)	-5.2, ±9.9%	small↓	16, ±15%	moderate↑**
Length(m)	-2.8, ±22%	trivial	23, ±26%	moderate↑**
Surface area(m^2)	-10, ±7.9%	**small↓****	22, ±27%	small↑**
Width(m)	-7.5, ±11%	small↓*⁰	3.0, ±10.7%	trivial
Width per length ratio	-4.6, ±29%	trivial	-15, ±20%	small↓*⁰
Centroid longitudinal(m)[a]	-0.46, ±1.78	small↓	-1.03, ±1.36	moderate↓**
Centroid lateral(m)[a]	0.10, ±0.31	trivial	0.12, ±0.29	trivial ⁰*
Variability				
Inter-player distance(m)	-7.4, ±21%	trivial	1.36, ×/÷1.32	moderate↑**
Length(m)	-11, ±27%	small↓	1.21, ×/÷1.39	small↑
Surface area(m^2)	0.84, ×/÷1.23	small↓	1.45, ×/÷1.42	moderate↑**
Width(m)	0.95, ×/÷1.37	trivial	1.07, ×/÷1.31	trivial
Width per length ratio	2.8, ±28%	trivial	-3.8, ±21%	trivial
Centroid longitudinal(m)	6.9, ±27%	trivial	1.52, ×/÷1.46	moderate↑**
Centroid lateral(m)	-1.2, ±24%	trivial	18, ±27%	small↑*⁰
Irregularity				
Inter-player distance	1.02, ×/÷1.45	trivial	1.09, ×/÷1.74	trivial
Length	1.04, ×/÷1.44	trivial	1.03, ×/÷1.43	trivial
Surface area	0.8, ±16%	trivial	3.0, ±29%	trivial
Width	2.3, ±21%	trivial	-8.8, ±17%	small↓
Width per length ratio	-7.5, ±13%	trivial ⁰*	-7.1, ±13%	trivial ⁰*
Centroid longitudinal	1.16, ×/÷1.31	small↑	-4.9, ±26%	trivial
Centroid lateral	-1.48, ±18%	trivial	1.09, ×/÷1.46	trivial

[a] This measure was analysed without log-transformation, hence shown in raw units.
↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardised changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely.
*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).
Reference-Bayesian likelihoods of trivial change: ⁰possibly.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

Table 6.3. Difference between small-sided-game conditions **6v6 and 4v4** for each of the derived measures of each collective tactical variable for attacking and defending teams, adjusted for possession duration and game trend. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent's. Data are effects (% units) and with 90% compatibility limits (% units) when both values are <30%; otherwise values are shown as factors. Decisions about the magnitude of the differences are also shown.

	Attacking team		**Defending team**	
Variables	**6v6 – 4v4**	**Decision**	**6v6 – 4v4**	**Decision**
Mean				
Inter-player distance(m)	-0.6, ±10%	trivial	15, ±14%	moderate↑**
Length(m)	7.6, ±24%	small↑	22, ±24%	moderate↑**
Surface area(m^2)	-9.1, ±9.3%	**small↓*^{0}**	15, ±25%	small↑
Width(m)	-15, ±10%	moderate↓**	-1.5, ±11%	trivial
Width per length ratio	-18, ±19%	small↓	-18, ±19%	small↓**
Centroid longitudinal(m)[a]	-0.56, ±1.77	small↓	-0.72, ±1.33	small↓
Centroid lateral(m)[a]	0.02, ±0.33	trivial	-0.03, ±0.3	trivial
Variability				
Inter-player distance(m)	-4.9, ±22%	trivial	-3.2, ±27%	trivial
Length(m)	-12, ±26%	small↓	-15, ±29%	small↓
Surface area(m^2)	0.82, ×/÷1.46	small↓	1.05, ×/÷1.41	trivial
Width(m)	-22, ±25%	small↓**	-3.8, ±27%	trivial
Width per length ratio	1.1, ×/÷1.3	trivial	12, ±26%	trivial ^{0}*
Centroid longitudinal(m)	-14, ±26%	small↓	0.90, ×/÷1.48	small↓
Centroid lateral(m)	-1.0, ±24%	trivial	-0.04, ± 25%	trivial
Irregularity				
Inter-player distance	1.03, ×/÷1.45	trivial	1.30, ×/÷1.73	small↑
Length	1.34, ×/÷1.44	moderate↑**	1.19, ×/÷1.42	small↑
Surface area	5.6, ±17%	trivial	1.31, ×/÷1.31	moderate↑**
Width	4.6, ±21%	trivial	8.0, ±20%	trivial
Width per length ratio	0.66, ×/÷1.16	**moderate↓********	-23, ±12%	**small↓****
Centroid longitudinal	-1.2, ±26%	trivial	-13, ±24%	small↓
Centroid lateral	19, ±20%	**small↑*^{0}**	0.90, ×/÷1,41	trivial

[a] This measure was analysed without log-transformation, hence shown in raw units.
↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardised changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.
*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).
Reference-Bayesian likelihoods of trivial change: ^{0}possibly.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

Table 6.4. Difference between small-sided game conditions **5v5 and 4v4** for each of the derived measures of each collective tactical variable for attacking and defending teams, adjusted for possession duration and game trend. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent's. Data are effects (% units) and with 90% compatibility limits (% units) when both values are <30%; otherwise values are shown as factors. Decisions about the magnitude of the differences are also shown.

	Attacking team		Defending team	
Variables	**5v5 – 4v4**	**Decision**	**5v5 – 4v4**	**Decision**
Mean				
Inter-player distance(m)	4.9, ±11%	small↑	-1.1, ±13%	trivial
Length(m)	11, ±25%	small↑	-0.6, ±20%	trivial
Surface area(m²)	1.4, ±9.9%	trivial	-5.6, ±21%	trivial
Width(m)	-8.1, ±11%	small↓*⁰	-4.4, ±10%	trivial
Width per length ratio	-14, ±26%	small↓	-3.2, ±23%	trivial
Centroid longitudinal(m)[a]	-0.11, ±1.82	trivial	0.31, ±1.58	trivial
Centroid lateral (m)[a]	-0.08, ±0.29	trivial	-0.15, ±0.26	trivial ⁰*
Variability				
Inter-player distance(m)	2.7, ±23%	trivial	-29, ±20%	moderate↓**
Length(m)	0.98, ×/÷1.36	trivial	0.70, ×/÷1.40	moderate↓**
Surface area(m²)	0.98, ×/÷1.46	trivial	-28, ±27%	moderate↓**
Width(m)	-18, ±27%	small↓	-10, ±25%	small↓
Width per length ratio	1.02, ×/÷1.29	trivial	16, ±23%	**trivial ⁰***
Centroid longitudinal(m)	-19, ±21%	small↓**	0.59, ×/÷1.46	moderate↓***
Centroid lateral(m)	0.16, ±24%	trivial	-15, ±20%	small↓*⁰
Irregularity				
Inter-player distance	1.02, ×/÷1.46	trivial	1.19, ×/÷1.73	small↑
Length	1.28, ×/÷1.45	small↑	1.15, ×/÷1.42	small↑
Surface area	4.6, ±17%	trivial	1.27, ×/÷1.31	small↑**
Width	2.2, ±21%	trivial	18, ±22%	small↑**
Width per length ratio	-29, ±11%	moderate↓***	-17, ±12%	**small↓**
Centroid longitudinal	-15, ±23%	small↓*⁰	-8.0, ±25%	trivial
Centroid lateral	21, ±17%	**small↑**	-18, ±29%	small↓

[a] This measure was analysed without log-transformation, hence shown in raw units.
↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardised changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.
*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).
Reference-Bayesian likelihoods of trivial change: ⁰possibly.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

The attacker' and defenders' irregularity of WPLratio was highest in 4v4 compared with 5v5 and 6v6 (moderate increases for attackers and small increases for defenders, at least likely substantial and mostly clear at the 99% level). The only other variable showing evidence of change in irregularity was lateral positioning, with the lowest value in 4v4 (possibly or likely small decreases compared with 5v5 and 6v6, clear at the 99% level).

6.4.3 Possession Duration

The most noteworthy effect of possession duration was a small to large increase in the variability of most collective tactical variables (mostly clear at the 99% level; WPLratio showed some decreases) for all three SSG conditions. The mean for longitudinal positioning of attackers and defenders also showed evidence for small to moderate increases in 4v4 and 5v5 SSGs. Evidence for other effects on the mean included: in 5v5, small to moderate decreases in length and inter- player distance and small increases in width and WPLratio for attackers; also in 5v5, defenders displayed a small increase in width and WPLratio and a small decrease in length; in 6v6, defenders displayed moderate increases in inter-player distance, width and surface area.

The effects of possession duration on irregularity for 4v4 and 5v5 were mostly unclear, while for 6v6 the attackers displayed small to moderate increases in inter-player distance, length, surface area and width.

6.4.4 Effect of time in match

In 6v6, effects of game time on the mean were all unclear, but there were small to moderate increases of variability of all variables apart from WPLratio for attackers' and defenders. In 5v5, attackers displayed moderate increases in mean inter-player distance and length, and a moderate decrease to mean width, WPLratio and lateral positioning; defenders displayed a moderate decrease in variability of lateral positioning and a moderate increase in the irregularity of inter-player distance. Changes in collective tactical variables throughout a SSG were limited in 4v4; the attackers and defenders did display moderate decreases in mean longitudinal positioning, and the attackers also showed a moderate increase in the irregularity of lateral positioning.

6.4.5 Possession outcome: score vs turnover

In 4v4, the mean and variability of collective tactical variables had limited clear effects. Only the increase in defenders' mean longitudinal positioning and increase in attackers' variability of longitudinal positioning showed clear evidence of differences between possessions resulting in a score compared with turnover. The irregularity of the attackers' length and surface area and defender's inter-player distance also showed evidence of small increases. For 5v5, attackers and defenders showed a small increase of mean longitudinal positioning, with attackers also displaying small decreases of mean inter-player distance and surface area. Attackers and defenders displayed strong evidence for increased longitudinal positioning variability, while the defenders displayed some evidence of small increases in length and width variability. Mostly unclear effects were apparent for the irregularity of collective tactical variables in 5v5, with the exception of a small increase in the defender's WPLratio. Finally, in 6v6 the effects for most variables and measures were unclear.

6.4.6 Weakly Informative Priors

The effect that showed the greatest weakly informative prior shrinkage was game time on variability of defenders' width in 5v5: with a minimally informative prior, the standardized effect was -0.63 ±0.56 (mean ±90% compatibility limits); after shrinkage with a weakly informative prior, the effect became -0.62 ±0.55, which obviously represents negligible shrinkage.

6.5 DISCUSSION

Overall, substantial effects were most well defined for means, and less well defined for variability and irregularity. The similarity of the effects for many variables often reflects the high correlations between variables, including high negative correlations, where the effects are of opposite sign (e.g., width and WPLratio for variability). While in a scientifically more research area the decision to eliminate some of these variables would have been appropriate, the decision was to include all as this is the first work exploring these factors in netball and so it was felt this path of reporting would be more beneficial for subsequent research.

6.5.1 Comparisons of training condition: 4v4 vs 5v5 vs 6v6

The smallest values of surface area in 6v6 compared with 5v5 and 4v4, and the minimal observed differences of mean collective tactical variables between 5v5 and 4v4, indicate that removing one player (5v5) provides less spatial restrictions for the original attackers' dispersion and that removing two players (4v4) adds little further difference (although where trivial, these differences were unclear).

For the defenders in 6v6, the larger longitudinal dispersion suggests the players positioned on the attacking transverse line allow the defenders to elongate their dispersion as additional defensive containment of their opposing attackers is provided. Conditions in the 6v6 being the most similar to that of matches allows defenders to better follow the defensive behaviours of defensive unity and full team defence, stated by expert (netball) coaches as important defensive properties (Coombe et al., 2020b). It has also been previously suggested in soccer, players display more consistent patterns in full match conditions (which the 6v6 represents) compared with SSGs, in which they less closely adhere to their specific positional requirements (Bartlett et al., 2012).

Previous research on SSGs in soccer has indicated that an increased number of players is associated with decreased variability of collective tactical variables (Olthof et al., 2019). However, in the present study for netball, the similarities of collective tactical variables for variability in 6v6 and 4v4 suggest that both SSG conditions generate increased movement compared to the 5v5, owing to the larger relative space (4v4) and additional support of players (6v6). The 5v5's smallest variability of inter-player distance, length, surface area and longitudinal positioning for the defenders may show an adaptation to the spatial affordances provided, whereby it is neither fully open nor restricted and the removal of one player provides the 5th player more freedom to move along the transverse line. While greater variability in multiple netball SSG conditions, when compared with previous research, has been highlighted, exclusion of the additional 5th and 6th players in collective tactical variable calculations must be considered. Inclusion of these generally stationary additional players in calculations could greatly decrease the variability initially found, aligning with previous SSG research showing lower variability and ApEn values with higher numbers of players, suggestive of greater organisational behaviours.

Irregularity of attackers' and defenders' WPLratio returned similar values for the 6v6 and 5v5, with the highest being in the 4v4, thus displaying a tendency to modify the shape of dispersion with the affordance of increased relative space, supporting previous research associating higher regularity with fewer players (Aguiar et al., 2015). For defenders, maintaining unit structure and positioning stability is a desired outcome (Gonçalves et al., 2018, McLean et al., 2019, Gonçalves et al., 2016), therefore to put the most strain on the defenders, it appears removing two players is required.

6.5.2 Possession duration

The increases in the variability of most collective tactical variables in all the SSG conditions with longer possession durations indicate the original attackers and defenders are able to explore more regions of the court as the possession progresses (Silva et al., 2014a). The increases in mean longitudinal positioning over the course of a possession in 5v5 and 4v4 must be due to the attacking players moving closer to the goal; however, in the 6v6 no clear changes were observed, which is consistent with the original players being constrained closer to the goal throughout the possession. In the 5v5 SSG, the decreases in mean longitudinal dispersion (length and inter-player distance) and the increases in mean lateral dispersion (width and WPLratio) show that, with longer possessions, players compact lengthwise as they move closer to the goal. As these effects were clear only for 5v5, the removal of one player from 6v6 is associated with the original players changing their positioning based on the more dynamic relative positioning of the 5th player. In 6v6 only, the attackers' increase in irregularity of inter-player distance, length, surface area and width suggests the defenders are better able to dictate the attacking player's movement in longer possessions. Defenders' increased ability to dictate movements may be due to exacerbation of attackers' fatigue during longer possessions and in smaller spaces (6v6).

6.5.3 Time in match

The most effects due to SSG time were in 5v5, where the attackers' adoption of a more elongated dispersion as the game progresses shows that the original players may have increased their use of the 5th player as a passing option. Potentially due to the 5th player in the 5v5 providing an easy reset due to the extra freedom of space (with no 6th player) along the transverse line and other passing options being unavailable as a result of fatigue later in the game. Another effect of game time in 5v5 was the defenders' positioning themselves more in the middle of the court (decreased lateral positioning variability) and also displaying increased irregularity of inter-player distance, potentially mirroring the attackers' increased elongation as they interact with the 5th player on the transverse line.

In 6v6 and 4v4, the changes of mean collective tactical variables over the course of a game were mainly trivial but unclear, which is consistent with (but is not good evidence for) consistent positional restrictions throughout a game (restricted or open respectively). In 6v6 only, the increased variability for all variables (except the WPLratio) indicates the greater restrictions of space may require some players to increase their dispersion to provide passing options as other players become fatigued.

6.5.4 Score vs turnover

Most of the clear effects of possession outcome occurred in 5v5. The attackers' decreased mean inter-player distance and surface area show they move closer together before successful possessions. For the defenders, increased variability of length and width during scoring possessions highlights increased movement as they trail their attackers instead of playing a more stationary zone-coverage defence; similar findings have been found in futsal SSGs, where fewer players are associated with more frequent player-to-player defending (Rico-González et al., 2020d). These findings further support the suggestions above that the 5v5 SSG may elicit more changes in collective tactical variables than the fully open 4v4 and fully restrictive 6v6.

When scoring in the less restricted 4v4, it seems that attackers are better able to dictate the opposing defenders' distance between one another: there is increased irregularity of defenders' inter-player distance as the attackers' aim to disrupt the defenders' collective positioning via the use of the additional space. In 6v6 most collective tactical variables showed mostly trivial and unclear changes in relation to possession outcome, suggesting that the greater restriction of movement in 6v6 (as discussed above) results in consistent collective behaviours regardless of the outcome.

6.5.5 Limitations and future research directions

There were many unclear effects in this study and even many clear effects with only possible or likely magnitudes (substantial and/or trivial). More SSGs need to be analysed to address this issue, and more than one team needs to be analysed to allow generalization to all elite netball teams.

In the current analysis, the values of the collective tactical variables were derived as possession averages with equal weighting across the entire possession. Although the outcome of each possession (score or turnover) is of less interest in SSGs, future analyses could put more weight on the values of the variables towards the end of the possession since these values are more likely to affect the outcome. Modifications of SSGs that may influence the collective tactical variables could also be investigated, including numerical imbalances, numerical overload, court-size restrictions and the addition of floating players.

6.5.6 Conclusion

Many collective tactical variables have been shown to differ between elite netball SSG conditions. The changes between the SSG conditions are consistent with the 6v6 placing the most restrictive conditions on attackers' space highlighted by the lowest attackers' surface area, and the 4v4 placing the most strain on defenders' collective positioning, as they displayed their highest amount of irregularity. Additional effects of possession duration, game time and possession outcome highlighted the consistent spatial restriction of 6v6 and consistent spatial openness of 4v4, while also showing the extent to which the 5v5 may present the most dynamic conditions for collective tactical variables. Research pertaining to collective tactical behaviours has been limited in netball, so the current study provides a baseline understanding of the differences in these behaviours during SSGs.

6.5.7 Practical applications

Coaches should consider the following adjustments to SSG conditions to elicit specific behaviours. Use the 6v6 if the aim is to restrict the attackers' space, the 4v4 to disrupt the defenders' collective positioning and the 5v5 to elicit varying collective behaviours. The 5v5, can also elicit the most dynamic collective behaviours throughout a game and during scoring possessions

CHAPTER 7 – GENERAL DISCUSSION, CONCLUSIONS, PRACTICAL APPLICATIONS AND FUTURE DIRECTIONS FOR RESEARCH

7.1 Introduction

This thesis explored the use and applicability of a suite of collective tactical variables in elite netball matches and training, to measure the collective behaviours of players. Initially, a validation study was conducted to ascertain the accuracy of a local positioning system to measure inter-unit distance. Then, several studies were conducted, first exploring the outputs of collective tactical variables during matches and the effects a number of contextual factors can have. A study pertaining to the probability of scoring associated with changes in collective tactical variables and finally the differences in collective tactical variables during small-sided games in training was conducted. The results of these studies have been presented and discussed in chapters 3-6; the following section will therefore review and appraise the main findings, conclusions and practical applications of this thesis.

7.2 Discussion and major findings

The major findings from this thesis are summarized below with additional discussion to contextualize the results:

- The LPS used in this thesis showed acceptable accuracy for measuring inter-unit distance, with a RMSE of 0.20 ± 0.05 m and a mean bias of 0.10 ± 0.06 m compared with the criterion system. The accuracy of the LPS used allows for accurate measurement of inter-unit distance within dynamic movement sequences found in team sports.
- When related to distance bands, inter-unit distance resulted in larger RMSE values at larger distances.

- Elite netball displays tactical behaviours of expansion and contraction on attack and defence respectively, which are typical elements of invasion sports.
- Collective tactical variables can be clustered into one of four clusters; lateral dispersion, longitudinal dispersion, lateral positioning and longitudinal positioning. These four clusters allow similar collective tactical variables to be grouped together in analysis, also allowing for better understanding of each variable's unique purpose.
- The netball team analysed in this thesis showed increased longitudinal dispersion when an attacking possessions ended in a score.
- Active phases of play for sub-groups invite more irregular behaviours. In netball, this alludes to the attacking sub-group during attacking possessions being more actively involved in the play as they are able to enter the attacking third and attacking shooting circle. On the other hand, while on defensive possessions players are restricted from entering the defensive third, limiting their ability to actively impact the game.
- Team-level behaviours fail to capture smaller sub-group behaviours. Especially in elite netball, where positional sub-groups are restricted to similar areas of the court, analysing only team-level behaviours fails to capture the behavioral intricacies that can be occurring within sub-groups at the same time.
- The effects of score difference and opposition strength on collective tactical variables during matches were generally unclear.
- Extremely short possession durations are associated with a decreased score probability. Extremely short possession lengths could be evident of general play turnover in netball, whereby the attacking team is unable to maintain possession of the ball.

- Proximity to goal (longitudinal centroid) is highly associated with an increased score probability. For the attacking team, getting the ball closer to the goal while in possession allows midcourters opportunities to feed the ball to the shooters in the shooting circle.
- Direct styles of play are associated with reduced irregularity of collective tactical behaviours associated with increased score probability.
- Lateral dispersion and lateral movements are associated with a decreased score probability. When attacking team players are positioned towards the wings of the courts, this would suggest the defending team players have gained optimal positioning in the middle channel of the court.
- The 6v6 SSG condition is the most restrictive on attacking team's space, the 5v5 SSG condition can elicit the most varying collective tactical behaviours and the 4v4 SSG condition can elicit more irregular collective behaviours from the defending team players. Each SSG type can provide different affordances required to train aspect of match environments and behaviours which players are likely to encounter.

As collective tactical variables have previously not been studied in elite netball, this thesis represents a novel investigation for this sport by demonstrating how collective tactical variables can measure the collective behaviours of netball players and specifically capturing their dispersion and expansion/contraction during the attacking and defending phases. Sub-group differences were also highlighted with netball court restrictions warranting specific analyses of each sub-group, particularly when most actively involved in the play. Increases in the probability of scoring as a result of changes to collective tactical variables were shown with varying results, thus requiring more substantial datasets to fully comprehend their relationship. Finally, SSGs have been shown to elicit differing physical capacities (Simpson et al., 2020b), and different tactical behaviours can also be stimulated based on the number of players within the drill.

7.3 Practical applications and future research

This thesis provides several practical applications associated with player tracking technology, collective tactical variables and drill design in netball. Practitioners and researchers using the Catapult LPS to measure inter-unit distances can be confident in the accuracy provided by the system, as measurement values at high distances still provide acceptable accuracy. Inter-unit distances, specifically inter-player distances form the base calculation of most other collective tactical variables, thus initial accuracy allows for use of collective tactical variables, but further research into the accuracy of other collective tactical variables with differing calculation steps is warranted.

From a basic understanding of tactical principles of attacking and defending, the collective tactical variables found in this group of elite netballers were behaviours of contraction in defence and expansion in attack, similar to those found in other sports and support coaching-based tactical movement and positioning principles. For more advanced applications, collective tactical variables in elite netball are most irregular for forward and defender sub-groups when they are most actively involved in the play. As netball court restrictions impede a player's movement options, coaches can utilise these findings to try decrease irregularity on attack, tactically focusing on attacking sequences which are direct to goal. While on defence focusing on increasing the defender's irregularity, to subsequently disrupt the attackers attacking behaviours and prevent easy access to the goal circle. These differences between sub-groups are important, as team-level behaviours overlooked such findings, supporting previous suggestions that team level analysis of collective tactical variables can lose player and sub-group specific information (Goes et al., 2020). Additionally, contextual effects such as score difference and opposition strength showed limited clear effects (as shown in Chapter 4). Distinguishing between signal and noise is important when assessing player behaviours and team tactics, therefore further research is required to analyse such contextual effects and their specific influence on collective tactical variables.

By increasing the probability of scoring on a possession, over the course of a match and season it is likely this will lead to an increased number of matches won. For coaches, avoiding extremely short possessions durations can help mitigate decreases to scoring probability, and specifically prevent easy transition goals from turnovers for the opposition. Additionally, using a direct style of play with proximity to the attacking goal, reduced irregularity of behaviours and minimizing lateral dispersion can increase scoring probability. For coaches, being tactically unpredictable is important to prevent the opposition from dictating behaviours, therefore further research should explore the optimal balance of different attacking strategies and amount of randomization of strategies to prevent the opposition working out trends or patterns.

To train such strategies, coaches can employ SSGs with player number differences, which simulate different task constraints and affordances frequently encountered in matches. Specifically, coaches whose focus is small spaces and high defensive pressure on the passer can utilize the 6v6 condition, which in Chapter 6 showed the greatest restriction on attacking players' space. Conversely, if isolation of defending players and restriction of their collective behaviours with other defenders is warranted, the 4v4 can be used to elicit more individual actions from defenders which are represented via increased irregularity of behaviours. Finally, coaches wanting to create a dynamic environment for players, which replicates the shifting nature of netball can integrate the 5v5 SSG condition, which due to uneven spacing on the transverse line can create movement sequences and task affordances for players which may be unavailable in other conditions.

As this thesis has explored collective tactical variables in elite netball, in both matches and training while also adjusting for several contextual factors, several future research directions are now available. Investigation of both attacking and defending teams during matches will provide additional context and understanding of the behaviors found in this thesis. Also, the implementation of ball tracking and the collective tactical variables in relation to ball position further enhances the contextual information present, advances in ball tracking have been displayed (Folgado et al., 2018a). Additionally, a collaboration between multiple countries or teams within countries, would provide a broader understanding of the collective tactical variables based on tactical styles. Finally, for training collective behaviours, research integrating a tactical intervention over the course of a training block or preseason to further understand how collective behaviours as measured by collective tactical variables can be adapted and enhanced.

7.4 CONCLUSIONS

The specific conclusions of this thesis are:

- The Catapult LPS has acceptable accuracy to measure inter-unit distance in indoors team sports environments.
- Collective tactical variables can provide a measure of attacking (expansion) and defending (contraction) principles in elite netball.
- Forward and defending sub-groups display greater irregularity of collective tactical variables when they are most active in the play.
- Sub-group analysis is required when using collective tactical variables as team level analysis overlooks lower dimension behaviours.

- Lateral dispersion associated with a decrease in scoring probability, as team or sub-group proximity to the goal is greater.
- SSG conditions with differing numbers of players can be used to increase player dispersion (4v4), vary player dispersion (5v5) and restrict player dispersion (6v6)
- Collective tactical variables found in 4v4 SSGs promote more direct styles of play, which were found in Chapter 5 (Study 3) to associate with greater scoring probability.

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APPENDIX A: Study 2 supplementary tables

A1 Table. Correlations between collective tactical variables for the forward sub-group on attack. Data shown are the range of the three correlations (mean, standard deviation and entropy). The variables have been ordered and outlined to show clusters with generally higher correlations between variables within the clusters than between the clusters.

Variable	1	2	3	4	5	6	7	8	9	10
1. Stretch index		1.00, .97, .98	.88, .78, .85	.87, .75, .82	.85, .67, .77	.38, .36, .62	.38, .45, .64	-.23, -.20, -.31	-.62, .36, .49	.15, .19, .32
2. Inter-player distance	1.00, .97, .98		.87, .76, .83	.87, .76, .83	.84, .70, .78	.38, .37, .64	.39, .42, .66	-.23, -.19, -.32	-.61, .38, .49	.16, .14, .34
3. Stretch index longitudinal	.88, .78, .85	.87, .76, .83		.99, .96, .95	.69, .46, .65	-.05, .17, .53	-.04, .27, .55	-.56, -.22, -.42	-.68, .43, .56	.13, .17, .34
4. Length	.87, .75, .82	.87, .76, .83	.99, .96, .95		.68, .44, .65	-.06, .21, .55	-.05, .28, .57	-.57, -.25, -.43	-.66, .43, .56	.14, .17, .34
5. Surface area	.85, .67, .77	.84, .70, .78	.69, .46, .65	.68, .44, .65		.51, .44, .69	.51, .39, .71	-.01, -.00, -.36	-.52, .19, .40	.11, .04, .32
6. Width	.38, .36, .62	.38, .37, .64	-.05, .17, .53	-.06, .21, .55	.51, .44, .69		.99, .97, .95	.67, -.36, -.45	.06, .12, .34	.03, .17, .42
7. Stretch index lateral	.38, .45, .64	.39, .42, .66	-.04, .27, .55	-.05, .28, .57	.51, .39, .71	.99, .97, .95		.67, -.43, -.46	.05, .15, .37	.03, .29, .41
8. Width per length ratio	-.23, -.20, -.31	-.23, -.19, -.32	-.56, -.22, -.42	-.57, -.25, -.43	-.01, .00, -.36	.67, -.36, -.45	.67, -.43, -.46		.32, -.10, -.32	-.06, -.10, -.22
9. Centroid longitudinal	-.62, .36, .49	-.61, .38, .49	-.68, .43, .56	-.66, .43, .56	-.52, .19, .40	.06, .12, .34	.05, .15, .37	.32, -.10, -.32		-.10, .21, .25
10. Centroid lateral	.15, .19, .32	.16, .14, .34	.13, .17, .34	.14, .17, .34	.11, .04, .32	.03, .17, .42	.03, .29, .41	-.06, -.10, -.22	-.10, .21, .25	

Uncertainty (90% compatibility limits): ~±0.1 to ~±0.01 for correlations of 0.00 to 0.95 respectively assuming a sample size of ~300.

A2 Table. Correlations between collective tactical variables for the forward sub-group on defence. Data shown are the range of the three correlations (mean, standard deviation and entropy). The variables have been ordered and outlined to show clusters with generally higher correlations between variables within the clusters than between the clusters.

Variable	1	2	3	4	5	6	7	8	9	10
1. Stretch index		1.00, .97, .98	.97, .88, .91	.96, .83, .86	.76, .55, .67	.22, .22, .47	.25, .20, .44	-.45, -.17, -.30	-.56, .22, .39	.03, .11, .33
2. Inter-player distance	1.00, .97, .98		.97, .86, .90	.97, .86, .87	.75, .52, .68	.22, .24, .47	.24, .22, .44	-.46, -.18, -.29	-.55, .22, .40	.03, .12, .33
3. Stretch index longitudinal	.97, .88, .91	.97, .86, .90		.99, .94, .93	.67, .41, .56	.02, .07, .41	.05, .05, .39	-.59, -.19, -.33	-.59, .15, .39	.02, .07, .32
4. Length	.96, .83, .86	.97, .86, .87	.99, .94, .93		.63, .32, .48	.00, .08, .39	.03, .07, .37	-.62, -.24, -.35	-.56, .15, .35	.02, .08, .31
5. Surface area	.76, .55, .67	.75, .52, .68	.67, .41, .56	.63, .32, .48		.54, .49, .64	.54, .46, .59	-.01, -.03, -.27	-.57, .24, .49	.08, .20, .35
6. Width	.22, .22, .47	.22, .24, .47	.02, .07, .41	.00, .08, .39	.54, .49, .64		.99, .96, .95	.66, -.37, -.54	-.11, .20, .41	.06, .37, .46
7. Stretch index lateral	.25, .20, .44	.24, .22, .44	.05, .05, .39	.03, .07, .37	.54, .46, .59	.99, .96, .95		.63, -.37, -.55	-.11, .20, .41	.07, .39, .49
8. Width per length ratio	-.45, -.17, -.30	-.46, -.18, -.29	-.59, -.19, -.33	-.62, -.24, -.35	-.01, -.03, -.27	.66, -.37, -.54	.63, -.37, -.55		.18, -.07, -.31	.05, -.10, -.36
9. Centroid longitudinal	-.56, .22, .39	-.55, .22, .40	-.59, .15, .39	-.56, .15, .35	-.57, .24, .49	-.11, .20, .41	-.11, .20, .41	.18, -.07, -.31		.02, .31, .44
10. Centroid lateral	.03, .11, .33	.03, .12, .33	.02, .07, .32	.02, .08, .31	.08, .20, .35	.06, .37, .46	.07, .39, .49	.05, -.10, -.36	.02, .31, .44	

Uncertainty (90% compatibility limits): ~±0.1 to ~±0.01 for correlations of 0.00 to 0.95 respectively assuming a sample size of ~300.

A3 Table. Correlations between collective tactical variables for the midcourt sub-group on attack. Data shown are the range of the three correlations (mean, standard deviation and entropy). The variables have been ordered and outlined to show clusters with generally higher correlations between variables within the clusters than between the clusters.

Variable	1	2	3	4	5	6	7	8	9	10
1. Stretch index		1.00, .98, .97	.86, .79, .82	.86, .76, .83	.79, .51, .73	.49, .24, .56	.50, .22, .55	-.15, -.20, -.36	.08, .19, .18	-.03, .16, .34
2. Inter-player distance	1.0, .98, .97		.85, .77, .81	.86, .77, .84	.78, .50, .74	.51, .25, .57	.52, .23, .56	-.15, -.21, -.38	.08, .21, .18	-.04, .17, .36
3. Stretch index longitudinal	.86, .79, .82	.85, .77, .81		.99, .95, .93	.56, .33, .58	.05, .15, .51	.05, .14, .52	-.51, -.31, -.47	.02, .19, .27	-.10, .12, .39
4. Length	.86, .76, .83	.86, .77, .84	.99, .95, .93		.54, .32, .60	.06, .17, .52	.06, .16, .53	-.52, -.34, -.46	-.01, .23, .25	-.13, .15, .38
5. Surface area	.79, .51, .73	.78, .50, .74	.56, .33, .58	.54, .32, .60		.63, .41, .60	.65, .43, .61	.19, -.03, -.33	.14, .34, .25	.06, .18, .39
6. Width	.49, .24, .56	.51, .25, .57	.05, .15, .51	.06, .17, .52	.63, .41, .60		.99, .96, .94	.68, -.35, -.57	.20, .20, .29	.13, .23, .42
7. Stretch index lateral	.50, .22, .55	.52, .23, .56	.05, .14, .52	.06, .16, .53	.65, .43, .61	.99, .96, .94		.66, -.35, -.57	.20, .21, .32	.12, .24, .44
8. Width per length ratio	-.15, -.20, -.36	-.15, -.21, -.38	-.51, -.31, -.47	-.52, -.34, -.46	.19, -.03, -.33	.68, -.35, .57	.66, -.35, -.57		.15, -.04, -.16	.17, -.07, -.27
9. Centroid longitudinal	.08, .19, .18	.08, .21, .18	.02, .19, .27	-.01, .23, .25	.14, .34, .25	.20, .20, .29	.20, .21, .32	.15, -.04, -.16		-.02, .23, .26
10. Centroid lateral	-.03, .16, .34	-.04, .17, .36	-.10, .12, .39	-.13, .15, .38	.06, .18, .39	.13, .23, .42	.12, .24, .44	.17, -.07, -.27	-.02, .23, .26	

Uncertainty (90% compatibility limits): ~±0.1 to ~±0.01 for correlations of 0.00 to 0.95 respectively assuming a sample size of ~300.

A4 Table. Correlations between collective tactical variables for the midcourt sub-group on defence. Data shown are the range of the three correlations (mean, standard deviation and entropy). The variables have been ordered and outlined to show clusters with generally higher correlations between variables within the clusters than between the clusters.

Variable	1	2	3	4	5	6	7	8	9	10
1. Stretch index		.99, .99, .97	.92, .89, .89	.91, .86, .86	.75, .66, .67	.45, .20, .48	.44, .20, .44	-.12, -.05, -.28	.22, .08, .18	.10, .11, .42
2. Inter-player distance	.99, .99, .97		.91, .87, .87	.91, .87, .89	.75, .64, .69	.47, .20, .50	.45, .20, .46	-.11, -.04, -.30	.23, .10, .20	.10, .14, .42
3. Stretch index longitudinal	.92, .89, .89	.91, .87, .87		.99, .96, .91	.58, .49, .56	.11, .11, .42	.10, .11, .41	-.41, -.12, -.33	.14, .10, .25	.09, .14, .45
4. Length	.91, .86, .86	.91, .87, .89	.99, .96, .91		.56, .46, .55	.10, .13, .42	.09, .14, .40	-.43, -.16, -.32	.18, .14, .25	.08, .20, .41
5. Surface area	.75, .66, .67	.75, .64, .69	.58, .49, .56	.56, .46, .55		.65, .45, .63	.65, .47, .60	.25, -.11, -.35	.03, .21, .26	.11, .12, .42
6. Width	.45, .20, .48	.47, .20, .50	.11, .11, .42	.10, .13, .42	.65, .45, .63		.99, .97, .91	.73, -.23, -.53	.15, .32, .37	.11, .29, .45
7. Stretch index lateral	.44, .20, .44	.45, .20, .46	.10, .11, .41	.09, .14, .40	.65, .47, .60	.99, .97, .91		.73, -.23, -.54	.13, .35, .35	.12, .30, .44
8. Width per length ratio	-.12, -.05, -.28	-.11, -.04, -.30	-.41, -.12, -.33	-.43, -.16, -.32	.25, -.11, -.35	.73, -.23, -.53	.73, -.23, -.54		.00, -.06, -.29	.01, -.07, -.37
9. Centroid longitudinal	.22, .08, .18	.23, .10, .20	.14, .10, .25	.18, .14, .25	.03, .21, .26	.15, .32, .37	.13, .35, .35	.00, -.06, -.29		.03, .32, .42
10. Centroid lateral	.10, .11, .42	.10, .14, .42	.09, .14, .45	.08, .20, .41	.11, .12, .42	.11, .29, .45	.12, .30, .44	.01, -.07, -.37	.03, .32, .42	

Uncertainty (90% compatibility limits): ~±0.1 to ~±0.01 for correlations of 0.00 to 0.95 respectively assuming a sample size of ~300.

A5 Table. Correlations between collective tactical variables for the defender sub-group on attack. Data shown are the range of the three correlations (mean, standard deviation and entropy). The variables have been ordered and outlined to show clusters with generally higher correlations between variables within the clusters than between the clusters.

Variable	1	2	3	4	5	6	7	8	9	10
1. Stretch index		1.00, .98, .97	.92, .85, .87	.90, .81, .84	.79, .61, .71	.28, .22, .51	.28, .22, .50	-.27, -.13, -.36	.55, .36, .45	-.05, .12, .29
2. Inter-player distance	1.00, .98, .97		.92, .82, .84	.90, .82, .85	.80, .61, .71	.29, .25, .50	.30, .25, .49	-.27, -.13, -.36	.54, .37, .45	-.04, .12, .29
3. Stretch index longitudinal	.92, .85, .87	.92, .82, .84		.99, .93, .91	.64, .37, .56	-.05, .06, .42	-.04, .06, .40	-.53, -.18, -.41	.56, .39, .46	-.02, .15, .32
4. Length	.90, .81, .84	.90, .82, .85	.99, .93, .91		.60, .34, .52	-.08, .09, .38	-.08, .09, .36	-.57, -.21, -.39	.53, .34, .43	-.01, .14, .29
5. Surface area	.79, .61, .71	.80, .61, .71	.64, .37, .56	.60, .34, .52		.55, .47, .67	.55, .46, .66	.11, -.05, -.37	.53, .25, .46	-.04, .07, .37
6. Width	.28, .22, .51	.29, .25, .50	-.05, .06, .42	-.08, .09, .38	.55, .47, .67		.99, .96, .95	.75, -.29, -.55	.12, .31, .40	-.14, .34, .48
7. Stretch index lateral	.28, .22, .50	.30, .25, .49	-.04, .06, .40	-.08, .09, .36	.55, .46, .66	.99, .96, .95		.74, -.28, -.52	.12, .32, .40	-.16, .34, .45
8. Width per length ratio	-.27, -.13, -.36	-.27, -.13, -.36	-.53, -.18, -.41	-.57, -.21, -.39	.11, -.05, -.37	.75, -.29, -.55	.74, -.28, -.52		-.17, -.09, -.27	-.11, -.16, -.38
9. Centroid longitudinal	.55, .36, .45	.54, .37, .45	.56, .39, .46	.53, .34, .43	.53, .25, .46	.12, .31, .40	.12, .32, .40	-.17, -.09, -.27		-.02, .29, .36
10. Centroid lateral	-.05, .12, .29	-.04, .12, .29	-.02, .15, .32	-.01, .14, .29	-.04, .07, .37	-.14, .34, .48	-.16, .34, .45	-.11, -.16, -.38	-.02, .29, .36	

Uncertainty (90% compatibility limits): ~±0.1 to ~±0.01 for correlations of 0.00 to 0.95 respectively assuming a sample size of ~300.

A6 Table. Correlations between collective tactical variables for the defender sub-group on defence. Data shown are the range of the three correlations (mean, standard deviation and entropy). The variables have been ordered and outlined to show clusters with generally higher correlations between variables within the clusters than between the clusters.

Variable	1	2	3	4	5	6	7	8	9	10
1. Stretch index		1.0, .98, .97	.90, .80, .88	.90, .78, .86	.84, .69, .76	.50, .42, .54	.51, .41, .60	-.20, -.09, -.40	.75, .49, .53	.01, .21, .44
2. Inter-player distance	1.0, .98, .97		.90, .78, .86	.90, .80, .88	.84, .70, .77	.50, .41, .54	.50, .40, .60	-.20, -.08, -.40	.77, .47, .52	.01, .20, .42
3. Stretch index longitudinal	.90, .80, .88	.90, .78, .86		.99, .96, .93	.69, .51, .65	.13, .30, .46	.14, .29, .52	-.50, -.15, -.48	.76, .54, .59	.00, .19, .41
4. Length	.90, .78, .86	.90, .80, .88	.99, .96, .93		.68, .51, .65	.12, .28, .50	.13, .27, .54	-.52, -.16, -.49	.77, .50, .56	.00, .17, .38
5. Surface area	.84, .69, .76	.84, .70, .77	.69, .51, .65	.68, .51, .65		.63, .49, .59	.63, .47, .63	.08, -.06, -.31	.64, .36, .45	-.01, .11, .40
6. Width	.50, .42, .54	.50, .41, .54	.13, .30, .46	.12, .28, .50	.63, .49, .59		.99, .97, .92	.64, -.24, -.47	.19, .28, .33	.01, .32, .43
7. Stretch index lateral	.51, .41, .60	.50, .40, .60	.14, .29, .52	.13, .27, .54	.63, .47, .63	.99, .97, .92		.63, -.25, -.49	.20, .27, .37	.00, .33, .48
8. Width per length ratio	-.20, -.09, -.40	-.20, -.08, -.40	-.50, -.15, -.48	-.52, -.16, -.49	.08, -.06, -.31	.64, -.24, -.47	.63, -.25, -.49		-.29, -.07, -.38	-.03, -.13, -.30
9. Centroid longitudinal	.75, .49, .53	.77, .47, .52	.76, .54, .59	.77, .50, .56	.64, .36, .45	.19, .28, .33	.20, .27, .37	-.29, -.07, -.38		.02, .26, .35
10. Centroid lateral	.01, .21, .44	.01, .20, .42	.00, .19, .41	.00, .17, .38	-.01, .11, .40	.01, .32, .43	.00, .33, .48	-.03, -.13, -.30	.02, .26, .35	

Uncertainty (90% compatibility limits): ~±0.1 to ~±0.01 for correlations of 0.00 to 0.95 respectively assuming a sample size of ~300.

A7 Table. Simple statistics provided by the mixed model (predicted mean for the middle of a match and mean possession duration; residual within-match standard deviation) for the team and positional sub-groups on attack. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as times/divide factors. Clusters of variables representing consecutively longitudinal dispersion, lateral dispersion, longitudinal position and lateral position are outlined.

Variable	Team	Forwards	Midcourts	Defenders
Mean				
Stretch index (m)	6.8 ×/÷ 1.07	3.3 ×/÷ 1.19	4.2 ×/÷ 1.16	4.7 ×/÷ 1.18
Inter-player distance (m)	10 ×/÷ 1.07	5.6 ×/÷ 1.19	7.4 ×/÷ 1.16	8.1 ×/÷ 1.19
Stretch index longitudinal (m)	6.1 ×/÷ 1.11	2.4 ×/÷ 1.30	3.2 ×/÷ 1.21	3.9 ×/÷ 1.28
Length (m)	22 ×/÷ 1.07	6.2 ×/÷ 1.30	8.1 ×/÷ 1.25	9.7 ×/÷ 1.26
Width (m)	7.3 ×/÷ 1.16	4.2 ×/÷ 1.26	5.6 ×/÷ 1.30	5.0 ×/÷ 1.27
Stretch index lateral (m)	2.0 ×/÷ 1.18	1.6 ×/÷ 1.29	2.2 ×/÷ 1.30	1.9 ×/÷ 1.27
Width per length ratio	0.30 ×/÷ 1.23	0.47 ×/÷ 1.76	0.53 ×/÷ 1.53	0.41 ×/÷ 1.54
Surface area (m^2)	86 ×/÷ 1.17	8.2 ×/÷ 1.51	15 ×/÷ 1.50	19 ×/÷ 1.51
Centroid longitudinal[a] (m)	18.3 ± 1.3	24.2 ± 2.1	19.0 ±1.3	11.5 ± 1.9
Centroid lateral (m)	7.5 ± 1.1	7.3 ± 1.4	7.7 ± 1.4	7.7 ± 1.2
Variability				
Stretch index (m)	0.80 ×/÷ 1.54	0.90 ×/÷ 1.42	0.99 ×/÷ 1.33	1.1 ×/÷ 1.48
Inter-player distance (m)	1.0 ×/÷ 1.44	1.6 ×/÷ 1.41	1.7 ×/÷ 1.40	1.8 ×/÷ 1.42
Stretch index longitudinal (m)	0.96 ×/÷ 1.52	0.93 ×/÷ 1.43	1.1 ×/÷ 1.43	1.1 ×/÷ 1.52
Length (m)	2.1 ×/÷ 1.43	2.4 ×/÷ 1.41	2.9 ×/÷ 1.31	2.5 ×/÷ 1.50
Width (m)	1.70 ×/÷ 1.33	1.8 ×/÷ 1.33	1.9 ×/÷ 1.45	1.6 ×/÷ 1.48
Stretch index lateral (m)	0.49 ×/÷ 1.52	0.68 ×/÷ 1.40	0.70 ×/÷ 1.40	0.62 ×/÷ 1.49
Width per length ratio	0.97 ×/÷ 1.69	0.58 ×/÷ 2.5	0.77 ×/÷ 2.12	0.79 ×/÷ 2.26
Surface area (m^2)	20 ×/÷ 1.41	6.6 ×/÷ 1.58	9.1 ×/÷ 1.57	10 ×/÷ 1.55
Centroid longitudinal (m)	2.0 ×/÷ 1.52	1.9 ×/÷ 1.42	2.5 ×/÷ 1.51	2.3 ×/÷ 1.49
Centroid lateral (m)	0.82 ×/÷ 1.55	1.2 ×/÷ 1.51	1.2 ×/÷ 1.59	0.87 ×/÷ 1.70
Irregularity				
Stretch index	0.19 ×/÷ 1.86	0.27 ×/÷ 1.56	0.25 ×/÷ 1.55	0.17 ×/÷ 1.70
Inter-player distance	0.20 ×/÷ 1.56	0.26 ×/÷ 1.51	0.25 ×/÷ 1.50	0.17 ×/÷ 1.69
Stretch index longitudinal	0.16 ×/÷ 1.87	0.25 ×/÷ 1.65	0.21 ×/÷ 1.54	0.15 ×/÷ 1.78
Length	0.20 ×/÷ 1.54	0.26 ×/÷ 1.50	0.22 ×/÷ 1.54	0.15 ×/÷ 1.83
Width	0.34 ×/÷ 1.44	0.34 ×/÷ 1.49	0.31 ×/÷ 1.39	0.28 ×/÷ 1.46
Stretch index lateral	0.31 ×/÷ 1.56	0.35 ×/÷ 1.46	0.31 ×/÷ 1.45	0.28 ×/÷ 1.45
Width per length ratio	0.25 ×/÷ 1.66	0.20 ×/÷ 1.74	0.17 ×/÷ 1.74	0.19 ×/÷ 1.72
Surface area	0.35 ×/÷ 1.48	0.34 ×/÷ 1.56	0.33 ×/÷ 1.55	0.24 ×/÷ 1.53
Centroid longitudinal	0.08 ×/÷ 1.86	0.12 ×/÷ 1.76	0.08 ×/÷ 1.83	0.10 ×/÷ 1.71
Centroid lateral	0.20 ×/÷ 1.47	0.21 ×/÷ 1.56	0.21 ×/÷ 1.50	0.20 ×/÷ 1.59

[a] Values shown were derived for log(30.5 – centroid longitudinal); actual means were therefore 18.6 m, 24.5 m, 19.1 m and 11.4 m respectively add actual means shown in output with decimal.

A8 Table. Simple statistics provided by the mixed model (predicted mean for the middle of a match and mean possession duration; residual within-match standard deviation) for the team and positional sub-groups on defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as times/divide factors. Clusters of variables representing consecutively longitudinal dispersion, lateral dispersion, longitudinal position and lateral position are outlined.

Variable	Team	Forwards	Midcourts	Defenders
Mean				
Stretch index (m)	6.6 ×/÷ 1.11	4.3 ×/÷ 1.17	3.9 ×/÷ 1.20	3.0 ×/÷ 1.20
Inter-player distance (m)	10 ×/÷ 1.09	7.5 ×/÷ 1.18	6.9 ×/÷ 1.20	5.1 ×/÷ 1.20
Stretch index longitudinal (m)	6.1 ×/÷ 1.14	3.8 ×/÷ 1.30	3.2 ×/÷ 1.26	2.2 ×/÷ 1.25
Length (m)	22 ×/÷ 1.08	9.5 ×/÷ 1.22	8.1 ×/÷ 1.24	5.9 ×/÷ 1.25
Width (m)	6.1 ×/÷ 1.18	3.8 ×/÷ 1.24	4.6 ×/÷ 1.28	3.7 ×/÷ 1.29
Stretch index lateral (m)	1.7 ×/÷ 1.19	1.5 ×/÷ 1.24	1.8 ×/÷ 1.28	1.4 ×/÷ 1.29
Width per length ratio	0.26 ×/÷ 1.22	0.34 ×/÷ 1.52	0.45 ×/÷ 1.49	0.49 ×/÷ 1.54
Surface area (m^2)	72 ×/÷ 1.17	14 ×/÷ 1.48	12 ×/÷ 1.54	7.0 ×/÷ 1.58
Centroid longitudinal[a] (m)	11.7 ± 1.7	18.9 ± 2.3	10.9 ± 1.6	5.8 ± 2.0
Centroid lateral (m)	7.5 ± 1.1	7.5 ± 1.2	7.4 ± 1.3	7.5 ± 1.3
Variability				
Stretch index (m)	0.89 ×/÷ 1.58	1.1 ×/÷ 1.42	1.0 ×/÷ 1.53	0.70 ×/÷ 1.50
Inter-player distance (m)	1.09 ×/÷ 1.45	1.8 ×/÷ 1.39	1.7 ×/÷ 1.51	1.2 ×/÷ 1.51
Stretch index longitudinal (m)	1.0 ×/÷ 1.55	1.1 ×/÷ 1.45	1.0 ×/÷ 1.52	0.73 ×/÷ 1.45
Length (m)	2.2 ×/÷ 1.48	2.6 ×/÷ 1.44	2.5 ×/÷ 1.52	1.9 ×/÷ 1.45
Width (m)	1.3 ×/÷ 1.43	1.3 ×/÷ 1.50	1.5 ×/÷ 1.41	1.4 ×/÷ 1.40
Stretch index lateral (m)	0.37 ×/÷ 1.44	0.50 ×/÷ 1.54	0.60 ×/÷ 1.37	0.55 ×/÷ 1.42
Width per length ratio	1.0 ×/÷ 1.70	0.68 ×/÷ 2.58	0.78 ×/÷ 2.28	0.65 ×/÷ 1.37
Surface area (m^2)	17 ×/÷ 1.48	7.9 ×/÷ 1.43	8.0 ×/÷ 1.64	4.7 ×/÷ 1.68
Centroid longitudinal (m)	1.50 ×/÷ 1.60	2.0 ×/÷ 1.42	2.4 ×/÷ 1.59	1.64 ×/÷ 1.43
Centroid lateral (m)	0.68 ×/÷ 1.61	0.76 ×/÷ 1.77	1.0 ×/÷ 1.60	0.94 ×/÷ 1.52
Irregularity				
Stretch index	0.16 ×/÷ 2.09	0.16 ×/÷ 1.65	0.22 ×/÷ 1.67	0.32 ×/÷ 1.57
Inter-player distance	0.17 ×/÷ 1.62	0.16 ×/÷ 1.80	0.23 ×/÷ 1.67	0.32 ×/÷ 1.62
Stretch index longitudinal	0.15 ×/÷ 2.02	0.15 ×/÷ 1.78	0.20 ×/÷ 1.64	0.28 ×/÷ 1.57
Length	0.18 ×/÷ 1.72	0.16 ×/÷ 1.83	0.22 ×/÷ 1.61	0.29 ×/÷ 1.54
Width	0.38 ×/÷ 1.44	0.32 ×/÷ 1.43	0.36 ×/÷ 1.35	0.39 ×/÷ 1.39
Stretch index lateral	0.37 ×/÷ 1.50	0.32 ×/÷ 1.40	0.36 ×/÷ 1.32	0.40 ×/÷ 1.37
Width per length ratio	0.33 ×/÷ 1.48	0.23 ×/÷ 1.70	0.21 ×/÷ 1.66	0.23 ×/÷ 1.73
Surface area	0.34 ×/÷ 1.46	0.27 ×/÷ 1.63	0.29 ×/÷ 1.52	0.39 ×/÷ 1.49
Centroid longitudinal	0.10 ×/÷ 1.98	0.12 ×/÷ 1.60	0.10 ×/÷ 1.87	0.12 ×/÷ 1.68
Centroid lateral	0.23 ×/÷ 1.61	0.23 ×/÷ 1.53	0.23 ×/÷ 1.53	0.26 ×/÷ 1.50

[a] Values shown were derived for log(30.5 – centroid longitudinal); actual means were therefore 18.6 m, 24.5 m, 19.1 m and 11.4 m respectively add actual means shown in output with decimal.

A9 Table. Collective tactical variables for the forward sub-group attack and defence possessions adjusted for possession duration, score difference, ladder point's difference, match trend and season trend. Dashed lines separate the variables into the clusters defined by the correlations in Table 2.2. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent. Data for attack and defence are predicted means (raw units) from the mixed model, and SDs are an appropriate residual representing differences between possessions. Data for attack minus defence are predicted mean differences (% units) with 90% compatibility limits (% units) and decisions about the magnitude of the differences.

Variables	Attack	Defence	Attack minus Defence	Magnitude
Mean				
Stretch index (m)	3.3 ± 19%	4.3 ± 17%	-28.8, ±8.9 %	**large↓******
Inter-player distance (m)	5.6 ± 19%	7.5 ± 17%	-27.8, ±8.8 %	**large↓******
Stretch index longitudinal (m)	2.39 ± 30%	3.75 ± 23%	-45, ±13 %	**large↓******
Length (m)	6.2 ± 30%	9.5 ± 22%	-42, ±13 %	**large↓******
Surface area (m^2)	8.2 ± 51%	13.5 ± 48%	-49, ±16 %	**moderate↓******
Width (m)	4.2 ± 30%	3.83 ± 24%	9.8, ±7.4 %	small↑**
Stretch index lateral (m)	1.61 ± 29%	1.47 ± 24%	9.5, ±7.1 %	small↑**
Width per length ratio (m)	0.47 ± 76%	0.34 ± 52%	33, ±16 %	**moderate↑*****
Centroid longitudinal (m)	24.2 ± 2.1	18.9 ± 2.3	5.4, ±1.3	**very large↑******
Centroid lateral (m)	7.29 ± 1.37	7.52 ± 1.21	-0.23, ±0.26	**small↓*^{0}**
Variability				
Stretch index (m)	0.90 ± 42%	1.06 ± 42%	-16.1, ±8.7 %	**small↓*****
Inter-player distance (m)	1.58 ± 41%	1.79 ± 40%	-12.7, ±7.5 %	**small↓****
Stretch index longitudinal (m)	0.93 ± 43%	1.08 ± 54%	-15.1, ±8.2 %	**small↓*****
Length (m)	2.41 ± 41%	2.6 ± 44%	-7.5, ±5.9 %	**small↓*^{0}**
Surface area (m^2)	6.6 ± 58%	8.0 ± 43%	-19, ±10 %	**small↓*****
Width (m)	1.80 ± 33%	1.32 ± 50%	31, ±13 %	**moderate↑******
Stretch index lateral (m)	0.68 ± 32%	0.50 ± 54%	30, ±13 %	**moderate↑******
Width per length ratio (m)	0.58 ± 151%	0.67 ± 154%	-16, ±15 %	**trivial↓^{0}***
Centroid longitudinal (m)	1.86 ± 50%	2.0 ± 42%	-6.7, ±9.7 %	trivial^{0}
Centroid lateral (m)	1.18 ± 51%	0.76 ± 77%	43.6, ±9.7 %	**moderate↑******
Irregularity				
Stretch index	0.27 ± 56%	0.16 ± 76%	52, ±20 %	**moderate↑******
Inter-player distance	0.26 ± 51%	0.16 ± 80%	65, ±28 %	**moderate↑******
Stretch index longitudinal	0.25 ± 65%	0.15 ± 78%	54, ±21 %	**moderate↑******
Length	0.26 ± 58%	0.16 ± 83%	52, ±19 %	**moderate↑******
Surface area	0.34 ± 57%	0.27 ± 63%	22, ±12 %	**small↑****
Width	0.34 ± 49%	0.32 ± 43%	8.2, ±7.9 %	**small↑*^{0}**
Stretch index lateral	0.35 ± 46%	0.32 ± 40%	8.5, ±7.9 %	**small↑*^{0}**
Width per length ratio	0.24 ± 74%	0.22 ± 70%	16, ±12 %	**small↑*^{0}**
Centroid longitudinal	0.12 ± 76%	0.12 ± 60%	4.7, ±14 %	trivial^{00}
Centroid lateral	0.21 ± 56%	0.23 ± 53%	-8, ±16 %	trivial↓^{0}*

90%CL, 90% compatibility limits; ↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A10 Table. Collective tactical variables for the midcourt sub-group attack and defence possessions adjusted for possession duration, score difference, ladder point's difference, match trend and season trend. Dashed lines separate the variables into the clusters defined by the correlations in Table 2.2. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent. Data for attack and defence are predicted means (raw units) from the mixed model, and SDs are an appropriate residual representing differences between possessions. Data for attack minus defence are predicted mean differences (% units) with 90% compatibility limits (% units) and decisions about the magnitude of the differences.

Variables	Attack	Defence	Attack minus Defence	Magnitude
Mean				
Stretch index (m)	4.24 ± 16%	3.94 ± 20%	7.2 ± 6.7 %	small↑**
Inter-player distance (m)	7.4 ± 16%	6.8 ± 20%	7.8 ± 6.6 %	small↑**
Stretch index longitudinal (m)	3.16 ± 21%	3.17 ± 26%	-0.5 ± 8.3 %	trivial
Length (m)	8.1 ± 25%	8.1 ± 24%	0.8 ± 7.8 %	trivial
Surface area (m²)	15 ± 50%	13 ± 54%	16 ± 13 %	small↑**
Width (m)	5.6 ± 30%	4.6 ± 28%	18.2 ± 9.0 %	**moderate↑********
Stretch index lateral (m)	2.16 ± 30%	1.77 ±28%	20.1 ± 5.3 %	**moderate↑********
Width per length ratio (m)	0.53 ± 53%	0.45 ± 49%	20 ± 1.0 %	**small↑******
Centroid longitudinal (m)	19.0 ± 1.3	10.9 ± 1.6	8.3 ± 2.0	**very large↑********
Centroid lateral (m)	7.7 ± 1.4	7.4 ± 1.3	0.24 ± 0.21	**trivial↑⁰***
Variability				
Stretch index (m)	1.08 ± 48%	0.72. ± 50%	52 ± 17 %	**moderate↑********
Inter-player distance (m)	1.78 ± 51%	1.18 ± 51%	46 ± 16 %	**moderate↑********
Stretch index longitudinal (m)	1.13 ± 52%	0.73 ± 45%	46 ± 20 %	**moderate↑********
Length (m)	2.4 ± 78%	1.9 ± 45%	28 ± 18 %	**small↑******
Surface area (m²)	10.1 ± 56%	4.7 ± 68%	114 ± 39 %	**large↑********
Width (m)	1.63 ± 48%	1.41 ± 40%	14 ± 11 %	**small↑****
Stretch index lateral (m)	0.62 ± 49%	0.54 ± 37%	14 ± 12 %	**small↑****
Width per length ratio (m)	0.53 ± 52%	0.45 ± 48%	19 ± 11 %	**small↑****
Centroid longitudinal (m)	2.3 ± 50%	1.61 ± 43%	40 ± 18 %	**moderate↑********
Centroid lateral (m)	0.87 ± 70%	0.99 ± 52%	-8.1 ± 7.7 %	**trivial↓⁰***
Irregularity				
Stretch index	0.25 ± 55%	0.22 ± 67%	13 ± 15 %	small↑*⁰
Inter-player distance	0.25 ± 50%	0.23 ± 66%	8 ± 14 %	trivial↑⁰*
Stretch index longitudinal	0.21 ± 54%	0.20 ± 64%	3 ± 15 %	trivial
Length	0.22 ± 54%	0.22 ± 61%	-2 ± 14 %	trivial
Surface area	0.33 ± 55%	0.29 ± 52%	10.1 ± 8.3 %	**small↑*⁰**
Width	0.31 ± 39%	0.36 ± 35%	-14 ± 11 %	**small↓****
Stretch index lateral	0.31 ± 45%	0.36 ± 32%	-15 ± 13 %	small↓**
Width per length ratio	0.21 ± 74%	0.17 ± 68%	18 ± 11 %	**small↑****
Centroid longitudinal	0.08 ± 83%	0.10 ± 87%	-15 ± 15 %	**small↓*⁰**
Centroid lateral	0.21 ± 50%	0.23 ± 53%	-9 ± 11 %	trivial↓⁰*

90%CL, 90% compatibility limits; ↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ⁰possibly.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A11 Table. Collective tactical variables for the defender sub-group attack and defence possessions adjusted for possession duration, score difference, ladder point's difference, match trend and season trend. Dashed lines separate the variables into the clusters defined by the correlations in Table 2.2. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent. Data for attack and defence are predicted means (raw units) from the mixed model, and SDs are an appropriate residual representing differences between possessions. Data for attack minus defence are predicted mean differences (% units) with 90% compatibility limits (% units) and decisions about the magnitude of the differences.

Variables	Attack	Defence	Attack minus Defence	Magnitude
Mean				
Stretch index (m)	4.73 ± 19%	2.96 ± 20%	47 ± 10 %	**very large↑******
Inter-player distance (m)	8.1 ± 19%	5.1 ± 20%	46 ± 10 %	**very large↑******
Stretch index longitudinal (m)	3.9 ± 28%	2.24 ± 25%	56 ± 13 %	**very large↑******
Length (m)	9.7 ± 26%	5.8 ± 25%	53 ± 13 %	**very large↑******
Surface area (m²)	19 ± 51%	6.7 ± 58%	101 ± 23 %	**very large↑******
Width (m)	4.95 ± 27%	3.74 ± 29%	28.2 ± 7.6 %	**moderate↑******
Stretch index lateral (m)	1.91 ± 27%	1.42 ± 29%	28.2 ± 7.6 %	**moderate↑******
Width per length ratio (m)	0.41 ± 54%	0.49 ± 54%	-17.2 ± 8.9 %	**small↓****
Centroid longitudinal (m)	11.5 ± 1.9	5.8 ± 2.0	5.9 ± 1.5	**very large↑******
Centroid lateral (m)	7.8 ± 1.2	7.5 ± 1.3	0.33 ± 0.26	**small↑*⁰**
Variability				
Stretch index (m)	1.07 ± 48%	0.70 ± 50%	42 ± 11 %	**moderate↑******
Inter-player distance (m)	1.80 ± 42%	1.22 ± 51%	39 ± 11 %	**moderate↑******
Stretch index longitudinal (m)	1.07 ± 52%	0.73 ± 45%	38 ± 13 %	**moderate↑******
Length (m)	2.5 ± 50%	1.89 ± 48%	26 ± 14 %	**moderate↑*****
Surface area (m²)	10.1 ± 55%	4.7 ± 68%	76 ± 18 %	**large↑******
Width (m)	1.63 ± 48%	1.44 ± 40%	12.7 ± 9.6 %	**small↑****
Stretch index lateral (m)	0.62 ± 49%	0.55 ± 37%	12 ± 10 %	small↑**
Width per length ratio (m)	0.79 ± 129%	0.65 ± 145%	19 ± 12 %	**small↑*⁰**
Centroid longitudinal (m)	2.3 ± 49%	1.64 ± 43%	34 ± 13 %	**moderate↑******
Centroid lateral (m)	0.87 ± 70%	0.94 ± 52%	-8.0 ± 8.3 %	**trivial↓⁰***
Irregularity				
Stretch index	0.17 ± 70%	0.32 ± 57%	-47 ± 7.1 %	**large↓******
Inter-player distance	0.17 ± 69%	0.32 ± 62%	-48 ± 7.7 %	**large↓******
Stretch index longitudinal	0.15 ± 79%	0.28 ± 57%	-48 ± 7.6 %	**large↓******
Length	0.15 ± 83%	0.29 ± 54%	-48 ± 8.6 %	**large↓******
Surface area	0.24 ± 53%	0.49 ± 47%	-37 ± 5.2 %	**moderate↓******
Width	0.28 ± 46%	0.39 ± 39%	-29 ± 5.6 %	**moderate↓******
Stretch index lateral	0.28 ± 45%	0.40 ± 37%	-30 ± 5.5 %	**moderate↓******
Width per length ratio	0.23 ± 72%	0.19 ± 73%	23 ± 14 %	**small↑****
Centroid longitudinal	0.10 ± 72%	0.12 ± 68%	-22 ± 14 %	**small↓****
Centroid lateral	0.20 ± 59%	0.26 ± 50%	-20 ± 7.8 %	**small↓*****

90%CL, 90% compatibility limits; ↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A12 Table. Difference between home score and home turnover (on attack) and between opposition score and opposition turnover (on defence) for each of the derived measures of each collective tactical variable for the forward sub-group. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

	Home (attack)		Opposition (defence)	
Variables	**Score – Turnover**	**Decision**	**Score – Turnover**	**Decision**
Mean				
Stretch index (m)	-5.6, ±3.2 %	**small↓****	6.8, ±3.7 %	**small↑****
Inter-player distance (m)	-5.5, ±3.2 %	**small↓****	6.8, ±3.6 %	**small↑****
Stretch index longitudinal (m)	-7.8, ±4.6 %	**small↓****	9.8, ±4.9 %	**small↑****
Length (m)	-7.8, ±4.6 %	**small↓****	8.9, ±4.6 %	**small↑****
Surface area (m²)	-8.8, ±8.2 %	**trivial↓^{0*}**	8.2, ±8.1 %	**trivial↑^{0*}**
Width (m)	-5.8, ±7.1 %	**trivial^{00}**	15, ±9.0 %	**small↑****
Stretch index lateral (m)	-0.80, ±4.3 %	trivial^{00}	-0.10, ±4.1 %	trivial^{000}
Width per length ratio (m)	9.6, ±9.9 %	**trivial↑^{0*}**	-7.6, ±6.9 %	**trivial↓^{0*}**
Centroid longitudinal (m)	0.77, ±0.36	**small↑****	-0.55, ±0.36	**small↓^{*0}**
Centroid lateral (m)	0.06, ±0.24	trivial^{00}	-0.15, ±0.20	**trivial^{00}**
Variability				
Stretch index (m)	-1.5, ±5.9 %	trivial^{00}	9.0, ±6.9 %	**small↑^{*0}**
Inter-player distance (m)	-2.6, ±5.7 %	**trivial^{00}**	9.3, ±6.9 %	**small↑^{*0}**
Stretch index longitudinal (m)	-0.50, ±6.1 %	trivial^{000}	11, ±7.2 %	**small↑****
Length (m)	-0.80, ±5.9 %	trivial^{000}	12, ±7.2 %	**small↑****
Surface area (m²)	-2.7, ±14 %	trivial^{00}	-4.6, ±14 %	trivial^{00}
Width (m)	-4.9, ±7.6 %	**trivial^{00}**	7.3, ±7.6 %	**trivial↑^{0*}**
Stretch index lateral (m)	-6.7, ±5.3 %	**trivial↓^{0*}**	-4.3, ±6.5 %	**trivial^{00}**
Width per length ratio (m)	-26, ±11 %	**small↓****	-30, ±10 %	**small↓*****
Centroid longitudinal (m)	8.9, ±7.5 %	**small↑^{*0}**	6.6, ±6.9 %	**trivial↑^{0*}**
Centroid lateral (m)	-8.2, ±6.6 %	**trivial↓^{0*}**	-7.0, ±9.0 %	**trivial↓^{0*}**
Irregularity				
Stretch index	-4.7, ±7.0 %	**trivial^{00}**	-10, ±9.2 %	**small↓^{*0}**
Inter-player distance	-10, ±8.9 %	**trivial↓^{0*}**	8.3, ±10 %	**trivial↑^{0*}**
Stretch index longitudinal	-4.1, ±7.5 %	**trivial^{00}**	-9.1, ±9.5 %	**trivial↓^{0*}**
Length	-7.3, ±7.0 %	**trivial^{00}**	-12, ±9 %	**small↓^{*0}**
Surface area	5.0, ±8.0 %	**trivial^{00}**	-5.0, ±8.4 %	**trivial^{00}**
Width	-9.5, ±6.6 %	**small↓^{*0}**	-8.8, ±7.8 %	**trivial↓^{0*}**
Stretch index lateral	-2.8, ±6.1 %	**trivial^{00}**	-7.7, ±6.4 %	**trivial↓^{0*}**
Width per length ratio	12, ±11 %	**trivial^{0*}**	-7.7, ±8.8 %	**small↓^{*0}**
Centroid longitudinal	-5.6, ±3.2 %	**small↓****	6.8, ±3.7 %	**small↑****
Centroid lateral	-19, ±8.0 %	**small↓****	-3.5, ±9.3 %	**trivial^{00}**

↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely.
*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).
Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely; ^{000}very likely.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

A13 Table. Difference between home score and home turnover (on attack) and between opposition score and opposition turnover (on defence) for each of the derived measures of each collective tactical variable for the midcourt sub-group. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

	Home (attack)		Opposition (defence)	
Variables	**Score – Turnover**	**Decision**	**Score – Turnover**	**Decision**
Mean				
Stretch index (m)	-0.1, ±2.5 %	trivial^{000}	2.5, ±3.1 %	**trivial↑^{0*}**
Inter-player distance (m)	-0.3, ±2.5 %	trivial^{000}	2.0, ±3.1 %	**trivial^{00}**
Stretch index longitudinal (m)	2.3, ±3.6 %	**trivial^{00}**	5.2, ±4.1 %	**small↑^{*0}**
Length (m)	1.7, ±3.6 %	**trivial^{00}**	3.8, ±3.9 %	**trivial↑^{0*}**
Surface area (m²)	-0.9, ±6.2 %	trivial^{000}	3.5, ±7.6 %	**trivial^{00}**
Width (m)	-3.0, ±3.8 %	**trivial^{00}**	-3.4, ±4.0 %	**trivial↓^{0*}**
Stretch index lateral (m)	-3.6, ±3.9 %	**trivial↓^{0*}**	-2.9, ±4.0 %	**trivial^{00}**
Width per length ratio (m)	-1.7, ±6.7 %	trivial^{00}	-8.1, ±5.9 %	**small↓^{*0}**
Centroid longitudinal (m)	0.98, ±0.44	**small↑*****	-1.21, ±0.45	**small↓*****
Centroid lateral (m)	0.15, ±0.23	**trivial^{00}**	-0.14, ±0.23	**trivial^{00}**
Variability				
Stretch index (m)	1.8, ±6.5 %	**trivial^{000}**	4.4, ±7.8 %	**trivial↑^{00}**
Inter-player distance (m)	1.3, ±6.9 %	trivial^{000}	3.8, ±7.7 %	**trivial↑^{00}**
Stretch index longitudinal (m)	0.00, ±6.8 %	trivial^{000}	5.7, ±7.4 %	**trivial↑^{0*}**
Length (m)	1.7, ±7.5 %	trivial^{00}	6.6, ±7.5 %	**trivial↑^{0*}**
Surface area (m²)	-2.2, ±7.6 %	**trivial^{000}**	-11, ±8.7 %	**small↓^{*0}**
Width (m)	-8.0, ±6.0 %	**small↓^{*0}**	-8.1, ±5.7 %	**small↓^{*0}**
Stretch index lateral (m)	-7.6, ±6.2 %	**small↓^{*0}**	-7.1, ±5.6 %	**trivial↓^{0*}**
Width per length ratio (m)	-1.1, ±6.8 %	trivial^{00}	-8.1, ±5.9 %	**small↓^{*0}**
Centroid longitudinal (m)	-4.6, ±6.4 %	**trivial^{00}**	21, ±8.4 %	**small↑*****
Centroid lateral (m)	-4.3, ±8.1 %	**trivial^{00}**	-6.2, ±7.5 %	**trivial^{00}**
Irregularity				
Stretch index	-15, ±6.3 %	**small↓****	-7.7, ±8.3 %	**trivial↓^{0*}**
Inter-player distance	-14, ±6.7 %	**small↓****	-6.3, ±8.2 %	**trivial↓^{0*}**
Stretch index longitudinal	-16, ±6.5 %	**small↓****	-13, ±7.7 %	**small↓****
Length	-15, ±6.6 %	**small↓****	-9.1, ±8.2 %	**trivial↓^{0*}**
Surface area	-8.5, ±5.9 %	**trivial↓^{0*}**	-3.1, ±8.3 %	trivial^{00}
Width	-6.8, ±5.3 %	**trivial↓^{0*}**	-6.5, ±5.8 %	**trivial↓^{0*}**
Stretch index lateral	-6.2, ±5.5 %	**trivial↓^{0*}**	-6.5, ±5.8 %	**trivial↓^{0*}**
Width per length ratio	17, ±12 %	**small↑^{*0}**	21, ±13 %	**small↑****
Centroid longitudinal	2.0, ±10 %	trivial^{000}	-16, ±9.4 %	**small↓****
Centroid lateral	-3.9, ±7.7 %	**trivial↓^{00}**	2.8, ±8.2 %	trivial^{00}

↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.
*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).
Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely; ^{000}very likely.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

A14 Table. Difference between home score and home turnover (on attack) and between opposition score and opposition turnover (on defence) for each of the derived measures of each collective tactical variable for the defender sub-group. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Home (attack) Score – Turnover	Home (attack) Decision	Opposition (defence) Score – Turnover	Opposition (defence) Decision
Mean				
Stretch index (m)	1.0, ±3.0 %	**trivial^{00}**	-8.5, ±3.2 %	**small↓*******
Inter-player distance (m)	1.0, ±2.9 %	**trivial^{00}**	-9.0, ±3.2 %	**small↓**********
Stretch index longitudinal (m)	5.8, ±4.3 %	**small↑*^{0}**	-8.9, ±4.2 %	**small↓******
Length (m)	5.6, ±4.2 %	**small↑*^{0}**	-9.2, ±4.2 %	**small↓******
Surface area (m²)	0.20, ±7.4 %	trivial^{000}	-16, ±7.2 %	**small↓******
Width (m)	-8.6, ±4.0 %	**small↓******	-5.9, ±4.2 %	**small↓*^{0}**
Stretch index lateral (m)	-8.2, ±4.0 %	**small↓******	-6.1, ±4.2 %	**small↓*^{0}**
Width per length ratio (m)	-12, ±6.8 %	**small↓*^{0}**	5.8, ±8.9 %	**trivial^{00}**
Centroid longitudinal (m)	0.43, ±0.33	**trivial↑^{0}***	-1.01, ±0.32	**moderate↓**********
Centroid lateral (m)	0.02, ±0.21	trivial^{000}	-0.13, ±0.21	**trivial^{00}**
Variability				
Stretch index (m)	1.8, ±6.5 %	**trivial^{000}**	4.4, ±7.8 %	**trivial^{00}**
Inter-player distance (m)	1.9, ±6.7 %	**trivial^{00}**	3.8, ±7.7 %	**trivial^{00}**
Stretch index longitudinal (m)	0.00, ±6.8 %	trivial^{000}	5.7, ±7.4 %	**trivial↑^{0}***
Length (m)	1.7, ±7.1 %	trivial^{00}	6.6, ±7.5 %	**trivial↑^{0}***
Surface area (m²)	-0.90, ±7.2 %	trivial^{000}	-11, ±8.7 %	**small↓*^{0}**
Width (m)	-8.0, ±6.0 %	**small↓*^{0}**	-8.2, ±5.6 %	**small↓*^{0}**
Stretch index lateral (m)	-7.6, ±6.2 %	**small↓*^{0}**	-7.2, ±5.5 %	**trivial↓^{0}***
Width per length ratio (m)	-2.0, ±14 %	trivial^{000}	-3.3, ±15 %	trivial^{00}
Centroid longitudinal (m)	-5.2, ±6.3 %	**trivial^{00}**	21, ±8.3 %	**small↑*******
Centroid lateral (m)	-4.3, ±8.1 %	**trivial^{00}**	-7.4, ±7.1 %	**trivial↓^{0}***
Irregularity				
Stretch index	-5.2, ±8.6 %	**trivial^{00}**	-1.1, ±7.9 %	trivial^{000}
Inter-player distance	-7.3, ±8.4 %	**trivial↓^{0}***	-1.0, ±8.0 %	trivial^{000}
Stretch index longitudinal	5.5, ±10 %	**trivial^{00}**	-4.7, ±8.1 %	**trivial^{00}**
Length	-1.0, ±9.8 %	trivial^{00}	-2.6, ±7.8 %	**trivial^{00}**
Surface area	-6.1, ±7.0 %	**trivial↓^{0}***	6.3, ±7.9 %	**trivial↑^{0}***
Width	-7.7, ±6.0 %	**small↓*^{0}**	9.4, ±6.4 %	**small↑*^{0}**
Stretch index lateral	-8.0, ±6.2 %	**small↓*^{0}**	9.7, ±6.3 %	**small↑*^{0}**
Width per length ratio	-2.9 ±9.3 %	trivial^{00}	-2.5, ±9.9 %	trivial^{00}
Centroid longitudinal	15, ±11 %	**small↑*^{0}**	-28, ±7.2 %	**small↓**********
Centroid lateral	-11, ±7.6 %	**small↓*^{0}**	9.6, ±8.7 %	**trivial↑^{0}***

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely; ^{000}very likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A15 Table. Effect of two SD of possession length (factor increases of 2.4 on attack and 2.7 on defence) on collective tactical variables for the team on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	3.0, ±1.3 %	**small↑****	2.4, ±1.7 %	**small↑*⁰**
Inter-player distance (m)	2.0, ±1.1 %	**small↑*⁰**	2.7, ±1.6 %	**small↑****
Stretch index longitudinal (m)	3.3, ±1.7 %	**small↑****	2.2, ±2.1 %	**trivial↑⁰***
Length (m)	0.90, ±1.2 %	**trivial⁰⁰**	3.4, ±1.5 %	**small↑*****
Width (m)	3.0, ±2.6 %	**trivial↑⁰***	4.7, ±3.0 %	**small↑****
Stretch index lateral (m)	3.4, ±2.7 %	**small↑*⁰**	5.5, ±3.2 %	**small↑****
Width per length ratio (m)	0.10, ±3.4 %	trivial⁰⁰⁰	1.8, ±3.8 %	**trivial⁰⁰**
Surface area (m²)	2.8, ±2.7 %	**trivial↑⁰***	6.7, ±3.2 %	**small↑*****
Centroid longitudinal (m)	0.57, ±0.22	**small↑****	-0.71, ±0.30	**small↓******
Centroid lateral (m)	0.07, ±0.17	**trivial⁰⁰**	0.19, ±0.17	**trivial↑⁰***
Variability				
Stretch index (m)	29, ±8.5 %	**moderate↑******	28, ±9.8 %	**moderate↑******
Inter-player distance (m)	27, ±7.7 %	**small↑******	28, ±9.9 %	**moderate↑******
Stretch index longitudinal (m)	28, ±7.8 %	**moderate↑******	28, ±9.5 %	**moderate↑******
Length (m)	21, ±6.9 %	**small↑******	26, ±10 %	**small↑******
Width (m)	22, ±6.9 %	**small↑******	13, ±7.3 %	**small↑****
Width per length ratio (m)	-16, ±7.0 %	**small↓****	-7.5, ±8.7 %	**trivial↓⁰***
Stretch index lateral (m)	17, ±6.9 %	**small↑*****	14, ±6.9 %	**small↑*****
Surface area (m²)	12, ±6.1 %	**small↑****	16, ±7 %	**small↑*****
Centroid longitudinal (m)	20, ±8.4 %	**small↑*****	33, ±11 %	**moderate↑******
Centroid lateral (m)	31, ±9.3 %	**small↑******	38, ±12 %	**moderate↑******
Irregularity				
Stretch index	-51, ±3.9 %	**large↓******	-52, ±4.9 %	**large↓******
Inter-player distance	-47, ±4.2 %	**moderate↓******	-53, ±4.4 %	**large↓******
Stretch index longitudinal	-52, ±3.9 %	**large↓******	-55, ±4.4 %	**large↓******
Length	-48, ±4.1 %	**large↓******	-52, ±4.7 %	**large↓******
Width	-42, ±3.3 %	**large↓******	-39, ±4.2 %	**large↓******
Stretch index lateral	-42, ±3.4 %	**large↓******	-40, ±3.8 %	**large↓******
Width per length ratio	-44, ±4.3 %	**large↓******	-45, ±4.1 %	**large↓******
Surface area	-40, ±3.2 %	**large↓******	-40, ±4.0 %	**large↓******
Centroid longitudinal	-47, ±5.7 %	**moderate↓******	-53, ±6.4 %	**moderate↓******
Centroid lateral	-46, ±4.2 %	**large↓******	-55, ±3.7 %	**large↓******

↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.
*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).
Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely; ^{000}very likely.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

A16 Table. Effect of two SD of possession length (factor increases of 2.4 on attack and 2.7 on defence) on collective tactical variables for the forward's sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	-2.6, ±3.2 %	**trivial⁰**	13, ±4.3 %	**moderate↑******
Inter-player distance (m)	-3.0, ±3.1 %	**trivial↓⁰***	12, ±4.2 %	**small↑******
Stretch index longitudinal (m)	-2.9, ±4.8 %	**trivial⁰**	16, ±5.7 %	**small↑******
Length (m)	-3.6, ±4.7 %	**trivial↓⁰***	13, ±5.3 %	**small↑*****
Surface area (m²)	-4.7, ±7.2 %	**trivial⁰**	23, ±11 %	**small↑*****
Width (m)	0.00, ±4.4 %	trivial⁰	3.6, ±4.5 %	**trivial↑⁰***
Stretch index lateral (m)	-0.10, ±4.2 %	trivial⁰	3.4, ±4.6 %	**trivial↑⁰***
Width per length ratio (m)	-3.8, ±8.4 %	**trivial⁰⁰**	-13, ±6.6 %	**small↓****
Centroid longitudinal (m)	0.58, ±0.33	**small↑*⁰**	-0.66, ±0.37	**small↓****
Centroid lateral (m)	0.11, ±0.22	**trivial⁰⁰**	0.39, ±0.20	**small↑****
Variability				
Stretch index (m)	28, ±7.9 %	**moderate↑******	26, ±8.4 %	**moderate↑******
Inter-player distance (m)	26, ±7.8 %	**moderate↑******	23, ±8.3 %	**small↑******
Stretch index longitudinal (m)	27, ±7.9 %	**moderate↑******	27, ±8.3 %	**moderate↑******
Length (m)	25, ±7.7 %	**small↑******	23, ±8.2 %	**small↑******
Surface area (m²)	14, ±8.7 %	**small↑****	34, ±11 %	**moderate↑******
Width (m)	18, ±6.5 %	**small↑******	26, ±8.7 %	**moderate↑******
Stretch index lateral (m)	17, ±6.2 %	**small↑*****	26, ±9.1 %	**moderate↑******
Width per length ratio (m)	-26, ±11 %	**small↓****	-30, ±10 %	**small↓*****
Centroid longitudinal (m)	27, ±9.1 %	**small↑******	27, ±8.9 %	**small↑******
Centroid lateral (m)	26, ±8.8 %	**small↑******	54, ±16 %	**moderate↑******
Irregularity				
Stretch index	-48, ±3.7 %	**large↓******	-42, ±6.4 %	**moderate↓******
Inter-player distance	-47, ±3.7 %	**moderate↓******	-45, ±6.5 %	**moderate↓******
Stretch index longitudinal	-52, ±3.5 %	**large↓******	-48, ±6.1 %	**moderate↓******
Length	-50, ±3.6 %	**large↓******	-46, ±5.8 %	**moderate↓******
Surface area	-43, ±3.8 %	**moderate↓******	-42, ±5.5 %	**moderate↓******
Width	-35, ±3.9 %	**moderate↓******	-41, ±4.6 %	**large↓******
Stretch index lateral	-35, ±3.8 %	**moderate↓******	-41, ±4.4 %	**large↓******
Width per length ratio	-75, ±18 %	**moderate↓******	-90, ±20 %	**moderate↓******
Centroid longitudinal	-49, ±5.1 %	**moderate↓******	-58, ±4.9 %	**large↓******
Centroid lateral	-40, ±4.4 %	**moderate↓******	-56, ±4.1 %	**large↓******

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ⁰possibly.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A17 Table. Effect of two SD of possession length (factor increases of 2.4 on attack and 2.7 on defence) on collective tactical variables for the midcourt's sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	7.2, ±2.5 %	**small↑*****	0.90, ±3.0 %	trivial^{00}
Inter-player distance (m)	7.0, ±2.5 %	**small↑*****	1.1, ±2.9 %	trivial^{00}
Stretch index longitudinal (m)	5.4, ±3.8 %	**small↑*^{0}**	-0.50, ±3.8 %	trivial^{00}
Length (m)	5.1, ±3.7 %	**small↑*^{0}**	-0.90, ±3.6 %	trivial^{00}
Surface area (m²)	22, ±7.3 %	**small↑******	14, ±8.7 %	**small↑****
Width (m)	8.1, ±4.0 %	**small↑****	4.7, ±5.0 %	**trivial^{0}***
Stretch index lateral (m)	10, ±4.2 %	**small↑*****	5.3, ±5.0 %	**trivial^{0}***
Width per length ratio (m)	0.60, ±6.7 %	trivial^{000}	7.5, ±7.6 %	**trivial^{0}***
Centroid longitudinal (m)	0.73, ±0.41	**small↑*^{0}**	-1.02, ±0.46	**small↓******
Centroid lateral (m)	0.10, ±0.20	**trivial^{00}**	0.51, ±0.24	**small↑****
Variability				
Stretch index (m)	26, ±8.2 %	**small↑******	24, ±9.9 %	**small↑******
Inter-player distance (m)	24, ±8.9 %	**small↑******	25, ±9.8 %	**small↑******
Stretch index longitudinal (m)	31, ±9.0 %	**moderate↑******	28, ±9.4 %	**small↑******
Length (m)	29, ±9.1 %	**small↑******	25, ±9.2 %	**small↑******
Surface area (m²)	28, ±9.9 %	**small↑******	18, ±11 %	**small↑****
Width (m)	28, ±8.0 %	**moderate↑******	18, ±8.1 %	**small↑*****
Stretch index lateral(m)	31, ±8.4 %	**moderate↑******	18, ±7.8 %	**small↑*****
Width per length ratio (m)	3.3, ±7.3 %	**trivial^{00}**	7.5 ±7.6 %	**trivial↑^{0}***
Centroid longitudinal (m)	37, ±8.9 %	**moderate↑******	37, ±11 %	**moderate↑******
Centroid lateral (m)	43, ±11 %	**moderate↑******	32, ±12 %	**small↑******
Irregularity				
Stretch index	-39, ±4.4 %	**moderate↓******	-50, ±4.7 %	**large↓******
Inter-player distance	-39, ±5.0 %	**moderate↓******	-52, ±4.3 %	**large↓******
Stretch index longitudinal	-47, ±4.1 %	**large↓******	-53, ±4.5 %	**large↓******
Length	-43, ±4.5 %	**moderate↓******	-53, ±4.8 %	**large↓******
Surface area	-38, ±3.3 %	**moderate↓******	-49, ±4.7 %	**large↓******
Width	-38, ±3.5 %	**large↓******	-38, ±3.9 %	**large↓******
Stretch index lateral	-40, ±3.4 %	**large↓******	-38, ±4.3 %	**large↓******
Width per length ratio	-43, ±5.8 %	**moderate↓******	-51, ±5.0 %	**moderate↓******
Centroid longitudinal	-48, ±5.2 %	**moderate↓******	-57, ±5.0 %	**large↓******
Centroid lateral	-40, ±4.9 %	**moderate↓******	-55, ±3.9 %	**large↓******

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely; ^{000}very likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A18 Table. Effect of two SD of possession length (factor increases of 2.4 on attack and 2.7 on defence) on collective tactical variables for the defender's sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	1.6, ±2.9 %	**trivial^{00}**	-5.2, ±3.3 %	**small↓****
Inter-player distance (m)	1.3, ±2.8 %	**trivial^{00}**	-5.3, ±3.3 %	**small↓****
Stretch index longitudinal (m)	2.1, ±3.9 %	**trivial^{00}**	-9.0, ±4.2 %	**small↓****
Length (m)	-0.40, ±3.8 %	trivial^{000}	-9.5, ±4.2 %	**small↓*****
Surface area (m²)	9.3, ±7.6 %	**trivial^{0*}**	-4.0, ±8.5 %	trivial^{00}
Width (m)	4.6, ±4.4 %	**trivial^{0*}**	3.6, ±5.0 %	**trivial^{00}**
Stretch index lateral (m)	5.5, ±4.5 %	**trivial^{0*}**	3.6, ±4.9 %	**trivial^{00}**
Width per length ratio (m)	5.4, ±7.0 %	**trivial^{00}**	13, ±9.7 %	**small↑*^{0}**
Centroid longitudinal (m)	0.42, ±0.30	**trivial^{00}**	-0.80, ±0.33	**small↓******
Centroid lateral (m)	0.10, ±0.20	**trivial^{00}**	0.33, ±0.21	**small↑*^{0}**
Variability				
Stretch index (m)	26, ±8.2 %	**small↑******	28, ±9.9 %	**small↑******
Inter-player distance (m)	23, ±8.8 %	**small↑******	25, ±9.8 %	**small↑******
Stretch index longitudinal (m)	31, ±9.0 %	**moderate↑******	28, ±9.4 %	**small↑******
Length (m)	28, ±9.0 %	**small↑******	25, ±9.2 %	**small↑******
Surface area (m²)	28, ±9.1 %	**small↑******	18, ±11 %	**small↑****
Width (m)	28, ±8.0 %	**moderate↑******	16, ±7.6 %	**small↑*****
Stretch index lateral (m)	31, ±8.4 %	**moderate↑******	14, ±6.9 %	**small↑****
Width per length ratio (m)	-34, ±9.7 %	**small↓******	-14, ±14 %	**trivial↓^{0*}**
Centroid longitudinal (m)	35, ±8.5 %	**moderate↑******	36, ±11 %	**moderate↑******
Centroid lateral (m)	43, ±11 %	**moderate↑******	35, ±11 %	**moderate↑******
Irregularity				
Stretch index	-45, ±5.2 %	**moderate↓******	-52, ±3.7 %	**large↓******
Inter-player distance	-48, ±4.8 %	**large↓******	-53, ±3.6 %	**large↓******
Stretch index longitudinal	-54, ±4.8 %	**large↓******	-55, ±3.8 %	**large↓******
Length	-43, ±4.1 %	**large↓******	-52, ±3.8 %	**large↓******
Surface area	-44, ±5.0 %	**moderate↓******	-47, ±3.8 %	**large↓******
Width	-44, ±3.4 %	**large↓******	-40, ±4.1 %	**large↓******
Stretch index lateral	-49, ±4.3 %	**large↓******	-42, ±3.7 %	**large↓******
Width per length ratio	-44, ±3.6 %	**large↓******	-54, ±4.5 %	**large↓******
Centroid longitudinal	-51, ±4.5 %	**large↓******	-59, ±4.3 %	**large↓******
Centroid lateral	-42, ±5.2 %	**moderate↓******	-49, ±4.4 %	**large↓******

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely; ^{000}very likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A19 Table. Effect of a +10 points score difference on collective tactical variables for the team on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	1.0, ±1.4 %	**trivial**^{00}	-0.60, ±2.2 %	trivial^{00}
Inter-player distance (m)	0.20, ±1.3 %	trivial^{00}	-1.0, ±1.9 %	**trivial↓**^{0*}
Stretch index longitudinal (m)	0.80, ±1.5 %	**trivial**^{00}	-0.7, ±2.7 %	trivial^{00}
Length (m)	-1.4, ±1.5 %	**trivial↓**^{0*}	-2.0, ±1.7 %	**small↓**^{*0}
Width (m)	2.0, ±2.2 %	**trivial**^{00}	-0.1, ±3.0 %	trivial^{00}
Stretch index lateral (m)	1.8, ±2.9 %	trivial^{00}	-1.2, ±2.9 %	trivial^{00}
Width per length ratio (m)	4.7, ±3.6 %	**small↑**^{*0}	0.80, ±4.3 %	**trivial**^{00}
Surface area (m²)	0.60, ±2.9 %	trivial^{00}	-2.5, ±3.0 %	**trivial↓**^{0*}
Centroid longitudinal (m)	-0.13, ±0.31	**trivial**^{00}	0.18, ±0.35	trivial↑^{0*}
Centroid lateral (m)	0.19, ±0.23	**trivial↑**^{0*}	0.06, ±0.14	**trivial**^{000}
Variability				
Stretch index (m)	-5.9, ±5.8 %	**trivial↓**^{0*}	0.90, ±8.3 %	trivial^{00}
Inter-player distance (m)	-6.3, ±4.7 %	**trivial↓**^{0*}	1.7, ±8.6 %	trivial^{00}
Stretch index longitudinal (m)	-2.4, ±7.8 %	trivial^{00}	1.2, ±8.7 %	trivial^{00}
Length (m)	-8.4, ±6.5 %	**small↓**^{*0}	1.1, ±8.0 %	trivial^{00}
Width (m)	-0.10, ±5.5 %	trivial^{000}	-1.1, ±6.2 %	trivial^{00}
Stretch index lateral (m)	0.10, ±5.8 %	trivial^{00}	-3.1, ±6.1 %	trivial^{00}
Width per length ratio (m)	11, ±7.9 %	**small↑**^{*0}	-5.9, ±9.5 %	**trivial**^{00}
Surface area (m²)	1.3, ±6.1 %	trivial^{00}	-6.1, ±4.8 %	**trivial↓**^{0*}
Centroid longitudinal (m)	5.2, ±8.6 %	**trivial**^{00}	17, ±9.2 %	**small↑****
Centroid lateral (m)	1.7, ±7.4 %	trivial^{000}	-2.0, ±9.3 %	trivial^{00}
Irregularity				
Stretch index	-1.6, ±8.3 %	trivial^{000}	5.3, ±8.6 %	**trivial**^{00}
Inter-player distance	-0.20, ±8.3 %	trivial^{000}	3.7, ±9.4 %	trivial^{00}
Stretch index longitudinal	0.60, ±9.9 %	trivial^{00}	6.8, ±8.5 %	**trivial**^{00}
Length	3.6, ±9.6 %	**trivial**^{00}	2.6, ±12 %	trivial^{00}
Width	-4.5, ±4.6 %	**trivial**^{00}	-1.8, ±4.9 %	**trivial**^{000}
Stretch index lateral	-3.0, ±4.6 %	**trivial**^{00}	0.40, ±4.4 %	**trivial**^{000}
Width per length ratio	1.6, ±6.8 %	**trivial**^{000}	13, ±9.2 %	**small↑****
Surface area	-11, ±5.5 %	**small↓****	0.80, ±6.2 %	trivial^{00}
Centroid longitudinal	-4.5, ±12 %	trivial^{00}	-16, ±13 %	**small↓**^{*0}
Centroid lateral	-4.8, ±7.9 %	**trivial**^{00}	2.3, ±9.7 %	trivial^{00}

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely.

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely; ^{000}very likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A20 Table. Effect of a +10 points score difference on collective tactical variables for the forward's sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	-3.4, ±4.2 %	**trivial**↓^{0*}	-10, ±4.0 %	**small**↓***
Inter-player distance (m)	-3.7, ±4.2 %	**trivial**↓^{0*}	-9.6, ±3.9 %	**small**↓***
Stretch index longitudinal (m)	-7.1, ±6.0 %	**small**↓^{*0}	-12, ±5.1 %	**small**↓***
Length (m)	-8.1, ±5.8 %	**small**↓**	-11, ±4.9 %	**small**↓***
Surface area (m²)	-3.6, ±9.3 %	trivial^{00}	-15, ±7.6 %	**small**↓**
Width (m)	3.0, ±5.5 %	trivial↑^{0*}	0.00, ±3.3 %	trivial^{000}
Stretch index lateral (m)	3.1, ±5.3 %	trivial↑^{0*}	-0.50, ±3.4 %	trivial^{000}
Width per length ratio (m)	21, ±13 %	**small**↑**	11, ±9.4 %	**small**↑^{*0}
Centroid longitudinal (m)	-0.33, ±0.48	**trivial**↓^{0*}	0.37, ±0.47	trivial↑^{0*}
Centroid lateral (m)	0.08, ±0.27	trivial^{00}	0.00, ±0.21	**trivial**^{000}
Variability				
Stretch index (m)	-11, ±6.1 %	**small**↓**	-12, ±6.2 %	**small**↓**
Inter-player distance (m)	-11, ±5.7 %	**small**↓**	-11, ±5.7 %	**small**↓**
Stretch index longitudinal (m)	-8.1, ±6.1 %	**small**↓^{*0}	-14, ±6.2 %	**small**↓***
Length (m)	-9.6, ±5.4 %	**small**↓**	-14, ±4.6 %	**small**↓***
Surface area (m²)	-11, ±8.2 %	**small**↓^{*0}	-16, ±5.6 %	**small**↓***
Width (m)	-8.8, ±5.7 %	**small**↓^{*0}	-6.7, ±7.9 %	**trivial**↓^{0*}
Stretch index lateral(m)	-7.7, ±5.5 %	**small**↓^{*0}	-8.9, ±7.9 %	**small**↓^{*0}
Width per length ratio (m)	27, ±21 %	**small**↑**	10, ±16 %	**trivial**↑^{0*}
Centroid longitudinal (m)	11, ±8.8 %	**small**↑^{*0}	14, ±7.7 %	**small**↑**
Centroid lateral (m)	-3.0, ±6.5 %	**trivial**^{000}	4.5, ±11 %	trivial^{00}
Irregularity				
Stretch index	4.6, ±12.8 %	trivial^{00}	-2.7, ±9.2 %	trivial^{00}
Inter-player distance	6.1, ±12.6 %	trivial^{00}	-1.4, ±9.0 %	trivial^{00}
Stretch index longitudinal	9.3, ±13.8 %	**trivial**↑^{0*}	-8.3, ±9.1 %	**trivial**↓^{0*}
Length	7.5, ±13.1 %	**trivial**↑^{0*}	-7.1, ±8.8 %	**trivial**↓^{0*}
Surface area	-3.8, ±8.4 %	trivial^{00}	-9.1, ±8.2 %	**small**↓^{*0}
Width	4.5, ±5.9 %	**trivial**^{00}	-6.9, ±6.7 %	**trivial**↓^{0*}
Stretch index lateral	2.0, ±5.7 %	**trivial**^{000}	-8.2, ±6.5 %	**small**↓^{*0}
Width per length ratio	0.2, ±11 %	trivial^{00}	1.4, ±7.9 %	**trivial**^{000}
Centroid longitudinal	-8.6, ±8.8 %	**trivial**↓^{0*}	-22, ±9.1 %	**small**↓***
Centroid lateral	-7.3, ±10 %	**trivial**↓^{0*}	-5.6, ±8.2 %	**trivial**^{00}

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely.

*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely; ^{000}very likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A21 Table. Effect of a +10 points score difference on collective tactical variables for the midcourt's sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	6.7, ±2.7 %	**small**↑***	11, ±4.4 %	**moderate**↑****
Inter-player distance (m)	6.9, ±2.7 %	**small**↑***	11, ±4.3 %	**moderate**↑****
Stretch index longitudinal (m)	8.5, ±3.1 %	**small**↑***	13, ±5.7 %	**small**↑***
Length (m)	8.8, ±3.1 %	**small**↑***	13, ±5.5 %	**small**↑****
Surface area (m²)	9.8, ±6.9 %	**small**↑^{*0}	17, ±11 %	**small**↑**
Width (m)	3.0, ±4.3 %	**trivial**^{00}	4.6, ±4.8 %	**trivial**↑^{0*}
Stretch index lateral (m)	2.8, ±4.2 %	**trivial**^{00}	4.4, ±4.8 %	**trivial**↑^{0*}
Width per length ratio (m)	-6.9, ±6.9 %	**trivial**^{0*}	-2.7, ±7.0 %	trivial^{00}
Centroid longitudinal (m)	-0.89, ±0.58	**small**↓**	0.96, ±0.59	**small**↑***
Centroid lateral (m)	0.05, ±0.23	trivial^{00}	0.19, ±0.19	**trivial**^{00}
Variability				
Stretch index (m)	-4.6, ±6.5 %	**trivial**^{00}	11, ±9.9 %	**small**↑^{*0}
Inter-player distance (m)	-4.9, ±6.7 %	**trivial**^{00}	11, ±9.7 %	**small**↑^{*0}
Stretch index longitudinal (m)	-4.3, ±7.8 %	trivial^{00}	14, ±9.9 %	**small**↑**
Length (m)	-2.3, ±8.8 %	trivial^{00}	13.6, ±9.7 %	**small**↑**
Surface area (m²)	-2.2, ±9.3 %	trivial^{00}	6.5, ±12.6 %	trivial↑^{0*}
Width (m)	1.3, ±8.0 %	trivial^{00}	1.2, ±5.2 %	**trivial**^{000}
Stretch index lateral (m)	0.00, ±8.2 %	trivial	1.4, ±5.1 %	**trivial**^{000}
Width per length ratio (m)	-7.3, ±7.0 %	**trivial**↓^{0*}	-2.9, ±7.0 %	trivial^{00}
Centroid longitudinal (m)	-4.9, ±7.7 %	**trivial**^{00}	5.9, ±8.8 %	**trivial**↑^{0*}
Centroid lateral (m)	5.8, ±9.3 %	**trivial**^{00}	-6.5, ±6.1 %	**trivial**^{00}
Irregularity				
Stretch index	-6.1, ±8.4 %	**trivial**↓^{0*}	-1.2, ±11 %	trivial^{00}
Inter-player distance	-7.6, ±8.1 %	**trivial**↓^{0*}	-3.3, ±10 %	trivial^{00}
Stretch index longitudinal	-2.6, ±8.7 %	trivial^{00}	-0.1, ±11 %	trivial
Length	-3.0, ±8.7 %	trivial^{00}	-5.9, ±9.8 %	trivial↓^{0*}
Surface area	-2.8, ±7.0 %	trivial^{00}	5.8, ±8.5 %	**trivial**^{00}
Width	-8.1, ±5.7 %	**small**↓^{*0}	-11, ±6.7 %	**small**↓**
Stretch index lateral	-6.2, ±5.6 %	**trivial**↓^{0*}	-15, ±6.6 %	**small**↓***
Width per length ratio	9.6, ±12 %	**trivial**↑^{0*}	-5.8, ±8.2 %	**trivial**^{00}
Centroid longitudinal	-1.3, ±10 %	trivial^{00}	-7.6, ±12 %	trivial↓^{0*}
Centroid lateral	-4.7, ±8.3 %	trivial^{00}	0.9, ±9.0 %	trivial^{00}

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely; ^{000}very likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A22 Table. Effect of a +10 points score difference on collective tactical variables for the defender's sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	-1.8, ±3.9 %	trivial^{00}	5.3, ±4.8 %	**small↑^{*0}**
Inter-player distance (m)	-1.7, ±3.8 %	trivial^{00}	5.6, ±4.8 %	**small↑^{*0}**
Stretch index longitudinal (m)	-2.1, ±5.2 %	trivial^{00}	7.0, ±6.5 %	**small↑^{*0}**
Length (m)	-2.6, ±5.1 %	trivial^{00}	6.4, ±6.5 %	**small↑^{*0}**
Surface area (m²)	-5.1, ±9.2 %	trivial^{00}	8.5, ±12 %	**trivial^{0*}**
Width (m)	0.00, ±4.7 %	trivial^{00}	3.4, ±5.7 %	**trivial^{0*}**
Stretch index lateral (m)	-0.70, ±4.8 %	trivial^{00}	3.2, ±5.7 %	trivial^{00}
Width per length ratio (m)	3.3, ±8.8 %	trivial^{00}	-7.1, ±6.5 %	**trivial^{0*}**
Centroid longitudinal (m)	-0.66, ±0.43	**small↓^{*0}**	0.39, ±0.43	**small↑^{*0}**
Centroid lateral (m)	0.22, ±0.24	**trivial↑^{0*}**	0.10, ±0.18	**trivial^{00}**
Variability				
Stretch index (m)	-4.6, ±6.5 %	**trivial^{00}**	11, ±9.9 %	**small↑^{*0}**
Inter-player distance (m)	-4.1, ±6.8 %	**trivial^{00}**	10, ±9.7 %	**small↑^{*0}**
Stretch index longitudinal (m)	-4.3, ±7.8 %	trivial^{00}	14, ±9.9 %	**small↑****
Length (m)	-2.2, ±8.5 %	trivial^{00}	14, ±9.7 %	**small↑****
Surface area (m²)	-0.60, ±9.1 %	trivial^{00}	6.5, ±13 %	trivial↑^{0*}
Width (m)	1.3, ±8.0 %	trivial^{00}	1.2, ±5.1 %	**trivial^{000}**
Stretch index lateral(m)	0.00, ±8.2 %	trivial	1.6, ±5.0 %	**trivial^{000}**
Width per length ratio (m)	2.6, ±12 %	**trivial^{000}**	1.2, ±13 %	trivial^{000}
Centroid longitudinal (m)	-4.2, ±7.8 %	trivial^{00}	6.2, ±8.7 %	**trivial↑^{0*}**
Centroid lateral (m)	5.8, ±9.3 %	**trivial^{00}**	-5.0, ±6.0 %	**trivial^{00}**
Irregularity				
Stretch index	4.5, ±9.5 %	trivial^{00}	-13, ±8.5 %	**small↓****
Inter-player distance	2.2, ±9.2 %	trivial^{00}	-16, ±8.4 %	**small↓****
Stretch index longitudinal	11, ±8.6 %	**trivial↑^{0*}**	-10, ±9.4 %	**small↓^{*0}**
Length	0.00, ±11 %	trivial	-16, ±8.5 %	**small↓****
Surface area	1.0, ±7.8 %	trivial^{00}	-6.2, ±6.9 %	**trivial↓^{0*}**
Width	-2.4, ±7.3 %	trivial^{00}	-6.9, ±4.4 %	**trivial↓^{0*}**
Stretch index lateral	-1.9, ±7.5 %	trivial^{00}	-7.1, ±4.3 %	**trivial↓^{0*}**
Width per length ratio	3.8, ±9.3 %	trivial^{00}	0.9, ±11 %	trivial^{00}
Centroid longitudinal	-0.3, ±9.1 %	trivial^{000}	-5.6, ±12 %	trivial^{00}
Centroid lateral	-7.6, ±7.6 %	**trivial↓^{0*}**	-5.6, ±8.2 %	**trivial^{00}**

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely.

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely; ^{000}very likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A23 Table. Change in collective tactical variables over a match for the team on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	-2.2, ±2.2 %	**small↓**^{*0}	-7.9, ±2.9 %	**moderate↓******
Inter-player distance (m)	-2.0, ±1.9 %	**small↓**^{*0}	-5.6, ±2.6 %	**moderate↓*****
Stretch index longitudinal (m)	-1.2, ±2.6 %	trivial↓^{0*}	-8.8, ±3.5 %	**moderate↓******
Length (m)	-1.6, ±2.2 %	small↓^{*0}	-1.4, ±2.5 %	trivial↓^{0*}
Width (m)	-5.1, ±4.0 %	**small↓****	-6.9, ±4.3 %	**small↓****
Stretch index lateral (m)	-5.3, ±4.2 %	**small↓****	-2.7, ±4.6 %	trivial↓^{0*}
Width per length ratio (m)	-6.4, ±5.5 %	**small↓**^{*0}	-3.6, ±5.9 %	trivial↓^{0*}
Surface area (m^2)	-5.4, ±4.3 %	**small↓****	-7.4, ±4.4 %	**small↓****
Centroid longitudinal (m)	0.51, ±0.45	**small↑**^{*0}	-0.80, ±0.50	**small↓*****
Centroid lateral (m)	-0.33, ±0.34	**small↓**^{*0}	-0.47, ±0.27	**small↓****
Variability				
Stretch index (m)	10, ±12 %	**small↑**^{*0}	-7.3, ±12 %	trivial↓^{0*}
Inter-player distance (m)	7.8, ±11 %	**trivial↑**^{0*}	-11, ±12 %	small↓^{*0}
Stretch index longitudinal (m)	13, ±13 %	**small↑**^{*0}	-9.8, ±11 %	small↓^{*0}
Length (m)	7.3, ±12 %	trivial↑^{0*}	-7.8, ±11 %	small↓^{*0}
Width (m)	1.7, ±9.1 %	trivial	-20, ±8.1 %	**moderate↓*****
Stretch index lateral(m)	-1.2, ±9.1 %	trivial	-15, ±8.4 %	**small↓****
Width per length ratio (m)	1.1, ±16 %	trivial	17, ±16 %	**small↑****
Surface area (m^2)	-4.2, ±9.1 %	trivial↓^{0*}	-15, ±8.5 %	**small↓****
Centroid longitudinal (m)	5.6, ±13 %	trivial↑^{0*}	-6.0, ±13 %	trivial↓^{0*}
Centroid lateral (m)	-12, ±11 %	**small↓**^{*0}	18, ±18 %	**small↑****
Irregularity				
Stretch index	-8.1, ±13 %	trivial↓^{0*}	0.70, ±16 %	trivial
Inter-player distance	-8.2, ±12 %	trivial↓^{0*}	-1.7, ±15 %	trivial
Stretch index longitudinal	-8.8, ±13 %	trivial↓^{0*}	-9.6, ±14 %	trivial↓^{0*}
Length	6.2, ±15 %	trivial↑^{0*}	-10, ±15 %	small↓^{*0}
Width	-4.4, ±8.9 %	trivial↓^{0*}	8.1, ±11 %	small↑^{*0}
Stretch index lateral	-5.9, ±8.7 %	trivial↓^{0*}	2.3, ±8.9 %	trivial↑^{00}
Width per length ratio	0.00, ±13 %	trivial	-12, ±11 %	**small↓**^{*0}
Surface area	1.5, ±9.9 %	trivial	-12, ±9.4 %	**small↓****
Centroid longitudinal	-9.5, ±18 %	trivial↓^{0*}	-3.4, ±21 %	trivial
Centroid lateral	26, ±16 %	**small↑*****	-13, ±12 %	**small↓**^{*0}

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A24 Table. Change in collective tactical variables over a match for the forward's sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	-7.8, ±5.8 %	**small↓****	6.3, ±6.8 %	**small↑^{*0}**
Inter-player distance (m)	-7.4, ±5.7 %	**small↓****	5.1, ±6.5 %	small↑^{*0}
Stretch index longitudinal (m)	-5.5, ±8.7 %	small↓^{*0}	6.8, ±8.8 %	small↑^{*0}
Length (m)	-5.2, ±8.6 %	trivial↓^{0*}	3.3, ±8.0 %	trivial↑^{0*}
Surface area (m^2)	-9.0, ±13 %	small↓^{*0}	22, ±17 %	**small↑****
Width (m)	-9.3, ±7.1 %	**small↓****	0.70, ±6.6 %	trivial
Stretch index lateral (m)	-9.6, ±6.8 %	**small↓****	1, ±6.7 %	trivial
Width per length ratio (m)	-8.1, ±15 %	trivial↑^{0*}	0.4, ±13 %	trivial
Centroid longitudinal (m)	-0.7, ±0.68	trivial	-0.38, ±0.65	small↓^{*0}
Centroid lateral (m)	-0.26, ±0.41	trivial↓^{0*}	-0.42, ±0.33	**small↓****
Variability				
Stretch index (m)	1.4, ±10 %	trivial	28, ±14 %	**moderate↑*****
Inter-player distance (m)	2.8, ±10 %	trivial↑	25, ±13%	**small↑*****
Stretch index longitudinal (m)	2.5, ±11 %	trivial	24, ±14 %	**small↑*****
Length (m)	5.2, ±10 %	trivial↑^{0*}	17, ±12 %	**small↑****
Surface area (m^2)	1.5, ±14 %	trivial	14, ±13 %	**small↑^{*0}**
Width (m)	2.5, ±9.9 %	trivial^{00}	-11, ±11 %	**small↓^{*0}**
Stretch index lateral(m)	2.0, ±9.5 %	trivial^{00}	-8.8, ±11 %	small↓^{*0}
Width per length ratio (m)	-3.1 ±24 %	trivial	4.9, ±25 %	trivial
Centroid longitudinal (m)	4.9, ±13 %	trivial↑^{0*}	-10, ±9.8 %	**small↓^{*0}**
Centroid lateral (m)	-2.4, ±12 %	trivial^{00}	7.8, ±18 %	trivial↑^{0*}
Irregularity				
Stretch index	-5.5, ±13 %	trivial↓^{0*}	-33, ±12 %	**moderate↓******
Inter-player distance	-6.2, ±12 %	trivial↓^{0*}	-30, ±13 %	**moderate↓*****
Stretch index longitudinal	1.4, ±15 %	trivial	-25, ±13 %	**small↓****
Length	2.9, ±14 %	trivial	-21, ±14 %	**small↓****
Surface area	-2.2, ±13 %	trivial	-21, ±11 %	**small↓****
Width	2.6, ±11 %	trivial	-1.7, ±11 %	trivial
Stretch index lateral	2.8, ±11 %	trivial	-2.2, ±11 %	trivial
Width per length ratio	-19, ±14 %	**small↓****	1.3, ±15 %	trivial
Centroid longitudinal	-11, ±16 %	trivial↓^{0*}	5.6, ±17 %	trivial↑
Centroid lateral	16, ±15 %	**small↑^{*0}**	-10, ±13 %	small↓^{*0}

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A25 Table. Change in collective tactical variables over a match for the midcourt's sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	-12, ±3.6 %	**moderate**↓****	-10, ±5.0 %	**moderate**↓***
Inter-player distance (m)	-12, ±3.6 %	**moderate**↓****	-10, ±5.0 %	**moderate**↓***
Stretch index longitudinal (m)	-13, ±4.8 %	**moderate**↓****	-13, ±6.3 %	**moderate**↓***
Length (m)	-13, ±4.9 %	**moderate**↓****	-12, ±6.0 %	**small**↓***
Surface area (m^2)	-24, ±7.8 %	**moderate**↓****	-15, ±11 %	**small**↓**
Width (m)	-13, ±5.8 %	**small**↓***	-6.6, ±6.6 %	**small**↓*^{0}
Stretch index lateral (m)	-12, ±5.8 %	**small**↓***	-6.9, ±6.6 %	**small**↓*^{0}
Width per length ratio (m)	-0.90, ±12 %	trivial	5.6, ±12 %	trivial↑^{0}*
Centroid longitudinal (m)	-0.29, ±0.82	trivial↓^{0}*	0.20, ±0.81	trivial
Centroid lateral (m)	-0.02, ±0.38	trivial	-0.61, ±0.37	**small**↓**
Variability				
Stretch index (m)	-21, ±8.4 %	**small**↓***	-19, ±11 %	**small**↓**
Inter-player distance (m)	-22, ±8.8 %	**small**↓***	-19, ±11 %	**small**↓**
Stretch index longitudinal (m)	-29, ±8.5 %	**moderate**↓****	-16, ±11 %	**small**↓**
Length (m)	-29, ±9.3 %	**moderate**↓****	-11, ±11 %	**small**↓*^{0}
Surface area (m^2)	-9.0, ±13 %	trivial↓^{0}*	-16, ±15 %	**small**↓**
Width (m)	-5.2, ±11 %	trivial↓^{0}*	-3.9, ±9.6 %	trivial↓^{0}*
Stretch index lateral (m)	-2.6, ±12 %	trivial	-3.0, ±9.5 %	trivial^{00}
Width per length ratio (m)	-0.1, ±12 %	trivial	5.9, ±13 %	trivial↓^{0}*
Centroid longitudinal (m)	9.2, ±13 %	small↑*^{0}	-4.5, ±12 %	trivial↓^{0}*
Centroid lateral (m)	-11, ±13 %	small↓*^{0}	12, ±15 %	**small**↑*^{0}
Irregularity				
Stretch index	1.7, ±13 %	trivial	3.0, ±16 %	trivial
Inter-player distance	2.7, ±14 %	trivial	0.70, ±16 %	trivial
Stretch index longitudinal	11, ±15 %	small↑*^{0}	1.4, ±16 %	trivial
Length	8.7, ±15 %	trivial↑^{0}*	4.9, ±17 %	trivial
Surface area	-0.90, ±11 %	trivial	-5.8, ±13 %	trivial↓^{0}*
Width	3.2, ±10 %	trivial	15, ±13 %	**small**↑**
Stretch index lateral	4.3, ±10 %	trivial↑^{0}*	22, ±14 %	**small**↑***
Width per length ratio	-10, ±16 %	trivial↓^{0}*	1.0, ±17 %	trivial
Centroid longitudinal	-4.5, ±16 %	trivial	-4.8, ±18 %	trivial
Centroid lateral	12, ±15 %	small↑*^{0}	2.6, ±14 %	trivial

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A26 Table. Change in collective tactical variables over a match for the defender sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	-3.4, ±5.3 %	trivial↓^{0}*	-7.4, ±5.9 %	**small**↓**
Inter-player distance (m)	-2.7, ±5.2 %	trivial↓^{0}*	-7.1, ±6.0 %	**small**↓**
Stretch index longitudinal (m)	-3.7, ±7.2 %	trivial↓^{0}*	-9.6, ±7.8 %	**small**↓**
Length (m)	-1.0, ±7.2 %	trivial	-8.9, ±7.9 %	**small**↓**
Surface area (m²)	-0.10, ±14 %	trivial	-9.9, ±14 %	small↓*^{0}
Width (m)	1.4, ±7.5 %	trivial	-0.4, ±7.8 %	trivial
Stretch index lateral (m)	2.2, ±7.7 %	trivial	0.10, ±7.8 %	trivial
Width per length ratio (m)	1.1, ±14 %	trivial	17, ±16 %	**small**↑**
Centroid longitudinal (m)	-0.06, ±0.61	trivial	0.65, ±0.60	small↑*^{0}
Centroid lateral (m)	-0.43, ±0.37	small↓**	-0.48, ±0.34	**small**↓**
Variability				
Stretch index (m)	-21, ±8.4 %	**small**↓***	-19, ±11 %	**small**↓**
Inter-player distance (m)	-22, ±8.5 %	**small**↓***	-19, ±11 %	**small**↓**
Stretch index longitudinal (m)	-29, ±8.5 %	**moderate**↓****	-16, ±11 %	**small**↓**
Length (m)	-29, ±8.8 %	**moderate**↓****	-11, ±11 %	**small**↓*^{0}
Surface area (m²)	-11, ±12 %	**small**↓*^{0}	-16, ±15 %	**small**↓**
Width (m)	-5.2, ±11 %	trivial↓^{0}*	-5.3, ±9.3 %	trivial↓^{0}*
Stretch index lateral (m)	-2.6, ±12 %	trivial	-5.5, ±9.0 %	trivial↓^{0}*
Width per length ratio (m)	22, ±29 %	**small**↑*^{0}	13, ±29 %	trivial↑^{0}*
Centroid longitudinal (m)	7.8, ±13 %	trivial↑^{0}*	-4.1, ±12 %	trivial↓^{0}*
Centroid lateral (m)	-11, ±13 %	small↓*^{0}	10, ±14 %	**small**↑*^{0}
Irregularity				
Stretch index	18, ±18 %	**small**↑**	23, ±18 %	**small**↑**
Inter-player distance	18, ±18 %	**small**↑**	23, ±18 %	**small**↑**
Stretch index longitudinal	36, ±21 %	**small**↑***	10, ±17 %	trivial↑^{0}*
Length	55, ±26 %	**moderate**↑****	10, ±16 %	trivial↑^{0}*
Surface area	-3, ±12 %	trivial	15, ±14 %	**small**↑*^{0}
Width	3.3, ±12 %	trivial	6.2, ±9.9 %	trivial↑^{0}*
Stretch index lateral	1.6, ±12 %	trivial	7.4, ±9.9 %	**trivial**↑^{0}*
Width per length ratio	-20, ±13 %	**small**↓**	3.6, ±18 %	trivial
Centroid longitudinal	-4.2, ±15 %	trivial^{00}	1.8, ±18 %	trivial
Centroid lateral	5.5, ±15 %	trivial↑^{0}*	2.6, ±14 %	trivial

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A27 Table. Effect of the strongest opposition minus the weakest opposition on collective tactical variables for the team on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	-0.9, ±4.3 %	trivial	-5.9, ±11 %	moderate↓
Inter-player distance (m)	-0.4, ±4.1 %	trivial	-4.3, ±8.1 %	small↓
Stretch index longitudinal (m)	-0.9, ±3.5 %	trivial	-6.6, ±13 %	moderate↓
Length (m)	-2.0, ±5.9 %	small↓	-2.8, ±6.9 %	small↓
Width (m)	4.8, ±4.0 %	**small↑*⁰**	-3.7, ±8.3 %	small↓
Stretch index lateral (m)	2.2, ±8.3 %	trivial	-4.6, ±7.0 %	small↓*⁰
Width per length ratio (m)	11, ±8.9 %	small↑**	0.10, ±17 %	trivial
Surface area (m²)	3.0, ±8.9 %	trivial	-6.5, ±7.5 %	small↓**
Centroid longitudinal (m)	1.34, ±1.24	moderate↑**	-1.83, ±1.77	large↓**
Centroid lateral (m)	0.14, ±0.77	trivial	0.05, ±0.25	trivial⁰⁰
Variability				
Stretch index (m)	-17, ±12 %	small↓**	4.1, ±27 %	trivial
Inter-player distance (m)	-11, ±7.9 %	**small↓*⁰**	5.1, ±27 %	trivial
Stretch index longitudinal (m)	-25, ±25 %	moderate↓**	-2.3, ±30 %	trivial
Length (m)	-4.4, ±20 %	trivial	3.1, ±23 %	trivial
Width (m)	-12, ±13 %	small↓**	-4.6, ±14 %	trivial
Stretch index lateral (m)	-11, ±15 %	small↓*⁰	-6.1, ±15 %	trivial
Width per length ratio (m)	-1.9, ±25 %	trivial	7.2, ±11 %	trivial
Surface area (m²)	-7.7, ±15 %	small↓	-8.5, ±8.4 %	**small↓*⁰**
Centroid longitudinal (m)	-2.6, ±29 %	trivial	-24, ±14 %	moderate↓***
Centroid lateral (m)	-3.6, ±17 %	trivial	-3.9, ±27 %	trivial
Irregularity				
Stretch index	0.60, ±23 %	trivial	-27, ±28 %	moderate↓**
Inter-player distance	-2.2, ±22 %	trivial	-12, ±13 %	**small↓*⁰**
Stretch index longitudinal	-2.3, ±34 %	trivial	16, ±63 %	small↑
Length	-6.4, ±27 %	trivial	-4.1, ±13 %	trivial
Width	3.2, ±8.6 %	trivial⁰⁰	-8.2, ±8.3 %	**small↓*⁰**
Stretch index lateral	6.1, ±8.7 %	**trivial↑⁰***	-6.3, ±29 %	trivial
Width per length ratio	-5.9, ±11 %	trivial↓⁰*	-0.2, ±28 %	trivial
Surface area	4.2, ±17 %	trivial	-11, ±13 %	small↓*⁰
Centroid longitudinal	-5.3, ±39 %	trivial	0.20, ±28 %	trivial
Centroid lateral	0.30, ±26 %	trivial	-16, ±17 %	small↓*⁰

↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.
*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).
Reference-Bayesian likelihoods of trivial change: ⁰possibly; ⁰⁰likely.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

A28 Table. Effect of the strongest opposition minus the weakest opposition on collective tactical variables for the forward's sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	5.1, ±21 %	small↑	1.2, ±23 %	trivial
Inter-player distance (m)	4.8, ±21 %	small↑	-0.10, ±22 %	trivial
Stretch index longitudinal (m)	10, ±32 %	small↑	1.3, ±33 %	trivial
Length (m)	9.0, ±31 %	small↑	-1.2, ±32 %	trivial
Surface area (m^2)	9.0, ±48 %	trivial	-5.0, ±29 %	trivial
Width (m)	0.50, ±24 %	trivial	-1.6, ±5.9 %	trivial^{00}
Stretch index lateral (m)	-0.30, ±23 %	trivial	-2.0, ±5.9 %	trivial^{00}
Width per length ratio (m)	1.0, ±56 %	trivial	1.3, ±28 %	trivial
Centroid longitudinal (m)	-0.11, ±3.41	trivial	-0.13, ±3.76	trivial
Centroid lateral (m)	0.19, ±0.78	trivial	-0.15, ±0.54	trivial
Variability				
Stretch index (m)	8.1, ±23 %	small↑	4.8, ±20 %	trivial
Inter-player distance (m)	8.1, ±21 %	small↑	3.0, ±16 %	trivial
Stretch index longitudinal (m)	-1.7, ±18 %	trivial	9.6, ±23 %	small↑
Length (m)	-2.8, ±14 %	trivial	6.5, ±10 %	trivial↑^{0}*
Surface area (m^2)	9.2, ±32 %	trivial	-4.0, ±15 %	trivial
Width (m)	-12, ±17 %	small↓*^{0}	3.0, ±39 %	trivial
Stretch index lateral (m)	-13, ±16 %	small↓**	1.4, ±40 %	trivial
Width per length ratio (m)	32, ±73 %	small↑	-1.8, ±33 %	trivial
Centroid longitudinal (m)	-19, ±21 %	small↓**	-16, ±16 %	small↓**
Centroid lateral (m)	-6.6, ±14 %	trivial↓^{0}*	11, ±30 %	trivial
Irregularity				
Stretch index	-18, ±33 %	small↓	-4.8, ±52 %	trivial
Inter-player distance	-15, ±36 %	small↓	-8.5, ±39 %	trivial
Stretch index longitudinal	7.1, ±43 %	trivial	-17, ±49 %	small↓
Length	-9.9, ±30 %	small↓	-18, ±42 %	small↓
Surface area	-17, ±36 %	small↓	8.3, ±27 %	trivial
Width	-0.60, ±22 %	trivial	-5.5, ±9.7 %	trivial↓^{0}*
Stretch index lateral	1.0, ±28 %	trivial	-2.1, ±9.8 %	trivial
Width per length ratio	-0.9,±28 %	trivial	12, ±16 %	**trivial↑^{0}***
Centroid longitudinal	0.90, ±29 %	trivial	18, ±29 %	small↑*^{0}
Centroid lateral	-18, ±35 %	small↓	-12, ±41 %	small↓

↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely.
Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

A29 Table. Effect of the strongest opposition minus the weakest opposition on collective tactical variables for the midcourt's sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	**Attack**	**Decision**	**Defence**	**Decision**
Mean				
Stretch index (m)	-1, ±6.4 %	trivial	-8.6, ±18.4 %	small↓
Inter-player distance (m)	-0.3, ±6.5 %	trivial	-8.6, ±17.9 %	small↓
Stretch index longitudinal (m)	-2.3, ±4.9 %	trivial↓^{0}*	-11, ±22 %	small↓
Length (m)	-2.5, ±5 %	trivial↓^{0}*	-13, ±21 %	moderate↓
Surface area (m²)	2.3, ±16 %	trivial	-3.4, ±39 %	trivial
Width (m)	8.5, ±13 %	small↑*^{0}	5.6, ±15 %	small↑
Stretch index lateral (m)	7.2, ±11 %	small↑*^{0}	5.8, ±15 %	small↑
Width per length ratio (m)	18, ±28 %	small↑**	27, ±28 %	small↑**
Centroid longitudinal (m)	0.16, ±3.92	trivial	0.06, ±4.75	trivial
Centroid lateral (m)	-0.14, ±0.61	trivial	0.28, ±0.34	**small↑*^{0}**
Variability				
Stretch index (m)	-13, ±16 %	small↓*^{0}	0.8, ±32 %	trivial
Inter-player distance (m)	-12, ±17 %	small↓*^{0}	-0.9, ±30 %	trivial
Stretch index longitudinal (m)	1.2, ±30 %	trivial	10, ±38 %	small↑
Length (m)	3.7, ±36 %	trivial	6.2, ±35 %	trivial
Surface area (m²)	-17, ±33 %	small↓	2.9, ±51 %	trivial
Width (m)	-6.3, ±27 %	trivial	-6.8, ±8.6 %	**trivial↓^{0}***
Stretch index lateral (m)	-3.3, ±29 %	trivial	-6.7, ±8.4 %	**trivial↓^{0}***
Width per length ratio (m)	16, ±23 %	trivial	23, ±29 %	**small↑*^{0}**
Centroid longitudinal (m)	-6.2, ±28 %	trivial	3.2, ±35 %	trivial
Centroid lateral (m)	0.9, ±23 %	trivial	-6.6, ±11 %	trivial↓^{0}*
Irregularity				
Stretch index	11, ±36 %	small	5.8, ±37 %	trivial
Inter-player distance	16, ±35 %	small	7.3, ±44 %	trivial
Stretch index longitudinal	5.7, ±32 %	trivial	-15, ±35 %	small↓
Length	6.1, ±32 %	trivial	-17, ±15 %	small↓**
Surface area	5, ±22 %	trivial	5.1, ±43 %	trivial
Width	-2.9, ±17 %	trivial	-1.6, ±33 %	trivial
Stretch index lateral	4.5, ±15 %	trivial	-11, ±26 %	small↓
Width per length ratio	-20, ±25 %	small↓*^{0}	-3.6, ±15 %	trivial^{00}
Centroid longitudinal	-35, ±19 %	moderate↓***	3.7, ±16 %	trivial^{00}
Centroid lateral	3.7, ±27 %	trivial	2, ±38 %	trivial

↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.
*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).
Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

A30 Table. Effect of the strongest opposition minus the weakest opposition on collective tactical variables for the defenders sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	1.1, ±23 %	trivial	9.3, ±29 %	small↑
Inter-player distance (m)	1.0, ±24 %	trivial	8.1, ±29 %	small↑
Stretch index longitudinal (m)	-1.3, ±31 %	trivial	15, ±39 %	small↑
Length (m)	2.0, ±32 %	trivial	14, ±39 %	small↑
Surface area (m²)	-9.7, ±51 %	small↓	2.4, ±58 %	trivial
Width (m)	1.2, ±13 %	trivial	-0.60, ±21 %	trivial
Stretch index lateral (m)	1.7, ±14 %	trivial	0.00, ±21 %	trivial
Width per length ratio (m)	-1.9, ±25 %	trivial	-14, ±11 %	**small↓****
Centroid longitudinal (m)	0.22, ±2.46	trivial	0.42, ±3.91	trivial
Centroid lateral (m)	0.11, ±0.77	trivial	0.25, ±0.31	trivial↑^{0}*
Variability				
Stretch index (m)	-13, ±16 %	small↓*^{0}	0.80, ±32 %	trivial
Inter-player distance (m)	-11, ±18 %	small↓	-0.90, ±30 %	trivial
Stretch index longitudinal (m)	1.2, ±30 %	trivial	10, ±38 %	small↑
Length (m)	2.9, ±38 %	trivial	6.2, ±35 %	trivial
Surface area (m²)	-20, ±31 %	small↓	2.9, ±51 %	trivial
Width (m)	-6.3, ±27 %	trivial	-7.5, ±8.4 %	**small↓*^{0}**
Stretch index lateral (m)	-3.3, ±29 %	trivial	-8.4, ±8.0 %	**small↓*^{0}**
Width per length ratio (m)	1.3, ±22 %	trivial	-19, ±19 %	**small↓*^{0}**
Centroid longitudinal (m)	-7.4, ±29 %	trivial	4.0, ±35 %	trivial
Centroid lateral (m)	0.90, ±23 %	trivial	-3.8, ±19 %	trivial^{00}
Irregularity				
Stretch index	-16, ±19 %	small↓*^{0}	-17, ±32 %	small↓
Inter-player distance	-14, ±19 %	small↓*^{0}	-17, ±36 %	small↓
Stretch index longitudinal	-26, ±10 %	**small↓*****	-20, ±35 %	small↓
Length	-35, ±20 %	moderate↓***	-24, ±34 %	small↓
Surface area	7.9, ±22 %	trivial	-4.3, ±18 %	trivial
Width	-2.6, ±22 %	trivial	-1.8, ±8.5 %	trivial^{0}
Stretch index lateral	-2.1, ±22 %	trivial	-4.2, ±8.1 %	trivial↓^{0}*
Width per length ratio	22, ±24 %	small↑**	24, ±39 %	small↑*^{0}
Centroid longitudinal	-16, ±18 %	small↓*^{0}	-16, ±45 %	small↓
Centroid lateral	-8.1, ±19 %	trivial	-2.3, ±25 %	trivial

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A31 Table. Change in collective tactical variables over the season for the team on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	1.3, ±4.1 %	trivial	-3.5, ±10 %	small↓
Inter-player distance (m)	0.80, ±3.9 %	trivial	-2.3, ±7.6 %	small↓
Stretch index longitudinal (m)	0.20, ±3.4 %	trivial	-5.8, ±12 %	small↓
Length (m)	-2.4, ±5.5 %	small↓	-1.9, ±6.5 %	small↓
Width (m)	8.5, ±3.7 %	**small**↑***	8.1, ±8.7 %	small↑**
Stretch index lateral (m)	9.5, ±8.8 %	small↑**	9.2, ±7.4 %	small↑**
Width per length ratio (m)	14, ±8.6 %	moderate↑***	13, ±18 %	small↑**
Surface area (m^2)	8.1, ±8.9 %	small↑**	5.3, ±7.8 %	small↑*^{0}
Centroid longitudinal (m)	0.15, ±1.14	trivial	-0.47, ±1.67	small↓
Centroid lateral (m)	-0.16, ±0.72	trivial	-0.08, ±0.23	trivial^{00}
Variability				
Stretch index (m)	-26, ±15 %	moderate↓***	-13, ±21 %	small↓
Inter-player distance (m)	-23, ±24 %	moderate↓**	-12, ±21 %	small↓
Stretch index longitudinal (m)	5.4, ±29 %	trivial	-11, ±26 %	small↓
Length (m)	-1.0, ±15 %	trivial	-8.4, ±19 %	small↓
Width (m)	-5.4, ±14 %	trivial	-11, ±13 %	small↓*^{0}
Stretch index lateral (m)	-2.6, ±16 %	trivial	-9.6, ±14 %	small↓*^{0}
Width per length ratio (m)	39, ±38 %	trivial	32, ±44 %	trivial↓^{0}*
Surface area (m^2)	-23, ±11 %	moderate↓***	-11, ±7.4 %	**small**↓**
Centroid longitudinal (m)	5.4, ±29 %	trivial	6.0, ±18 %	trivial
Centroid lateral (m)	-2.6, ±15 %	trivial	-4.2, ±25 %	trivial
Irregularity				
Stretch index	27, ±27 %	small↑**	31, ±18 %	**small**↑***
Inter-player distance	27, ±27 %	small↑**	25, ±24 %	small↑**
Stretch index longitudinal	28, ±41 %	small↑**	25, ±16 %	**small**↑**
Length	36, ±37 %	small↑**	5.2, ±38 %	trivial
Width	7.7, ±8 %	**trivial↑^{0}***	7.6, ±8.8 %	**trivial**↑^{0}*
Stretch index lateral	2.6, ±7.6 %	trivial^{00}	11, ±8.2 %	**small**↑**
Width per length ratio	-13, ±9.1 %	**small↓****	-12, ±23 %	small↓
Surface area	6.4, ±17 %	trivial	12, ±15 %	small↑*^{0}
Centroid longitudinal	16, ±44 %	small↑	19, ±60 %	small↑
Centroid lateral	11, ±27 %	small↑	15, ±33 %	small↑

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** and **** indicate rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly; ^{00}likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A32 Table. Change in collective tactical variables over the season for the forward's sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index(m)	5.8, ±20 %	small↑	-10, ±19 %	small↓
Inter-player distance (m)	5.8, ±20 %	small↑	-11, ±19 %	small↓
Stretch index longitudinal (m)	6.8, ±29 %	small↑	-15, ±25 %	small↓
Length (m)	5.1, ±28 %	trivial	-17, ±25 %	moderate↓
Surface area (m²)	32, ±54 %	small↑	-3.6, ±27 %	trivial
Width (m)	7.6, ±24 %	small↑	9.5, ±6.0 %	**small**↑**
Stretch index lateral (m)	6.4, ±23 %	small↑	8.8, ±6.0 %	**small**↑**
Width per length ratio (m)	23, ±64 %	small↑	32, ±35 %	small↑**
Centroid longitudinal (m)	-0.85, ±3.15	small↓	0.62, ±3.53	small↑
Centroid lateral (m)	-0.22, ±0.73	trivial	-0.35, ±0.51	small↓*⁰
Variability				
Stretch index(m)	6.2, ±21 %	trivial	-6.6, ±17 %	trivial
Inter-player distance (m)	5.3, ±19 %	trivial	-8.3, ±13 %	small↓*⁰
Stretch index longitudinal (m)	-1.4, ±17 %	trivial	-8.2, ±18 %	small↓
Length (m)	-4.2, ±13 %	trivial	-11, ±7.8 %	**small↓*⁰**
Surface area (m²)	21, ±33 %	small↑**	-5.7, ±13 %	trivial↓⁰*
Width (m)	-14, ±16 %	small↓**	-4.9, ±34 %	trivial
Stretch index lateral(m)	-15, ±14 %	small↓**	-7.2, ±34 %	trivial
Width per length ratio (m)	73, ±99 %	moderate↑**	33, ±42 %	small↑**
Centroid longitudinal (m)	-5.2, ±23 %	trivial	3.2, ±18 %	trivial
Centroid lateral (m)	-2.5, ±13 %	trivial	16, ±30 %	small↑
Irregularity				
Stretch index	-9.7, ±34 %	trivial	24, ±63 %	small↑
Inter-player distance	-8.3, ±37 %	trivial	26, ±49 %	small↑
Stretch index longitudinal	30, ±49 %	small↑**	17, ±64 %	small↑
Length	-13, ±27 %	small↓	18, ±56 %	small↑
Surface area	-9.7, ±36 %	trivial	15, ±27 %	small↑*⁰
Width	4.1, ±21 %	trivial	18, ±11 %	**small**↑**
Stretch index lateral	5.3, ±27 %	trivial	22, ±11 %	**small**↑***
Width per length ratio	-12, ±24 %	small	-4.6, ±12 %	trivial↓⁰⁰
Centroid longitudinal	14, ±30 %	small↑	12, ±25 %	trivial↑⁰*
Centroid lateral	-7.6, ±37 %	trivial	12, ±49 %	small↑

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely.

*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).

Reference-Bayesian likelihoods of trivial change: ⁰possibly; ⁰⁰likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A33 Table. Change in collective tactical variables over the season for the midcourt's sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	6.4, ±6.6 %	small↑**	6.4, ±20 %	small↑
Inter-player distance (m)	7.6, ±6.7 %	small↑**	6.3, ±19 %	small↑
Stretch index longitudinal (m)	5.8, ±4.8 %	**small↑*⁰**	3.0, ±24 %	trivial
Length (m)	7.6, ±4.9 %	**small↑****	3.3, ±23 %	trivial
Surface area (m²)	6.5, ±16 %	trivial	11, ±41 %	small↑
Width (m)	9.4, ±12 %	small↑**	18, ±16 %	moderate↑**
Stretch index lateral (m)	8.3, ±11 %	small↑*⁰	18, ±16 %	moderate↑**
Width per length ratio (m)	-1.0, ±23 %	trivial	20, ±25 %	small↑**
Centroid longitudinal (m)	-2.06, ±3.56	moderate↓	2.07, ±4.50	moderate↑
Centroid lateral (m)	-0.38, ±0.59	small↓*⁰	0.12, ±0.31	trivial↑
Variability				
Stretch index (m)	-17, ±15 %	small↓**	21, ±36 %	small↑
Inter-player distance (m)	-16, ±15 %	small↓**	19, ±34 %	small↑
Stretch index longitudinal (m)	-19, ±23 %	small↓**	18, ±38 %	small↑
Length (m)	-15, ±27 %	small↓	17, ±36 %	small↑
Surface area (m²)	-17, ±31 %	small↓	44, ±66 %	moderate↑**
Width (m)	-5.0, ±25 %	trivial	1.8, ±8.5 %	trivial⁰⁰
Stretch index lateral (m)	-4.4, ±27 %	trivial	3.2, ±8.5 %	trivial⁰⁰
Width per length ratio (m)	-3.1, ±21 %	trivial	16, ±19 %	small↑**
Centroid longitudinal (m)	-6.9, ±26 %	trivial	2.0, ±32 %	trivial
Centroid lateral (m)	-5.6, ±20 %	trivial	-7.5, ±10 %	**trivial↓⁰***
Irregularity				
Stretch index	24, ±38 %	small↑**	28, ±48 %	small↑
Inter-player distance	21, ±34 %	small↑**	27, ±44 %	small↑
Stretch index longitudinal	25, ±35 %	small↑**	34, ±50 %	small↑**
Length	17, ±33 %	small↑	28, ±41 %	small↑**
Surface area	16, ±23 %	small↑*⁰	30, ±21 %	small↑***
Width	2.0, ±16 %	trivial	-1.0, ±31 %	trivial
Stretch index lateral	2.6, ±14 %	trivial	-2.9, ±38 %	trivial
Width per length ratio	-7.6, ±27 %	trivial	-18, ±12 %	**small↓****
Centroid longitudinal	-4.8, ±26 %	trivial	2.9, ±40 %	trivial
Centroid lateral	5.1, ±26 %	trivial	18, ±32 %	small↑

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely.

*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05 and <0.005 respectively).

Reference-Bayesian likelihoods of trivial change: ⁰possibly; ⁰⁰likely.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

A34 Table. Change in collective tactical variables over the season for the defenders sub-group on attack and defence. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence data are the predicted changes (%, ±90% compatibility limits) and decisions about the magnitude of the changes.

Variables	Attack	Decision	Defence	Decision
Mean				
Stretch index (m)	-9.1, ±20 %	small↓	25, ±30 %	moderate↑**
Inter-player distance (m)	-8.6, ±20 %	small↓	24, ±31 %	moderate↑**
Stretch index longitudinal (m)	-14, ±25 %	small↓	30, ±41 %	moderate↑**
Length (m)	-14, ±25 %	moderate↓	30, ±41 %	moderate↑**
Surface area (m²)	-15, ±44 %	small↓	57, ±83 %	moderate↑**
Width (m)	7.4, ±13 %	small↑*⁰	14, ±22 %	small↑
Stretch index lateral (m)	7.7, ±14 %	small↑*⁰	15, ±22 %	small↑**
Width per length ratio (m)	30, ±30 %	small↑**	-7.4, ±11 %	trivial⁰*
Centroid longitudinal (m)	-1.09, ±2.26	small↓	1.23, ±3.67	small↑
Centroid lateral (m)	-0.28, ±0.72	trivial	0.01, ±0.29	trivial
Variability				
Stretch index (m)	-17, ±15 %	small↓**	21, ±36 %	small↑
Inter-player distance (m)	-14, ±17 %	small↓**	19, ±34 %	small↑
Stretch index longitudinal (m)	-19, ±23 %	small↓**	18, ±38 %	small↑
Length (m)	-14, ±30 %	small↓	17, ±36 %	small↑
Surface area (m²)	-16, ±30 %	small↓	44, ±66 %	moderate↑**
Width (m)	-5.0, ±25 %	trivial	2.3, ±8.5 %	trivial⁰⁰
Stretch index lateral (m)	-4.4, ±27 %	trivial	4.2, ±8.3 %	trivial
Width per length ratio (m)	29, ±25 %	**small↑*⁰**	17, ±25 %	**trivial↑⁰***
Centroid longitudinal (m)	-6.3, ±27 %	trivial	2.1, ±32 %	trivial
Centroid lateral (m)	-5.6, ±20 %	trivial	-7.1, ±9.6 %	**trivial↓⁰***
Irregularity				
Stretch index	7.4, ±23 %	trivial	-21, ±28 %	small↓
Inter-player distance	9.4, ±29 %	trivial	-28, ±29 %	moderate↓**
Stretch index longitudinal	13, ±14 %	**small↑*⁰**	-17, ±34 %	small↓
Length	14, ±33 %	small	-23, ±32 %	small↓
Surface area	3.5, ±19 %	trivial	-15, ±15 %	small↓**
Width	4.2, ±22 %	trivial	-6.8, ±7.3 %	**trivial↓⁰***
Stretch index lateral	1.5, ±21 %	trivial	-7.0, ±7.2 %	**trivial↓⁰***
Width per length ratio	-5.3, ±18 %	trivial	-7.7, ±27 %	trivial
Centroid longitudinal	-7.3, ±19 %	trivial	26, ±62 %	small
Centroid lateral	7.2, ±21 %	trivial	2.5, ±24 %	trivial

↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardized changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely.
Reference-Bayesian likelihoods of trivial change: ⁰possibly; ⁰⁰likely.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

APPENDIX B: Study 3 supplementary tables

B1 Table. Simple statistics (mean of the match means, and overall within-match standard deviations) for the team and positional sub-groups on attack. With the exception of mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as times/divide factors. The SDs were squared to evaluate the effects of these variables on probability of scoring (for mean centroid longitudinal and lateral, the SD was doubled). Clusters of variables representing consecutively longitudinal dispersion, lateral dispersion, longitudinal position and lateral position are outlined.

Variable	Team	Forwards	Midcourts	Defenders
Mean				
Stretch index (m)	6.8 ×/÷ 1.08	3.2 ×/÷ 1.23	4.3 ×/÷ 1.17	4.7 ×/÷ 1.20
Inter-player distance (m)	10.3 ×/÷ 1.07	5.6 ×/÷ 1.23	7.5 ×/÷ 1.17	8.1 ×/÷ 1.19
Stretch index longitudinal (m)	6.1 ×/÷ 1.11	1.6 ×/÷ 1.29	3.2 ×/÷ 1.25	3.9 ×/÷ 1.28
Length (m)	22 ×/÷ 1.08	6.1 ×/÷ 1.35	8.4 ×/÷ 1.24	9.7 ×/÷ 1.27
Width (m)	7.0 ×/÷ 1.17	4.3 ×/÷ 1.30	5.7 ×/÷ 1.28	4.9 ×/÷ 1.31
Stretch index lateral (m)	2.0 ×/÷ 1.18	2.6 ×/÷ 1.36	2.2 ×/÷ 1.29	1.9 ×/÷ 1.31
Width per length ratio	0.31 ×/÷ 1.24	0.50 ×/÷ 1.72	0.53 ×/÷ 1.50	0.41 ×/÷ 1.58
Surface area (m²)	87 ×/÷ 1.18	8.3 ×/÷ 1.60	15.1 ×/÷ 1.51	18.0 ×/÷ 1.55
Centroid longitudinal (m)	18.5 ± 1.5	24.2 ± 2.2	18.8 ± 2.7	11.3 ×/÷ 2.0
Centroid lateral (m)	7.6 ± 1.1	7.3 ± 1.4	7.7 ± 1.4	7.9 ± 1.3
Variability				
Stretch index (m)	0.80 ×/÷ 1.54	0.88 ×/÷ 1.48	1.00 ×/÷ 1.44	1.03 ×/÷ 1.54
Inter-player distance (m)	0.99 ×/÷ 1.48	1.53 ×/÷ 1.47	1.71 ×/÷ 1.44	1.74 ×/÷ 1.53
Stretch index longitudinal (m)	0.96 ×/÷ 1.52	0.90 ×/÷ 1.47	1.12 ×/÷ 1.43	1.05 ×/÷ 1.56
Length (m)	2.1 ×/÷ 1.46	2.3 ×/÷ 1.46	2.8 ×/÷ 1.42	2.4 ×/÷ 1.56
Width (m)	1.67 ×/÷ 1.42	1.71 ×/÷ 1.43	1.89 ×/÷ 1.46	1.61 ×/÷ 1.50
Stretch index lateral (m)	0.49 ×/÷ 1.52	0.65 ×/÷ 1.41	0.73 ×/÷ 1.47	0.61 ×/÷ 1.51
Width per length ratio	1.01 ×/÷ 1.69	0.60 ×/÷ 2.47	0.78 ×/÷ 2.23	0.80 ×/÷ 2.50
Surface area (m²)	19.5 ×/÷ 1.41	6.5 ×/÷ 1.62	9.0 ×/÷ 1.58	9.8 ×/÷ 1.60
Centroid longitudinal (m)	2.0 ×/÷ 1.52	1.9 ×/÷ 1.57	2.7 ×/÷ 1.53	2.2 ×/÷ 1.51
Centroid lateral (m)	0.81 ×/÷ 1.58	1.14 ×/÷ 1.56	1.15 ×/÷ 1.59	0.88 ×/÷ 1.70
Irregularity				
Stretch index	0.19 ×/÷ 1.86	0.26 ×/÷ 1.73	0.25 ×/÷ 1.73	0.17 ×/÷ 1.90
Inter-player distance	0.19 ×/÷ 1.82	0.26 ×/÷ 1.70	0.25 ×/÷ 1.74	0.16 ×/÷ 1.87
Stretch index longitudinal	0.16 ×/÷ 1.87	0.24 ×/÷ 1.80	0.21 ×/÷ 1.77	0.15 ×/÷ 1.97
Length	0.19 ×/÷ 1.80	0.25 ×/÷ 1.76	0.21 ×/÷ 1.75	0.15 ×/÷ 2.0
Width	0.33 ×/÷ 1.59	0.34 ×/÷ 1.57	0.30 ×/÷ 1.55	0.27 ×/÷ 1.65
Stretch index lateral	0.31 ×/÷ 1.56	0.34 ×/÷ 1.55	0.31 ×/÷ 1.56	0.27 ×/÷ 1.66
Width per length ratio	0.2 ×/÷ 1.78	0.25 ×/÷ 1.96	0.17 ×/÷ 1.99	0.19 ×/÷ 1.96
Surface area	0.34 ×/÷ 1.53	0.32 ×/÷ 1.69	0.31 ×/÷ 1.60	0.24 ×/÷ 1.71
Centroid longitudinal	0.08 ×/÷ 2.07	0.12 ×/÷ 2.05	0.08 ×/÷ 2.01	0.10 ×/÷ 2.05
Centroid lateral	0.20 ×/÷ 1.74	0.21 ×/÷ 1.70	0.21 ×/÷ 1.75	0.20 ×/÷ 1.86

B2 Table. Simple statistics (mean of the match means, and overall within-match standard deviations) for the team and positional sub-groups on defence. With the exception of the mean centroid lateral, the statistics were derived via log-transformation, hence SDs are shown as times/divide factors. The SDs were squared to evaluate the effects of these variables on probability of scoring (for the mean centroid lateral, the SD was doubled). Clusters of variables representing consecutively longitudinal dispersion, lateral dispersion, longitudinal position and lateral position are outlined.

Variable	Team	Forwards	Midcourts	Defenders
Mean				
Stretch index (m)	6.6 ×/÷ 1.11	4.2 ×/÷ 1.24	4.1 ×/÷ 1.20	3.0 ×/÷ 1.23
Inter-player distance (m)	9.9 ×/÷ 1.09	7.2 ×/÷ 1.23	7.0 ×/÷ 1.19	5.3 ×/÷ 1.23
Stretch index longitudinal (m)	6.1 ×/÷ 1.14	1.5 ×/÷ 1.27	3.3 ×/÷ 1.25	2.3 ×/÷ 1.31
Length (m)	22 ×/÷ 1.09	9.0 ×/÷ 1.30	8.3 ×/÷ 1.24	5.9 ×/÷ 1.31
Width (m)	6.0 ×/÷ 1.19	3.8 ×/÷ 1.27	4.7 ×/÷ 1.31	3.8 ×/÷ 1.33
Stretch index lateral (m)	1.7 ×/÷ 1.19	3.6 ×/÷ 1.32	1.8 ×/÷ 1.31	1.5 ×/÷ 1.33
Width per length ratio	0.26 ×/÷ 1.24	0.35 ×/÷ 1.55	0.45 ×/÷ 1.51	0.47 ×/÷ 1.64
Surface area (m²)	72 ×/÷ 1.20	12.8 ×/÷ 1.61	13.1 ×/÷ 1.56	7.0 ×/÷ 1.65
Centroid longitudinal (m)	11.6 ± 1.7	19 ± 2.1	11.3 ± 2.7	5.9 ×/÷ 2.0
Centroid lateral (m)	7.5 ± 1.0	7.5 ± 1.2	7.5 ± 1.3	7.5 ± 1.2
Variability				
Stretch index (m)	0.89 ×/÷ 1.58	1.0 ×/÷ 1.49	1.0 ×/÷ 1.53	0.73 ×/÷ 1.57
Inter-player distance (m)	1.12 ×/÷ 1.58	1.75 ×/÷ 1.48	1.66 ×/÷ 1.55	1.27 ×/÷ 1.56
Stretch index longitudinal (m)	1.00 ×/÷ 1.55	1.05 ×/÷ 1.49	1.04 ×/÷ 1.53	0.78 ×/÷ 1.56
Length (m)	2.2 ×/÷ 1.57	2.5 ×/÷ 1.49	2.5 ×/÷ 1.51	2.0 ×/÷ 1.52
Width (m)	1.32 ×/÷ 1.47	1.29 ×/÷ 1.51	1.54 ×/÷ 1.46	1.42 ×/÷ 1.52
Stretch index lateral (m)	0.37 ×/÷ 1.44	0.49 ×/÷ 1.53	0.60 ×/÷ 1.44	0.55 ×/÷ 1.42
Width per length ratio	1.0 ×/÷ 1.68	0.70 ×/÷ 2.38	0.74 ×/÷ 2.29	0.64 ×/÷ 2.47
Surface area (m²)	16.9 ×/÷ 1.47	7.6 ×/÷ 1.58	7.9 ×/÷ 1.65	4.9 ×/÷ 1.73
Centroid longitudinal (m)	1.57 ×/÷ 1.63	2.0 ×/÷ 1.49	2.3 ×/÷ 1.57	1.68 ×/÷ 1.61
Centroid lateral (m)	0.68 ×/÷ 1.66	0.79 ×/÷ 1.80	1.01 ×/÷ 1.61	0.92 ×/÷ 1.61
Irregularity				
Stretch index	0.16 ×/÷ 2.09	0.16 ×/÷ 1.96	0.22 ×/÷ 1.85	0.29 ×/÷ 1.79
Inter-player distance	0.17 ×/÷ 2.00	0.16 ×/÷ 1.97	0.23 ×/÷ 1.85	0.29 ×/÷ 1.80
Stretch index longitudinal	0.15 ×/÷ 2.02	0.15 ×/÷ 2.00	0.20 ×/÷ 1.91	0.26 ×/÷ 1.86
Length	0.18 ×/÷ 1.96	0.15 ×/÷ 1.96	0.21 ×/÷ 1.91	0.26 ×/÷ 1.78
Width	0.37 ×/÷ 1.57	0.32 ×/÷ 1.62	0.34 ×/÷ 1.54	0.38 ×/÷ 1.54
Stretch index lateral	0.37 ×/÷ 1.50	0.32 ×/÷ 1.61	0.34 ×/÷ 1.56	0.38 ×/÷ 1.53
Width per length ratio	0.31 ×/÷ 1.66	0.23 ×/÷ 1.88	0.21 ×/÷ 2.06	0.23 ×/÷ 2.00
Surface area	0.34 ×/÷ 1.58	0.27 ×/÷ 1.78	0.29 ×/÷ 1.80	0.37 ×/÷ 1.69
Centroid longitudinal	0.09 ×/÷ 2.33	0.11 ×/÷ 2.07	0.09 ×/÷ 2.18	0.12 ×/÷ 2.18
Centroid lateral	0.23 ×/÷ 1.82	0.22 ×/÷ 1.88	0.23 ×/÷ 1.81	0.25 ×/÷ 1.74

APPENDIX C: Study 4 supplementary tables

C1 Table. Effects of possession duration collective tactical variables in **6v6** small-sided games for the attacking and defending team. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent's. Data are effects (% units) and with 90% compatibility limits (% units) when both values are <30%; otherwise values are shown as factors. Decisions about the magnitude of the differences are also shown.

Variables	Attacking team	Decision	Defending team	Decision
Mean				
Inter-player distance(m)	1.6, ±6.9%	trivial	12.1, ±9%	**moderate**↑***
Length(m)	-2.9, ±12%	trivial	7.4, ±13%	small↑*⁰
Surface area(m²)	-0.7, ±13%	trivial	1.32, ×/÷1.15	**moderate**↑***
Width(m)	8.9, ±10%	small↑*⁰	1.31, ×/÷1.13	**moderate**↑****
Width per Length ratio	2.7, ±24%	trivial	15, ±25%	small↑*⁰
Centroid longitudinal(m)	-0.33, ±0.87	small↓	-0.70, ±0.86	small↓**
Centroid lateral(m)	-0.32, ±0.48	small↓*⁰	-0.08, ±0.45	trivial
Variability				
Inter-player distance(m)	23, ±22%	**small**↑**	1.63, ×/÷1.23	**moderate**↑****
Length(m)	15, ±24%	small↑*⁰	1.52, ×/÷1.12	**moderate**↑****
Surface area(m²)	19, ±22%	small↑*⁰	1.91, ×/÷1.28	**large**↑****
Width(m)	25, ±24%	**small**↑**	1.72, ×/÷1.21	**large**↑****
Width per Length ratio	0.7, ×/÷1.51	small↓**	-24, ±27%	small↓*⁰
Centroid longitudinal(m)	1.39, ×/÷1.22	**moderate**↑***	1.68, ×/÷1.18	**moderate**↑****
Centroid lateral(m)	1.39, ×/÷1.25	**moderate**↑***	1.85, ×/÷1.23	**large**↑****
Irregularity				
Inter-player distance	1.39, ×/÷1.24	**moderate**↑***	10, ±19%	small↑*⁰
Length	1.31, ×/÷1.21	**small**↑**	6.4, ±19%	trivial
Surface area	1.34, ×/÷1.20	**moderate**↑***	13, ±20%	small↑*⁰
Width	22, ±21%	**small**↑**	-1.5, ±19%	trivial
Width per Length ratio	-13, ±16%	small↓*⁰	9.5, ±23%	trivial
Centroid longitudinal	16, ±25%	small↑*⁰	18, ±29%	small↑*⁰
Centroid lateral	1.38, ×/÷1.32	small↑**	20, ±28%	small↑*⁰

↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardised changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.
*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).
Reference-Bayesian likelihoods of trivial change: ⁰possibly.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

C2 Table. Effects of possession duration collective tactical variables in **5v5** small-sided games for the attacking and defending team. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent's. Data are effects (% units) and with 90% compatibility limits (% units) when both values are <30%; otherwise values are shown as factors. Decisions about the magnitude of the differences are also shown.

Variables	Attacking team	Decision	Defending team	Decision
Mean				
Inter-player distance(m)	-6.4, ±4.6%	**small↓****	-1.4, ±3.8%	trivial⁰⁰
Length(m)	-18, ±7.1%	**moderate↓******	-12, ±6.5%	**small↓****
Surface area(m^2)	-0.40, ±11%	trivial	4.6, ±9.3%	trivial ⁰*
Width(m)	16, ±10%	**small↑*****	15, ±7.8%	**small↑*****
Width per Length ratio	1.34, ×/÷1.21	**small↑*****	28, ±18%	**small↑*****
Centroid longitudinal(m)	1.23, ±0.47	**moderate↑******	0.92, ±0.36	**small↑******
Centroid lateral(m)	-0.23, ±0.36	small↓*⁰	-0.37, ±0.32	**small↓****
Variability				
Inter-player distance(m)	1.33, ×/÷1.16	**moderate↑*****	25, ±19%	**small↑****
Length(m)	21, ±15%	**small↑****	1.43, ×/÷1.14	**moderate↑******
Surface area(m^2)	26, ±21%	**small↑****	12, ±21%	small↑*⁰
Width(m)	17, ±20%	small↑*⁰	26, ±20%	**small↑****
Width per Length ratio	1.09, ×/÷1.35	trivial	-2.4, ±23%	trivial
Centroid longitudinal(m)	24, ±18%	**small↑****	1.52, ×/÷1.20	**moderate↑******
Centroid lateral(m)	1.36, ×/÷1.17	**moderate↑*****	1.34, ×/÷1.21	**small↑*****
Irregularity				
Inter-player distance	8.5, ±18%	trivial⁰*	-10, ±13%	small↓*⁰
Length	5.4, ±17%	trivial	-11, ±13%	small↓*⁰
Surface area	13, ±16%	small↑*⁰	-6.2, ±13%	trivial⁰*
Width	11, ±18%	small↑*⁰	15, ±16%	**small↑*⁰**
Width per Length ratio	0.21, ±19%	trivial	4.5, ±18%	trivial
Centroid longitudinal	-6.9, ±17%	trivial⁰*	-6.4, ±15%	trivial⁰*
Centroid lateral	9.6, ±21%	trivial⁰*	5.1, ±17%	trivial

↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardised changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.
*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).
Reference-Bayesian likelihoods of trivial change: ⁰possibly; ⁰⁰likely.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

C3 Table. Effects of possession duration collective tactical variables in **4v4** small-sided games for the attacking and defending team. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent's. Data are effects (% units) and with 90% compatibility limits (% units) when both values are <30%; otherwise values are shown as factors. Decisions about the magnitude of the differences are also shown.

Variables	Attacking team	Decision	Defending team	Decision
Mean				
Inter-player distance(m)	-5.6, ±5.8%	small↓**	-0.4, ±7.4%	trivial
Length(m)	-8.8, ±9.3%	small↓*^{0}	-2, ±10%	trivial
Surface area(m²)	-15, ±13%	small↓**	-2.3, ±15%	trivial
Width(m)	-0.10, ±9.1%	trivial	1.4, ±9.8%	trivial
Width per Length ratio	-7.3, ±18%	trivial	4.3, ±17%	trivial
Centroid longitudinal(m)	0.70, ±0.61	**small↑****	0.87, ±0.57	**small↑*****
Centroid lateral(m)	0.40, ±0.42	small↑**	0.33, ±0.37	small↑*^{0}
Variability				
Inter-player distance(m)	24, ±21%	**small↑****	1.33, ×/÷1.20	**moderate↑*****
Length(m)	18, ±13%	**small↑****	15, ±19%	small↑*^{0}
Surface area(m²)	21, ±25%	small↑**	21, ±26%	small↑*^{0}
Width(m)	23, ±17%	**small↑****	15, ±19%	small↑*^{0}
Width per Length ratio	0.62, ×/÷1.46	**small↓****	-5.8, ±28%	trivial
Centroid longitudinal(m)	1.34, ×/÷1.17	**moderate↑*****	20, ±17%	**small↑****
Centroid lateral(m)	1.30, ×/÷1.20	**small↑****	26, ±19%	**small↑****
Irregularity				
Inter-player distance	-6.3, ±18%	trivial	8.0, ±25%	trivial
Length	17, ±20%	small↑*^{0}	-3.0, ±19%	trivial
Surface area	-1.1, ±15%	trivial	17, ±26%	small↑*^{0}
Width	16, ±20%	small↑*^{0}	-6.1, ±19%	trivial
Width per Length ratio	-25, ±18%	small↓**	21, ±27%	small↑*^{0}
Centroid longitudinal	-12, ±20%	small↓*^{0}	-3.0, ±22%	trivial
Centroid lateral	18, ±21%	**small↑*^{0}**	-6.6, ±27%	trivial

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardised changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely.

*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).

Reference-Bayesian likelihoods of trivial change: ^{0}possibly.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

C4 Table. Effects of match time on collective tactical variables in **6v6** small-sided games for the attacking and defending team. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent's. Data are effects (% units) and with 90% compatibility limits (% units) when both values are <30%; otherwise values are shown as factors. Decisions about the magnitude of the differences are also shown.

Variables	Attacking team	Decision	Defending team	Decision
Mean				
Inter-player distance(m)	8.5, ±12%	small↑**	10, ±14%	moderate↑**
Length(m)	3.4, ±20%	trivial	15, ±22%	small↑**
Surface area(m²)	5.0, ±22%	trivial	13, ±25%	small↑
Width(m)	12, ±16%	small↑**	8.4, ±20%	small↑
Width per Length ratio	1.10, ×/÷1.43	small↑	18, ±28%	small↑
Centroid longitudinal(m)	-0.54, ±1.36	small↓	-0.79, ±1.34	small↓
Centroid lateral(m)	0.21, ±0.75	trivial	0.06, ±0.70	trivial
Variability				
Inter-player distance(m)	1.31, ×/÷1.32	small↑**	1.26, ×/÷1.38	small↑
Length(m)	1.46, ×/÷1.38	moderate↑**	1.56, ×/÷1.38	**moderate**↑***
Surface area(m²)	1.46, ×/÷1.33	**moderate**↑**	1.47, ×/÷1.46	moderate↑**
Width(m)	1.62, ×/÷1.35	**moderate**↑***	1.33, ×/÷1.34	moderate↑**
Width per Length ratio	0.47, ×/÷1.90	moderate↓**	0.46, ×/÷1.72	**moderate**↓***
Centroid longitudinal(m)	1.32, ×/÷1.37	moderate↑**	1.31, ×/÷1.30	moderate↑**
Centroid lateral(m)	1.19, ×/÷1.41	small↑	1.29, ×/÷1.38	small↑**
Irregularity				
Inter-player distance	1.08, ×/÷1.39	trivial	-1.9, ±26%	trivial
Length	1.07, ×/÷1.35	trivial	1.17, ×/÷1.33	small↑
Surface area	1.09, ×/÷1.32	small↑	1.16, ×/÷1.32	small↑
Width	1.11, ×/÷1.31	small↑	1.27, ×/÷1.35	small↑**
Width per Length ratio	-14, ±25%	small↓	0.71, ×/÷1.37	moderate↓**
Centroid longitudinal	0.64, ×/÷1.4	**moderate**↓**	1.13, ×/÷1.46	small↑
Centroid lateral	0.86, ×/÷1.55	small↓	1.33, ×/÷1.43	small↑**

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardised changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely.

*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

C5 Table. Effects of match time collective tactical variables in **5v5** small-sided games for the attacking and defending team. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent's. Data are effects (% units) and with 90% compatibility limits (% units) when both values are <30%; otherwise values are shown as factors. Decisions about the magnitude of the differences are also shown.

Variables	Attacking team	Decision	Defending team	Decision
Mean				
Inter-player distance(m)	17, ±9.1%	**moderate↑*****	-5.5, ±5.7%	small↓*⁰
Length(m)	1.32, ×/÷1.15	**moderate↑******	-6.9, ±11%	small↓*⁰
Surface area(m²)	6.6, ±18%	trivial	-11, ±13%	small↓*⁰
Width(m)	-16, ±12%	**moderate↓****	-0.30, ±11%	trivial
Width per Length ratio	0.62, ×/÷1.35	**moderate↓*****	15, ±26%	small↑*⁰
Centroid longitudinal(m)	-1.75, ±0.74	**moderate↓******	-0.40, ±0.56	small↓*⁰
Centroid lateral(m)	-0.19, ±0.58	trivial	-0.19, ±0.51	trivial
Variability				
Inter-player distance(m)	15, ±28%	small↑	-15, ±21%	small↓*⁰
Length(m)	16, ±23%	small↑*⁰	-16, ±18%	small↓**
Surface area(m²)	0.62, ±27%	trivial	-20, ±24%	small↓**
Width(m)	1.11, ×/÷1.31	small↑	-25, ±19%	moderate↓**
Width per Length ratio	0.65, ×/÷1.63	small↓**	1.30, ×/÷1.46	small↑*⁰
Centroid longitudinal(m)	-5.4, ±22%	trivial	-10, ±27%	small↓
Centroid lateral(m)	-11, ±23%	small↓	0.66, ×/÷1.36	**moderate↓*****
Irregularity				
Inter-player distance	0.88, ×/÷1.3	small↓	1.55, ×/÷1.26	**moderate↑*****
Length	-17, ±22%	small↓*⁰	1.8, ±24%	trivial
Surface area	-5.0, ±22%	trivial	21, ±27%	small↑**
Width	-2.4, ±25%	trivial	-8.5, ±20%	trivial
Width per Length ratio	1.03, ×/÷1.35	trivial	1.15, ×/÷1.32	small↑
Centroid longitudinal	1.07, ×/÷1.33	trivial	-8.7, ±24%	trivial
Centroid lateral	-15, ±27%	small↓	2.2, ±27%	trivial

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardised changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely, ****most likely.

*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).

Reference-Bayesian likelihoods of trivial change: ⁰possibly.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

C6 Table. Effects of match time on collective tactical variables in **4v4** small-sided games for the attacking and defending team. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent's. Data are effects (% units) and with 90% compatibility limits (% units) when both values are <30%; otherwise values are shown as factors. Decisions about the magnitude of the differences are also shown.

Variables	Attacking team	Decision	Defending team	Decision
Mean				
Inter-player distance(m)	3.5, ±10%	small↑	8.1, ±13%	small↑
Length(m)	10, ±18%	small↑	7.3, ±18%	small↑
Surface area(m²)	6.5, ±26%	trivial	18, ±29%	small↑
Width(m)	0.30, ±14%	trivial	12, ±17%	small↑*⁰
Width per Length ratio	-11, ±28%	small↓	4.9, ±27%	trivial
Centroid longitudinal(m)	-1.14, ±0.95	moderate↓**	-1.00, ±0.81	**moderate**↓**
Centroid lateral(m)	-0.17, ±0.67	trivial	0.01, ±0.58	trivial
Variability				
Inter-player distance(m)	-13.1, ±23%	small↓	1.25, ×/÷1.33	small↑**
Length(m)	-8.9, ±16%	small↓*⁰	1.18, ×/÷1.29	small↑
Surface area(m²)	-19, ±26%	small↓*⁰	1.23, ×/÷1.41	small↑
Width(m)	6.6, ±24%	trivial	9.3, ±28%	trivial
Width per Length ratio	-0.17, ±63%	trivial	0.79, ×/÷1.59	small↓
Centroid longitudinal(m)	-14, ±21%	small↓	16, ±26%	small↑*⁰
Centroid lateral(m)	-22, ±23%	small↓**	-5.6, ±23%	trivial
Irregularity				
Inter-player distance	-2.5, ±29%	trivial	1.01, ×/÷1.43	trivial
Length	1.25, ×/÷1.31	small↑**	1.10, ×/÷1.36	trivial
Surface area	-8.3, ±22%	trivial	0.96, ×/÷1.41	trivial
Width	4.3, ±28%	trivial	-11, ±29%	small↓
Width per Length ratio	0.98, ×/÷1.44	trivial	1.08, ×/÷1.42	trivial
Centroid longitudinal	1.27, ×/÷1.43	small↑	0.95, ×/÷1.42	trivial
Centroid lateral	1.73, ×/÷1.32	**moderate**↑***	1.03, ×/÷1.57	trivial

↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardised changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely.
*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).
Reference-Bayesian likelihoods of trivial change: ⁰possibly.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

C7 Table. Difference between attacking team score and attacking team turnover (on attack) in **6v6** small-sided games for each of the derived measures of each collective tactical variable for the attacking team and defending team. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent's. Data are effects (% units) and with 90% compatibility limits (% units) when both values are <30%; otherwise values are shown as factors. Decisions about the magnitude of the differences are also shown.

Variables	Attacking team	Decision	Defending team	Decision
Mean				
Inter-player distance(m)	-0.70, ±6.9%	trivial	-2.3, ±7.9%	trivial
Length(m)	-2.8, ±12%	trivial	-1.2, ±12%	trivial
Surface area(m²)	0.70, ±13%	trivial	-7.9, ±13%	small↓*⁰
Width(m)	5.3, ±10%	small↑*⁰	0.90, ±12%	trivial
Width per Length ratio	4.1, ±25%	trivial	-3.8, ±21%	trivial
Centroid longitudinal(m)	0.33, ±0.88	small↑	0.31, ±0.87	small↑
Centroid lateral(m)	0.40, ±0.49	small↑*⁰	0.12, ±0.46	trivial
Variability				
Inter-player distance(m)	-5.1, ±17%	trivial	-9.5, ±19%	small↓
Length(m)	-2.2, ±21%	trivial	-5.0, ±20%	trivial
Surface area(m²)	-2.1, ±18%	trivial	-7.3, ±23%	trivial
Width(m)	14, ±22%	small↑*⁰	6.3, ±20%	trivial
Width per Length ratio	0.95, ×/÷1.52	trivial	0.85, ×/÷1.43	trivial
Centroid longitudinal(m)	-6.5, ±19	trivial	-6.7, ±16%	trivial
Centroid lateral(m)	-0.48, ±23	trivial	-12, ±18%	small↓*⁰
Irregularity				
Inter-player distance	2.7, ±22%	trivial	18, ±20%	small↑*⁰
Length	-0.21, ±20%	trivial	15, ±21%	small↑*⁰
Surface area	-11, ±16%	small↓*⁰	-0.55, ±18%	trivial
Width	1.4, ±18%	trivial	-8.4, ±18%	trivial
Width per Length ratio	-3.0, ±18%	trivial	5.3, ±21%	trivial
Centroid longitudinal	12, ±25%	trivial	-0.21, ±25%	trivial
Centroid lateral	-20, ±23%	small↓*⁰	22, ±29%	small↑*⁰

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardised changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely.

*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).

Reference-Bayesian likelihoods of trivial change: ⁰possibly.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

C8 Table. Difference between attacking team score and attacking team turnover (on attack) in **5v5** small-sided games for each of the derived measures of each collective tactical variable for the attacking team and defending team. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent's. Data are effects (% units) and with 90% compatibility limits (% units) when both values are <30%; otherwise values are shown as factors. Decisions about the magnitude of the differences are also shown.

Variables	Attacking team	Decision	Defending team	Decision
Mean				
Inter-player distance(m)	-6.9, ±5.0%	**small**↓**	-3.0, ±4.1%	trivial⁰*
Length(m)	-8.5, ±8.6%	small↓*⁰	-2.9, ±7.9%	trivial⁰*
Surface area(m^2)	-12, ±11%	**small**↓**	-7.4, ±9.0%	small↓*⁰
Width(m)	0.80, ±9.8%	trivial	-1.2, ±7.4%	trivial
Width per Length ratio	7.8, ±23%	trivial	-6.2, ±14%	trivial⁰*
Centroid longitudinal(m)	0.87, ±0.51	**small**↑***	0.55, ±0.39	**small**↑**
Centroid lateral(m)	-0.10, ±0.40	trivial	0.08, ±0.35	trivial
Variability				
Inter-player distance(m)	2.5, ±17%	trivial	16, ±20%	small↑*⁰
Length(m)	5.5, ±15%	trivial	20, ±18%	**small**↑**
Surface area(m^2)	-7.3, ±17%	trivial⁰*	19, ±25%	small↑*⁰
Width(m)	4.8, ±20%	trivial	23, ±21%	**small**↑**
Width per Length ratio	-18, ±28%	small↓*⁰	-28, ±19%	**small**↓**
Centroid longitudinal(m)	1.40, ×/÷1.17	**moderate**↑***	1.70, ×/÷1.23	**moderate**↑****
Centroid lateral(m)	5.2, ±18%	trivial	27, ±28%	small↑**
Irregularity				
Inter-player distance	11, ±20%	small↑*⁰	-12, ±14%	small↓*⁰
Length	-13, ±16%	small↓*⁰	-13, ±14%	small↓*⁰
Surface area	-1.8, ±16%	trivial	-14, ±13%	small↓*⁰
Width	0.24, ±18%	trivial	-10, ±14%	small↓*⁰
Width per Length ratio	20, ±25%	small↑*⁰	1.31, ×/÷1.21	**small**↑**
Centroid longitudinal	13, ±23%	small↑*⁰	-4.0, ±17%	trivial
Centroid lateral	16, ±25%	small↑*⁰	-12, ±16%	small↓*⁰

↑, increase; ↓, decrease.
Magnitudes are based on the following scale for standardised changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large
Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely.
*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).
Reference-Bayesian likelihoods of trivial change: ⁰possibly.
Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).
Effects in **bold** have adequate precision at the 99% level (p<0.005).

C9 Table. Difference between attacking team score and attacking team turnover (on attack) in **4v4** small-sided games for each of the derived measures of each collective tactical variable for the attacking team and defending team. With the exception of the mean centroid longitudinal and lateral, the statistics were derived via log-transformation, hence SDs are shown as percent's. Data are effects (% units) and with 90% compatibility limits (% units) when both values are <30%; otherwise values are shown as factors. Decisions about the magnitude of the differences are also shown.

Variables	Attacking team	Decision	Defending team	Decision
Mean				
Inter-player distance(m)	-2.1, ±6.3%	trivial	0.30, ±7.8%	trivial
Length(m)	-6.1, ±9.9%	small↓*⁰	-6.3, ±10%	small↓*⁰
Surface area(m²)	-5.7, ±15%	trivial	4.1, ±17%	trivial
Width(m)	6.5, ±10%	small↑*⁰	10, ±11%	small↑**
Width per Length ratio	17, ±24%	small↑*⁰	15, ±19%	small↑*⁰
Centroid longitudinal(m)	0.47, ±0.63	small↑*⁰	0.58, ±0.54	**small**↑**
Centroid lateral(m)	0.48, ±0.44	small↑**	0.37, ±0.39	small↑**
Variability				
Inter-player distance(m)	8.5, ±19%	trivial	7.7, ±20%	trivial
Length(m)	7.8, ±13%	trivial⁰*	-5.5, ±16%	trivial
Surface area(m²)	4.7, ±22%	trivial	7.7, ±25%	trivial
Width(m)	3.1, ±15%	trivial	13, ±19%	small↑*⁰
Width per Length ratio	1.20, ×/÷1.49	small↑	1.03, ×/÷1.36	trivial
Centroid longitudinal(m)	25, ±20%	**small**↑**	2.3, ±15%	trivial
Centroid lateral(m)	1.4, ±20%	trivial	6.3, ±17%	trivial
Irregularity				
Inter-player distance	9.2, ±21%	trivial	1.33, ×/÷1.27%	**small**↑**
Length	26, ±23%	**small**↑**	7.4, ±22%	trivial
Surface area	21, ±19%	**small**↑**	23, ±28%	small↑**
Width	3.2, ±18%	trivial	0.90, ±21%	trivial
Width per Length ratio	-7.7, ±23%	trivial	11, ±26%	small↑
Centroid longitudinal	-2.5, ±24%	trivial	5.6, ±25%	trivial
Centroid lateral	8.3, ±20%	trivial⁰*	1.13, ×/÷1.35	small↑

↑, increase; ↓, decrease.

Magnitudes are based on the following scale for standardised changes in the mean: <0.2, trivial; 0.2-0.6, small; 0.6-1.2, moderate; 1.2-2.0, large; 2.0-4.0, very large; >4.0 extremely large

Reference-Bayesian likelihoods of substantial change: *possibly; **likely; ***very likely.

*** indicates rejection of the non-superiority or non-inferiority hypothesis (p_{N-} or p_{N+} <0.05).

Reference-Bayesian likelihoods of trivial change: ⁰possibly.

Likelihoods are not shown for effects with inadequate precision at the 90% level (failure to reject any hypotheses: p>0.05).

Effects in **bold** have adequate precision at the 99% level (p<0.005).

C10 Table. Correlations between collective tactical variables for the **attacking team** in **4v4** SSG. The three values are the correlations for the mean, standard deviation and entropy respectively.

Variable	1	2	3	4	5	6	7
1. Inter-player distance (m)		0.87, 0.73, 0.77	0.80, 0.52, 0.62	0.43, 0.20, 0.15	-0.12, 0.02, -0.12	-0.52, 0.32, 0.22	-0.02, 0.19, 0.44
2. Surface area (m²)	0.87, 0.73, 0.77		0.61, 0.42, 0.46	0.57, 0.28, 0.14	0.16, 0.02, -0.12	-0.28, 0.24, 0.25	-0.08, 0.32, 0.36
3. Length (m)	0.80, 0.52, 0.62	0.61, 0.42, 0.46		-0.14, 0.41, 0.26	-0.53, -0.41, -0.40	-0.74, 0.42, 0.26	-0.05, -0.04, 0.42
4. Width (m)	0.43, 0.20, 0.15	0.57, 0.28, 0.14	-0.14, 0.41, 0.26		0.70, -0.66, -0.57	0.18, 0.20, 0.15	-0.03, 0.24, 0.26
5. Width per Length ratio	-0.12, 0.02, -0.12	0.16, 0.02, -0.12	-0.53, -0.41, -0.40	0.70, -0.66, -0.57		0.37, -0.11, -0.10	-0.08, -0.09, -0.35
6. Centroid Longitudinal (m)	-0.52, 0.32, 0.22	-0.28, 0.24, 0.25	-0.74, 0.42, 0.26	0.18, 0.20, 0.15	0.37, -0.11, -0.10		0.18, 0.16, 0.21
7. Centroid Lateral (m)	-0.02, 0.19, 0.44	-0.08, 0.32, 0.36	-0.05, -0.04, 0.42	-0.03, 0.24, 0.26	-0.08, -0.09, -0.35	0.18, 0.16, 0.21	

Uncertainty (90% compatibility limits): ~±0.1 to ~±0.01 for correlations of 0.00 to 0.95 respectively assuming a sample size of ~251.

C11 Table. Correlations between collective tactical variables for the **defending team** in **4v4** SSG. The three values are the correlations for the mean, standard deviation and entropy respectively.

Variable	1	2	3	4	5	6	7
1. Inter-player distance (m)		0.93, 0.79, 0.74	0.88, 0.74, 0.70	0.49, 0.30, 0.11	-0.18, 0.06, -0.10	-0.62, 0.49, 0.18	0.06, 0.28, 0.58
2. Surface area (m²)	0.93, 0.79, 0.74		0.72, 0.50, 0.40	0.67, 0.48, 0.26	0.09, -0.01, -0.07	-0.52, 0.20, 0.30	0.00, 0.28, 0.33
3. Length (m)	0.88, 0.74, 0.70	0.72, 0.50, 0.40		0.05, 0.22, 0.21	-0.58, -0.17, -0.45	-0.74, 0.62, -0.03	0.09, 0.14, 0.63
4. Width (m)	0.49, 0.30, 0.11	0.67, 0.48, 0.26	0.05, 0.22, 0.21		0.70, -0.42, -0.61	-0.04, 0.20, 0.08	-0.13, 0.30, 0.05
5. Width per Length ratio	-0.18, 0.06, -0.10	0.09, -0.01, -0.07	-0.58, -0.17, -0.45	0.70, -0.42, -0.61		0.36, 0.01, -0.08	-0.16, 0.11, -0.32
6. Centroid Longitudinal (m)	-0.62, 0.49, 0.18	-0.52, 0.20, 0.30	-0.74, 0.62, -0.03	-0.04, 0.20, 0.08	0.36, 0.01, -0.08		0.11, 0.15, 0.18
7. Centroid Lateral (m)	0.06, 0.28, 0.58	0.00, 0.28, 0.33	0.09, 0.14, 0.63	-0.13, 0.30, 0.05	-0.16, 0.11, -0.32	0.11, 0.15, 0.18	

Uncertainty (90% compatibility limits): ~±0.1 to ~±0.01 for correlations of 0.00 to 0.95 respectively assuming a sample size of ~251.

C12 Table. Correlations between collective tactical variables for the **attacking team** in **5v5** SSG. The three values are the correlations for the mean, standard deviation and entropy respectively.

Variable	1	2	3	4	5	6	7
1. Inter-player distance (m)		0.68, 0.53, 0.64	0.87, 0.69, 0.59	-0.20, 0.17, 0.16	-0.53, -0.05, -0.16	-0.80, 0.57, 0.33	0.01, 0.38, 0.31
2. Surface area (m^2)	0.68, 0.53, 0.64		0.48, 0.24, 0.28	0.41, 0.45, 0.44	0.07, 0.04, -0.17	-0.36, 0.32, 0.14	-0.01, 0.22, 0.12
3. Length (m)	0.87, 0.69, 0.59	0.48, 0.24, 0.28		-0.54, 0.20, 0.13	-0.77, -0.22, -0.45	-0.85, 0.70, 0.20	0.02, 0.45, 0.45
4. Width (m)	-0.20, 0.17, 0.16	0.41, 0.45, 0.44	-0.54, 0.20, 0.13		0.84, -0.45, -0.53	0.5, 0.18, 0.25	-0.10, 0.28, 0.03
5. Width per Length ratio	-0.53, -0.05, -0.16	0.07, 0.04, -0.17	-0.77, -0.22, -0.45	0.84, -0.45, -0.53		0.68, -0.02, -0.22	-0.05, -0.14, -0.23
6. Centroid Longitudinal (m)	-0.80, 0.57, 0.33	-0.36, 0.32, 0.14	-0.85, 0.70, 0.20	0.50, 0.18, 0.25	0.68, -0.02, -0.22		0.03, 0.49, 0.13
7. Centroid Lateral (m)	0.01, 0.38, 0.31	-0.01, 0.22, 0.12	0.02, 0.45, 0.45	-0.10, 0.28, 0.03	-0.05, -0.14, -0.23	0.03, 0.49, 0.13	

Uncertainty (90% compatibility limits): ~±0.1 to ~±0.01 for correlations of 0.00 to 0.95 respectively assuming a sample size of ~251.

C13 Table. Correlations between collective tactical variables for the **defending team** in **5v5** SSG. The three values are the correlations for the mean, standard deviation and entropy respectively.

Variable	1	2	3	4	5	6	7
1. Inter-player distance (m)		0.81, 0.72, 0.66	0.81, 0.51, 0.61	0.05, 0.27, 0.15	-0.40, -0.12, -0.13	-0.60, 0.42, 0.38	-0.17, 0.36, 0.32
2. Surface area (m^2)	0.81, 0.72, 0.66		0.51, 0.30, 0.34	0.41, 0.47, 0.43	0.00, -0.19, -0.11	-0.37, 0.29, 0.30	-0.11, 0.39, 0.22
3. Length (m)	0.81, 0.51, 0.61	0.51, 0.3, 0.34		-0.45, 0.27, 0.19	-0.8, -0.28, -0.52	-0.73, 0.68, 0.47	-0.09, 0.43, 0.41
4. Width (m)	0.05, 0.27, 0.15	0.41, 0.47, 0.43	-0.45, 0.27, 0.19		0.81, -0.47, -0.43	0.27, 0.35, 0.30	-0.15, 0.39, 0.27
5. Width per Length ratio	-0.40, -0.12, -0.13	0.00, -0.19, -0.11	-0.80, -0.28, -0.52	0.81, -0.47, -0.43		0.53, -0.14, -0.23	0.00, -0.14, -0.30
6. Centroid Longitudinal (m)	-0.60, 0.42, 0.38	-0.37, 0.29, 0.30	-0.73, 0.68, 0.47	0.27, 0.35, 0.30	0.53, -0.14, -0.23		0.01, 0.44, 0.28
7. Centroid Lateral (m)	-0.17, 0.36, 0.32	-0.11, 0.39, 0.22	-0.09, 0.43, 0.41	-0.15, 0.39, 0.27	0.00, -0.14, -0.30	0.01, 0.44, 0.28	

Uncertainty (90% compatibility limits): ~±0.1 to ~±0.01 for correlations of 0.00 to 0.95 respectively assuming a sample size of ~251.

C14 Table. Correlations between collective tactical variables for the **attacking team** in 6v6 SSG. The three values are the correlations for the mean, standard deviation and entropy respectively.

Variable	1	2	3	4	5	6	7
1. Inter-player distance (m)		0.76, 0.67, 0.73	0.88, 0.70, 0.63	-0.03, 0.22, 0.20	-0.57, -0.24, -0.16	-0.53, 0.39, 0.14	-0.22, 0.46, 0.29
2. Surface area (m^2)	0.76, 0.67, 0.73		0.56, 0.45, 0.34	0.36, 0.40, 0.31	-0.09, -0.30, -0.07	-0.33, 0.17, 0.08	-0.16, 0.31, 0.17
3. Length (m)	0.88, 0.70, 0.63	0.56, 0.45, 0.34		-0.43, 0.28, 0.19	-0.78, -0.53, -0.38	-0.57, 0.56, 0.31	-0.23, 0.51, 0.59
4. Width (m)	-0.03, 0.22, 0.20	0.36, 0.40, 0.31	-0.43, 0.28, 0.19		0.69, -0.61, -0.33	0.22, 0.13, 0.20	0.12, 0.39, 0.23
5. Width per Length ratio	-0.57, -0.24, -0.16	-0.09, -0.30, -0.07	-0.78, -0.53, -0.38	0.69, -0.61, -0.33		0.37, -0.14, -0.28	0.15, -0.45, -0.29
6. Centroid Longitudinal (m)	-0.53, 0.39, 0.14	-0.33, 0.17, 0.08	-0.57, 0.56, 0.31	0.22, 0.13, 0.20	0.37, -0.14, -0.28		0.21, 0.46, 0.38
7. Centroid Lateral (m)	-0.22, 0.46, 0.29	-0.16, 0.31, 0.17	-0.23, 0.51, 0.59	0.12, 0.39, 0.23	0.15, -0.45, -0.29	0.21, 0.46, 0.38	

Uncertainty (90% compatibility limits): ~±0.1 to ~±0.01 for correlations of 0.00 to 0.95 respectively assuming a sample size of ~251.

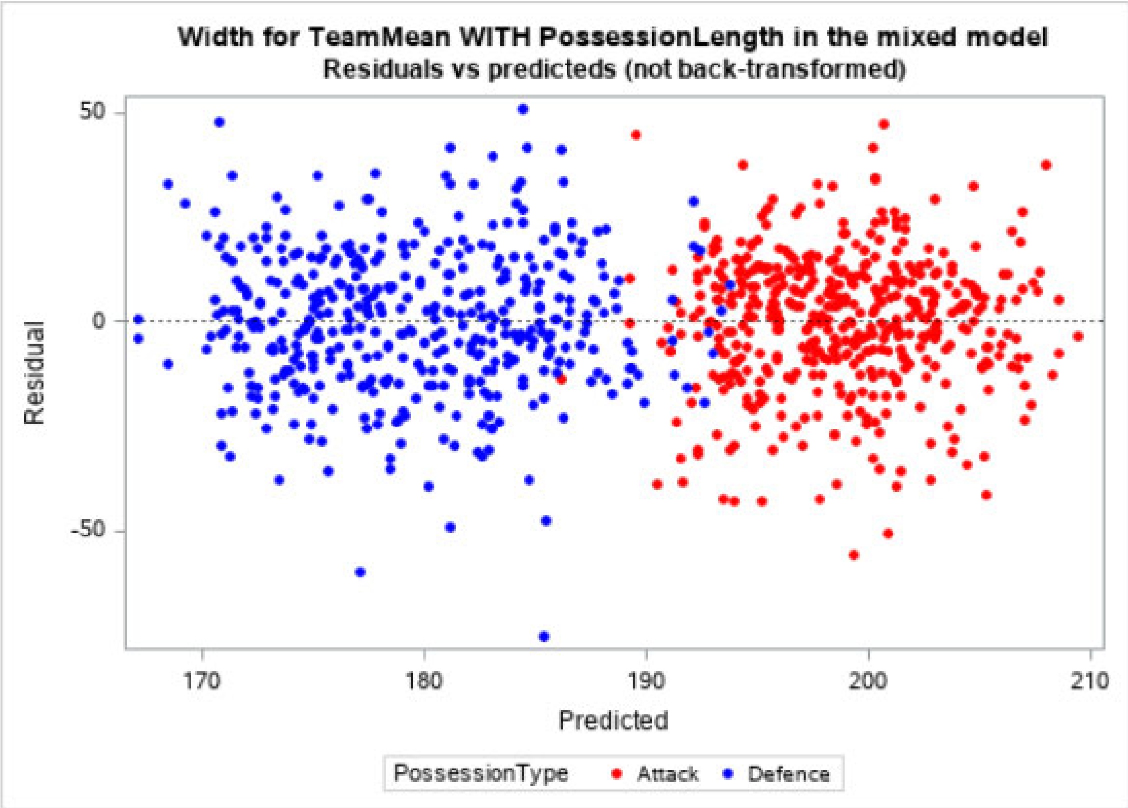
C15 Table. Correlations between collective tactical variables for the **defending team** in **6v6** SSG. The three values are the correlations for the mean, standard deviation and entropy respectively.

Variable	1	2	3	4	5	6	7
1. Inter-player distance (m)		0.8, 0.83, 0.71	0.88, 0.81, 0.52	0.33, 0.44, 0.27	-0.33, -0.21, -0.02	-0.82, 0.52, 0.43	-0.13, 0.45, 0.3
2. Surface area (m^2)	0.8, 0.83, 0.71		0.50, 0.68, 0.35	0.70, 0.56, 0.55	0.18, -0.19, -0.23	-0.63, 0.45, 0.40	-0.16, 0.42, 0.27
3. Length (m)	0.88, 0.81, 0.52	0.5, 0.68, 0.35		-0.11, 0.51, 0.31	-0.70, -0.45, -0.45	-0.78, 0.65, 0.46	-0.17, 0.52, 0.53
4. Width (m)	0.33, 0.44, 0.27	0.7, 0.56, 0.55	-0.11, 0.51, 0.31		0.71, -0.44, -0.69	-0.19, 0.4, 0.29	0.06, 0.58, 0.25
5. Width per Length ratio	-0.33, -0.21, -0.02	0.18, -0.19, -0.23	-0.70, -0.45, -0.45	0.71, -0.44, -0.69		0.36, -0.22, -0.20	0.08, -0.39, -0.36
6. Centroid Longitudinal (m)	-0.82, 0.52, 0.43	-0.63, 0.45, 0.40	-0.78, 0.65, 0.46	-0.19, 0.40, 0.29	0.36, -0.22, -0.20		0.09, 0.51, 0.37
7. Centroid Lateral (m)	-0.13, 0.45, 0.30	-0.16, 0.42, 0.27	-0.17, 0.52, 0.53	0.06, 0.58, 0.25	0.08, -0.39, -0.36	0.09, 0.51, 0.37	

Uncertainty (90% compatibility limits): ~±0.1 to ~±0.01 for correlations of 0.00 to 0.95 respectively assuming a sample size of ~251.

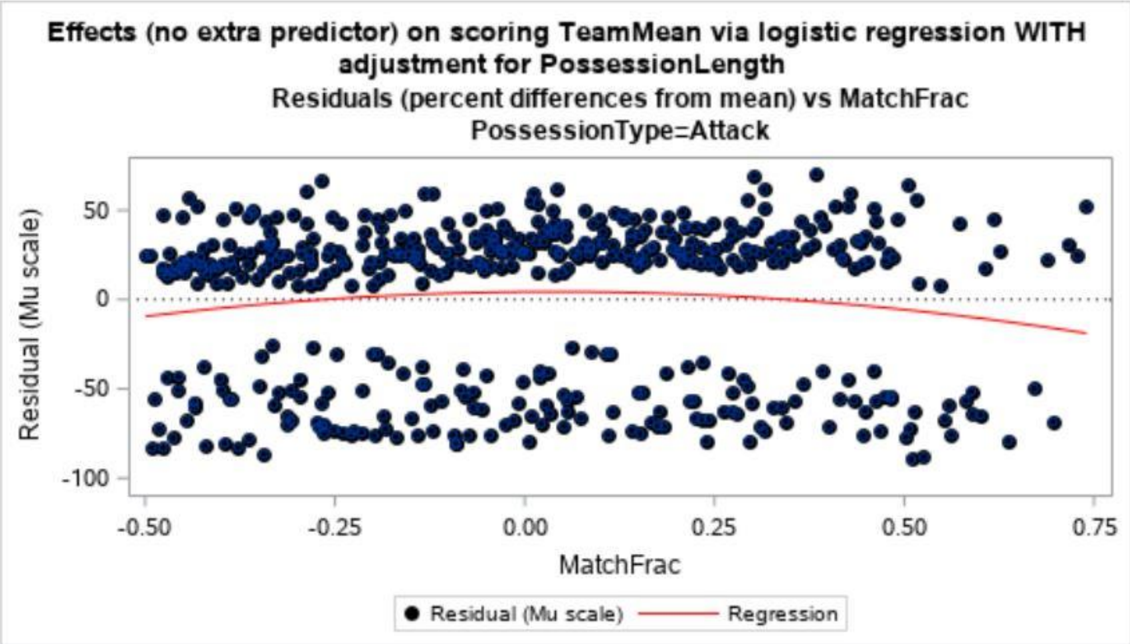
APPENDIX D: Video animations of the collective tactical variables for one possession, for each sub-group

APPENDIX E: Residuals vs predicteds for team mean of width, with adjustment for possession length.

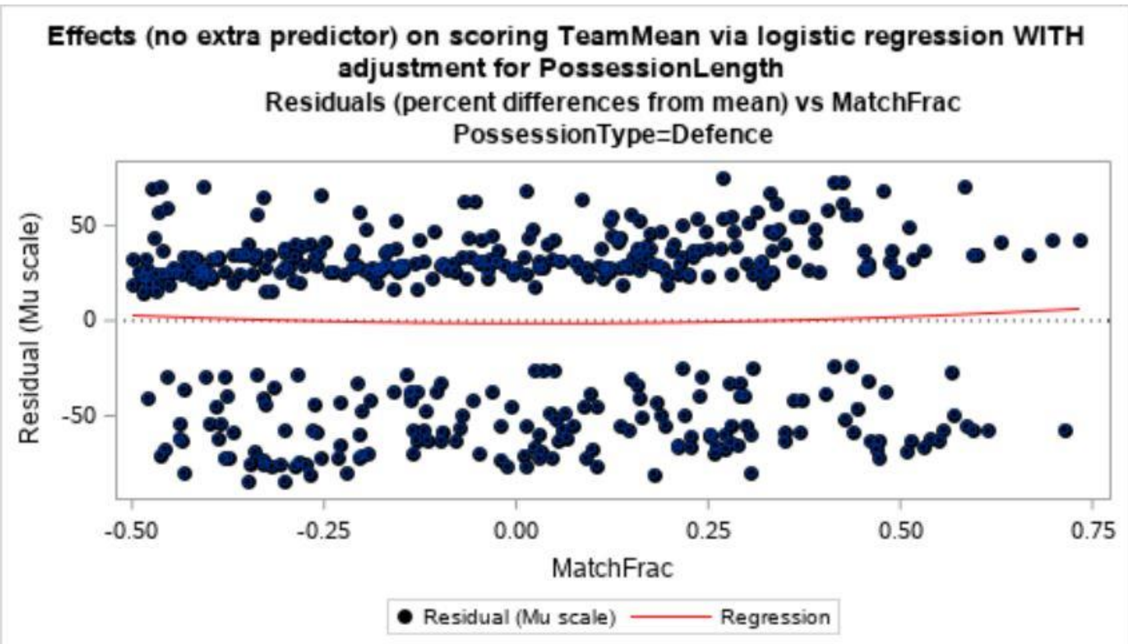


E1. Residuals vs predicteds for the teams mean width with possession length included in the mixed model.

APPENDIX F: Residuals vs possession length; effects on scoring for the team mean with adjustment for possession length on attack and defence.



F1. Effects on scoring for the team mean with adjustment for possession length on attack



F2. Effects on scoring for the team mean with adjustment for possession length on defence