An Investigation into Representative Training Design in Men's Domestic Ice Hockey

Conrad Fletcher

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School of Sport, Rehabilitation and Exercise Sciences

University of Essex

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Abstract

Participation in British ice hockey remains relatively small but is steadily increasing. As the sport grows, a need to understand how training environments reflect the perceptual-action demands of competition also emerges. Representativeness provides a valuable lens for examining this relationship by using match environments to inform the design and evaluation of training activities.

The thesis aimed to investigate the representativeness of training structures within a British senior domestic ice hockey context through three interconnected studies. Study one was a systematic review evaluating the scientific literature surrounding the representativeness of training activities across sport. The review revealed a narrow evidence base dominated by senior male Australian samples and revealed substantial methodological inconsistencies, including unclear operational definitions and limited reporting of reliability. These issues restricted cross-study comparisons commonly assumed to simulate match play were often less representative than expected. This presented the need for coaches to critically examine how training activities are designed.

Study two addressed the absence of ice hockey research by describing the distribution and sequencing of training activities across a competitive season within a domestic men’s team. Structural patterns emerged, including increased use of playing-state activities during fixture-dense or high importance periods and a consistent part-whole-part sequencing within sessions. These findings provide a foundation for understanding how coaches scaffold learning and manage physical demands.

Study three quantified and compared the technical-tactical characteristics of shooting. Although some activities were not intended to replicate match-play, key contextual constraints differed notably from match-play, shaping the representativeness of shooting behaviours. The study reported that shooting tasks should be aligned with specific match moments rather than assuming whole activities inherently reflect competitive demands.

Collectively, this thesis offers practical implications for governing bodies, coach educators and practitioners, and identifies future research including integrating coach intention into representativeness analyses and examining transitional and management states.

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Publications

1. Fletcher C, Cushion E, Quick S, Harkness-Armstrong A. Representativeness of training activities in competitive sports: A systematic review. Int J Sports Sci Coach. Under review.
2. Fletcher C, Quick S, Cushion E, Harkness-Armstrong A. An investigation into the training structures and activities of a senior men's domestic ice hockey team. Int J Sports Sci Coach. Under review.
3. Fletcher C, Quick S, Cushion E, Harkness-Armstrong A. Evaluating the representativeness of shooting during training activities in senior men's domestic ice hockey. [Anonymised for peer review purposes]. Under review.

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List of Abbreviations

AU	-	Arbitrary Unit
Beats·min^{-1}	-	Beats per minute
CAIS	-	Coach Analysis and Intervention System
CD	-	Central defender
CM	-	Central midfielder
COND	-	Conditioned game
COSG	-	Coaches Observation System for Games
D	-	Defensive
DC	-	Defensive centre
DL	-	Defensive left
DR	-	Defensive right
ES	-	Effect size
F	-	Female
FUNC	-	Functional practice
FW	-	Forward
GK	-	Goalkeeper
GPS	-	Global positioning system
HI	-	High-intensity
HR	-	Heart rate
IIHF	-	International Ice Hockey Federation
INT	-	International
INT-NAT	-	Inter-national
km·h^{-1}	-	Kilometres per hour
L	-	Length
LPS	-	Local positioning system
m	-	Metres
M	-	Male
m·min^{-1}	-	Metres per minute
m·s^{-1}	-	Metres per second
mL·kg ·min^{-1}	-	Millilitres of oxygen per kilogram per minute
min	-	Minutes
n	-	Number
n:n	-	Ratio
n·min^{-1}	-	Number per minute
n·h^{-1}	-	Number per hour
N	-	No
NAT	-	National
NC	-	Neutral centre
ND	-	Not distinguishable
NHL	-	National Hockey League
NL	-	Neutral left
NR	-	Neutral right
NS	-	Not stated
OC	-	Offensive centre
OL	-	Offensive left
OR	-	Offensive right
PHASE	-	Phase of play
PHYS	-	Physiological

PRISMA	**-**	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
Q	**-**	Question
REG	**-**	Regional
RHIE	**-**	Repeated high-intensity exercise
RLD	**-**	Representative learning design
RPE	**-**	Rate of perceived exertion
s	**-**	Seconds
SD	**-**	Standard deviation
SE	**-**	Standard error
SI	**-**	International system of units
SKILL	**-**	Skills practice
SSG	**-**	Small-sided game
STE	**-**	Standard typical error
TE	**-**	Typical error
TECH	**-**	Technical practice
U	**-**	Under
UK	**-**	United Kingdom
VO_2 max	**-**	Maximal rate of oxygen consumption
W	**-**	Width
WD	**-**	Wide defender
WM	**-**	Wide midfielder
Y	**-**	Yes

CHAPTER 1: GENERAL INTRODUCTION

1.1 English Ice Hockey Structure

England Ice Hockey is the national governing body for ice hockey within England. The governing body oversees all domestic development, competition structures and more than 140 affiliated clubs within England.[1] Throughout the United Kingdom (UK), England Ice Hockey operates in partnership with Ice Hockey UK, who are responsible for coordinating the sport nationally and managing Great Britain's national ice hockey teams. Both organisations operate within the governance of the International Ice Hockey Federation (IIHF), the global authority for the sport. As of April 2026, Great Britain Men's ice hockey team is currently 17th (of 58 competing nations) in the world rankings.[2]

Ice hockey within England has a single professional league, the Elite Ice Hockey League. The league includes 10 teams from all four home nations (England, Wales, Scotland, Northern Ireland).[3] Below this, there are three further leagues. The Planet Ice National League is the second tier within the English ice hockey pyramid, consisting of 11 teams within England.[4] The third and fourth tiers of English ice hockey are split regionally into north and south, known as the National Ice Hockey League Division 1 (North/South) and the National Ice Hockey League Division 2 (North/South), respectively.[5] Each of these leagues have between 8 and 12 teams.[5]

Historically, participation in ice hockey within the UK has been low. However, a recent census (2024; Sport England) reported that approximately 19,800 adults participated in at least two 30-minute sessions of ice hockey within a 28-day period during the data collection window.[6] Whilst considerably lower than participation in more popular sports (e.g., football; >2.2 million, tennis; >900,000),[6] there was 7,159 registered players within Great Britain during the 2024-25 season,[7] which was a ~10% increase from the previous season (n=6,591)[8] and a >200% increase since the beginning of COVID (2019; n=3,522)[9]. Despite the relatively small participation base, these trends evidence recent growth within competitive ice hockey within the UK.

There may be an expectation that with increased growth and development in the sport, there would also be increased research within the sport (as has been observed with other sporting populations; e.g., women's football,[10] netball[11]). Early research surrounding the sport in Britain focused on areas largely unrelated to performance, such as fan engagement,[12] recruitment into the league,[13-15] and historical account of England's connection to the sport through bandy.[16, 17] More recently, only three studies have been conducted within Britain, all of which investigated injury incidence and were published within the last eight years (2019, 2025, and 2026).[18-20] Despite this emerging interest, there remains no research offering insight into performance characteristics or the demands of the sport within a British context. While this research provides useful context to the ice hockey landscape, further empirical research is required to improve understanding of training and match practices within British ice hockey, extending beyond injury management and incidence alone.

1.2 Understanding Match-play

Understanding match-play is essential for the planning and delivery of practice structures as it represents the primary environment in which athletes perform at their peak. Match-play provides practitioners with contextual information about how players behave, make decisions and execute skills within competitive environments, context needed to deliver evidence-informed recommendations within practice.[21] Alongside this, match-play also offers insight into how teams operate collectively[22] and the key behaviours that emerge during competition.[10] As competition environments are continuously evolving with multiple information sources acting simultaneously,[23-25] athletes must detect and interpret emerging patterns, requiring ongoing evaluation and re-evaluation of the unfolding environment to guide effective decision making.[26, 27] The challenge of dynamic environments is amplified when acknowledging the complex system of team sports, whereby many parts interact together (i.e., team coordination affecting the actions an individual performs).[26, 27] Recognising this complexity is therefore fundamental for practitioners, as it enables them to interpret the behaviours and interactions that emerge during match-play more accurately and subsequently design training which may reflect these demands.

To interpret the inherently complex and dynamic nature of match-play, *ecological dynamics* provides a valuable framework by linking the environmental information to the actions athletes decide to make.[24] Central to the framework is the performers' ability to perceive and act upon affordances (i.e., an opportunity for an action to be performed made available by the present environment),[28] reinforcing the interaction between the athlete and the environment.[27] A core principle of ecological dynamics is that behaviour emerges through the competitive constraints athletes must respond to, whereby performers attune their actions in response to the information they receive within the environment (termed *perception-action coupling*[26]).[27] Consequently, a detailed understanding of the match environment is essential, as the constraints present in competition shape the information available to performers and therefore the physical and technical outcomes that emerge.[24, 27] These outcomes provide context for the decision-making processes that underpin expert performance.[27] Viewing match-play through this lens highlights the inherently complex and interconnected nature of competitive performance, where behaviour emerges from the continuous interaction between athletes and their environment.

Understanding behaviour within the lens of ecological dynamics can also help practitioners understand the variety of methodological approaches to quantify and analyse performance during match-play. Each methodology offers an attempt to quantify how athletes perceive and act within the constraints of competition. Examples of this are, aggregating team or individual data to whole match performances,[29] or examine distinct segments of competition (i.e., set plays,[30, 31] phases of play,[32, 33] or temporal segments of competition[34, 35]). Further, researchers have focused on specific performance outcomes, including physical characteristics (quantifying individual effort or playing intensity),[36, 37] technical actions (reflecting skill execution),[38-40] and tactical behaviours (revealing emerging patterns of team coordination).[34, 41] Psychosocial measures have also been adopted to explore athletes' perceptions of performance, adding further depth to the understanding of competitive behaviour.[42, 43] Match-play has also been frequently examined in relation to contextual factors (e.g., opposition quality,[44, 45] match status,[32, 39, 44] or playing location[44, 46]), and understanding how this might influence performance. Taken together these approaches illustrate diverse ways in which researchers have attempted to interpret the demands and behaviours which emerge during competition. While these approaches provide valuable insight, they differ in the extent to which they can capture the dynamic environment by which match-play exists. Whole-match analyses may offer this perspective.

Understanding match-play requires capturing the full context of the environment. Whole-match analyses offer an overview of the cumulative demands athletes experience during competition, however, this approach can mask important fluctuations in performance that occur within a fixture (i.e., moment-specific outcomes)[47, 48]. To address this limitation, research frequently segments match-play into half-match or other temporal intervals (e.g., comparing early versus late periods of a fixture)[35] to identify more nuanced changes in performance that may be overlooked when analysing whole matches.[32, 33, 49] Segmenting match-play in this way allows researchers to identify specific patterns in performance that whole-match analyses may neglect (e.g., longer possession durations in the first half[50] or increase scoring probability later in a fixture[35]). One additional approach regards quantifying peak match outputs (e.g., total distance covered)[37] offering distinct perspectives on performance outcomes. While these methods provide valuable insight, they only capture a partial representation of the performance landscape. A clear understanding of the physical, technical and contextual demands players experience (and the outcomes they produce across different segments of match-play) is therefore essential, as these underpin population-specific interpretations of performance.[10] Segmenting match-play not only reveals specific patterns, but also enables these behaviours to be interpreted in relation to evolving contextual factors.

Research examining contextual factors has shown that performance can also be influenced by evolving contexts which emerge within competition. Match status (i.e., winning, losing, drawing) provides a clear example of this influence. Studies have demonstrated that total distance can vary dependent of match status, with U16 football players covering greater distances when leading.[32] Similarly, time in possession has been observed to decrease when teams are winning,[44] and passing frequency tends to increase when teams are losing,[51] reflecting shifts in tactical and technical outcomes according to match status. Other contextual variables (e.g., quality of opposition[44, 51] or opposition tactics[52]) have also demonstrated changes in the constraints in which players respond. Collectively, these findings illustrate how analysing segmented match-play (i.e., analysing matches based on match status) can further reveal context-specific behavioural patterns which would not initially be observed when analysing a complete fixture. This provides practitioners with valuable insight for designing representative tasks. Recognising how these contextual influences shape performance is essential for practitioners, as it directly informs how training tasks should be designed to reflect the demands athlete's face during competition.

Analysing match outcomes with this level of nuance (i.e., through analysing specific moments of a fixture alongside consideration of contextual influences on performance) provides coaches with deeper insight into how performance unfolds within competitive environments. Such analysis enables practitioners to evaluate the effectiveness of team-specific strategies and understand the extent to which intended behaviours are expressed under match conditions.[53] By identifying actions that consistently contribute to positive or negative outcomes, coaches gain a broader picture of performance behaviours. These insights form a critical foundation for evidence-based adjustments to training prescription, ensuring that practice environments are aligned with the demands and behaviours observed during competition.[54]

1.3 Understanding Training

Training (or practice) operates as the athlete's learning environment,[55] purposefully constructed to prepare performers for competition.[56] As such, effective training is essential to improve and develop performance.[57] Within training environments, coaches deliberately manipulate task and individual constraints (i.e., something that shapes the actions available to a performer) to guide the behaviours they intend to develop to steer toward desired outcomes, for example; placing performers in situations intended to promote skill development,[58] decision-making practices[59] and confidence (in some environments)[60]. Training typically emerges in two forms; *skill-focused practice* aimed at refining technical execution,[61] and *game-based practice*, intended to develop familiarity with competition demands[54] and to develop physical fitness.[61] Importantly, training is typically designed to be progressive, for example; throughout a competitive season in response to factors such as proximity to competition,[62, 63] season periodisation,[64, 65] or coaching intentions, whilst phases may also be regressive within training design (i.e., to reinforce skill acquisition or development).[66] Understanding the nature of training therefore requires recognising both its structured design and its capacity to adapt to changing session aims and seasonal demands.

To understand training, it is necessary to view the practice environment which provides opportunity for athletes to both consolidate existing skills and learn new ones. Several theoretical frameworks have been proposed to guide what constitutes effective training. *Skill acquisition theories* include a range of approaches for understanding how individuals learn and refine skills.[67] For example, ecological dynamics represents one framework to achieve this, emphasising the importance of how performers interact with their environment.[68] Whilst the constraints-led approach emphasises how coaches can manipulate task, or individual constraints to promote the emergence of specific skills and behaviours.[69] Lastly, *Teaching Games for Understanding*[70] offers a further perspective, advocating the utilisation of game-based scenarios to promote tactical awareness and help performers recognise when and how to apply particular skills in context.[71] Although these theoretical frameworks differ, they share a common focus of promoting environments which encourage decision-making,[72] and encourages athletes to draw upon prior knowledge, supporting the development of functional skill execution.[73] When such principles are applied effectively, the impact can be observed across multiple aspects of athlete development (e.g., adaptations in load management, such as injury prevention,[74, 75] improvements in physiological conditioning,[76] and enhanced skill execution[77, 78]).

Research examining different types of training activity (i.e., skill-focused and game-based) has highlighted clear differences in both the outcomes they produce and the frequency with which coaches prescribe them. Studies have highlighted that coaches tend to favour skill-based activities (particularly in youth populations)[79] likely due to an emphasis on technical development.[80] This is particularly noteworthy given that coaches often express a desire to prioritise player development and decision making, yet research indicates that coaches show limited self-awareness regarding the mismatch between their intended practice and the activities they actually prescribe.[79] When comparing multiple activity types (e.g., match simulations, small-sided games (SSGs), technical drills) studies have identified distinct performance outcomes between activities. For example, SSGs in Australian rules football elicited higher rates of disposals and greater disposal efficiency,[81] while basketball players experienced higher playing loads during SSGs compared to closed, technical drills (e.g., defensive and offensive drills).[82] These findings demonstrate that different training activities afford different opportunities for actions, different environmental information to process and ultimately, place varied demands on athletes. Understanding how training activities provide differing opportunities enables coaches to implement activities that align with their intended session outcomes.

Similarly to match-play, training is rarely analysed in its entirety. Instead, researchers have typically examined isolated practice activities (i.e., small sided games (SSGs),[83, 84] match simulations[85, 86]), to capture the specific demands associated with particular training tasks. Beyond individual activities, training is also broken down into distinct performance characteristics (i.e., physical,[87] technical,[88, 89] tactical[90]) or discrete phases of skill execution (i.e., take-off within Olympic diving,[91] disposals[92]). This level of analysis is often necessary to generate detailed insights into performance, particularly given how training often emerges as a result of the constraints prescribed within a given activity.[22, 55, 93] Analysing training in this way allows practitioners to; i) account for the wide range of skills required for performance,[55] ii) understand how manipulating constraints shape behaviour toward desired outcomes,[93] and iii) evaluate how specific training activities prepare athletes for the demands of competition.[94] With an understanding of how training operates alongside knowledge of match-play, practitioners can begin to evaluate the extent to which training environments align with (or diverge from) the demands of competition.

1.4 Understanding Representativeness

Representative practice gained prominence through early work in ecological dynamics[27] and Brunswik's concept of *representative design*,[95] both of which emphasised the need for training environments to reflect the informational and movement demands of competition. From this perspective, training must preserve the perception-action coupling so that performers can use information in ways that reflect the demands of competition.[27] Achieving this requires coaches to ensure that key informational stimuli (e.g., defensive pressure,[89] time to action,[96] spatial constraints[81]) are present within training tasks. Embedding these constraints into training helps align the environment with match-play. This occurs as the behaviours which emerge in practice are shaped by the same information sources (i.e., environment) that produce performance in competition.

As performance is shaped by the specific informational cues available in a given moment,[26, 95, 97] representative practice therefore aims to design training tasks which preserve those cues and opportunities for skill execution that are present in match-play.[26] Designing representative tasks depends on identifying the informational constraints that shape behaviour in competition, and ensuring that these are preserved in training environments. This is achieved by ensuring that key constraints, such as, opponent behaviour,[98] time pressure,[96] and task-specific environmental features (e.g., wave-height and variability in surfing,[99] and wind direction and strength[100]) are present in training.[26] Embedding these constraints into practice enhances the likelihood that decision-making process and skill execution will transfer effectively from training to performance.[98, 101, 102] *Representative learning design* provides a framework for achieving this alignment, offering a means of evaluating how well training tasks reflect the demands of competition.[26]

When practitioners understand which training activities elicit match-like behaviour (particularly when informed by match data), they can intentionally promote these aspects within training activities. When implemented appropriately, representative practice has been shown to support skill transfer and enhance performers' understanding of competitive environments.[26, 98, 103] Research highlights how exposure to representative training supports the development of decision-making processes and strengthens perception-action coupling by ensuring athletes act on information that closely resembles competitive demands.[102, 104] This is achieved through deliberate manipulation of constraints (i.e., space available, time, equipment) to align training tasks with match-specific informational cues. However, recognising which activities are suited to representative design is essential. Representativeness operates on a spectrum,[105] and not all training tasks benefit from being aligned to match demands.[106] Certain activities (e.g., isolated technical work) are intentionally less representative yet still play a valuable role in skill refinement and athlete development.[26] Consequently, representative practice offers substantial benefits when prescribed appropriately, but relying on this in isolation can limit development. Effective training therefore requires a balance of both representative and non-representative tasks.[26, 28]

A clear understanding of both match-play and training environments is essential for evaluating the representativeness of practice tasks.[26] Analysing competition provides insight into how performance unfolds under contextual constraints[44, 51] and helps identify the performance outcomes associated with success.[32] Similarly, a detailed examination of training activities enables practitioners to determine how constraints shape behaviour[93] and how effectively training prepares athletes for competition.[94] However, as highlighted previously, despite the value of such analyses, empirical research examining both training and match-play remains sparse within ice hockey, leaving a substantial gap in understanding how representative current training environments are within this population.

Despite the value in analysing both training and match environments, and in understanding how closely they align, there remains limited research directly comparing these contexts. This gap is particularly evident within British ice hockey, where participation continues to rise, yet empirical research describing performance characteristics is scarce. The lack of evidence within ice hockey limits coaches' ability to design training that reflects the demands of competition, overall, improving performance (i.e., transfer of skills). Given England Ice Hockey's stated aim to enhance participation and support coach development,[107] research that quantifies and compares the demands of match-play and training would provide valuable insight to inform practice. Such work would offer an evidence-base to support coaching practice, guide task design, and, ultimately, contribute to the continued development of the sport within the UK.

1.5 Aims and Objectives

1.5.1 Aims

To understand the representativeness of training structures within a British, domestic men's ice hockey setting

1.5.2 Objectives

1. To systematically review the scientific literature evaluating the representativeness of training activities across multiple sports
2. To describe the distribution of training activities within a senior men's domestic ice hockey team across a competitive season
3. To quantify and compare the technical-tactical characteristics of shooting during competition and training activities

CHAPTER 2: REPRESENTATIVENESS OF TRAINING ACTIVITIES IN COMPETITIVE SPORTS: A SYSTEMATIC REVIEW

The information presented in this chapter has been updated and submitted for publication

Fletcher C, Cushion E, Quick S, Harkness-Armstrong A. Representativeness of training activities in competitive sports: A systematic review. Int J Sports Sci Coach. Under review.

Abstract

Effective coaching practice comprises planning, delivery and reflection. Regarding these facets, representative learning design (RLD) offers a method for coaches to utilise data-driven insights, and link to planning and reflection processes. This study aimed to systematically review the scientific literature evaluating the representativeness of training activities in sports. A systematic search of electronic databases (APA PsycInfo, CINAHL, MEDLINE, PubMed, Scopus and SPORTDiscus) was conducted in September 2024 with keywords relating to representative learning design ("representative learning" OR "representativeness" OR "learning design" OR "ecological dynamics"), training activities ("training" OR "practice" OR "activit*") and sport coaching ("sport" OR "coach"). Studies which quantified the representativeness of a training activity, within any sport, involving participants of any age, gender, and playing experience were included. Eighteen studies met the eligibility criteria to be included. Small-sided games (n=12; 67%) and match simulations (n=11; 61%) were the most investigated training activities, whilst the influence of task constraints on representativeness of training activities has received limited investigation (n=3; 17%). Studies evaluated representativeness using technical (n=11; 61%), physical (n=10; 56%), and tactical (n=5; 28%) variables. Furthermore, the majority of studies investigated the representativeness of Australian rules football (n=7; 39%) and included predominantly male (n=12; 67%) and national-level (n=9; 50%) participants. Overall, training activities, including match simulations, often failed to replicate competition demands. Coaches and coach education can use these findings to inform design, delivery and reflection of representative practices; however, results should be interpreted cautiously due to methodological limitations. Future research should quantify tactical variables, adopt multi-team, longitudinal designs and manipulate task constraints in isolation to identify causal drivers of representativeness. This will provide better support for coaches aligning practice with competition demands.

Keywords: ecological dynamics, action fidelity, practice design, planning, reflection

2.1 Introduction

Sport coaching is inherently complex, shaped by the dynamic, unpredictable, and context-specific nature of the individuals involved and environment in which it occurs.[97, 108, 109] Consequently, coaches must be adaptable in their decision-making, drawing on a range of knowledge sources (i.e., professional, inter and intra)[110] to respond effectively to the unique demands of their coaching context. To do so, coaches are required to systematically plan, implement and evaluate their coaching practices.[111, 112]

For planning to be effective, coaches must create goals, design activities and formulate strategies to achieve them.[113] Coaching sessions should support athletes' skill development and decision-making, while also replicating the level of challenge present in competition (Chapter 1).[114] Therefore, how coaches devise these goals and structure their practices depends on access to relevant knowledge and what information is readily available to them (i.e., sport-specific, aspects of pedagogy).[115] Planning is a continuous, cyclical and adaptive process. Coaches need to regularly revisit and revise their intentions based on new insights gained through experience and analysis.[56] Therefore, effective planning is grounded in informed (perhaps better expressed as evidence-based) decision-making.[116] Ultimately, the effectiveness of planning depends on the quality of information available to support it.

Many coaches often engage in some form of reflection, for example, conversations with peers or coach developer(s) (as part of reflection), which may offer useful insights into features of coaching practice.[109] However, obtaining access to objective information about how hard players worked, the complexity of decisions made, or how closely the training mirrors competitive conditions is problematic. Dialogue with peers and coach developers can facilitate the exploration of ideas, test assumptions, and make sense of experiences.[117] However, reflection that uses data may be more impactful on coaches' practice, as it provides a clearer picture of what happened in training. As with planning, reflection is only as good as the quality of information that supports it.[118] In short, while dialogue plays an important role in the reflective process, coaches who also engage with objective data are better placed to refine their practice and make evidence-based decisions moving forward.

Without tangible data to guide coaches' thinking, the processes of planning and reflection become difficult. Thus, there is a clear need for an evidence-informed understanding to support coaches,[119] although the available empirical evidence remains limited. To address this gap, the framework of Representative Learning Design (RLD) has been proposed. Grounded in Brunswik's theory of representative design,[95] RLD emphasises the importance of preserving key perceptual and movement demands within training to ensure effective skill transfer to competition (Chapter 1). These demands may include physical, technical and, in some cases, psychological elements (e.g., cognitive responses). It comprises two core components: *functionality*, which reflects how well a task replicates the perceptual-cognitive demands of the game; and *action fidelity*, which concerns the extent to which behaviours in training mirror those in competition. Pinder et al. (2011) emphasised that RLD requires practitioners to create dynamic interventions to account for *"interacting constraints on movement behaviours, (…) informational variables from the specific performance environments, and (…) functional coupling between perception and action processes"* (p. 151).[26]

Despite the theoretical value of RLD, its application in the scientific literature remains inconsistent. Recommendations for the application of RLD are presented as hypothetical or anecdotal examples without underpinning data (e.g., conceptual outlines of task-design in football),[120] or in ways that are not easily digestible or practical for coaches (e.g., highly technical presentations of existing coaching frameworks)[121]. For example, studies may assess either training or competition environments in isolation,[101, 122-124] relying on indirect comparisons with previously published data rather than direct assessments of representativeness. Consequently, it is difficult to understand the current state and extent of the scientific literature which has attempted to evaluate the representativeness of training activities. Therefore, this review aims to 1) systematically review the scientific literature evaluating the representativeness of training activities in sports, 2) identify the methods used to assess representativeness, and 3) summarise how training activities can be designed to more (or less) closely mirror the demands of competition.

2.2 Methods

2.2.1 Design and Search Strategy

This systematic review was completed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).[125] A systematic search of electronic databases (APA PsycInfo, CINAHL, MEDLINE, PubMed, Scopus and SPORTDiscus) was conducted on 2nd September 2024, with no date restrictions. The search strategy included terms for representative learning design ("representative learning" OR "representativeness" OR "learning design" OR "ecological dynamics") AND training activities ("training" OR "practice" OR "activit*") AND sport coaching ("sport*" OR "coach*"). The reference list of included studies were manually reviewed against the eligibility criteria for potentially eligible studies. A review protocol was not registered.

2.2.2 Eligibility Criteria

Included studies quantified the representativeness of a training activity, within any sport, and involving participants (athletes and coaches) of any age, gender, playing standard and playing (or coaching) experience. Only peer-reviewed, full-text journal articles were included, with abstracts, conference proceedings, book chapters, review studies, and student theses excluded. Studies could be written in any language. Studies quantifying representativeness (i.e., differences or relationships in technical, tactical, physical or psychological demands) of a whole training session (i.e., not an individual training activity)[126] or only analysing training activities (i.e., no quantification of competition)[101] were excluded. For example, Franks et al. collected data in both environments but did not quantify any relationships or differences between them, and was therefore excluded.[127]

2.2.3 Study Selection

Duplicate studies were identified and removed prior to screening. A two-stage screening process was conducted, with two researchers (CF, AHA) independently reviewing studies against the eligibility criteria. Initial screening (first-stage) involved reviewing the title, abstract, and keywords, with remaining studies included for full-text screening (second-stage). Disagreements (n=2) following initial or full-text screening, were resolved through discussion among three researchers (CF, AHA, EC), with the third researcher (EC) providing the final decision. Studies remaining following full-text screening were included within this review.

2.2.4 Methodological Quality

The methodological quality of included studies were reviewed against a modified version of the Downs and Black checklist[128] (Appendix 2.1). This tool was selected as it is one of the few validated tools appropriate for assessing methodological quality in observational designs, with intervention-specific items removed to ensure relevance to the studies included in this review (e.g., criteria only relevant for intervention studies: reporting (Q4, 8, 9), external validity (Q12, 13), internal validity (Q14, 15, 16, 17, 19, 21, 22, 23, 24)). Subsequently, a study could attain a maximum score of 12 from 11 criteria. The methodological quality was independently reviewed by two researchers (CF, SQ), with any disagreements (n=15) resolved by discussion with a third researcher (EC), who provided the final decision.

2.2.5 Data Extraction

Data were extracted by CF and reviewed by AHA. Data relating to study characteristics (e.g., year of publication, country, year of data collection), participant characteristics (e.g., sex, age group, playing standard), methods of data collection and analysis (e.g., number of competition observations, number of training observations, inclusion criteria), and representativeness of training activities (e.g., physical, technical, or tactical variables) were extracted. Where data were presented as figures, WebPlotDigitizer v5.2[129] was used to extract data. ‘Competition observations’ referred to the number of matches analysed, whilst ‘individual competition observations’ referred to the number of player-level observations within those matches. Similarly, ‘activity observations’ referred to the number of training activities analysed, and ‘individual activity observations’ referred to the number of player-level observations within those activities. If studies presented irrelevant data alongside comparisons between training and competition, only relevant data were extracted. If data were not distinguishable (e.g., number of training sessions, activities, or individual observations). When this information could not be obtained or remained indistinguishable, data were reported as ND (not distinguishable). These datapoints were acknowledged but excluded from format-specific analyses due to their lack of separation. Irrelevant data included (but was not limited to); data only presented in one environment (i.e. only quantified during competition)[130], when data was not distinguishable[49] or fixtures were not competitive.[49] To distinguish individual variables, physical variables were defined as measures which described the physiological demands of training (e.g., heart rate (HR), distance covered, accelerations), technical variables were defined as measures describing discrete, sport-specific skills (e.g., passes, shots, disposals), tactical variables were defined as measures describing team or player-specific behaviours related to positioning, spacing or coordination (e.g., team length, interpersonal distance, team surface area), and psychological variables were defined as measures capturing cognitive responses to training or competition (e.g., mental effort, confidence, cognitive anxiety), allowing these variables to be clearly differentiated within subsequent analyses. To facilitate comparisons, all data were reported in standard units (e.g., distance covered (m)), with data converted if required and denoted if not possible.

2.2.6 Statistical Analysis

Due to the range of study aims (e.g., developing a drill classification system,[131] or to investigate gender differences[130]), different methods of data collection and varied statistical analysis approaches (e.g., Cluster analysis,[131] association rules algorithm[81]) adopted across studies, a meta-analysis was not conducted. Data were presented as mean ± SD unless otherwise stated.

2.3 Results

2.3.1 Study Selection

The study selection process is presented in Figure 2.1. Searching electronic databases identified 1,357 studies. The screening process eliminated 1,349 studies, whilst 10 studies were retrieved from manually reviewing the reference lists from included studies,[49, 82, 92, 96, 131-136] resulting in 18 studies included in this review.[33, 34, 42, 49, 81, 82, 85, 92, 96, 130-138]

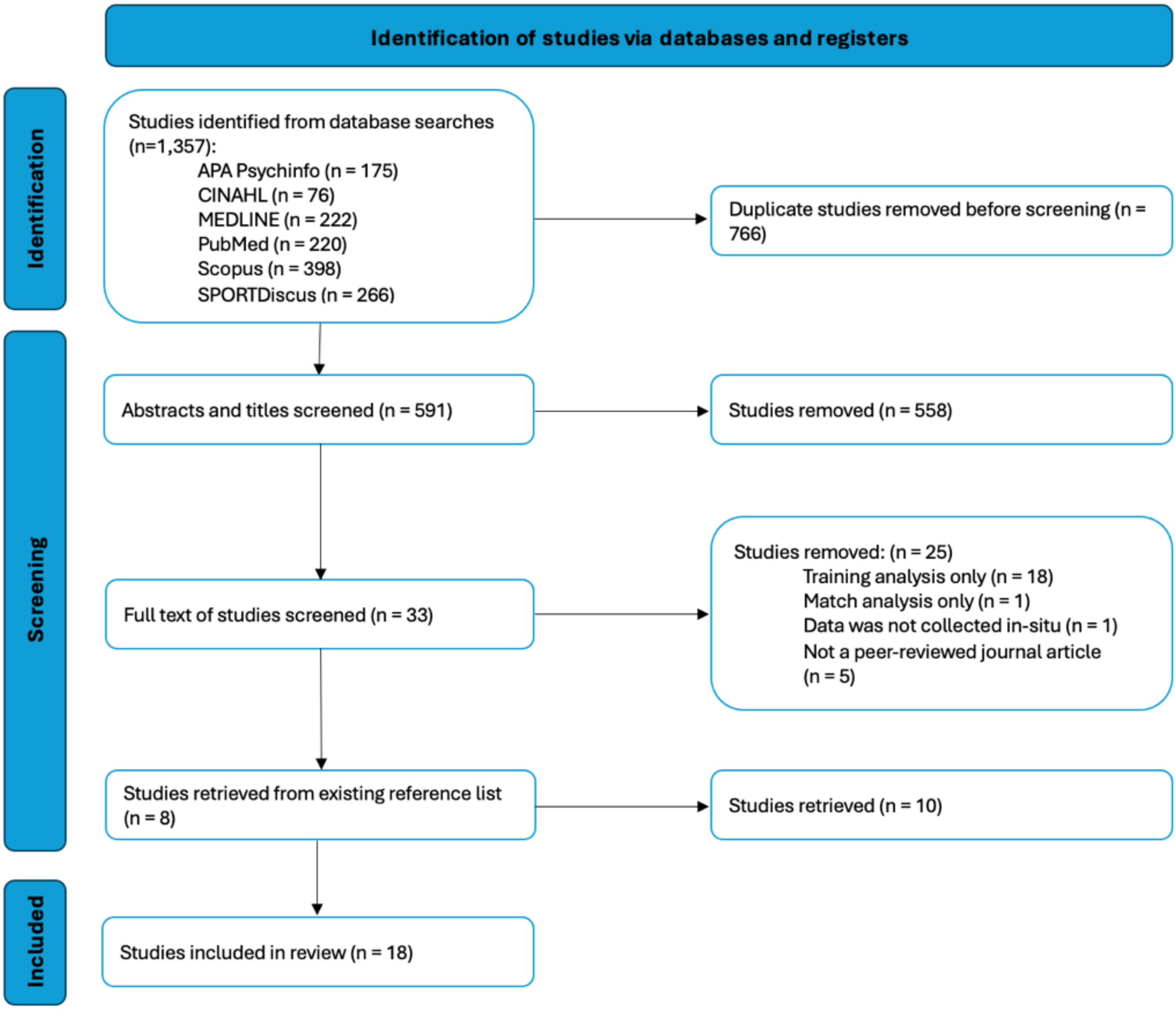

Figure 2.1. Flow chart of the study selection process for studies included in this review

2.3.2 Methodological Quality of Studies

The methodological quality of included studies are presented in Table 2.1. The quality of studies ranged between 7 and 12 (mean = 9.4 ± 1.2). Overall, the methodological quality was high, with all studies, excluding one,[136] receiving a score of ≥8. All studies received a maximum score on criteria 1 (i.e., clearly stating hypotheses), 2 (i.e., clearly outlining the main outcomes measured), 3 (i.e., reporting participant characteristics), and 6 (i.e., describing main findings). The criterion with the lowest score (n=4; 22%)[34, 92, 96, 133] was question 10 (i.e., reporting style of p-values). Ireland et al.[92] received the maximum score (n=12), whilst Boyd et al.[136] achieved the lowest score (n=7).

Table 2.1. Methodological quality of included studies

Study	**Criteria**											**Total**
	1	**2**	**3**	**5**	**6**	**7**	**10**	**11**	**18**	**20**	**25**	
Bonney et al. (2020)[96]	1	1	1	2	1	1	1	1	1	1	0	11
Boyd et al. (2013)[136]	1	1	1	0	1	1	0	0	1	1	0	7
Browne et al. (2020)[81]	1	1	1	2	1	0	0	0	1	1	1	9
Casamichana et al. (2012)[132]	1	1	1	0	1	1	0	1	1	1	0	8
Corbett et al. (2018)[131]	1	1	1	2	1	0	0	0	1	1	0	8
Couto et al. (2024)[34]	1	1	1	2	1	0	1	0	1	1	1	10
Djaoui et al. (2017)[134]	1	1	1	1	1	1	0	1	1	1	1	10
Fernández-Fernández et al. (2015)[133]	1	1	1	2	1	1	1	0	1	1	1	11
Gabbett et al. (2008)[49]	1	1	1	2	1	1	0	0	1	1	1	10
Ireland et al. (2019)[92]	1	1	1	2	1	1	1	1	1	1	1	12
Krause et al. (2019)[130]	1	1	1	2	1	1	0	1	1	1	0	10
Maloney et al. (2018)[42]	1	1	1	1	1	1	0	1	1	1	0	9
Montgomery et al. (2010)[82]	1	1	1	2	1	1	0	1	0	0	1	9
Olthof et al. (2019a)[137]	1	1	1	1	1	1	0	1	1	1	0	9
Olthof et al. (2019b)[138]	1	1	1	2	1	1	0	1	1	1	0	10
Svilar et al. (2019)[135]	1	1	1	2	1	1	0	1	1	1	0	10
Tribolet et al. (2022)[85]	1	1	1	0	1	1	0	1	1	1	1	9
Wallace et al. (2023)[33]	1	1	1	0	1	1	0	1	1	1	0	8
Total	18	18	18	25	18	15	4	12	17	17	8	9.4

2.3.3 Study and Participant Characteristics

Study and participant characteristics of included studies are presented in Table 2.2. The earliest study was published in 2008,[49] with the greatest number of studies published in 2019 (n=5; 28%)[92, 130, 135, 137, 138]. Of the 11 studies (61%)[33, 81, 85, 92, 130-132, 135-138] reporting year(s) of data collection, data were collected between 2003 and 2019, with most studies (n=9; 82%)[33, 81, 85, 92, 130, 135, 137, 138] collecting data from 2015 onwards. Country of data collection included; Australia (n=11; 61%)[33, 42, 49, 81, 82, 85, 92, 96, 130, 131, 136], Netherlands (n=2; 11%)[137, 138], Spain (n=2; 11%)[132, 135], Brazil (n=1; 6%)[34], and France (n=1; 6%)[134], with one study (6%)[133] not reporting this information. All studies were published in English.

Table 2.2. Study and participant characteristics of studies evaluating representativeness of training activities

Study	Year(s) of Data Collection	Country	Sport	Sex	Age-Group	Playing Standard	Teams (n)	Participants (n)	Participant Characteristics (age, height, body mass)
Bonney et al. (2020)[96]	NS	Australia	Australian Rules Football	NS	Youth	NS	1	22*	16.5 ± 1.0 yrs 179.1 ± 8.0 cm 69.5 ± 9.5 kg
Boyd et al. (2013)[136]	2008 - 2009	Australia	Australian Rules Football	M	Senior	NAT	1	19	25.2 ± 3.8 yrs 187.0 ± 6.0 cm 87.9 ± 8.6kg
						REG		21	21.3 ± 2.4 yrs 185.3 ± 17.2 cm 87.7 ± 18.4 kg
Browne et al. (2010)[81]	2018 - 2019	Australia	Australian Rules Football	M	Senior	NAT	1	NS	NS
Casamichana et al. (2012)[132]	2010 – 2011	Spain	Football	M	Senior	REG	1	27	22.8 ± 4.5 yrs 177.0 ± 5.3 cm 74.4 ± 4.8 kg
Corbett et al. (2018)[131]	2014 – 2015	Australia	Australian Rules Football	M	Senior	NAT	1	40	23 ± 4 yrs 187 ± 8 cm 86 ± 9 kg
Couto et al. (2024)[34]	NS	Brazil	Football	M	U20	NAT	1	24	19.8 ± 0.9 yrs 177 ± 6cm 72.0 ± 7.8 kg
Djaoui et al. (2017)[134]	NS	France	Football	NS	Senior	NAT	2	Training elite n=24	24.3 ±2.6 yrs 180.1 ± 4.1 cm 75.0 ± 5.3 kg
								Training sub elite n=24	20.9 ± 2.9 yrs 177.2 ± 3.7 cm 72.8 kg ± 4.4 kg
								Competition group n=14	23.1 ± 4.0 yrs 178.4 ± 5.7 cm 73.7 ± 5.1 kg

Fernández-Fernández et al. (2015)[133]	NS	NS	Tennis	F	U14	NAT/INT	NS	12		13.0 ± 0.3 yrs 168 ± 3.3 cm 51.4 ± 1.2 kg
Gabbett et al. (2008)[49]	NS	Australia	Football	F	Senior	INT	1	13		21 ± 2 yrs
Ireland et al. (2019)[92]	2017	Australia	Australian Rules Football	M	Senior	NAT	1	33		26.2 ± 3.8 yrs 188.5 ± 6.9 cm 90.3 ± 7.9 kg
Krause et al. (2019)[130]	2012 - 2018	Australia	Tennis	F&M	Youth	INT-NAT	NS	Competition	F n=10	16.7 ± 2.2 yrs
									M n=16	17.5 ± 0.5 yrs
								Training	F n=2	17.1 ± 2.3 yrs
									M n=10	17.5 ± 0.5 yrs
Maloney et al. (2018)[42]	NS	Australia	Taekwondo	F&M	Senior	INT	1	10 (F n=3, M n=7)		23 ± 5 yrs
Montgomery et al. (2010)[82]	NS	Australia	Basketball	M	Youth	NS	NS	11		19.1 ± 2.1 yrs 191 ± 9 cm 87.9 ± 15.1 kg
Olthof et al. (2019a)[137]	2015 - 2016	Netherlands	Football	M	U13s	NAT	U13s n=3	n=57		12.7 ± 0.4 yrs
					U15s		U15s n=3	n=74		14.2 ± 0.6 yrs
					U17s		U17s n=3	n=73		16.3 ± 2.1 yrs
					U19s		U19s n=3	n=76		18.3 ± 2.5 yrs
Olthof et al. (2019b)[138]	2015 - 2016	Netherlands	Football	M	U17s, U19s	NAT	3	143		U17s 16.1 ± 1.4 yrs
										U19s 18.1 ± 1.2 yrs
Svilar et al. (2019)[135]	2017 – 2018	Spain	Basketball	M	Senior	NAT/ INT-NAT	1	16		NS
Tribolet et al. (2022)[85]	2019	Australia	Australian Rules Football	M	Senior	NAT	1	48		23.3 ± 4.4 yrs
Wallace et al. (2023)[33]	2019	Australia	Australian Rules Football	M	Senior	NAT	1	35		26.2 ± 3.7 yrs

*NS = not stated. Sex: F = female, M = male. Age-group: U = Under. Playing standard: INT = International. INT-NAT = Inter-national NAT = National. REG = Regional. *Only 16 participants were included in statistical analyses due to equipment error.*

Studies predominantly (n=15; 83%) investigated the representativeness of training activities of team sports; Australian rules football (n=7; 39%)[33, 85, 92, 96, 131, 136] football (n=6; 33%)[34, 49, 132, 134, 137, 138], and basketball (n=2; 11%)[82, 135]. Only three studies (17%) involved individual sports; tennis (n=2; 11%)[130, 133], and taekwondo (n=1; 6%)[42]. Participants were predominantly male athletes (n=12; 67%)[33, 81, 82, 85, 92, 131, 132, 135-138], with two studies (11%)[49, 133] involving female athletes, two studies (11%)[42, 130] including a mixed-sex sample, and two studies (11%)[96, 134] not reporting participants' sex. The majority of studies (n=11; 61%)[33, 42, 49, 81, 85, 92, 131, 132, 134-136] involved senior athletes, with only seven studies (39%)[34, 82, 96, 130, 133, 137, 138] involving youth athletes (U13s–U20s). Sixteen studies (89%) reported playing standard, with participants competing in international (n=2; 13%)[42, 49], inter-national (i.e., individuals that do not represent their country, however, play in competition against opponents (i.e., individuals/clubs) from other countries (e.g., Champions League in football); n=1; 6%)[130], national (n=9; 56%)[33, 34, 81, 85, 92, 131, 134, 137, 138], and regional (n=1; 6%)[132] competitions. Three studies (17%) involved multiple levels of playing standard (national and regional,[136] national and inter-national,[135] national and international[133]). Only three studies (17%) used a multi-team/club sample, all of which investigated representativeness within football populations (2 clubs,[134] 3 clubs[137, 138]). Considering only studies that investigated team sports (n=15; 83%), the number of participants ranged from 11 to 280 (mean = 57± 72). When excluding the two studies with the largest number of participants (n=280,[137] n=143[138]), the number of participants ranged from 11 to 62 (mean = 31 ± 15). Participant numbers in studies which investigated individual sports (n=3; 17%), ranged between 10 and 38 (mean = 20 ± 16).

2.3.4 Evaluating Representativeness of Training Activities

The methods for data collection and analysis used to evaluate representativeness of training activities within different sports are presented in Table 2.3. Sixteen studies (89%)[33, 34, 49, 81, 82, 85, 92, 96, 130-132, 134-138] reported the number of competition observations, which ranged between 1 and 29 (mean = 12.0 ± 8.6). The two studies[42, 133] which did not outline competition observations, were both individual sports. Only four studies (22%)[82, 130, 132, 135] explicitly reported the number of individual competition observations, which ranged between 27 and 177 (mean = 90.5 ± 74.3). Nine studies (50%) detailed inclusion criteria for competition observations; minimum number of observations (n=1,[33, 131] n=2[92]), excluding stoppages in play,[135, 137, 138] and minimum/maximum competition observation duration (15 minutes,[132] ≥45 minutes,[134] ≤45 minutes[34]).

Table 2.3. Methods used to evaluate representativeness of training activities

Study	Aim	Competition sample: Competition Observations (n)	Competition sample: Individual Competition Observations (n)	Competition sample: Inclusion Criteria	Training Sample: Activity	Training Sample: Training Sessions (n)	Training Sample: Activity Observations (n)	Training Sample: Individual Activity Observations (n)	Training Sample: Inclusion Criteria	Data collection	Variables: Physical	Variables: Tactical	Variables: Technical	Analyses: Differences	Analyses: Relationships
Australian rules football (n=7)															
Bonney at al. (2020)[96]	Compare the technical and physical demands of a SSG to match-play	1	NS	NS	SSG	1	2	NS	Y	GPS (NS). Video recording; SportsCode (v10.3.25)	Y	-	Y	Y	-
Boyd et al. (2013)[136]	Describe and compare external load during training activities and matches	Elite n=24	ND	NS	Closed skills	ND	NS	412	Y	100Hz accelerometer (MinimaxX 2.0, Catapult)	Y	-	-	Y	-
					Open Skills	ND	NS	256							
		Sub elite n=29	ND		Tactical	ND	NS	184							
					SSG	ND	NS	193							
					Match simulation	ND	NS	312							

Browne et al. (2020)[81]	Compare constraint interactions and frequency within match simulations, SSG and matches	22	NS	NS	Match simulations	NS	13	NS	NS	Commercial data provider (Champion Data), video recording; SportsCode (v11.2.3, HUDL)	-	-	Y	-	-
					SSGs (varied)	NS	24	NS							
Corbett et al. (2017)[131]	Determine the extent to which training activities reproduce physical and technical demands of competition	22	NS	Y	Conditioning activities	ND	ND	NS	NS	10Hz GPS (Optimeye S5, Catapult). Video recording; SportsCode (v10.3.3, SportsTec)	Y	-	Y	-	Y
					Match simulation	ND	ND	NS							
					SSG	ND	ND	NS							
Ireland et al. (2019)[92]	Examine task-constraints between match simulations and competitive matches	16	NS	Y	Match simulations	NS	12	NS	Y	Commercial data provider (Champion Data), video recording; SportsCode (v11.1.3, HUDL)	-	-	Y	Y	-

Tribolet et al. (2022)[85]	Compare task-constraints and tactical behaviours between match simulation and matches	22	NS	Y	Match simulations	NS	21	NS	-	Commercial data provider (Champion Data), video recording; SportsCode (v9.4.1, SportTec)	-	Y	Y	Y	-
Wallace et al. (2023)[33]	Determine the extent to which game-based training replicated match-play for Inside-50 entries	22	ND	Y	Match simulations	ND	ND	ND	Y	Video recording; SportsCode (v.11.2.14, SportsTec)	-	-	Y	Y	Y
					SSG	ND	ND	ND							
Football (n=6)															
Casamichana et al. (2012)[132]	Compare physical demands between SSGs and matches	7	27	Y	SSGs (varied)	9	27 (8.0 ± 1.9 per SSG)	217	NS	10Hz GPS & 100Hz accelerometer (MinimaxX S4, Catapult)	Y	-	-	Y	-
Couto et al. (2024)[34]	Compare positional dynamics between SSG and matches	18	NS	Y	SSG (5v5; L 40m x W 26m)	6	36	NS	NS	10Hz GPS & 200Hz accelerometer (Polar Team Pro, Polar)	-	Y	-	Y	-
					SSG (5v5; L 26m x W 40m)	6	36	NS							
Djaoui et al. (2017)[134]	Comparing maximum velocity achieved in SSGs with differing	6	NS	Y	Match simulation (11v11 + GK, 102x66m, 306m^2 per player)	ND	ND	NS	NS	15Hz GPS (SPI Elite, GPSports)	Y	-	-	Y	Y
					SSGs x 14, each with different task	ND	ND	NS							

	task-constraints to matches				constraints (*players*: 5v5 - 10v10; *rules*: with GK, scoring in mini-goals or possession; *dimensions*: L = 34-70m x W = 30-60m; *playing area*: 92 - 212m^2 per player)										
Gabbett et al. (2008)[49]	Compare physical demands of SSGs to national and international matches	NAT n=10	NS	NS	SSGs (3v3, ~50x50m pitch)	ND	NS	NS	Y	Video recording; time-motion analysis	Y	-	Y	Y	-
		INT n=12			SSG (varied task-constraints; ~50x50m)	ND	NS	NS							
Olthof et al. (2019a)[137]	Determine the relationship in tactical behaviours between SSGs and matches	U13s n=5	NS	Y	SSG (4v4 + GK (68x47m))	NS	10	NS	NS	34-91Hz LPS (Inmotio), video recording; Noldus The Observer XT (Noldus Information Technology)	-	Y	Y	Y	Y
					SSG (6v6 + GK (80x56m))	NS	5	NS							
					SSG (8v8 + GK (91x63m))	NS	3	NS							
		U15s n=6	NS		SSG (4v4 + GK (68x47m))	NS	15	NS							
					SSG (6v6 + GK (80x56m))	NS	15	NS							
					SSG (8v8 + GK (91x63m))	NS	9	NS							

		U17s n=10	NS		SSG (4v4 + GK (68x47m))	NS	10	NS							
					SSG (6v6 + GK (80x56m))	NS	10	NS							
					SSG (8v8 + GK (91x63m))	NS	3	NS							
		U19s n=4	NS		SSG (4v4 + GK (68x47m))	NS	10	NS							
					SSG (6v6 + GK (80x56m))	NS	11	NS							
					SSG (8v8 + GK (91x63m))	NS	6	NS							
Olthof et al. (2019b)[138]	Compare physical, technical, and tactical demands between match simulations and matches	U17s n=3*	NS	Y	Match simulations	1	6	NS	NS	34 – 91Hz LPS (Inmotio), video recording; Noldus The Observer XT (Noldus Information Technology)	Y	Y	Y	Y	Y
		U19s n=2*	NS		Match simulations	1	9	NS							
Basketball (n=2)															
Montgomery et al. (2010)[82]	Compare physical and physiological demands between training	3	128	NS	SSG	ND	48	NS	NS	HR monitor (Suunto Pro Team, Vantaa), 100Hz accelerometer	Y	-	-	Y	-
					Offensive activities	ND	57	NS							

	activities and matches				Defensive activities	ND	190	NS		(MinimaxX, Catapult)					
Svilar et al. (2019)[135]	Comparing physical demands between drills intended to replicate or overload match demands	5	177	Y	Match simulation	ND	7	174	Y	LPS & 100Hz accelerometer (T6, Catapult)	Y	-	-	Y	-
					SSG (removal of stoppages)	ND	5	34							
Tennis (n=2)															
Fernández-Fernández et al. (2015)[133]	Compare physiological stress response between training and competition	NS	NS	NS	Match simulation	NS	NS	NS	NS	0.2Hz HR monitor** (S610, Polar), RPE scale (15-category Borg scale)	Y	-	-	Y	Y
Krause et al. (2019)[130]	Determine representativeness of serve and return training activities	15	30	Y	Technical: Serves and returns	ND	ND	ND	Y	Commercial data provider (Hawkeye), video recording; SportsCode	-	Y	-	Y	-
Taekwondo (n=1)															
Maloney et al. (2018)[42]	Determine whether match simulation represented	NS	NS	NS	Match simulation	NS	NS	NS	NS	Video recording; Kinovea (v0.8.25)	Y	-	Y	Y	Y

	demands of competition	Typical training fight***	NS	NS	NS

*NS = not stated. ND = not distinguishable. Y = yes. Competition sample: NAT = national, INT = international, U = under. Training sample: SSG = small-sided game, L = length, W = width, GK = goalkeeper. Data collection: GPS = global positioning system, LPS = local positioning system, HR = heart rate, RPE = rate of perceived exertion. * All but one U17 match was played between academies within the studies. This may make them less competitive than in a formal league or cup structure. **Converted to SI units ***A typical training fight would include coach instruction administered throughout the whole activity (not just in rest periods between rounds).*

A variety of training activities were explored, including; small-sided games (SSGs) (n=12; 67%)[33, 34, 49, 81, 82, 96, 131, 132, 134-137], match simulations (n=11; 61%)[33, 42, 81, 85, 92, 131, 133-136, 138], technical (n=2; 11%)[42, 130], conditioning (n=1; 6%)[131] and tactical activities (n=1; 6%)[136]. Twenty-five unique variations of SSGs were investigated, involving different task-constraints; number of players/opponents,[33, 49, 81, 96, 132, 134, 137] playing dimensions,[33, 34, 82, 96, 134, 137] duration,[137] and rule variations (i.e. smaller goals,[132, 134] ball-conservation,[134] inclusion of goalkeepers,[132, 134, 137] removal of stoppages,[135] and minimum kick number[96]). Of the twelve studies investigating representativeness of SSGs, three analysed a single SSG activity,[82, 96, 135] two analysed three SSG activities,[132, 137] and one study analysed two SSG activities.[34] In contrast, five studies[33, 49, 81, 131, 136] grouped all SSG variations together without clearly detailing the task-constraints. One study analysed 14 different types of SSGs (with variations to number of players, playing dimensions and task constraints).[134]

Five studies (28%)[33, 34, 96, 132, 138] reported the number of training sessions observed according to each training activity, whilst the number of observations were indistinguishable for seven studies (39%)[49, 82, 130, 131, 134-136], and were not reported for six studies (33%)[42, 81, 85, 92, 133, 137]. The number of training sessions observed in studies ranged between 1 and 62 (mean = 13.3 ± 3.7), which reduced to between 1 and 12 observations (mean = 6.0 ± 5.4), when removing the study with the largest number of training session observations (n=62)[33]. Eleven studies (61%)[33, 34, 81, 82, 85, 92, 96, 132, 135, 137, 138] reported the number of training activities observed, however, the number of training activities observed could not be identified for three studies (17%)[130, 131, 134], and was not reported for four studies (22%)[42, 49, 133, 136]. The number of training activities observed ranged between 2 and 190 (mean = 23.6 ± 36.7). When removing the study with the most training activity observations (n=190)[82], the range was 2 to 57 (mean = 17.0 ± 14.4). Three studies (17%)[132, 135, 136] reported the number of individual observations per training activity, whilst this number was indistinguishable in two studies (11%)[33, 130] or not reported in the majority of studies (n=13; 72%)[34, 42, 49, 81, 82, 85, 92, 96, 131, 133, 134, 137, 138]. Where stated, the number of individual observations per training activity ranged between 34 and 412 (mean = 210.0 ± 112.7). Six studies (33%) detailed inclusion criteria for training activity observations; specific task constraints (n=3; >2 kicks before shot attempt,[96] serve and return activities only,[130]

≥6v6 player discrepancy[33]), ball-in play data only (n=2)[96, 135], playing position (n=1)[49], and analysis of specific data collection groups (n=1; 1st team only)[85].

Representativeness of training activities were determined using technical (n=11; 61%)[33, 42, 49, 81, 85, 92, 96, 130, 131, 137, 138], physical (n=10; 56%)[49, 82, 96, 131-136, 138], and tactical (n=5; 28%)[34, 42, 85, 137, 138] variables. Most studies (n=11; 61%)[33, 34, 81, 82, 92, 130, 132-136] quantified either technical, physical or tactical variables, followed by a combination of variables across two groupings (n=6; 33%;[42, 49, 85, 96, 131, 137] technical, physical, or tactical), whilst only one study (6%)[138] investigated all three variable types.

All studies provided descriptive statistics (e.g., frequencies, effectiveness/success) to evaluate representativeness. Only one study evaluated representativeness of training activities using solely descriptive statistics.[81] Studies predominantly (n=16; 89%)[34, 49, 82, 85, 92, 96, 130, 132, 135, 136] evaluated representativeness by determining whether differences existed between training activities and competition, and less frequently (n=7; 39%)[33, 42, 96, 132, 134, 137, 138] by analysing the relationships between training activities and competition.

2.3.5 Quantification of Performance

2.3.5.1 Technical Variables

Most studies evaluated the representativeness of training activities using technical variables (n=11; 61%; Table 2.4)[33, 42, 49, 81, 85, 92, 96, 130, 131, 137, 138]. To collect technical data, all studies used video recordings, computerised notational analyses (n=10; 91%)[33, 42, 81, 85, 92, 96, 130, 131, 137, 138], commercial data providers (n=4; 36%; Champion Data,[81, 85, 92] Hawkeye[130]) and/or manual notational analyses (n=2; 18%)[42, 49]. For six studies (55%)[33, 81, 85, 92, 130, 131], the methods of data collection for competition differed to those for training activities (e.g., commercial data providers vs computerised notational analysis)[81].

Table 2.4. Technical variables quantified to determine representativeness of training activities

Study	Technical variable		Competition	Training Activity 1	Activity 2	Activity 3
Australian rules football (n=6)						
Bonney et al. (2020)[96]			*Competition*	*SSG*		
	Kicks (n)		5.34 ± 3.74	**11.83 ± 2.40**		
	Kick efficiency (%)		50.13 ± 9.52	**59.83 ± 5.19**		
	Disposal time (n)	<2s	1.13 ± 0.64	**3.33 ± 0.82**		
		2 - 4s	0.63 ± 0.52	**4.00 ± 1.55**		
		>4s	0.38 ± 0.74	**1.50 ± 0.84**		
Browne et al. (2020)[81]			*Competition*	*Match Simulation*	*SSG*	
	Disposals (n) §		3478	1298	2677	
	Disposal efficiency (%) §		54 – 89	49 - 84	77 – 87	
Corbett et al. (2017)[131]			*Competition*	*Activity Clusters**		
	Kicks under pressure (%) §	Under pressure	73	13 – 33		
		No pressure	27	67 – 79		
	Kicks at velocities (%) §	Moving (Velocity NS)	61	38 – 74		
		Stationary	39	26 – 34		
	Time in possession (%) §	Kicks <2s	49	17 – 74		
		Kicks >2s	51	25 – 69		
Ireland et al. (2019)[92]	*Disposals Data reported as n/120 minutes of gameplay*		*Competition*	*Match Simulation*		
	Time in possession (n)	0-1s	7.37 ± 3.93	**13.54 ± 4.17**		
		1-2s	2.37 ± 1.12	**4.57 ± 1.71**		
		2-3s	0.65 ± 0.48	**1.28 ± 0.79**		
		3-4s	0.23 ± 0.27	**0.39 ± 0.29**		
		4+s	0.23 ± 0.27	0.34 ± 0.35		
	Type of play (n)	General	9.51 ± 3.84	10.39 ± 3.93		
		Stoppage	1.33 ± 1.56	1.10 ± 1.04		
	Speed of disposing player (n)	Dynamic	5.61 ± 2.41	**9.87 ± 3.74**		
		Static	5.24 ± 3.09	**10.26 ± 3.26**		
	Speed of receiving player (n)	Dynamic	6.77 ± 3.22	**10.48 ± 3.27**		
		Static	4.08 ± 1.90	**9.63 ± 3.29**		

Disposal distance (n)	0 – 5m	4.03 ± 2.32	**9.84 ± 2.73**
	5 - 15m	5.6 ± 2.40	**8.66 ± 3.32**
	15m+	1.21 ± 0.89	1.6 ± 0.99
Type of pressure (n)	Implied	6.68 ± 3.32	**13.22 ± 4.36**
	Physical	3.10 ± 1.70	3.24 ± 1.36
	No pressure	1.06 ± 0.63	**3.63 ± 1.21**
Direction of pressure (n)	Front on	4.09 ± 2.30	9.48 ± 3.24
	Side on	2.63 ± 1.64	**4.31 ± 1.65**
	Chase	4.20 ± 1.77	**4.10 ± 1.74**
Proximity of target opposition (n)	0-5m	6.92 ± 3.25	**11.13 ± 3.65**
	5m +	3.22 ± 1.52	**5.43 ± 1.96**
	No pressure	0.71 ± 0.60	**3.52 ± 1.16**
Prior disposal type (n)	Crumb/ground ball	5.54 ± 2.49	4.68 ± 1.80
	Free kick/mark	1.34 ± 0.70	**2.01 ± 0.81**
	Handball	3.97 ± 2.47	**13.43 ± 4.4**
Kicks *Data reported as n/120 minutes of gameplay*		*Competition*	*Match Simulation*
Time in possession (n)	0-1s	2.63 ± 1.57	**1.44 ± 0.82**
	1-2s	3.86 ± 1.90	4.64 ± 2.22
	2-3s	1.77 ± 0.87	**2.3 ± 0.92**
	3-4s	0.9 ± 0.52	**1.27 ± 0.45**
	4+s	2.92 ± 1.06	**2.05 ± 0.72**
Type of play (n)	General	11.05 ± 3.51	10.64 ± 3.76
	Stoppage	1.04 ± 1.03	0.49 ± 0.58
Speed of disposing player (n)	Dynamic	6.31 ± 2.71	6.48 ± 2.69
	Static	5.78 ± 2.06	5.23 ± 2.07
Speed of receiving player (n)	Dynamic	6.36 ± 2.7	6.41 ± 2.71
	Static	5.73 ± 1.76	5.25 ± 1.94
Kick distance (n)	0 – 20m	2.43 ± 2.09	2.74 ± 1.21
	20 - 40m	5.31 ± 1.99	6.06 ± 2.09
	40m+	4.35 ± 1.59	**2.91 ± 1.35**
Type of pressure (n)	Implied	7.25 ± 2.84	7.03 ± 2.92
	Physical	1.19 ± 0.83	**0.44 ± 0.31**
	No pressure	3.63 ± 1.54	4.23 ± 1.41
Direction of pressure (n)	Front on	3.92 ± 1.45	3.76 ± 1.68
	Side on	2.61 ± 1.45	2.42 ± 1.25
	Chase	2.82 ± 1.31	**1.9 ± 0.99**

	Proximity of target opposition (n)	0-5m	7.88 ± 2.83	**5.55 ± 2.25**
		5m +	2.23 ± 1.12	**3.37 ± 1.52**
		No pressure	1.36 ± 0.92	**12.64 ± 1.12**
	Prior disposal type (n)	Crumb/ground ball	2.50 ± 1.40	**1.54 ± 0.81**
		Free kick/mark	5.49 ± 1.89	5.76 ± 1.67
		Handball	4.10 ± 2.36	4.41 ± 2.51
Tribolet et al. (2022)[85]			*Competition*	*Match Simulation*
	Kicks ($n \cdot min^{-1}$)		2.21 ± 0.25	**1.63 ± 0.30**
	Kick efficiency (%)		63.87 ± 5.90	60.57 ± 11.65
	Handballs ($n \cdot min^{-1}$)		1.56 ± 0.25	**1.36 ± 0.26**
	Handball efficiency (%)		82.70 ± 3.23	86.52 ± 7.05
	Goals ($n \cdot min^{-1}$)		0.11 ± 0.03	**0.19 ± 0.10**
	Shots on goal ($n \cdot min^{-1}$)		0.21 ± 0.03	0.27 ± 0.12
	Turnovers ($n \cdot min^{-1}$)		0.72 ± 0.08	**0.42 ± 0.14**
	Tackles ($n \cdot min^{-1}$)		0.67 ± 0.11	**0.23 ± 0.15**
	Marks ($n \cdot min^{-1}$)		0.94 ± 0.23	1.03 ± 0.30
Wallace et al. (2023)[33]	*Data reported as n/60 minutes of gameplay*		*Competition*	*Match Simulation*
	I-50 entries (n)		23.49 ± 3.91	**47.22 ± 19.20**
	Received (%)	Mark	23.76	**42.53**
		General play	65.17	**51.22**
		Free kick	11.07	**6.25**
	Time in possession (%)	0-1s	16.60	**7.34**
		1-2s	34.35	**39.54**
		2-3s	17.75	**18.89**
		3s+	31.30	**34.24**
	Launch Zone (%)	Wing	66.98	**61.14**
		Corridor	33.02	**38.86**
	Landing Zone (%)	Wing skinny	51.91	**47.01**
		Wing fat	0.76	**0.82**
		Corridor	24.62	**27.85**

		Corridor left	9.83	11.28
		Corridor right	12.88	13.04
	Pressure (%)	Set position	29.10	**35.60**
		Physical	12.60	**6.66**
		Corralling	15.36	13.99
		Chasing	13.84	10.05
		Closing	15.74	**17.26**
		No pressure	13.36	16.44
	Decision (%)	Handball	96.76	**94.29**
		Kick	3.24	5.71
	Distance (%)	Shallow (35 – 50m)	59.54	**53.40**
		Deep (0 -35m)	40.46	**46.60**
	Disposal endpoint (%)	Uncontested	14.69	**42.66**
		Defensive uncontested	8.30	7.34
		Even contest	40.36	25.00
		Offensive outnumber	5.25	**2.17**
		Defensive outnumber	15.27	**4.21**
		Ground ball/to space	16.13	**18.48**
		Coach	0.00	0.14
	Efficiency (%)	Effective	47.23	**67.53**
		Neutral	18.89	11.41
		Ineffective	33.87	21.06
Football (n=3)				
Gabbett et al. (2008)[49]			*Competition*	*SSG*
	Passing contacts (n)		NAT 28.12 ± 7.97	**30.14 ± 12.90**
			INT 29.13 ± 8.97	

	Dribbling contacts (n)	NAT	17.14 ± 4.94	**16.23 ± 6.96**		
		INT	14.21 ± 6.05			
	Tackling contacts (n)	NAT	10.18 ± 4.94	**7.26 ± 2.92**		
		INT	10.08 ± 5.14			
	Trapping contacts (n)	NAT	21.98 ± 28.12	**26.31 ± 9.78**		
		INT	24.09 ± 8.07			
Olthof et al. (2019a)[137]		*Competition*		*SSG (4v4 + GK)*	*SSG (6v6 + GK)*	*SSG (8v8 + GK)*
	Passes ($n \cdot min^{-1}$)	U13s	0.7 ± 0.13	**1.9 ± 0.44**	**2.0 ± 1.45**	1.0 ± 0.15
		U15s	0.9 ± 0.19	**1.9 ± 0.65**	**1.7 ± 0.32**	1.4 ± 0.65
		U17s	0.7 ± 0.19	**2.3 ± 0.60**	**1.7 ± 0.54**	1.3 ± 0.21
		U19s	0.8 ± 0.26	**2.4 ± 0.50**	**1.7 ± 0.49**	**1.4 ± 0.17**
	Effective playing time (%)	U13s	69.70 ± 5.55	85.10 ± 9.68	90.20 ± 1.32	80.80 ± 1.45
		U15s	67.60 ± 9.15	80.10 ± 5.98	79.30 ± 7.95	84.80 ± 5.78
		U17s	66.30 ± 7.27	81.90 ± 4.58	85.20 ± 6.23	77.90 ± 9.18
		U19s	69.50 ± 5.41	86.80 ± 6.16	83.90 ± 6.94	91.30 ± 5.11
Olthof et al. (2019b)[138]		*Competition*		*Match simulation*		
	Transitions ($n \cdot min^{-1}$)	6.40 ± 1.70		**4.4 ± 0.50**		
	Effective playing time (min) §	30.50 ± 3.30		8.70 ± 1.10		
	Relative playing time (%)	67.70 ± 6.40		**14.00 ± 1.90**		
	Ball possession duration (s)	8.7 ± 1.1		**14.0 ± 1.9**		
	Game pace (passes per minute) ($n \cdot min^{-1}$) **	10.94 ± 1.69		**8.59 ± 1.58**		
	Forward pass efficiency (%) **	15.21 ± 5.84		20.97 ± 7.04		
	Incorrect pass efficiency (%) **	50.00 ± 9.21		**47.30 ± 2.54**		
Tennis (n=1)						

Krause et al. (2019)[130]				*Competition*	*Technical*
	Shots (n) §		Serve only	11228	2719
			Serve returner		624
			Serve + 3rd		1601
			Return only		967
			Return + 4th		1097
	Serves (n) §	Deuce court	Serve only	1541	1461
			Serve returner		370
			Serve + 3rd		424
		Ad court	Serve only	1419	1270
			Serve returner		254
			Serve + 3rd		397
	Serve efficiency (%)	Deuce court	Serve only	68.33	**61.05**
			Serve returner		63.78
			Serve + 3rd		72.88
		Ad court	Serve only	68.71	**61.02**
			Serve returner		64.96
			Serve + 3rd		74.56
	Serve return (n) §	Deuce court	Return only	962	485
			Return + 4th		229
		Ad court	Return only	893	377
			Return + 4th		289
	Serve return efficiency (%)	Deuce court	Return only	81.29	**70.31**
			Return + 4th		75.55
		Ad court	Return only	80.40	**68.44**
			Return + 4th		75.43
	3rd shot in rally (n) §		Serve + 3rd	1439	456
	3rd shot in rally efficiency (%)		Serve + 3rd	84.64	**72.37**
	4th shot in rally (n) §		Return + 4th	1119	253
	4th shot in rally efficiency (%)		Return + 4th	82.40	79.84
Taekwondo (n=1)					
				Competition	*Match Simulation*

Maloney et al. (2018)[42]	Kicks (n)	67.40 ± 13.23	**55.80 ± 12.14**

NS = not stated. ***Bold*** *= training activity is significantly different from competition (p<0.05). § = statistical significance was not reported between training activities and competition. Competition: INT. = international, NAT = national, U = under. Training: GK = goalkeeper, SSG = small-sided game. *Activity clusters were defined through means of hierarchal clustering measures and defined groups of training activities with similar physical and technical skill profiles, when related to competition. ** Displayed as mean ± SE*

Studies investigating team sports (n=9; 82%; Australian rules football,[33, 81, 85, 92, 96, 131] football[49, 137, 138]) only quantified technical variables on a team level as opposed to position-specific or an individual player-level. Possession variables (e.g., number of disposals, kicks or passes; sequences of disposal events) were quantified most often (n=8; 89%)[33, 81, 85, 92, 96, 131, 137, 138], followed by offensive (n=2; 22%; e.g., number of goals or shots)[33, 85] and defensive variables (n=2; 22%; e.g., number of tackles)[49, 85]. A full list of operational definitions was provided by three studies (27%)[33, 81, 130], three studies (27%)[92, 131, 137] provided some operational definitions, and three (27%)[85, 96, 138] studies provided no operational definitions. In two studies,[33, 92] technical variables were quantified according to situational variables (e.g., pitch location, defensive pressure). Two studies (18%) explored the influence of contextual factors on technical variables; match outcome,[85] and playing standard (international, national league)[49]. Lastly, technical variables were quantified for the whole-match (n=5; 45%)[42, 85, 92, 96, 130], quarter-match (n=1; 9%)[131], segmental (n=1; 9%; 15 minute periods)[49], phase of play (n=2; 18%; I-50 entries,[33] disposals[81]), or possession (n=2; 18%)[137, 138]. Data were either quantified as absolute (n=3; 22%)[49, 81, 96] or relative (n=5; 56%; per minute of ball-in-play data,[137, 138] per 60 minutes,[92] per 120 minutes,[33] and per minute[85]).

Technical variables were quantified for three types of training activities; match simulations (n=6; 55%)[33, 42, 81, 85, 92, 138], SSGs (n=4; 36%)[49, 81, 96, 137], and technical (n=1; 9%)[130], whilst Corbett et al.[131] quantified technical variables according to activity clusters (or groups), which involved categorising 35 distinct training activities into five groups via a cluster analysis approach. Only one study[137] investigated the influence of task constraints on the representativeness of technical variables; number of players (4v4, 6v6, 8v8) during SSGs. Studies predominantly (n=9; 82%) reported significant differences between technical variables during training activities and competition (team-sports: n=7; 78%;[33, 49, 85, 92, 96, 137, 138] individual sports: n=2; 100%[42, 130]). Furthermore, significant differences were reported for technical variables during match simulations (n=5; 83%)[33, 42, 85, 92, 138], SSGs (n=3; 75%)[49, 96, 137], and technical activities (n=1; 100%)[130]. Within these studies, the proportion of variables which were significantly different during respective training activities and competition ranged from 25% to 100% (mean = 75.0 ± 31.9%).

2.3.5.2 Physical Variables

Representativeness of training activities was quantified using physical variables in 10 studies (56%; Table 2.5)[49, 82, 96, 131-136, 138]. To collect physical data, researchers used global positioning system (GPS) units (n=4; 40%)[96, 131, 132, 134], accelerometers (n=4; 40%)[82, 132, 135, 136], heart rate monitors (n=2; 20%)[82, 133], local positioning system (LPS) units (n=2; 20%)[135, 138], video-based time motion analyses (n=1; 10%)[49], and rate of perceived exertion (RPE) (borg scale; n=1; 10%)[133].

Table 2.5. Physical variables quantified to determine representativeness of training activities

Study	Physical variable			Competition	Training		
					Activity 1	Activity 2	Activity 3
Australian rules football (n=3)							
Bonney et al. (2020)[96]				*Competition*	*SSG*		
	Total distance (m)			8776.38 ± 1198.87	**1590.33 ±103.86**		
	Total distance covered (m·min^{-1})			104.51 ±13.64	**132.53 ± 8.66**		
	Maximum velocity (m·s^{-1})			7.10 ± 0.43	**5.88 ± 0.20**		
	HI running per quarter (%)			61.34 ± 7.05	**68.86 ± 5.15**		
Boyd et al. (2013)[136]				*Competition*	*Match Simulation*	*Tactical*	
	PlayerLoad (A.U.·min^{-1}) §	Midfielders	Elite	16.03 ± 4.21	15.34 ± 2.84	9.51 ± 3.26	
			Sub-elite	15.07 ± 2.02			
		Nomadics	Elite	14.96 ± 2.35	14.30 ± 2.89	8.06 ± 3.24	
			Sub-elite	13.03 ± 2.36			
		Deeps	Elite	11.01 ± 2.63	11.68 ± 3.34	8.73 ± 3.26	
			Sub-elite	10.34 ± 1.59			
		Ruckmen	Elite	14.91 ± 3.30	10.62 ± 2.57	5.87 ± 2.70	
			Sub-elite	12.78 ± 5.49			
	Low-velocity (<2 m·s^{-1}) PlayerLoad (A.U.·min^{-1}) §	Midfielders	Elite	4.19 ± 1.33	3.29 ± 0.69	4.23 ± 1.42	
			Sub-elite	3.88 ± 0.88			
		Nomadics	Elite	4.21 ± 0.90	3.43 ± 2.52	3.58 ± 1.35	
			Sub-elite	3.69 ± 0.65			
		Deeps	Elite	3.75 ± 0.90	3.20 ± 2.59	3.49 ± 1.58	

			Sub-elite	3.81 ± 1.56			
		Ruckmen	Elite	4.41 ± 0.78	3.27 ± 0.53	3.27 ±1.16	
			Sub-elite	3.81 ± 0.81			
			Competition		*Closed Skill*	*Open Skill*	*SSG*
	PlayerLoad (A.U.·min^{-1}) *§*				10.84 ± 2.72	10.46 ± 3.37	15.52 ± 4.95
	Low-velocity (<2 m·s^{-1}) PlayerLoad (A.U.·min^{-1}) *§*				3.39 ± 1.54	3.03 ± 0.90	6.07 ± 3.39
Corbett et al. (2017)[131]			*Competition*		*Activity Clusters**		
	Metres per minute (m·min^{-1}) *§*		130.5		49.0 – 204.1		
	HI running per minute (m·min^{-1}) *§*		33.5		0.5 – 144.1		
	% of distance in HI running (%) *§*		26		0 - 72		
Football (n=4)							
Casamichana et al. (2012)[132]			*Competition*		*SSG*		
	Distance covered (m·min^{-1})		113.0 ± 8.9		**118.3 ± 18.7**		
	Distance covered in velocity zones (m·min^{-1}) **	0.0 – 6.9 km·h^{-1}	2530.12 ± 54.55		2471.22 ± 42.84		
		7.0 – 12.9 km·h^{-1}	2607.76 ± 85.68		**3068.27 ± 112.45**		
		13.0 – 17.9 km·h^{-1}	1135.21 ± 26.77		1135.21 ± 66.93		
		18.0 – 20.9 km·h^{-1}	289.16 ± 26.77		289.16 ± 26.77		
		>21.0 km·h^{-1}	240.96 ± 26.78		**240.96 ± 26.78**		
	Time spent in velocity zones (%) **	0.0 – 6.9 km·h^{-1}	63.22 ± 1.38		**59.10 ± 1.47**		
		7.0 – 12.9 km·h^{-1}	25.93 + 0.85		**31.23 ± 1.14**		
		13.0 – 17.9 km·h^{-1}	7.33 ± 0.62		8.09 ± 0.47		

	18.0 – 20.9 km·h^{-1}	1.51 ± 0.09	1.28 ± 0.24	
	>21.0 km·h^{-1}	0.90 ± 0.38	**0.43 ± 0.19**	
Maximum speed (km·h^{-1})		27.0 ± 1.8	**20.3 ± 2.6**	
Player workload (A.U./min)		13.5 ± 1.5	**15.8 ± 2.7**	
Exertion index (A.U./min)		2.0 ±0.9	**5.1 ± 1.5**	
Work:rest ratio (A.U)		2.4 ± 0.5	**3.5 ± 2.2**	
Sprints (n·h^{-1})	Total	15.3 ± 6.1	**7.5 ± 11.3**	
	0 – 5m	1.0 ± 1.2	0.6 ± 2.8	
	5 – 10m	4.6 ± 2.6	2.6 ± 6.3	
	10 – 40m	9.1 ± 4.2	**4.3 ± 7.8**	
	>40m	0.4 ± 1.0	**0.0 ± 0.0**	
Mean sprint distance (m)		15.2 ± 3.2	**4.4 ± 6.7**	
Maximum sprint distance (m)		34.4 ± 12.4	**4.8 ± 7.4**	
Mean sprint duration (s)		2.3 ± 0.5	**0.7 ± 1.1**	
Maximum sprint duration (s)		5.1 ± 1.7	**0.8 ± 1.2**	
RHIE (n·h^{-1})		9.4 ± 4.5	12.9 ± 12.6	
Mean efforts per RHIE (n)		3.8 ± 0.5	4.0 ± 1.8	
Maximum efforts per RHIE (n)		5.6 ± 1.9	**4.2 ± 1.9**	
Mean duration of efforts in RHIE (s)		3.6 ± 0.7	**3.0 ± 1.1**	
Maximum duration of efforts in RHIE (s)		10.0 ± 2.9	**5.4 ± 2.8**	
Duration between efforts in RHIE (s)		10.5 ± 1.4	11.9 ± 8.7	
Maximum duration between efforts in RHIE (s)		19.2 ± 2.0	**16.1 ± 4.0**	
Duration between RHIE (s)		340.4 ± 208.4	**19.6 ± 33.3**	
Maximum duration between RHIE (s)		736.0 ± 399.5	**20.3 ± 34.4**	
		Competition	*Match Simulation*	*SSGs****

Djaoui et al. (2017)[134]	Maximal sprinting speed ($km \cdot h^{-1}$) §	All players	28.66 ± 1.93	24.49 ± 2.31	23.64 ± 3.08
		CD	29.53 ± 1.34	23.07 ± 0.32	22.89 ± 3.53
		WD	30.25 ± 1.48	25.95 ± 1.54	24.82 ± 3.12
		CM	26.48 ± 0.95	24.10 ± 1.64	22.95 ± 2.44
		WM	29.40 ± 0.57	23.20 ± 5.37	24.13 ± 2.81
		FWD	27.00 ± 0.00	27.00 ± 0.00	23.02 ± 3.04
	Competition maximal sprinting speed (%) §	All players		85.73 ± 9.37	82.67 ± 1.074
		CD		78.18 ± 2.53	77.62 ± 12.30
		WD		85.83 ± 4.49	82.10 ± 10.11
		CM		91.05 ± 5.79	86.70 ± 8.98
		WM		79.10 ± 19.80	82.07 ± 9.62
		FWD		100.00 ± 0.00	85.26 ± 11.27
Gabbett et al. (2008)[49]			*Competition*	*SSG*	
	Distance covered (m) §	INT	9968 ± 1143	4448 ± 1304	
		NAT	9706 ± 484		
	Work:rest ratio (n:n) §	INT	1:12	1:13	
		NAT	1:16		
	Distance covered in velocity zones (m)** §	Walking	INT 3184.75 ± 381.14	1298.45 ± 458.66	
			NAT 3378.55 ± 303.62		
		Jogging	INT 4315.25 ± 542.63	2280.36 ± 781.66	
			NAT 4308.79 ± 510.33		
		Striding	INT 1505.17 ± 497.41	542.64 ± 180.87	
			NAT 1124.03 ± 297.16		
		Sprinting	INT 968.99 ± 310.08	381.14 ± 135.66	
			NAT NS		
		Walking	INT 32.18 ± 3.96	29.15 ± 5.98	

Distance covered in velocity zones (%) ** §		NAT	35.05 ± 4.04	
	Jogging	INT	43.06 ± 4.12	51.22 ± 6.91
		NAT	44.15 ± 3. 96	
	Striding	INT	15.08 ± 3.96	12.12 ± 3.04
		NAT	11.11 ± 3.04	
	Sprinting	INT	10.03 ± 3.10	9.17 ± 3.89
		NAT	9.02 ± 3.03	
Time spent in velocity zones (s)** §	Standing	INT	881.82 ± 168.18	259.09 ± 136.36
		NAT	727.27 ± 200.00	
	Walking	INT	2809.09 ± 281.82	1118.18 ± 359.09
		NAT	3054.55 ± 204.54	
	Jogging	INT	1509.09 ± 190.91	804.55 ± 245.45
		NAT	1536.36 ± 263.64	
	Striding	INT	272.73 ± 86.36	100.00 ± 31.82
		NAT	213.64 ± 54.54	
	Sprinting	INT	154.55 ± 59.09	68.18 ± 13.64
		NAT	140.91 ± 45.45	
Time spent in velocity zones (%)** §	Standing	INT	15.90 ± 3.42	12.31 ± 7.48
		NAT	13.09 ± 3.43	
	Walking	INT	50.18 ± 3.59	47.53 ± 8.26
		NAT	54.39 ± 2.96	
	Jogging	INT	26.81 ± 3.74	34.13 ± 6.23
		NAT	26.96 ± 4.83	
	Striding	INT	4.83 ± 1.40	4.21 ± 1.24

			NAT	3.90 ± 0.93			
		Sprinting	INT	2.96 ± 0.62	2.81 ± 0.62		
			NAT	2.65 ± 0.62			
	Repeated sprints (n) §	INT	4.8 ± 2.8		1.0 ± 1.4		
		NAT	1.0 ± 1.0				
	Efforts per repeated sprint (n) §	INT	3.4 ± 0.8		3.3 ± 0.5		
		NAT	3.2 ± 0.4				
	Duration of efforts (s) §	INT	2.1 ± 0.7		1.9 ± 0.7		
		NAT	2.9 ± 1.1				
	Recovery between repeated sprints (s) §	INT	5.8 ± 4.0		8.3 ± 4.4		
		NAT	7.8 ± 5.4				
	Recovery between efforts (min) §	INT	19.4 ± 22.4		38.2 ± 16.6		
		NAT	94.4 ± 44.1				
Olthof et al. (2019b)[138]			*Competition*		Match simulation		
	Distance covered (m·min^{-1}) **		184.24 ± 19.02		**158.70 ± 17.39**		
	HI Distance covered (%) **		6.25 ± 2.22		6.36 ± 3.15		
	Sprints (n·min of ball-in-play^{-1}) **		0.17 ± 0.13		**0.14 ± 0.15**		
Basketball (n=2)							
Montgomery et al. (2010)[82]			*Competition*		*SSG*	*Offensive Drills*	*Defensive Drills*
	Mean HR (beats·min^{-1}) §		162 ± 7		147 ± 10	147 ± 5	152 ± 7
	Peak HR (beats·min^{-1}) §		173 ± 6		171 ± 12	165 ± 6	170 ± 7
	Predicted VO_2 max (ml·kg·min^{-1}) §		51.2 ± 3.4		40.2 ± 7.1	42.3 ± 3.0	45.1 ± 3.6
	Predicted VO_2 max (%)§		70 ± 16		59 ± 10	63 ± 6	66 ± 5
	Accumulated load (A.U.·min^{-1})		279 ± 58		**171 ± 84**	**55 ± 15**	**58 ± 26**
	RPE (A.U.) §		7		9	7	7
	****		*Competition*		*Match Simulation*	*SSG*	

Svilar et al. (2019)[135]	PlayerLoad (A.U.·min^{-1}) §		11.13 ± 2.00	11.27 ± 3.61	13.15 ± 1.65
	Accelerations (n·min^{-1}) §		2.19 ± 0.84	1.92 ± 0.97	2.20 ± 0.76
	High-band accelerations (>3.5 m·s^{-2}; n·min^{-1}) §		0.38 ± 0.25	0.33 ± 0.26	0.25 ± 0.20
	Decelerations (n·min^{-1}) §		2.38 ± 0.63	2.40 ± 1.08	2.95 ± 0.88
	High-band decelerations (<-3.5 m·s^{-2}; n·min^{-1}) §		0.25 ± 0.19	0.24 ± 0.22	0.36 ± 0.27
	Jumps (n·min^{-1}) §		1.11 ± 0.53	1.13 ± 0.64	1.76 ± 0.76
	High-band jumps (n·min^{-1}) §		0.25 ± 0.21	0.23 ± 0.25	0.38 ± 0.21
	Changes of direction (n·min^{-1}) §		10.62 ± 3.26	10.61 ± 4.40	13.25 ± 3.69
	High-band changes of direction (<-3.5 m·s^{-2}; n·min^{-1}) §		0.79 ± 0.45	0.73 ± 0.46	0.95 ± 0.58
Tennis (n=1)					
Fernández-Fernández et al. (2015)[133]			*Competition*	*Match Simulation*	
	HR (beats·min^{-1})	Winners	158.9 ± 8.3	160.3 ± 3.0	
		Losers	168.0 ± 6.7	161.7 ± 6.3	
	Maximum HR (%)	Winners	79.7 ± 4.3	80.6 ± 3.1	
		Losers	84.8 ± 3.2	**81.5 ± 3.3**	
	RPE (A.U)	Winners	12.9 ± 1.2	11.9 ± 2.0	
		Losers	15.0 ± 0.8	12.0 ± 1.8	

Bold** = training activity is significantly different from competition (p<0.05). § = statistical significance was not reported between training activities and competition. Physical variable: HI = high-intensity. RHIE = repeated high-intensity exercise. A.U = arbitrary unit. HR = heart rate. RPE = rate of perceived exertion. Competition: CD = central defender. WD = wide defender. CM = central midfielder. WM = wide midfielder. FW = forward. NAT = national. INT = international. Training: SSG = small-sided game. *Activity clusters were defined through means of hierarchal clustering measures and defined groups of training activities with similar physical and technical skill profiles, when related to match-play **Values displayed as mean ± SE ***Displayed as a combined mean of all 14 SSG activities. * Data displayed as relative to match/activity duration.*

Studies investigating team sports (n=9; 90%; Australian rules football,[96, 131, 136] basketball,[82, 135] football[49, 132, 134, 138]) quantified physical variables for individual players, with three studies (33%)[49, 134, 136] quantifying position-specific data. Physical variables were quantified for the whole-match (n=5; 56%)[82, 96, 132, 134, 136], quarter-match (n=2; 22%)[131, 135], segmental (n=1; 11%; 15-minutes)[49], or possession (n=1; 11%)[138]. Physical variables were predominantly quantified relative to match duration (n=5; 78%)[131, 132, 134-136] or ball-in-play time (n=1; 11%)[138], with only three studies (33%)[49, 82, 96] reporting absolute data. Only one study (11%)[82] quantified internal load (i.e., the psychophysiological response to work performed) variables (e.g., mean heart rate, RPE), whilst all remaining studies quantified external load variables (i.e. the work performed), including distance (n=5; 56%;[49, 96, 131, 132, 138] e.g., total distance covered, high-speed running or sprinting distance), arbitrary units (n=4; 44%;[82, 132, 135, 136] e.g., PlayerLoad), velocity (n=3; 33%;[49, 132, 138] e.g., maximum velocity), frequency (n=3; 33%;[49, 132, 135] e.g., number of sprints) and time (n=2; 22%;[49, 132] e.g., time spent in velocity zones, mean sprint duration) variables. In contrast, only one study (10%)[133] investigated an individual sport (tennis), with only internal load variables quantified (mean heart rate; maximum heart rate; RPE), and analysed segmentally (per game). Two studies (18%) explored the influence of contextual factors on physical variables; match outcome,[133] and playing standard (international, national league)[49, 136].

Physical variables were quantified for five different categories of training activities; SSGs (n=7; 70%)[49, 82, 96, 132, 134-136], match simulations (n=5; 50%)[133-136, 138], tactical (n=1; 10%)[136], offensive/defensive drills (n=1; 10%)[82], and open/closed skills (n=1; 10%)[136], in addition, Corbett et al.[131] quantified physical variables according to activity clusters (or groups). Of the eight studies investigating representativeness of SSGs, only one study[134] compared physical variables between differing task constraints, manipulating the number of players, rules pitch size and area per player. Task constraints were reported albeit not compared in other studies; playing area (n=5; 63%)[49, 82, 96, 132, 134], number of players (n=5; 63%)[49, 96, 131, 132, 134], rule constraints (n=3; 38%; possession-based,[134] minimum number of kicks before a goal attempt,[96] use of multiple balls[49]), time constraints (n=3; 38%)[131, 132, 135], equipment (n=1; 13%) (i.e., inclusion of smaller goals)[134], removal of stoppages (n=1; 13%)[135]. Isolated SSGs[82, 96, 135] or grouped SSGs (i.e., various task constraints analysed as SSG)[134] were analysed.

Significant differences in physical variables between training activities and competition were reported in half of the studies (n=5; 50%)[42, 82, 96, 132, 133, 138]. The proportion of variables which were significantly different during training activities compared to competition ranged between 17 and 100% (mean = 57.0 ± 25.2%). Significant differences were reported for physical variables during SSGs (n=3; 33%)[82, 96, 132], match simulations (n=2; 50%)[133, 138], and offensive/defensive drills (n=1; 100%)[82].

2.3.5.3 Tactical Variables

The representativeness of training activities was quantified using tactical variables in five studies (28%; Table 2.6)[34, 42, 85, 137, 138]. To collect tactical data, studies used commercial data providers (n=2; 40% Champion Data,[85] Hawkeye[130]), LPS (n=2; 40%)[137, 138], computerised notational analysis (n=2; 40%)[137, 138], and GPS (n=1; 20%)[34]. For one study (20%)[85], the methods of data collection for competition differed to those for training activities (i.e., commercial data provider vs computerised notational analysis).

Table 2.6. Tactical variables quantified to determine representativeness of training activities

Study	**Tactical variable**		**Competition**	**Training**		
				Activity 1	**Activity 2**	**Activity 3**
Australian rules football (n=1)						
Tribolet et al. (2022)[85]			*Competition*	*Match Simulation*		
	Field length (m)		158.64 ± 4.63	**155.57 ± 0.75**		
	Field width (m)		132.38 ± 4.73	132.35 ± 5.90		
	Length per width ratio		1.20 ± 0.09	1.18 ± 0.05		
	Space per player (m^2)		457.39 ± 12.94	453.00 ± 12.21		
	Passing network connectedness		97.12 ± 14.18	95.31 ± 10.77		
	Passing network outdegree variability		104.46 ± 16.55	**114.24 ± 11.45**		
	Passing network indegree variability		98.01 ± 11.08	**111.73 ± 12.01**		
Football (n=3)						
Couto et al. (2024)[34]			*Competition*	*SSG (width; L 40m x W26m)*	*SSG (length; L 26m x W 40m)*	
	Team length (m) §		34.0 ± 4.1	6.8 ± 0.9	9.6 ± 1.3	
	Relative team length (m)		0.32 ± 0.04	**0.26 ± 0.03**	**0.24 ± 0.03**	
	Team width (m) §		40.7 ± 4.1	14.8 ± 3.0	13.7 ± 1.7	
	Relative team width (m)		0.60 ± 0.06	**0.37 ± 0.07**	**0.53 ± 0.07**	
	Length per width ratio (A.U.)		0.84 ± 0.08	**0.48 ± 0.13**	**0.71 ± 0.13**	
	Space exploration index (A.U.)		20.5 ± 2.1	**5.7 ± 0.5**	**7.1 ± 0.9**	
	Stretch index (A.U.)		24.5 ± 1.3	**16.8 ± 7.0**	**14.4 ± 5.4**	
Olthof et al. (2019a)[137]			*Competition*	*SSG (4 vs 4 + GK)*	*SSG (6 vs 6 + GK)*	*SSG (8 vs 8 + GK)*
	Team length (m) *	U13	34.17 ± 1.87	**16.56 ± 1.57**	**19.90 ± 1.56**	**26.56 ± 2.19**
		U15	35.83 ± 1.46	**16.88 ± 2.08**	**23.02 ± 2.61**	**29.17 ± 2.08**
		U17	35.10 ± 1.15	**15.83 ± 1.46**	**24.48 ± 1.77**	30.94 ± 1.56
		U19	34.17 ± 1.46	**15.94 ± 1.77**	**22.50 ± 1.25**	27.19 ± 1.35
	Team width (m) *	U13	40.25 ± 2.20	**17.67 ± 2.45**	28.22 ± 1.72	34.36 ± 1.71
		U15	39.02 ± 1.47	**18.53 ± 2.33**	**25.52 ± 3.44**	34.11 ± 2.21
		U17	41.23 ± 2.70	**18.16 ± 1.47**	**25.15 ± 2.33**	**30.31 ± 2.57**
		U19	41.35 ± 2.33	**18.04 ± 1.84**	**26.01 ± 3.44**	34.36 ± 1.96
	Team surface area (m^2) *	U13	957.04 ± 62.54	**145.77 ± 17.87**	**367.61 ± 41.48**	621.13 ± 46.00
		U15	969.72 ± 81.33	**152.11 ± 36.70**	**348.59 ± 66.79**	659.15 ± 52.04
		U17	1014.08 ± 81.02	**145.77 ± 24.16**	**373.94 ± 54.03**	583.10 ± 58.86
		U19	1033.10 ± 99.77	**139.44 ± 24.20**	342.25 ± 54.25	595.77 ± 77.66

	Interpersonal distance (m) ** *§*	U13	23.38 ± 0.84	15.04 ± 1.63	18.08 ± 0.85	20.55 ± 1.13
		U15	23.45 ± 0.99	15.61 ± 1.62	17.66 ± 1.83	21.05 ± 1.05
		U17	24.01 ± 0.92	15.04 ± 0.85	18.08 ± 1.27	20.06 ± 1.06
		U19	24.15 ± 1.13	14.90 ± 1.20	17.58 ± 1.49	20.27 ± 1.13
Olthof et al. (2019b)[138]			*Competition*	Match simulation		
	Team length (m)		34.8 ± 1.6	33.6 ± 1.9		
	Team width (m)		41.6 ± 2.7	43.0 ± 1.9		
	Length per width ratio (A.U.)		0.9 ± 0.1	**0.8 ± 0.1**		
	Team surface area (m^2)		1035.0 ± 104.4	1011.9 ± 84.2		
	Inter-team distance (m)		5.4 ± 0.4	5.4 ± 0.8		
	Stretch index (m)	x	10.1 ± 0.4	9.7 ± 0.6		
		y	11.1 ± 0.8	11.3 ± 0.5		
Taekwondo (n=1)						
Maloney et al. (2018)[42]			*Competition*	*Match simulation*		
	Peak interpersonal distance (m)**		1.77 ± 0.08	**1.87 ± 0.12**		
	Peak attack initiation interpersonal distance (m)**		1.88 ± 0.14	**2.06 ± 0.19**		

***Bold** = training activity is significantly different from competition (p<0.05). § = statistical significance was not reported between training activities and competition. A.U. = arbitrary unit. U = under. Training: SSG = small-sided game. GK = goalkeeper. * Displayed as mean ± SE. ** Converted to SI unit*

Studies investigating team sports (n=4; 80%; Australian rules football,[85] football[34, 137, 138]) quantified tactical variables which provide insight into collective behaviour of the team (e.g., team length/width, team surface area, space per player, interpersonal distance). Two studies explored the influence of contextual factors on tactical variables (match-outcome,[85] age-group; U13 – U19[137]). The only study[42] investigating tactical variables of individual sports (taekwondo), examined tactical behaviour in relation to the opponent (i.e., peak interpersonal distance, peak attack initiation interpersonal distance). Tactical variables were quantified for the whole-match (n=2; 40%)[42, 85], half-match (n=1; 20%)[34], or possession (n=2; 40%)[137, 138].

Tactical variables were quantified for only two training activities; match simulations (n=3; 60%)[42, 85, 138] and SSGs (n=2; 40%)[34, 137]. Both studies analysing SSGs[34, 137] quantified and compared representativeness of multiple SSGs, manipulating individual task constraints (playing area,[34] number of players[137]). All studies reported significant differences in tactical variables between training activities and competition. The proportion of variables which were significantly different to competition ranged between 14 and 100% (mean = 70.6 ± 37.1%).

2.4 Discussion

This study aimed to 1) systematically review the scientific literature evaluating the representativeness of training activities in sports, 2) identify the methods used to assess representativeness and, 3) summarise how training activities can be designed to more (or less) closely mirror the demands of competition. The review included 18 studies, predominantly investigating the representativeness of training activities within team sports (n=15; 83%), with Australian rules football the most researched sport (n=7; 39%). Studies quantified technical (n=11; 61%), physical (n=10; 56%), and tactical (n=5; 28%) variables. SSGs (n=12; 67%) and match simulations (n=11; 61%) were the most investigated training activities. Of the studies which evaluated differences between training activities and competition (n=16; 89%), 13 studies (81%) reported a statistically significant difference in at least one variable. Further, of the 109 variables (technical n=47; physical n=45; and tactical n=17) quantified across studies, 61% were significantly different between training and competition environments. This systematic review provides insight into the evidence-base investigating the representativeness of training activities, offering coaches a foundation for more rigorous planning and reflection. By highlighting these discrepancies, coaches are better positioned to design training environments that more closely replicate competitive demands, thereby improving the precision and effectiveness of prescribed sessions.

2.4.1 Methodological Considerations for Evaluating Representativeness of Training

There are several key methodological limitations within the included studies to be aware of when interpreting the results, comparing data between studies, and informing practical applications.

Firstly, studies predominantly investigated the representativeness of training activities for team sports, and specifically invasion sports (Australian rules football, football, basketball), with the only individual sport studies investigating net-wall (tennis) and combat (taekwondo) sports. Due to the differing internal logic between sport types,[139] the resulting physical, technical, tactical and psychological characteristics of performance may differ due to the differing phases or moments of the game (e.g., invasion games; in possession, out of possession, transition, set pieces) and the subsequent interactions which may occur (e.g., between teammates, between the opposition), there may be limited value in comparing the representativeness of training activities between sports (or sport types). Therefore, there is a need for future research to develop a sport-specific evidence-base investigating the representativeness of training activities.

Secondly, there was homogeneity observed in the participants across studies, for example, predominantly male (67%), senior (61%), and competing at national playing standards (56%). Due to the population-specific (e.g., physiological, biomechanical) and contextual differences (e.g., training provision, competition structures) which exist between sporting populations (i.e., male and female, senior and youth), it may be inappropriate to inform applied practices from research derived from other populations.[140, 141] Therefore, future research should aim to develop a population-specific evidence-base relating to the representativeness of training activities, to inform the design, delivery and review of coaching practices which are appropriate for the respective population.

Thirdly, the sample size of studies was either limited (i.e., single team samples (61%), low number of observations), and/or poorly reported (e.g., number of competitions/training sessions observed, number of individual training competition/training activity observations). Consequently, single team samples may reflect team-specific strategies or philosophies which may influence performance during competition or training, contributing to highly contextual findings rather than outcomes intended to be generalisable to wider populations. Further, the low (or unclear) number of observations contributing to analyses and subsequent results may not sufficiently account for such between-competition[142-144]/session[90, 145, 146] variation in observations. Therefore, future research should aim to adopt a multi-team data collection approach and conduct data collection over a greater longitudinal period (e.g., competitive season) to increase the number of competition/training observations and account for such variation, whilst also ensuring a sufficient level of and clarity in description of the methods adopted (i.e., number of observations, inclusion criteria) to aid interpretation of results and comparisons between studies.

Lastly, there are specific considerations and necessary cautions for comparing the physical, technical or tactical characteristics quantified across studies. Considering physical variables, due to between-system differences (e.g., video-based time-motion analyses, GPS units, optical tracking), sampling frequencies (e.g., GPS; 10Hz,[34, 131, 132] 15Hz[134]),[147] manufacturer-specific data processing methods (e.g., GPS; Catapult [131, 132, 135] vs SPI Elite GPSports[134])[148] and variable definitions (e.g., high-speed running threshold: $14.4 km \cdot h^{-1}$;[131] $19.8 km \cdot h^{-1}$[138]) direct comparison between studies may not be appropriate. Likewise, readers should be cautious of absent/inconsistent operational definitions for variables[149] and absence of reliability assessments when comparing technical variables. Further, particular caution is required when evaluating the representativeness of training activities where studies have implemented differing methods of data collection to quantifying characteristics during training and during competition.[33, 81, 85, 92, 130, 131] Future research should ensure consistency in data collection between training and competition environments, and where this is not possible, assess the interchangeability of data obtained via differing data collection methods.[150, 151] Accordingly, coaches should interpret training and competition data with caution, recognising that methodological inconsistencies may lead to misleading conclusions about performance demands.

2.4.2 Representativeness of Training Activities

Match simulations (or full-sided games)[152] are training activities played to regulation rules, and thus should be the training activity expected to most closely replicate the demands of competition activity.[138] However, results from this review showed match simulations often failed to replicate competition demands. Across all studies analysing match simulations, 72% (± 22%) of variables quantified were significantly different to competition. This finding challenges the assumption that match simulations replicate the demands of competition.[26] Recognising this discrepancy is a key component of a coach's reflective process.[109] Effective reflection requires challenging the 'why' training environments designed to mirror competition often fail to do so. Several methodological and contextual factors may contribute to the variation between environments. One of which is the lack of pressure or challenge in replicating the competitive environment (e.g., lack of crowd noise, unpredictability of officiants etc.)[153]. Research reports that coaches combat this factor by introducing sanctions to players not performing to a high enough level[154] and add performance scores[155] or using audio cues to mimic the stadium environment/pressure within training.[156] All actions appeared to increase playing effort and demands within these studies. However, within this review, no study reported implementing any of these methods to increase performance demands, if done, this may have elicited demands closer to competition performance. Further investigating environment manipulation may offer insights into how performance demands can be more effectively elicited in match simulation training. The representativeness of match simulations may be compromised by coach-prescribed load management strategies[74, 75, 157] which can reduce training intensity to competition. This is especially relevant in collision sports[158, 159] (such as Australian rules football)[160, 161] where coaches often adjust training loads to mitigate injury risk. Whilst these precautions aim to maximise performance, they may limit the fidelity of match-based training activities. Coaches should critically evaluate the intended aim of each session/drill to determine whether a match simulation is the most appropriate format.[104] Where replicating competition demands is not the primary objective, coaches should consider alternative training modalities (e.g., SSGs).

The most frequently analysed training activity within the review was SSGs. These training activities also lacked representativeness, with 76% (±29.2%) of variables significantly different to competition. This demonstrates that, despite their popular use within traditional coaching[80] and literature,[83, 162, 163] SSGs may not adequately represent the physical and tactical demands of competition. The lack of resemblance to competition may reflect intentional design as opposed to a misinterpretation of representativeness. SSGs have frequently been reported to have an objective of skill acquisition,[162] decision-making,[162, 164], developing/replicating physiological demands,[84, 162] and tactical awareness.[83, 165] Furthermore, this review revealed 25 different SSG formats, highlighting flexibility of this training activity. This difference also reflects the nuanced planning processes regarding a coach's session design, where task constraints and intended outcomes shape the structure and objective of each SSG format.[164] In total, two studies[34, 137] specifically analysed variations in playing numbers and field dimensions, respectively. Both studies demonstrated that manipulation of task constraints can affect performance outcomes, reinforcing the importance of understanding how the planning process can directly influence the outcomes of a training activity. Aside from this, Djaoui et al.[134] examined compounded task constraints (e.g., combinations of playing numbers, pitch dimensions and rule variations) and reported significant differences from various training activities. This would indicate that task constraints can interact between each other to achieve specific performance outcomes as opposed to operating in isolation. Therefore, judging the effectiveness of SSGs solely by how closely they replicate full-match conditions may not be an appropriate protocol. Future research examining SSGs and representativeness should report session aims and coach intentionality to clarify whether observed mismatches reflect a deliberate technical focus or a failure to represent match demands. From a coaching perspective, this highlights the need for critical reflection on the purpose and design of SSGs, ensuring that task constraints are intentionally aligned with specific learning outcomes rather than implicitly assumed to mirror match-play. Coaches should therefore interrogate the extent to which SSG-derived data informs decision-making, recognising that misalignment between training design and competitive demands may reflect intentional pedagogy or, conversely, limitations in reflective practice.

After considering two game-based formats, it is important to acknowledge drill-based training activities. Whilst they were less commonly reviewed (n=4)[82, 130, 131, 136], 57.1% (±53.5%) of variables within these studies deviated significantly from the values observed within competition. These activity types tend to focus on skill development (i.e., reinforcement or refinement of an already acquired skill) and do not encompass a full competition environment,[166] potentially explaining the high differences between training and competition. Drill-based activity can be designed to target isolated components of competition, rather than the full match environment. This is reflected in the results of this review with both match simulations and SSGs showing higher percentage of variables deviating significantly between training activities and competition, than in drill-based training. Acknowledging this can reveal that representativeness should be interpreted relative to the intended focus of the activity. A drill may be representative of a specific set play or tactical moment in isolation, even if it does not reflect the broader demands of a full match environment. Krause's research[130] demonstrates how drill-based activities can replicate phases of match-play. For example, the serving drills produced fault percentages similar to match conditions, despite focusing exclusively on the serve, an isolated but essential component of a tennis match.[167] This highlights how drill-based activities, whilst seeming to lack the contextual demands of a game-based activities, offer action fidelity. To reinforce this, Pinder[26] emphasised that training environments do not need to mirror competition directly. These environments should instead present comparable situations and challenges which align with those that typically align with competition contexts.

2.4.3 Task Constraints and the Representativeness of Training Activities

Whilst only a minority of studies (n=3)[34, 134, 137] within this review directly compared task constraints (e.g., playing numbers and field dimensions), many other studies reported the structure of their training activities and how these structures could influence representativeness. Although studies applying only one task constraint[33, 49, 92, 96, 130, 135, 136] do not establish direct causality to representativeness, variations in how these constraints are implemented (e.g., removal[96] versus inclusion of stoppages[33]) can lead to different performance outcomes. This implies deliberate manipulation of task constraints can alter the functionality and fidelity of training activities.

Player numbers were a commonly analysed task constraint manipulated within the studies of this review (n=8; 66%)[33, 34, 49, 81, 96, 132, 134, 137] and are also frequently utilised within literature.[83, 165, 168] Training formats with playing numbers closer to match conditions (e.g., 8vs8, 9vs9 in football) are more likely to elicit demands comparable to competition,[137] likely due to preservation of functionality and perception-action coupling. In contrast, training formats with much smaller playing numbers (e.g., 2vs2) exhibit higher technical demands (e.g., passing frequency)[168], and a reduction in task representativeness observed. These findings were replicated within the present review.[134, 137] Utilisation of small playing numbers are useful when aiming to overload specific skill within training formats,[169] whereas larger playing numbers to preserve aspects of match conditions.[137] It should be acknowledged that many of the results presented from the reviewed studies were descriptive rather than comparative. These insights offer practical recommendations for coaches to adopt for their particular context rather than definitive laws governing practice.[99] The application of deliberate task constraint manipulation enables coaches to refine prescriptions of training, achieving precise session outcomes.

Area-based task constraints (e.g. field size, space per player) appeared as frequently analysed within this review (n=9; 75%)[33, 34, 49, 81, 82, 96, 132, 134, 137]. The results presented amongst the reviewed studies indicate that altering field width can alter tactical variables (e.g. length per width ratio, stretch index)[34]. Djaoui et al.[134] described that field area does not consistently change the rate of maximal sprinting speeds, larger playing areas did tend to produce higher sprinting velocities. In wider research, larger playing areas are associated with increased between-session variability regarding technical outputs,[168] In contrast, analysis of smaller playing areas result in an increased display of technical action density (shots, tackles, passes), but a reduction of representativeness.[168] Recognising these patterns highlight the need for coaches to holistically review their administered task constraints to minimise unwanted fluctuations amongst comparable training activities. Increased space per player has shown to provide more time for prompt decision-making and technical skills execution.[168] Reduced functionality and action fidelity within segments of a session can impede skill transfer into a competition environment, as performers have been less exposed to realistic opposition tactics (e.g., high/low defensive pressure)[89]. As a practical example for coaches, reducing pitch size to increase passes and tackles may support technical repetition but is unlikely to expose players to realistic defensive spacing. Conversely, increasing space per player may better replicate opposition structure and decision-making demands, even if technical actions occur less frequently.

Despite numerous studies manipulating task constraints to create a representative training environment, there remains a limited understanding of how specific task constraints can be utilised to achieve representativeness. Among the reviewed studies, prescribed task constraints varied considerably, with only 5vs5,[34, 134] 6vs6[134, 137] and 8vs8[134, 137] formats appearing across multiple studies within the same sport. However, differences in pitch dimensions and time durations make comparisons difficult. Even where formats overlapped, studies focused on different performance variables. Couto et al.[34] examined tactical variables, Djaoui et al.[134] analysed sprinting speed and Olthof et al.[137] analysed a wider range of variables across multiple domains (technical and tactical), none of which aligned across studies. To advance both research and practice, future studies should build on existing analyses, across a wider population rather than examining formats in isolation. Greater consistency across studies would allow coaches to interpret findings more precisely and apply task constraints with greater accuracy and confidence. As clearer empirical guidance emerges, coaching expertise in constraint manipulation will continue to develop.

2.4.4 Representative Variables During Training Activities

Technical variables were the most frequently analysed variable across the reviewed studies, with team possession-based variables receiving significant attention. However, when compared to match data, 73% of possession-based variables differed significantly, suggesting possession during training activities are not reflective of competition. Although possession-based metrics are commonly used to assess technical performance, they require further refinement to accurately reflect game conditions. Research surrounding possession length in elite male European league football has indicated team success within match-play.[170-172] Furthermore, Bradley and colleagues[173] discovered that football teams operating with increased ball possession percentages perform more high intensity running and execute greater technical events (e.g. passes). In contrast, research within youth female match-play revealed that a team with a higher individual number of possessions had low ball retention characteristics,[174] which can offer insights towards further prescription of training activities. Team-based findings should be approached with caution, as inter-team variation, driven by factors such as location,[175] individual player skill,[176] and previous match outcome,[175] could make results context-dependent.[177] Coaches who plan and deliver sessions with match representative constraints (e.g., spatial limitations, defensive pressure) would be able recreate the prolonged possessions observed in competition within their training that can drive performance.

The present review revealed that 57.0% (±25.2%) of all physical variables differed significantly between competition and training. The large standard deviation observed was likely due to the diverse range of activity aims and methodologies used amongst studies. This disparity is also reported in wider research, specifically in Petway et al. systematic review examining physical demands in basketball.[36] Their research found that competition elicited higher internal and external loads than training, despite its shorter duration. Due to methodological diversity across studies, comparisons remained descriptive, reiterating the need for alignment within representative training design in coaching practice. Of the three variable types examined (physical, technical, tactical) physical variables across all training activities proved the most representative of competition demands. Within specific training activities, match simulations yielded the highest average representativeness of competition demands (33.3 ± 16.7), however still remaining highly variable across studies (ranging from 50%[82] to 16.6%[42] of physical variables differing significantly from competition environments).

Despite this, their overall similarity to competition remained limited, with a mean representativeness of just above 50%. Variation in physical training is often due to a coach's targeted stimuli, such as high-intensity training, aerobic condition or recovery-based work. The variability typically reflects the dynamic needs of the team, influenced by factors like such as seasonal periodisation[178] and proximity to matchday.[179] This highlights the need for coaches to standardise or contextualise training activities to replicate competition load for physical variables.

Tactical variables were the least analysed across the reviewed literature, with only 17 unique variables (26 in total) examined across five studies. Of these, 14 variables were statistically compared, with 70.6 ± 37.1% of variables showing significant differences. Notably, four training activities (of 8 activities quantifying tactical variables; 50%) reported no representative tactical outputs when related to competition, suggesting that the small sample size and high proportion of unrepresentative training variables may reflect the complexity and context-dependence of tactical behaviour. This has been explored in both rugby union and football, whereby differing tactics emerged amongst successful and unsuccessful teams,[180] and within intra-team analysis.[41, 83, 181] Both studies, and the present review, reveal how tactical representativeness is difficult to assess without accounting for variation amongst contexts, populations and training environments. For coaches that are planning training activities and designing sessions, the first aim should be to establish their team's tactical identity. After doing this training should then be tailored to cater to the context-specific environment which has been established. Further, the prescribed training, should be consistently reviewed and altered to account for the dynamic nature of a team's tactics and structure.[56]

Lastly, no study evaluated the representativeness of psychological characteristics (i.e., in-situ psychological responses) during training activities. The limited research investigating psychological characteristics is reflective of wider literature within sport, where physical,[182] technical,[183] and tactical[184] performance has predominantly been investigated to understand training and competition demands. This may be consequential of the methodological challenges in quantifying psychological characteristics of performance. Typically sport psychology research has quantified non-behavioural variables (e.g., collected via questionnaire or interview-based methods pre- or post-performance),[185] or has utilised performance outcomes (e.g., physical, technical or tactical actions, win/loss) as outcome variables for assessing the efficacy of psychological interventions on sporting performance.[186] However, such approaches would be inappropriate for evaluating the representativeness of training activities for psychological characteristics. Therefore, future research is warranted which provides insight into the functionality of a training activity (i.e., the degree to which an athlete is able to use the same information sources during competition to help contextualise decisions and movements)[26], for example quantifying *visual exploratory activity* (e.g., scanning),[43, 187] to inform the design, delivery and review of representative training environments.

This systematic review has implemented a methodologically rigorous approach to reviewing the scientific literature evaluating the representativeness of training activities. For example, the review adhered to the PRISMA guidelines,[125] searching relevant electronic databases, with no date nor language restrictions, whilst using search terms relating to representative learning design, training activities and sport coaching. Further, two researchers independently completed the two-stage screening process (CF, AHA), whilst the lead researcher completed data extraction for all studies, and subsequently, all data was checked independently by another researcher (AHA). However, as in all research, there are limitations which should be acknowledged.

Firstly, to be eligible for inclusion, studies were required to quantify performance in both training and competition environments to evaluate representativeness, therefore, excluding studies which only quantified performance during training or competition. Given the body of evidence which exists investigating training or competition demands in isolation within different sports[188] (e.g., football,[163] rugby league,[189, 190] Australian rules football,[191] volleyball,[192] tennis[193]) and populations (e.g., youth[194] and senior,[195] female[10] and male,[188] competitive standard[36, 196]), a critical understanding of the findings within this evidence-base may be useful in lieu of the limited research studies explicitly comparing training and competition demands. Secondly, whilst no explicit language restrictions were applied to eligibility criteria, only English search terms were included in the search strategy. Therefore, this may have limited the identification of studies written in other languages, and consequentially there may be a language bias within the study,[197] particularly given all included studies were written in English. Lastly, this review has discussed the heterogeneity of included studies (i.e., participants, data collection methods) and the potential implications. Researchers and practitioners should be cautious in their interpretation of data and findings presented, whilst future research requires clearer reporting of methods adopted (e.g., number of training observations, inclusion criteria for observations, description of training activities) and greater consistency in the methods adopted (e.g., operational definitions, inclusion criteria for observations) to facilitate comparisons between studies.

2.5 Conclusion

This review provides an evidence-base to support the systematic planning, delivery and evaluation of representative coaching practice. Across the research, three key findings emerged. Firstly, when evaluating the representativeness of training activities (Aim 1), methodological inconsistencies were prevalent across all studies. Operational definitions, sampling frequencies, and reliability assessments were frequently omitted, and activities labelled similarly (e.g., SSGs or match simulations) varied in format, duration and the measured outcomes. Both of which limited cross-study comparisons. Comprehensive reporting of data collection procedures and reliability checking is essential to improve methodological clarity and interpretability. Ensuring methodological homogeneity would directly benefit coaches and strengthen the knowledge base from which they draw upon. This would enable coaches to make more informed, evidence-based decisions when designing and reflecting on training sessions.

Secondly, the methods within the identified studies (Aim 2) highlighted a concentrated evidence base, with most studies analysing male participants competing at national level or higher and focusing on team sports. Whilst this makes up a large demographic, the outcomes may not be representative of other populations such as youth or female athletes. Furthermore, there was a focus towards technical and physical variables with training activities restricted mostly to SSGs and match simulation (most of which failed to reflect competition). Expanding the evidence-base to include more diverse groups and training modalities can improve specificity to practical environments. This would further allow coaches to integrate context-relevant training activities into their practice, leading to elevated action fidelity and effectiveness of prescribed coaching interventions.

Third, when summarising how training activities can be designed to more closely mirror competition (Aim 3), many training activities (particularly match simulations) failed to replicate the physical, technical and tactical demands of competition. This pronounced mismatch demands coaches to design each session plan with representativeness at the forefront of session design and to reflect critically on whether real-game benchmarks are being met. To better support coaching practice, future research must improve reporting standards, expand athlete sampling and clarify how specific constraints shape representativeness. Closing this gap will enhance skill transfer, promote effective decision-making and, ultimately, prepare athletes and teams to perform at the highest of standards within competition.

Finally, from a coach education perspective, these findings underscore the importance of developing coaches' capacity to critically engage with research and training design principles. Rather than simply teaching activity structures such as small-sided games or match simulations, coach education programmes should prepare coaches to evaluate the rigour of existing research that they may read to inform their practice. Equally, there should be a focus on the representativeness of training activities in relation to competitive demands. Integrating representative learning design principles within formal coach education and continuing professional development may promote more intentional planning, delivery, and reflection of practice. Put simply; by including research literacy and critical decision-making skills, coach education can better support the translation of evidence into effective, context-specific coaching practice.

2.6 Implications for Future Chapters

The present study highlights several gaps in the current understanding of training representativeness in sport. Despite growing interest in representative design,[98, 99, 103] existing research remains heavily concentrated in Australian contexts, and predominantly elite level samples. Notably, no studies investigated ice hockey, and amateur level research remained sparse among the evidence base. This limits the availability of context-specific insights for coaches operating within these populations. Further, the present review highlighted a mismatch between intended outcomes of training activities and the performance characteristics they elicited. This was most evident in match simulations, where numerous variables differed significantly from match outcomes, similar inconsistencies were also present in SSGs and other training activities. These findings emphasise the importance of understanding the structure and content of training environments before progressing to direct comparisons between training and match performance. The review also revealed methodological inconsistencies across studies (e.g., inconsistent operational definitions, lack of reliability testing). These limitations highlight the need for more rigorous research to ensure that the evidence available to practitioners is both robust and relevant to the context they operate in. Addressing these issues will also enhance the quality of insights that future research will produce to contribute to the evidence base. Therefore, Chapter 3 will research the structure of training activities within a domestic senior ice hockey team. Chapter 4 will build on these findings by comparing the training activities identified in Chapter 3 with match environments, determining their representativeness within the same domestic, senior ice hockey team.

CHAPTER 3: AN INVESTIGATION INTO TRAINING STRUCTURES AND ACTIVITIES OF A SENIOR MEN'S DOMESTIC ICE HOCKEY TEAM

The information presented in this chapter has been updated and submitted for publication

Fletcher C, Quick S, Cushion E, Harkness-Armstrong A. An investigation into the training structures and activities of a senior men's domestic ice hockey team. Int J Sports Sci Coach. Under Review.

Abstract

Understanding the context-specific nature of coaching practice is essential for effective planning and delivery. Providing coaches with clear information about practice demands and training structures can support evidence-informed session design. Therefore, this study aimed to describe the distribution of training activities within an amateur, senior men's domestic ice hockey team across a competitive season. Data were collected from 23 training sessions (after two were removed due to technical issues) during the 24/25 competitive season, from one senior amateur men's ice hockey team. The frequency and duration of training activities, and the characteristics of training activities were quantified for the season, between and within training sessions. Among active training states, technical practice was the most frequently observed activity (n=79), and phase of play activities accounted for the greatest proportion of training time (34.4%). Shooting was the most observed primary skill (n=68; 41.5%). State – other (management/transition states) was the most frequently observed activity state (n=315; 63.8%). The proportion of playing state activities were highest as fixture-dense periods (December; 52.4%) or important fixtures (March; 46.4%) approached, and these activities typically occurred during the final half of training sessions (78.2%). This research observed a consistent part-whole-part sequencing pattern across the season, suggesting that coaches may intentionally scaffold learning by moving from isolated technical work, into representative tasks, before returning to technical practice. By demonstrating the value of examining session-level sequencing of training activities, this study provides a foundation for future research to explore these patterns across different sports, competitive levels, and coaching contexts.

Keywords: coaching prescription, practice environments, practice design, activity sequencing, micro-structures

3.1 Introduction

Understanding how training is structured is a vital part of coaching expertise.[110, 198] Consequently, coaches must recognise how environmental constraints can be manipulated[28] and how such adaptations shape the opportunities available to athletes during practice.[199] Additionally, effective coaching is shaped by coaches' prior experiences[111] and the subsequent sense-making (i.e., reflection) of these experiences.[200] However, reflection often relies on intuition or retrospective judgement, facilitated through conversations (e.g., with other coaches or coach developers) or internalised problem-solving.[201, 202] The difficulty of meaningful reflection within coaching practice is heightened by the context dependent nature of representativeness (e.g., differing rules of competition according to player age)[203, 204], the methodological inconsistencies within research (e.g., inconsistent operational definitions) and its narrow focus (e.g., senior men's professional sport) (Chapter 2). Considering the above and the broader findings so far within this thesis, understanding the environment from which training emerges is essential for interpreting practice meaningfully and supporting more accurate planning. Therefore, providing an objective summary of a population's training structure can strengthen coaches' planning and reflection, by offering a more accurate account of how sessions unfold in practice.[115]

Coaching practice is inherently complex, shaped by context-specific demands, environmental affordances,[61, 202] the need to manage multiple tasks simultaneously,[152] and the diverse knowledge sources from which coaches draw.[205] Although training structures can be quantified systematically, their interpretation is complicated due to the multifactorial nature of coaching environments. This complexity has resulted in limited research investigating training structures (Chapter 2). Further research observing coach performance (as opposed to player performance) often examine coach behaviours[111, 202] and their prescribed activities (Chapter 2). Two categories of training activities ('*training form*' and '*playing form'*) are typically quantified[61, 79] through systematic observation tools.[94, 152] These categories provide insight into the structure and design of practice. Playing form activities have shown to support decision-making behaviours more closely aligned with competition,[54, 59] while training form activities typically focus on isolated skill execution and long-term development.[206, 207] Research has investigated *what* the distribution of activities is across training sessions (e.g., the frequency, duration or proportion of training activities across a season)[94], however, no research has yet examined *how* activity types are organised within training sessions (i.e., the order or sequence of individual training activities). Without the consideration of session-level structures, the understanding of practice design remains partial, as important patterns in how training is sequenced over time cannot be fully identified. Addressing this gap requires quantifying training structures with greater alignment to performance environments to deepen understanding of how practice is planned and delivered across different sports and populations.

Research on coaching practice has primarily focused on football, volleyball and basketball,[208] utilising systematic observation tools to analyse coach behaviour and practice structures. Within ice hockey, the *Coaches Observation System for Games* (COSG) represents one of the only existing tools designed for the sport, albeit analysing youth contexts.[205, 209] Beyond this, interest in ice hockey is growing[210] as player- and team-level performance metrics have been increasingly examined,[211] however, systematic analyses of coaching behaviour and training structures remain scarce.[208] Consequently, little is known about how training is structured within ice hockey, how coaches organise practice in these settings, or how these environments may compare to patterns observed in other sports. This lack of population-specific evidence is particularly relevant for amateur men's ice hockey, where no research currently exists (Chapter 2).[36, 134, 196] The present study therefore aimed to describe the distribution of training activities within an amateur, senior men's domestic ice hockey team across a competitive season. The chapter contributes to the understanding of ice hockey and amateur sport; both areas remain underrepresented within the coaching literature.

3.2 Methods

3.2.1 Participants

One amateur club competing in the third tier of senior men's domestic ice hockey in England was recruited for this study. Throughout the 2024/25 season (September to

April) the team received one or two 60-minute rink-based (56m x 26m) training sessions per week, alongside off-rink strength and conditioning provision. The team participated in league and cup competitions. All players representing the club (n=25; age = 25.7 ± 5.5 years) were recruited. Written informed consent (or assent and player/guardian consent) was collected prior to participation. Ethics approval was granted by the University of Essex Research Ethics Committee (ETH2425-2089).

3.2.2 Procedures

An observational study design was conducted, in which data were collected from 23 training sessions during the 2024/25 competitive season (October 2024 to March 2025). Two sessions were excluded due to technical errors (e.g., partial capture of the training session). Thus, the final sample consisted of 21 training sessions (mean = 55.2 ± 4.8 minutes), consisting of 494 player observations (n=23.5 ± 3.6 per session). This sample represents ~72% of the participating club's training sessions across the 2024/25 competitive season.

Training sessions were recorded using a video camera (n=4 sessions: HDR-CX625, Sony, Japan; n=17 sessions: Hero 4, GoPro, USA) from a fixed position. The camera was positioned behind the goal, at an elevated height to achieve a full-rink view, for all but one session, which was recorded from the corner of the rink due to restricted access. Recordings were imported to Metrica PlayBase (v.2.23; Metrica Sports, Spain) and analysed using a customised coding panel. The categorisation of training activities and operational definitions were informed by previous research.[152] The primary observed skill within each activity was identified based on the most prominent technical action displayed during that activity. Training activities and characteristics quantified in this study are presented in Table 3.1.

All notational analyses were completed by the lead researcher (CF). To determine intra-operator reliability, two randomly selected training sessions were reanalysed four weeks after initial analysis.[212, 213] Cohen's kappa was used as it is the appropriate reliability statistic for categorical data and accounts for chance agreement. The frequency of training activities and training characteristics demonstrated perfect intra-operator agreement (κ=1)[212], whilst the mean difference of training activity duration was 18.87 ± 42.46s, demonstrating small levels of intra-operator disagreement (STE = 0.22)[213]. To evaluate inter-operator reliability, one randomly selected training session was analysed independently by another member of the research team with performance analysis expertise (AHA). The frequency of training activities demonstrated very good levels of inter-operator agreement (κ=0.92)[212], and the mean difference of training activitiy duration was 0.33 ± 60.67s, demonstrating small disagreement between the two operators (STE = 0.33)[213]. The outputs from the reliability assessments are presented in Appendix 3.1.

Table 3.1. Definitions of training activities and associated task characteristics

Training Activities[152]	
Practice/Training States	
Preparation	Activities regarding readiness for competition (e.g., warm-up, cool-down).
Physiological	Primary goal of the physiological aspects of the game (e.g., conditioning, stretching).
Technical practice	Individual or group activity covering isolated technical skills under limited or no pressure
Skills practice	Individual or with a group covering technical skills under pressure from opponent(s).
Functional practice	Re-enacting isolated simulated game incidents with or without a focus on a particular skill. These can be unopposed (i.e., under no pressure from opponent(s) such as shadow play/game simulated patterns of play/movement) or opposed.
Playing States	
Phase of play	Attack vs defence play covering team cognitive strategies used to outsmart opponents which involve ONLY one team of players scoring, or the two teams of players scoring in different ways (i.e., attackers score in a main regulation goal/basket and the other team runs the ball out through some marker cones/over a line, or by outletting the ball to a feeder/coach etc.).
Possession game	No goals/targets in which retention of possession rather than scoring is the primary objective.
Conditioned game	Restrictions/variations to rules, goals or area of play, but with both teams scoring in the same way.
Small sided game	Two goals, realistic to regulation rules, with both teams scoring in the same way
Full sided game	Two goals, regulation rules and players (i.e., 11 vs 11 in case of field hockey), with both teams scoring in the same way.
Management/Transition States	
State - other	Time when coaches are managing/addressing the team of players to explain up-and-coming practices, transition or move players from one practice state (i.e., technical practice) to a NEW or DIFFERENT practice state (i.e., skills practice), and time when players are taking breaks from practice.
Task Characteristics	
Direction of play	
Length	Players moving along the longitudinal axis of the playing surface, in the standard match direction (end board to end board).

Width	Players moving along the lateral axis of the playing surface, in a direction perpendicular to standard match-play (side board to side board).
Playing area and rink location	
Full rink	The entire area of the playing surface.
Half rink	One longitudinal half of the playing surface, spanning from the end boards to the central red line on either side.
Forward zone	The area encompassing the final two thirds of the playing surface. This begins at the first blue line and extends to the end boards.
One third of rink	Space within the playing surface which encompasses the space between either the end boards and its nearest blue line, or the area in between the two central blue lines (with space allowed behind the goal line).
One third (Final)	The area encompassing the final attacking third of the plating surface. Starting from the second blue line (left to right) towards the end board.
One third (Neutral)	The centre third of the playing surface, in-between the two blue lines.
Half of one third	One-sixth of the total playing surface, which makes up half of a singular third within the area. This is not bound to a specific location on the ice.
Player Activity	
Active player	An individual who directly influences the progression of play or the organisation and positioning of other players.
Inactive player	An individual involved in the activity, but does not influence the progression of play, or organisation and positioning of other players (e.g., a feeder player).
Skill	
Shooting	Aiming to score a goal against a goalkeeper.
Passing	Distribution of the puck between two or more players within the same team.
Offensive entry	Advancing the puck into the final third of the playing surface (beyond the second blue line), whilst maintaining a coherent structure, and adhering to the offside regulations.
Attacking structure	Organisation and alignment of players, attempting to create scoring opportunities or sustaining a presence in-front of goal.
Defensive play	Actions taken by players to prevent a shot attempt or goal from occurring, without focus on a specific defensive technique (e.g., stick check, body check).

No specific skill observed	Actions and movements that do not focus on a particular skill, however, contribute to competition environments, these may include many skills within one specific drill.

3.2.3 Statistical Analyses

Raw data were exported and imported into MS Excel (v16.99.1, Microsoft, USA) for initial data formatting, before subsequently being imported for data transformation and descriptive statistics within RStudio (v4.1.2; R Core Team, Austria). Descriptive statistics (mean ± SD) were calculated for frequencies, durations and proportions of training activities according to individual sessions or competitive season.

3.3 Results

3.3.1 Distribution of Training Activities Across a Competitive Season

The distribution and characteristics of training activities across the competitive season are presented in Table 3.2. State – other was the most frequently observed activity state (n=315; 63.8%), accounting for 27.5% of training time across the competitive season. Considering all other activity states, technical practice occurred most frequently (n=79; 19.7% of total duration) and were typically the shortest in duration (excluding physiological; mean = 2:51 ± 1:20 mins). However, the greatest time was spent on phase of play activities (34.4%). On average, 23.0 ± 0.1% of players participating in the session were involved per training activity, compared to 22.5 ± 0.1% who were actively engaged. Shooting was the most frequently observed primary skill (n=68; 41.5%), most often within technical practice activities (n=44; 55.7%). Notably, 11% of training activities (n=18) did not have a defined primary skill. Activities were typically delivered on a full rink (n=56; 33.9%), and the direction of play was predominantly lengthwise (n=157; 95.7%).

Table 3.2. Distribution of training activities and characteristics across the competitive season

	COND	FUNC	PHASE	PHYS	SKILL	SSG	TECH	Total
Frequency (n; %)	17 (10.4)	11 (6.7)	33 (20.1)	1 (0.6)	18 (11.0)	5 (1.8)	79 (48.2)	**164**
Duration (mins; %)								
Mean ± SD	7:24 ± 1:53 (16.1%)	5:20 ± 2:38 (7.5%)	8:09 ± 3:35 (34.4%)	1:07 (0.1%)	3:42 ± 1:35 (8.5%)	7:14 ± 1:33 (4.6%)	2:51 ± 1:20 (28.8%)	**6:04 ± 2:07**
Range	4:59 – 10:54	1:39 – 9:36	1:42 – 16:17	-	0:50 - 7:51	5:33 – 9:44	0:27 – 6:59	
Playing area and rink location (n; %)								
Full rink	2 (11.8)	5 (45.4)	10 (30.3)	1 (100)	8 (44.4)	5 (100)	25 (31.6)	**56 (33.9)**
Half rink	2 (11.8)	0 (0)	0	0 (0)	0 (0)	0 (0)	0 (0)	**2 (1.2)**
Forward zone	0 (0)	2 (18.1)	4 (12.1)	0 (0)	7 (38.9)	0 (0)	30 (38.0)	**43 (26.2)**
Third – no specific area	5 (29.4)	0 (0)	1 (3.0)	0 (0)	0 (0)	0 (0)	1 (1.3)	**7 (4.3)**
Third – final third	0 (0)	4 (36.3)	18 (54.6)	0 (0)	2 (11.1)	0 (0)	23 (29.1)	**47 (28.7)**
Third – neutral	6 (35.3)	0 (0)	0 (0)	0 (0)	1 (5.6)	0 (0)	0 (0)	**7 (4.3)**
Half of one third	2 (11.8)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	**2 (1.2)**
Direction of play (n; %)								
Length	12 (70.6)	11 (100)	32 (97.0)	1 (100)	18 (100)	5 (100)	78 (98.7)	**157 (95.7)**
Width	5 (29.4)	0 (0)	1 (3.0)	0 (0)	0 (0)	0 (0)	1 (1.3)	**7 (4.3)**
Players involved in training activity (%)								
Mean ± SD	37.4 ± 0.13	32.9 ± 0.09	40.2 ± 0.07	100	14.1 ± 0.03	37.7 ± 0.09	13.1 ± 0.07	**23.0 ± 0.07**
Range	20.0 – 58.8	25.0 – 56.3	21.7 - 52.9	-	10.0 – 22.0	23.5 – 47.1	5.0 – 35.7	
Players actively involved in training activity (%)								
Mean ± SD	37.4 ± 0.13	32.0 ± 0.09	38.1 ± 0.09	100	13.5 ± 0.03	37.7 ± 0.09	9.7 ± 0.07	**22.5 ± 0.07**
Range	20.0 – 58.8	25.0 – 56.3	21.7 – 52.9	-	5.0 – 18.8	23.5 – 47.1	4.4 – 27.8	
Observed primary skill (n;%)								
Attacking structure	6 (35.3)	0 (0)	29 (87.9)	-	0 (0)	0 (0)	0 (0)	**35 (21.3)**
Offensive entry	0	4 (36.3)	1 (3.0)	-	0 (0)	0 (0)	0 (0)	**5 (3.0)**
Passing	0	1 (9.0)	1 (3.0)	-	1 (5.6)	0 (0)	35 (44.3)	**38 (23.2)**
Shooting	1 (5.9)	4 (36.3)	2 (6.1)	-	17 (94.4)	0 (0)	44 (55.7)	**68 (41.5)**

None	10 (58.8)	2 (18.2)	0 (0)	-	0 (0)	5 (100)	0 (0)	**18 (11.0)**

COND = conditioned game. FUNC = functional practice. PHASE = phase of play. PHYS = physiological. SKILL = skills practice. SSG = small sided game. TECH = technical practice. SD = standard deviation

3.3.2 Distribution of Training Activities Between Sessions

The distribution of training activities within training sessions are presented in Figure 3.1. Cumulatively, the proportion of time allocated to practice states was highest after the Christmas break (January 2025; 43.5%). Preparation activities were administered a maximum of once per session and were observed in 15 sessions (71.4%). Functional practice appeared in nine sessions (42.9%), ranging between one and three activities per session (mean = 1.2 ± 0.7). Only a singular physiological activity was prescribed across the entire season. Skills practice activities were prescribed in 15 sessions (71.4%), ranging between one and two activities per session (mean = 1.2 ± 0.4). Between two and six technical practice activities were administered in every session (mean = 3.8 ± 0.8). State – other was the most frequently administered activity in every session (mean = 15.0 ± 3.1; range = 8 - 21).

Across the season, the proportion of time allocated to playing state activities was highest in December 2024 (52.4%) and again in March 2025 (46.4%), both periods preceding multiple (n=6) or important fixtures. Conditioned games were prescribed in various sessions (n=11; 52.4%) across the season and varied between one and three activities per session (mean = 1.5 ± 0.8). SSGs only appeared five times across the season and never occurred more than once in a single session. Phase of play activities were observed in 20 f the 21 sessions (mean – 1.7 ± 0.8), with the exception of session two.

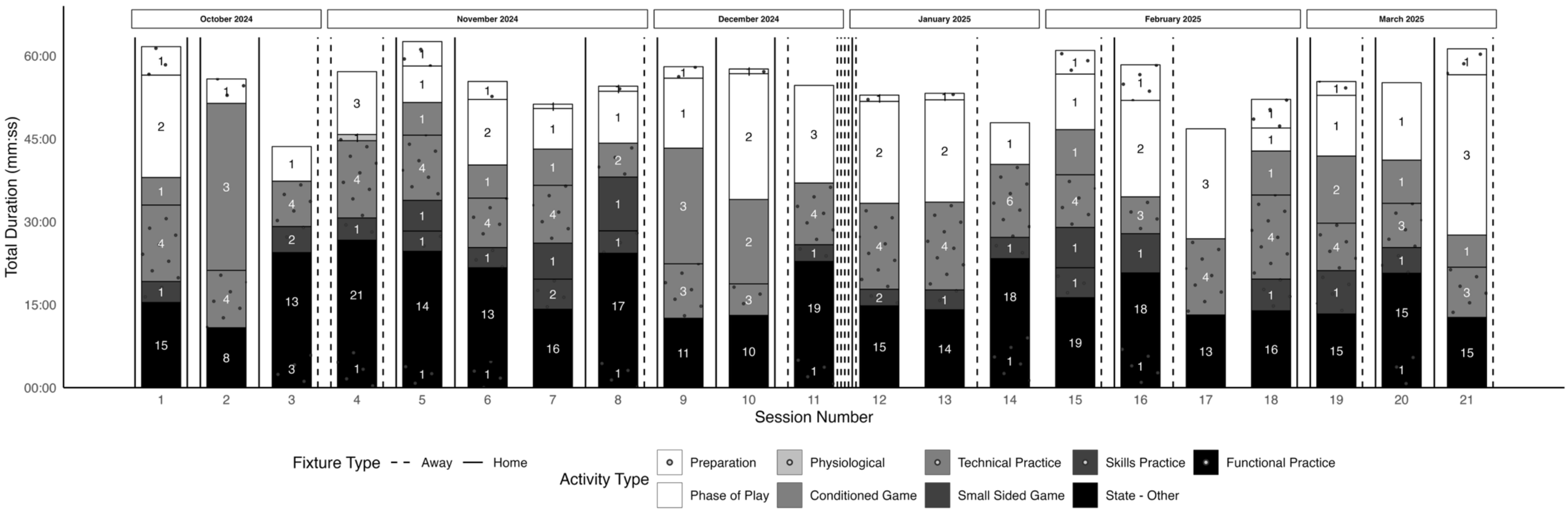

Figure 3.1. Total duration (minutes) and frequency (n) of training activities within training sessions and timings of competitive fixtures across the competitive season

3.3.3 Distribution of Training Activities Within Sessions

The structure and distribution of training activities within sessions are presented in Figure 3.2. Training sessions typically started with a preparation activity (sessions n=15; 71.4%), where this occurred technical practice always followed (excluding state – other activity). Across all sessions, 78.2% (n=43) of playing state activities were prescribed in the final 50% of the session. In contrast, 70.1% (n=87) of all practice/training state activities occurred in the initial 50% of each session. Alongside this, 16 training activities (76.2%) had a sequence of three consecutive technical practice activities at the beginning of the session. All training form activities occurred an average of 5.7 ± 1.7 times per session and lasted an average of 3 min 13 s ± 1 min 43 s per activity. Playing state activities were less frequent, occurring 2.5 ± 1.0 times per session, however, were longer in duration (7 min 50 seconds ± 2 min 58 s). Training sessions typically finished with a practice state activity (n=12; 57.4%) or as the penultimate activity (n=4; 19.0%), most observed as technical practice (n=10; 47.6%).

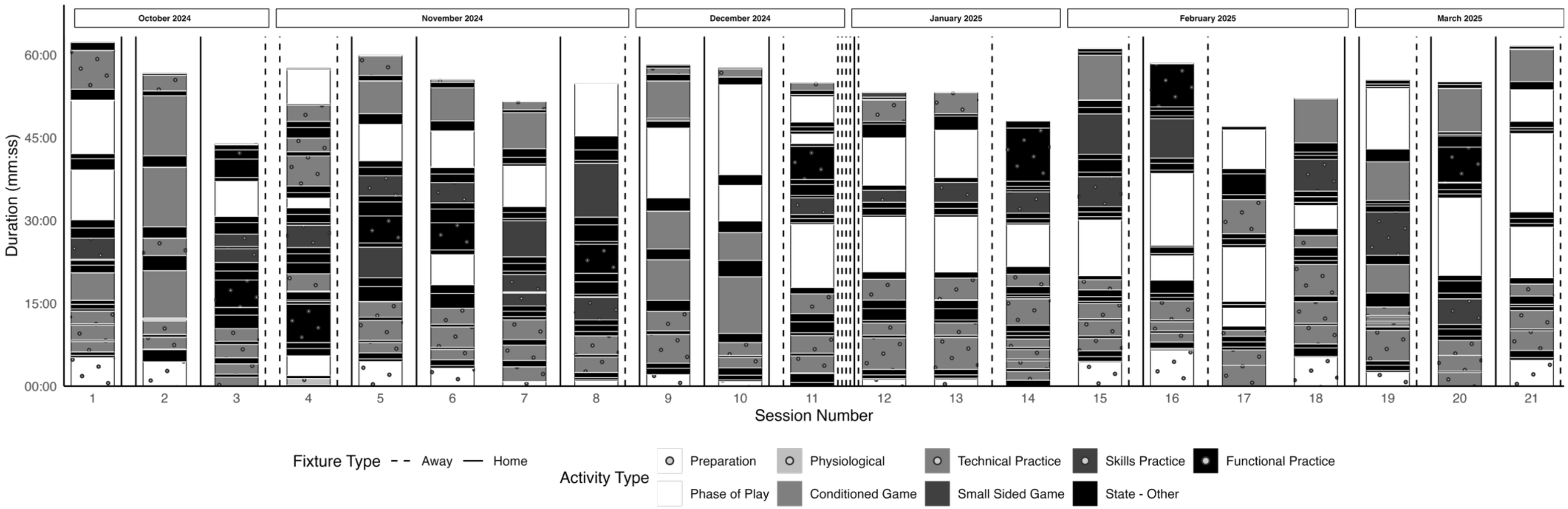

Figure 3.2. Chronological distribution of training activities within training sessions and timings of competitive fixtures across the competitive season

3.4 Discussion

This study aimed to describe the distribution of training activities within a senior men's domestic ice hockey team across a competitive season. This research is the first to describe training structures, distribution and characteristics of training activities within ice hockey, and to describe the *within-session* structure of training sessions in any sporting population. Due to the novelty of this aspect, reference to wider literature is necessarily limited, as no directly comparable studies examining within-session design currently exist. When looking *between training sessions*, technical practice was observed in every session. Playing state activities (78.2%) mostly occurred within the last 50% of each individual session. Alongside this, at the start of over three quarters of all sessions (76.2%), a sequence of three technical practice activities was observed. The most observed activities were management/transition states (i.e., state – other; 63.8%). These findings offer coaches a clearer understanding of how training is structured, highlighting the dominant activity types, the sequencing patterns that underpin session design, and the balance between practice, playing and management/transition states across the season.

Technical practice (n=79) and phase of play (n=33) were the most prominent training activities, with phase of play comprising 34.4% training time across the season. This is consistent with trends observed in other sports (e.g., youth women's football,[214] senior Gaelic football[66]) which have highlighted frequent use of technical practice and suggestions that 'playing form' (playing state) activities may offer limited opportunities for technical development.[66] Phase of play activities were longer in duration than other activity types (both accumulated and average per activity). This pattern aligns with the structural design of game-based formats, which typically require longer periods of time to allow for tactical dynamics (similar to match-play) to emerge.[26] Acknowledging this, practitioners benefit from understanding the specific demands associated within each activity type, as this enables them to sequence activities in ways where activities can interact amongst each other so that they reinforce the overarching training objective.

State – other accounted for 27.5% of total training time, which is consistent with wider research.[215-218] Although coded simply as 'state – other' in the present sample, management/transition states may function as important components of the training process, enabling coaching interactions,[80, 218] rest and water breaks,[218] player reflection.[216] Alternatively, large accumulations of management/transition states may be associated with potential misalignment between coaches' planned and actual in-session behaviours.[111] Whilst previous research highlights the value of analysing transitional states, the present study focused specifically on the structural characteristics of training activities. As a result, primary coaching behaviours were beyond the scope of this study and therefore not quantified. Considering the volume and potential role of management/transition states within training sessions, future research should quantify primary coaching behaviours to clarify the organisational functions embedded within these states, enabling a more complete interpretation of session design.

Physiological activities were only observed once across the season. This could reflect the design of training activities, where physical demands are embedded within technical-tactical or game-based formats rather than delivered through isolated conditioning tasks.[134] However, it is also possible that coaches did not prioritise on-ice conditioning, instead focusing available rink time on technical-tactical development. The limited ice time available to the team (one-two 45–60-minute sessions per week) may have contributed to this, encouraging coaches to maximise technical and tactical work during sessions. Further, as the players received regular strength and conditioning provision[219] this may have further reduced the need for dedicated physiological practice during on-ice sessions. Interpretation remains limited as the coach's intentions were not captured in this study. Considering session plans (or at least session goals) within future research would provide a more complete understanding into why specific training activities are selected and how they are intended to support session outcomes.

Shooting was the most frequently observed primary skill amongst all training activities (41.5%). No existing research has quantified the distribution of primary skills in this format, meaning the present study offers a novel insight into how skills are structured across training sessions. Shooting efficiency consistently emerges as a key performance indicator in determining match outcomes in ice hockey[35] and other sports.[220, 221] Research within basketball highlighted how teams with higher field goal percentages consistently outperformed the opponents,[220, 221] and ice hockey research highlighted a strong association between shot quality and shooting efficiency with successful scoring and match outcomes.[35] The prominence of shooting within the present sample may therefore reflect an emphasis on developing a key skill for successful performance. Although the participating team had a successful season (73.2% of fixtures won), the study cannot determine whether the focus on shooting during training contributed to this success. Previous research[222] has demonstrated targeted shooting practice can contribute to improved performance, but establishing a causal relationship between these two factors was beyond the scope of this study. Understanding whether successful teams and coaches consistently prioritise shooting (or other skills) in their training structures may offer insight into what constitutes effective practice design in ice hockey. Comparative research examining successful and unsuccessful teams would help clarify whether shooting-focused training is a consistent marker of success.

Player involvement within activities was low (≤60%), indicating that players spent substantial proportion of training time not directly engaged in the primary task. Although individual player involvement was not measured, previous research shows that reducing the number of active players can meaningfully alter physiological,[88, 223] technical[137] and tactical outcomes.[137, 224] Notably, no research to date has examined player-level inactivity across a full training session(s), limiting understanding of how involvement may differ within and between activities. Periods of inactivity (beyond management/transition states) may also serve a deliberate purpose, such as providing recovery within a drill or managing cumulative load, as reducing intensity within periods of training assists in lowering overall training loads, which is associated with reduced injury risk.[157-159, 225] Understanding whether low involvement reflects intentional design or unintended inefficiency has direct implications for how coaches structure training to optimise intensity[88] and engagement.[226] Distinguishing between these possibilities is essential for interpreting session quality and for supporting coaches in designing activities which balance engagement, recovery, and performance outcomes. Examining player-level inactivity and coach intentions of prescribed training activities would clarify how involvement is managed and how it contributes to session outcomes.

When examining the results across the entire season, playing state activities gained the highest proportion of activity in December 2024 (52.4%) and March 2025 (46.4%). This likely reflected the fixture schedule at the time, with five away games and one home game occurring between sessions 11 and 12, followed by the start of playoffs in March. Such a change might be expected due to the need for coaches to adapt training sessions as the season progresses (i.e., a series of important playoff fixtures).[66, 227] During these periods, the proportion of playing-state activities increased, potentially reflecting a shift in emphasis toward short-term match performance rather than longer-term development.[228] Research examining how ice hockey training adapts based on match importance or 'playoff season' is yet to be explored, and addressing this gap would strengthen season-long planning for coaches. Understanding how training structure shifts in response to competitive demands would help coaches plan when to increase representativeness, when to consolidate technical work, and how to balance this across a season.

Technical practice was consistently prescribed throughout the season, occurring at least twice per session. This consistency may reflect coaches relying on habitual or inherited routines, rather than a deliberate evaluation of whether these activities were the most appropriate means of developing the intended performance behaviours.[111, 201, 206] Some coaching literature, particularly in collegiate sport emphasises the value of prolonged technical practice to reinforce fundamental skills[218] and provide continuity within a season (as tactical and contextual demands differ throughout training sessions)[229]. However, research in Australian rules football presented a contrasting perspective suggesting that exposure to closed, decontextualised environments have minimal benefit for performers, given the limited cognitive demands and poor representativeness of competition. The contrasting findings may reflect differences in coaching philosophy. As a result, understanding *why* coaches prescribe drills become essential. Capturing coach intent within further research would help determine whether technical activities are used strategically or exist as habitual prescriptions and would support more evidence-informed planning across the season.

Within-session analysis revealed three distinct patterns across the season. The first was, of all playing state activities prescribed, 78.2% occurred in the final 50% of their respective training sessions, whereas 70.1% of all practice state activities occurred in the first 50% of their sessions. A sequence of three technical practice activities was frequently prescribed at the start of the session (76.2% of sessions). Training/practice state activities typically concluded or were the penultimate activity within a session (final; 57.4%, penultimate; 19.0%). Collectively, these findings present a clear progression consistent with 'simple-to-complex' training design.[218] This process can help stabilise key movement patterns[230] to prepare players for the perceptual and decision-making demands of later representative tasks.[231] In contrast, this structure also appeared to invert typical pedagogical principles associated with 'whole-part-whole' approaches,[232] instead resembling a 'part-whole-part' pattern. This may reflect the coach's intention to scaffold learning by isolating technical elements, embed them within game-based contexts, and then refining again based on what emerged during the representative task.[233] As this study is the first attempt to analyse within-session training structures in this level of detail, it highlights clear value of examining practice design at the micro-level. Extending this approach further across a wider range of sports would provide coaches with context-specific insights, enabling more tailored and informed decisions about how to structure training within their own environment.

There are limitations of the current study which should be acknowledged. Whilst, the sample accounted for ~72% of training sessions throughout the competitive season, practical challenges (e.g., poor alignment between the start of the competitive season and the start date of the lead researcher's postgraduate research studies, unforeseen delays in institutional ethics approval, establishing systematic observation procedures in a training venue with restricted filming accessibility) resulted in pre-season and early-season sessions not being observed (~28%). Research has highlighted seasonal differences in player performance across other sports,[234-236] suggesting that coaching practices may also vary across the entire season, and in turn, affect player performance. Additionally, as the study focused exclusively on on-ice training, information relating to physiological demands, technical development, and how off-ice components interact with on-ice structures was not captured.[237] Consequently, the findings only represent one component of the team's preparation and cannot be generalised to the full scope of their training programme. Research including comprehensive observations of both on- and off-ice training to provide a more complete understanding of how different training components combine to support performance, and to better inform coaches' planning decisions across the competitive season. Finally, this study only involves a single club within a single competitive season, which may have limited generalisability to the wider population. Therefore, future research should analyse multiple teams across different competitive contexts to account for inter-team differences and to identify broader patterns in training design within the sport. Capturing variation across teams, playing standards and populations would strengthen the existing training design research and can provide coaches with more representative guidance for planning and delivery.

3.5 Conclusions

The present study provided a comprehensive description of the training structures and activities within a senior domestic men's ice hockey team across a competitive season. Technical practice was the most frequently prescribed training activity, occurring at least twice in every session, whilst phase of play activities accounted for the greatest proportion of total training time. State – other was the most observed training activity, whereas physiological activities were only observed once. Shooting activities were the most commonly observed primary skill, and player involvement across activities was generally low. Playing state activities occurred most frequently in the latter half of training sessions, with their proportion increasing as fixture-dense or important fixtures approached. These findings contribute valuable insight to both ice hockey research and amateur level sport, two populations that remain under-examined. By quantifying the structure and content of training sessions, the study offers practitioners a clearer understanding of how sessions are typically organised and where adjustments may enhance practice design. Future research should extend this observational approach across multiple teams and competitive levels to determine whether the training patterns identified here, represent broader trends within ice hockey. Establishing these wider patterns would provide coaches with clearer, evidence-based benchmarks for planning and structuring their own sessions. This work may also support coaches in reviewing how their current session structures align with their session or activity aims, and whether adjustments across a season would better achieve those aims.

Incorporating qualitative methods in future research would further deepen understanding by capturing coach intentionality and the rationale underpinning planning decisions, thereby strengthening the evidence base for coaching within ice hockey.

3.6 Implications for Future Chapters

The present study provides understanding of the training activities and characteristics that characterise this team’s training environment across a competitive season. By identifying the most prominent training activities (e.g., technical practice and phase of play), and the prominence of shooting-focused activities, the study established which components of training the coach frequently planned into their practice design. Importantly, the prominence of shooting activities directs focus towards examining specific training actions in greater depth throughout the subsequent chapter. Shots emerged as the most common primary skill within training, and an understanding of their importance for match outcomes,[222, 238] gives clear rationale for exploring shooting in more depth. Examining shooting provides a meaningful way to explore representativeness between training and competition. Furthermore, understanding the distribution of activities, such as the limited prescription of SSGs, can inform which activities would present difficulty when attempting to establish trends within a training environment. As a result, the following chapter will aim to quantify how representative to matches shooting actions are within specific training activities.

CHAPTER 4: INVESTIGATING THE REPRESENTATIVENESS OF SHOOTING IN MEN'S DOMESTIC ICE HOCKEY

The information presented in this chapter has been updated and submitted for publication
Fletcher C, Quick S, Cushion E, Harkness-Armstrong A. Evaluating the representativeness of shooting during training activities in senior men's domestic ice hockey. [Anonymised for peer review purposes]. Under review.

Abstract

Performance emerges from the context in which it occurs, meaning representativeness must be assessed within specific training activities level rather than assumed simply because the task resembles match-play (i.e., match simulations). Although shooting is an important action of offensive success, the representativeness of shooting situations within training environments has not yet been examined. This chapter aimed to quantify and compare the technical-tactical characteristics of shooting during competition and training activities within senior domestic men's ice hockey. Data were collected during 21 training sessions (after two were removed due to technical issues) and 14 matches, totalling 2,997 shots during training and 977 shots during matches. Linear mixed models estimated possession-based and shot-based technical-tactical characteristics and determined differences between training activities and competition. Technical practice emerged as the least representative training design. Numerical balance rarely reflected match-play environments, with numerical overloads overrepresented during training activities. Open-play possessions and single-shot sequences were more frequent in training. Goal frequency did not differ significantly between training and competition. Within the sample, possession-based variables (such as number of defenders and possession type) often differed significantly from match-play, especially within practice state activities. Similarly, with shot-based variables, shot type and shot outcome also differed significantly from match-play across activity types. This study highlights that representativeness of shooting differs according to the training activity. These findings have practical implications for informing training design and coaching practices relating to shooting within ice hockey.

Keywords: training prescription, offensive sequences, ecological dynamics, team sports

4.1 Introduction

It is well established that performance outcomes arise from the contextual conditions in which they emerge.[22, 95] Within practice, different activity types (e.g., technical vs match simulation) are designed to elicit different behaviours, and therefore, their representativeness may also vary (Chapter 2). For example, the design and structure of 'playing form' and 'training form' activities[61] provide differing levels of functionality (i.e., informational cues present in competition) and action fidelity (i.e., required movements present in competition) particularly when decision making, teammate or player interactions are removed.[206, 215] Accordingly, representativeness needs to be evaluated for each specific activity, as different task designs preserve different informational cues and movement demands.[152] Chapter 2 further demonstrated that most research compares training to the whole match, with only two studies analysing specific phases of play (inside-50 entries[33] and disposals in Australian rules football[81]). The lack of existing research is surprising considering that evidence from RLD[26] and ecological dynamics[28, 239] emphasise how behaviours emerge through the interaction of the performer with environmental constraints. Recognising how these contextual constraints shape behaviour enables coaches to judge whether an activity genuinely reflects competitive demands and to design practice environments that more effectively support skill development.[102]

Within invasion sports, there are key phases or moments of the game (i.e., in- and out-of-possession,[32] transition,[240, 241] set pieces[31, 242]) each producing different structural and behavioural demands.[243] These phases can further be divided into sub-phases (e.g., build-up, progression, finishing), where specific performance behaviours emerge in response to the contextual constraints within that moment. Despite this, Chapter 2 highlighted that research rarely evaluates the representativeness of performance within these phases or sub-phases. Consequently, a more contextualised understanding of performance during these moments would enable both researchers, coaches and coach developers to evaluate training and match outcomes with greater precision. This can subsequently inform the design of training activities which more accurately reflect the demands of specific moments of play.

Shooting is a key determinant of successful offensive play within invasion sports,[244] including ice hockey.[35, 245] The shot represents the final action of an attacking sequence[246] and therefore plays a decisive role in converting possession into scoring outcomes.[247] Shooting actions vary in both frequency and efficiency according to contextual factors (e.g., playing standard)[44, 248], team-specific behaviours[22, 44, 92, 249] and situational variables (e.g., match status)[44, 249, 250]. These factors are particularly pronounced in ice hockey, as the low-scoring nature of the sport[35, 251] and regulations such as “golden goal” overtime formats,[252, 253] highlight the importance for players to be able to create and convert shooting opportunities.[35] Given the importance of shooting within the wider performance literature, and its prominence across the training structures observed in this sample (Chapter 3), examining shooting provides valuable insights into how training environments shape key performance behaviours.

To date, no research has examined the representativeness of shooting (or goalscoring) within training activities in any sport. Shooting is a multi-phase action[247] shaped by both possession-based variables (e.g., passes prior to shot, possession type by which the shot occurs) and shot-based variables (type of shot, shot speed, shot outcome) meaning its representativeness can only be understood within the conditions from which it emerges. Therefore, the current chapter aims to quantify and compare the technical-tactical characteristics of shooting during competition and training activities.

4.2 Methods

4.2.1 Participants

Details of participant characteristics can be found in Chapter 3 (3.2.1). This study was approved by the University of Essex Research Ethics Committee (ETH2425-2089), and all participants provided informed consent (or assent and parent/guardian consent) prior to participation.

4.2.2 Procedures

Eighteen matches during the 2024/25 competitive season (October 2024 to April 2025) were recorded The final sample within this chapter consisted of 21 training sessions and 14 matches (competition: league n =10, cup n=2, league/cup n=2; match location: home n=12, away n=2; match outcome: win n=10, draw n=2, loss n=2). League/cup fixtures represent matches that simultaneously contributed to league points and formed part of the cup knockout structure. Overall, the sample represents ~72% of the club’s training sessions and 32% of their competitive fixtures during the respective season.

The data collection process for training sessions was previously described in Chapter 3 (3.2.2). Home matches were recorded from a fixed position, behind the team’s attacking goal, at an elevated height to maximise rink coverage. Away matches were filmed by the host club, where footage tracked gameplay throughout the entire match. One match was recorded from an elevated, central sideline position set back from the rink, whilst the other was filmed from a similarly elevated position, situated halfway into the home team’s offensive zone in the first period.

Training sessions were imported into Metrica PlayBase (v.2.23; Metrica Sports, Spain) and coded using a customised coding panel. The training activities previously coded for Chapter 3, which had shooting as their primary skill were included for analysis (*practice/training state activities:* technical practice: n=79, 53.7%; skills practice: n=18, 12.2%; *playing state activities*: phase of play: n=33, 22.5%*;* conditioned game; n=17, 11.6%). The overall activity-level structure of these training sessions can be viewed in Table 3.1. Match recordings were also imported into Metrica PlayBase, with only regulation-time shots included (i.e., overtime shots excluded; n=4). The variables (possession-based n=9; shot-based n=9) quantified and respective operational definitions are presented in Table 4.1. Operational definitions were developed by the research team drawing upon sport and performance analysis expertise. A total of 2,997 training shots (143 ± 33.9 shots per training session) and 973 match shots (66.1 ± 12.7 shots per match) were analysed.

Prior to data analysis, a data filtering process was conducted, which identified and removed shots which were represented within matches but not training activities, including a disallowed goal (n=1) and shots originating from set-plays (n=71). Thus, a total of 7.4% of shots from match observations were excluded. This resulted in a total of 901 shots during matches (mean per match = 64.4 ± 17.4; range = 41 - 108), and 2,997 shots from training activities (*technical practice*: n=1,526; mean per activity = 21.2 ± 1.1; range = 1 – 47; *skills practice*: n=379; mean per activity = 19.0 ± 2.4; range = 2 – 33; *phase of play* =732; mean per activity = 22.9 ± 2.2; range = 2 – 48; *conditioned game*: n=360; mean per activity = 20.0 ± 2.2; range = 1 – 38) included for data analysis (Appendix 4.2). Alongside this, specific variables (e.g., number of defenders/attackers; in front, behind, inactive) were excluded due to a high proportion of missing values (empty levels of variables) within training activities.

Shot-level data were aggregated to create observation-level data for each match and training activity. For each observation, the frequency of all categorical variables (shot characteristics) was summarised, and all continuous variables (possession and individual possession duration) were averaged. To account for differing durations of competition and training activity observations, variables were presented relative to the total duration of the observation (i.e., $n \cdot min^{-1}$).

Table 4.1. Shot characteristics included in the analysis with operational definitions for training and match contexts

Variable Grouping	Variable	Level (if Categorical Variable)	Definition
Possession-Based	Attackers In Front (n)	N/A	Teammates between the shooter and attacking goal line
	Attackers Behind (n)	N/A	Teammates behind the puck and in front of the goal line when the player shoots
	Attackers Inactive (n)	N/A	Teammates behind the goal line or in the neutral zone when the player shoots
	Defenders In Front (n)	N/A	Opponents between the shooter and attacking goal line
	Defenders Behind the Shooting Player (n)	N/A	Opponents behind the puck and in front of the goal line when the player shoots
	Defenders inactive (n)	N/A	Opponents behind the goal line or in the neutral zone when the player shoots
	Possession Type	Open play	A period of play which develops from passing around the subject progressing through a minimum of 2 thirds
		Counter-attack	A period of play in which one or more attacking players progress towards the goal. The attacking team has a significant playing number advantage as the defending team is unable to reorganise.
		Set play	Period of play that leads directly to a shot from a structured restart in play (i.e., faceoff),
	Possession Location	(see Appendix 4.1)	The zone on the rink (Appendix 4.1) whereby the subject team gains clear possession of the puck, defined by the first uncontested receiver achieving possession, through faceoff, tackle or a loose puck recovery. The location of which refers to Appendix 4.1 and is always defined relative to the team's direction of attack.
	Numerical Balance	Balanced	Equal skaters on each team (5v5, 4v4)
		Superiority	The subject team has more skaters when compared to the opposing team (5v4, 5v3)
		Inferiority	The subject team has fewer skaters when compared to the opposing team (4v5, 3v5)
	Number of Defenders (n)	Defenders	The total number outfield opposition players on the ice
	Number of Attackers (n)	Attackers	The total number of outfield players of the subject team on ice
	Players Involved (n)	N/A	The number of distinct individuals from the subject team who had a puck involved (i.e. pass) throughout the possession
	Goalkeeper	Both in	Situation where both goalkeepers are on the ice
		Team Pulled	Situation where the subject team's goalkeeper has been substituted in exchange for an extra skater

		Opposition Pulled	Situation where the opposition goalkeeper has been substituted in exchange for an extra skater
	Possession Duration (s)	N/A	The duration of the team's possession, determined by the time between the team's first and last touch (i.e. shot). The team must be in clear possession (i.e. contested possession (e.g., face-offs) is not considered clear possession)
	Number of Passes (n)	N/A	The number of passes from the start of possession to shot
Shot-Based	Preceding Action	Pass	The shooter received a pass from another player
		Dribble	The shooter carried the puck forward
		Regain	Regathering the puck after a shot or loose puck
		Other	Any action that does not conform to the above levels
	Individual Possession Duration (s)	N/A	The duration of the shooting player's first touch to their last touch (i.e. shot)
	Pre-Shot Movement	In Motion	The shot taker is actively in motion at the point in which the puck is struck
		Stationary	The shot taker is showing no movement at the point in which the puck is struck
	Shot Location	(See Appendix 4.1)	Spatial zone on the ice where the shot is completed (Appendix 4.1)
	Shot Type	Wrist Shot	A quick release shot using wrist flexion and minimal wind-up.
		Slap Shot	A full stick wind-up shot with stick raised
		Backhanded	Shot taken with the back side of the stick, relative to the player's dominant shooting side
	Shot Outcome	Goal	The puck fully crosses the goal line between the posts and under the crossbar
		Saved	The goalkeeper makes direct contact with the puck, preventing a goal
		Missed	The puck is directed wide or high of the goal frame without interjection from a goalkeeper or defender
		Blocked	An opponent (excluding the goalkeeper) intercepts or deflects the shot from reaching the goal frame
		Disallowed	A goal that is initially scored but subsequently nullified due to a rule infringement or violation
	Shots in Possession	Single	Exactly one shot attempt, whereby puck possession is not retained, by puck freeze or turnover
		Multiple (Rebound)	Coded when a shot is taken immediately after the subject team regains possession
		Multiple (Retention)	Coded when the subject team regathers possession in an attempt to rebuild another shooting opportunity

4.2.3 Reliability

All notational analysis were conducted by the lead researcher (CF). Reliability was evaluated for the frequency of coded events and labelling of task characteristics, using a weighted kappa statistic.[212, 213] Intra-operator reliability was determined by re-analysing approximately 10% of the dataset, equating to 9.5% of the training shots (n=300) and 6.8% of the match shots (n=97). To meet this threshold, the closest full training or match observation were selected, resulting in two training sessions and one match being re-analysed. This approach aligns with the minimum acceptable proportion of data recommended for reliability assessments.[254] Sessions were re-analysed ≥ five weeks after initial analyses were completed. Kappa values indicated good agreement (κ=0.63) for training and moderate agreement (κ=0.51) for matches.[212] The confusion matrices for both training sessions and matches are presented in Appendices 4.5 - 4.8. STE values for possession duration showed moderate disagreement for both matches (STE = 1.03) and training (STE = 0.99), and individual possession duration showed moderate disagreement for both matches (STE = 1.08) and training (STE = 1.03)[213].

Inter-operator reliability was determined by another member of the research team within performance analysis expertise (AHA), independently analysing one randomly selected match. Kappa values indicated fair agreement (κ=0.33) between the two operators for the analysed match.[212] The confusion matrix for the inter-operator reliability assessment is presented in Appendices 4.9a, 4.9b, and 4.10. STE values for possession duration showed moderate disagreement (STE = 1.14), while individual possession duration showed small disagreement between the two operators (STE = 0.54)[213].

4.2.4 Statistical Analysis

Statistical analyses were conducted using RStudio (v4.1.2; R Core Team, Austria). A linear mixed model (lme4 package) was developed to quantify technical-tactical characteristics for matches and training activities, and included a log-transformed technical-tactical variable (e.g., possession duration, number of passes) as the dependent variable, observation type (match, technical practice, skills practice, phase of play or conditioned game) as a fixed effect, and observation ID as a random effect. Model assumptions were checked and verified for each dependent variable. Estimated means (± SE) were derived from the model for each technical-tactical variable (emmeans package), by back-transforming each estimate. Pairwise comparisons with a Bonferroni correction were conducted to determine differences between levels of fixed effect (observation types), with statistical significance set at $p<0.05$. Effect size (ES) was calculated (effsize package), and categorised as trivial (<0.2), small (0.2 – 0.59), moderate (0.6 – 1.19), large (1.2 – 1.99), very large (≥2.0). Effects were considered unclear if 90% confidence intervals included substantial (>0.2) positive and negative values.

4.3 Results

4.3.1 Possession-Based Variables

The possession-based variables according to match and training activity are presented in Table 4.2. The comparisons (statistical significance and ES) between matches and respective training activities are presented in Figures 4.1 (practice/training state activities) and 4.2 (playing state activities).

Table 4.2. Estimated marginal means (±SE) of possession-based variables during shooting events across training sessions and matches

	Match	*Practice/Training State*		*Playing State*	
		Technical Practice	**Skills Practice**	**Phase of Play**	**Conditioned Game**
Possession Type ($n \cdot min^{-1}$)					
Open Play	0.99 ± 0.23	7.52 ± 0.10	3.92 ± 0.20	2.55 ± 0.15	2.16 ± 0.21
Counter-attack	0.04 ± 0.28	<0.01 ± 0.12	<0.01 ± 0.24	<0.01 ± 0.19	0.01 ± 0.25
Possession Location ($n \cdot min^{-1}$)					
DL	0.04 ± 0.90	0.01 ± 0.40	0.10 ± 0.76	0.01 ± 0.60	0.01 ± 0.81
DC	0.08 ± 0.89	0.01 ± 0.49	0.02 ± 0.76	0.02 ± 0.64	0.02 ± 0.82
DR	0.09 ± 0.88	0.01 ± 0.39	0.02 ± 0.74	0.01 ± 0.58	0.01 ± 0.79
NL	0.06 ± 0.90	0.04 ± 0.47	0.06 ± 0.77	0.01 ± 0.63	0.04 ± 0.83
NC	0.03 ± 0.79	0.01 ± 0.35	0.02 ± 0.67	<0.01 ± 0.53	0.04 ± 0.47
NR	0.03 ± 0.87	0.04 ± 0.47	0.02 ± 0.74	<0.01 ± 0.62	0.04 ± 0.80
OL	0.26 ± 0.77	0.02 ± 0.39	<0.01 ± 0.66	0.53 ± 0.54	0.05 ± 0.71
OC	0.13 ± 0.71	0.01 ± 0.31	<0.01 ± 0.60	0.15 ± 0.47	0.02 ± 0.64
OR	0.23 ± 0.82	0.03 ± 0.37	0.01 ± 0.69	0.36 ± 0.55	0.02 ± 0.74
Numerical Balance ($n \cdot min^{-1}$)					
Balanced	0.87 ± 0.52	<0.01 ± 0.23	0.04 ± 0.44	<0.01 ± 0.34	1.52 ± 0.46
Superiority	0.11 ± 0.57	7.03 ± 0.25	0.71 ± 0.48	1.25 ± 0.38	0.02 ± 0.51
Inferiority	0.01 ± 0.23	<0.01 ± 0.10	<0.01 ± 0.19	<0.01 ± 0.15	<0.01 ± 0.21
Number of Defenders ($n \cdot min^{-1}$)					
0	<0.01 ± 0.48	7.01 ± 0.22	0.03 ± 0.41	<0.01 ± 0.32	<0.01 ± 0.43
1	<0.01 ± 0.45	<0.01 ± 0.20	1.54 ± 0.38	<0.01 ± 0.30	<0.01 ± 0.41
2	<0.01 ± 0.64	<0.01 ± 0.28	<0.01 ± 0.54	0.04 ± 0.43	0.01 ± 0.57
3	<0.01 ± 0.54	<0.01 ± 0.25	<0.01 ± 0.46	0.01 ± 0.37	0.16 ± 0.49
4	0.11 ± 0.53	<0.01 ± 0.24	<0.01 ± 0.45	0.02 ± 0.36	0.01 ± 0.48
5	0.88 ± 0.24	<0.01 ± 0.11	<0.01 ± 0.20	<0.01 ± 0.16	<0.01 ± 0.22

Number of Attackers (n·min^{-1})					
1	<0.01 ± 0.84	0.03 ± 0.43	0.04 ± 0.72	<0.01 ± 0.59	<0.01 ± 0.77
2	<0.01 ± 0.90	0.17 ± 0.45	0.24 ± 0.77	<0.01 ± 0.62	0.01 ± 0.83
3	<0.01 ± 1.01	0.15 ± 0.45	0.01 ± 0.86	0.01 ± 0.68	0.17 ± 0.91
4	0.01 ± 0.75	0.01 ± 0.37	<0.01 ± 0.64	0.01 ± 0.52	0.01 ± 0.69
5	1.00 ± 0.51	<0.01 ± 0.23	<0.01 ± 0.43	0.35 ± 0.34	<0.01 ± 0.46
Players Involved (n·min^{-1})					
1	0.28 ± 0.86	0.04 ± 0.42	0.13 ± 0.73	0.10 ± 0.59	0.35 ± 0.79
2	0.37 ± 0.86	0.25 ± 0.40	0.48 ± 0.73	0.33 ± 0.58	0.57 ± 0.78
3	0.24 ± 0.92	0.16 ± 0.45	0.01 ± 0.78	0.38 ± 0.63	0.25 ± 0.84
4	0.09 ± 0.66	0.01 ± 0.33	<0.01 ± 0.56	0.11 ± 0.46	0.01 ± 0.61
5	0.01 ± 0.48	<0.01 ± 0.22	<0.01 ± 0.41	0.01 ± 0.32	<0.01 ± 0.44
Goalkeeper (n·min^{-1})					
Both in	1.04 ± 0.48	4.71 ± 0.21	2.82 ± 0.40	2.46 ± 0.32	2.23 ± 0.43
Team Pulled	<0.01 ± 0.46	<0.01 ± 0.20	<0.01 ± 0.38	<0.01 ± 0.30	<0.01 ± 0.41
Opposition Pulled	<0.01 ± 0.11	<0.01 ± 0.05	<0.01 ± 0.09	<0.01 ± 0.07	<0.01 ± 0.10
Possession Duration (s)	6.52 ± 0.59	6.04 ± 0.27	7.37 ± 0.50	9.44 ± 0.40	6.77 ± 0.54
Number of Passes (n)	1.48 ± 0.48	2.80 ± 0.24	2.19 ± 0.41	2.79 ± 0.33	1.85 ± 0.44

Possession location: DL = defensive left. DR = defensive right. DC = defensive centre. NL = neutral left. NR = neutral right. NC = neutral centre. OL = offensive left. OR = offensive right. OC = offensive centre.

Shots from open play possessions occurred more frequently during technical practice (6.54 n·min^{-1}; p<0.001; very large ES: 2.35 ± 0.29), skills practice (2.94 n·min^{-1}; p<0.001; large ES: 1.59 ± 0.35) and phase of play activities (1.57 n·min^{-1}; p<0.01; moderate ES: 1.10 ± 0.32) than during match-play. In contrast, shots from counter-attack possessions occurred less frequently during all training activities compared to match-play (0.03 – 0.04 n·min^{-1}; p<0.001; large – very large ESs: 1.90 - 3.53).

There were no differences in the frequency of possessions (resulting in a shot) starting in the defensive (DL, DC, DR) or neutral (NL, NC, NR) zones for any training activity. Further, there was no difference for possessions starting in the neutral zone during playing state training activities. However, possessions starting in the offensive zone occurred less frequently during technical (OL: 0.24 n·min^{-1}; p<0.05; moderate ES: 0.95 ± 0.32; OC: 0.13 n·min^{-1}; p<0.01; moderate ES: 1.09 ± 0.29) and skills practice (OL: 0.25 n·min^{-1}; p<0.01; large ES: 1.51 ± 0.37; OC: 0.13 n·min^{-1}; p<0.01; large ES: 1.45 ± 0.35; OR: 0.23 n·min^{-1}; p<0.01; large ES: 1.23 ± 0.35) activities.

Possessions with numerical balance occurred less frequently during technical practice (0.87 n·min^{-1}; p<0.001; very large ES: 3.43 ± 0.29), skills practice (0.83 n·min^{-1}; p<0.001; large ES: 1.59 ± 0.35) and phase of play (0.87 n·min^{-1}; p<0.001; very large ES: 3.06 ± 0.32) activities compared to competition. Whilst possessions with numerical superiority occurred more frequently during technical practice (6.92 n·min^{-1}; p<0.001; large ES: 1.96 ± 0.29) and phase of play (1.14 n·min^{-1}; p<0.01; moderate ES: 1.15 ± 0.32) activities, possessions with numerical inferiority occurred more frequently during competition compared to all training activities (0.01 n·min^{-1}; p<0.001; very large ESs: 2.07 – 2.74).

Technical practice (7.01 n·min^{-1}; p<0.001; very large ES: 5.02 ± 0.30) and skills practice (0.03 n·min^{-1}; p<0.001; small ES: 0.39 ± 0.36) had a greater frequency of possessions with zero defenders present compared to match-play. Only skills practice activities (1.54 n·min^{-1}; p<0.001; very large ES: 4.35 ± 0.35) had more frequent possessions with one defender present, whilst two defenders present occurred more frequently during phase of play activities (0.04 n·min^{-1}; p<0.001; large ES: 1.52 ± 0.32) and three defenders present was more frequent in conditioned games (0.15 n·min^{-1}; p<0.001; very large ES: -2.00 ± 0.37). However, the presence of four (0.09 – 0.11

$n \cdot min^{-1}$; $p<0.05$ – $p<0.001$; moderate – very large ESs: 0.95 – 2.41) or five (0.87 - 0.88 $n \cdot min^{-1}$; $p<0.001$; very large ESs: 6.36 – 7.54) defenders occurred more frequently during competition than all training activities.

One- and two-attacker situations occurred more frequently during technical (one-attacker: 0.03 $n \cdot min^{-1}$; $p<0.01$; large ES: 1.24 ± 0.38; two-attacker: 0.17 $n \cdot min^{-1}$; $p<0.001$; large ES: 1.61 ± 0.32) and skills practices (one-attacker: 0.04 $n \cdot min^{-1}$; $p<0.05$; large ES: 1.61 ± 0.38; two-attacker: 1.73 $n \cdot min^{-1}$; $p<0.001$; large ES: 1.73 ± 0.37) than during competition. Three attacker situations were more frequent during technical practices (0.15 $n \cdot min^{-1}$; $p<0.01$; large ES: 1.21 ± 0.29) and conditioned games (0.17 $n \cdot min^{-1}$; $p<0.01$; large ES: 1.25 ± 0.36) compared to match-play. No differences were observed between training activities and competition in the frequency of four-attacker situations. However, five-attacker situations occurred more frequently during competition than technical practices (1.00 $n \cdot min^{-1}$; $p<0.001$; very large ES: 3.52 ± 0.29), skills practices (1.00 $n \cdot min^{-1}$; $p<0.001$; very large ES: 3.64 ± 0.35) and conditioned games (1.00 $n \cdot min^{-1}$; $p<0.001$; very large ES: 3.10 ± 0.36).

There were no differences between match-play and training activities in the number of possessions with one, two or three players involved. Possessions with four players involved occurred more frequently during match-play than technical practice (0.08 $n \cdot min^{-1}$; $p<0.01$; large ES: 1.20 ± 0.31), skills practice (0.09 $n \cdot min^{-1}$; $p<0.001$; large ES: 1.78 ± 0.37) and conditioned game (0.08 $n \cdot min^{-1}$; $p<0.05$; moderate ES: 1.15 ± 0.38), whilst possessions with five players involved were more frequent in competition compared to technical practice (0.01 $n \cdot min^{-1}$; $p<0.01$; moderate ES: 1.10 ± 0.30) and skills practice (0.01 $n \cdot min^{-1}$; $p<0.01$; large ES: 1.23 ± 0.35).

Possessions with both goalkeepers present (“both in”) were more frequent in technical practice (3.67 $n \cdot min^{-1}$; $p<0.05$; moderate ES: 0.85 ± 0.29) compared to matches. There was no difference in the number of possessions were the team’s or opposition’s goalkeeper had been pulled.

Lastly, possession duration was longer during phase of play activities compared to matches (2.92 s; $p<0.01$; large ES: 1.34 ± 0.33), and there were no differences in the number of passes per possession between match-play and training activities.

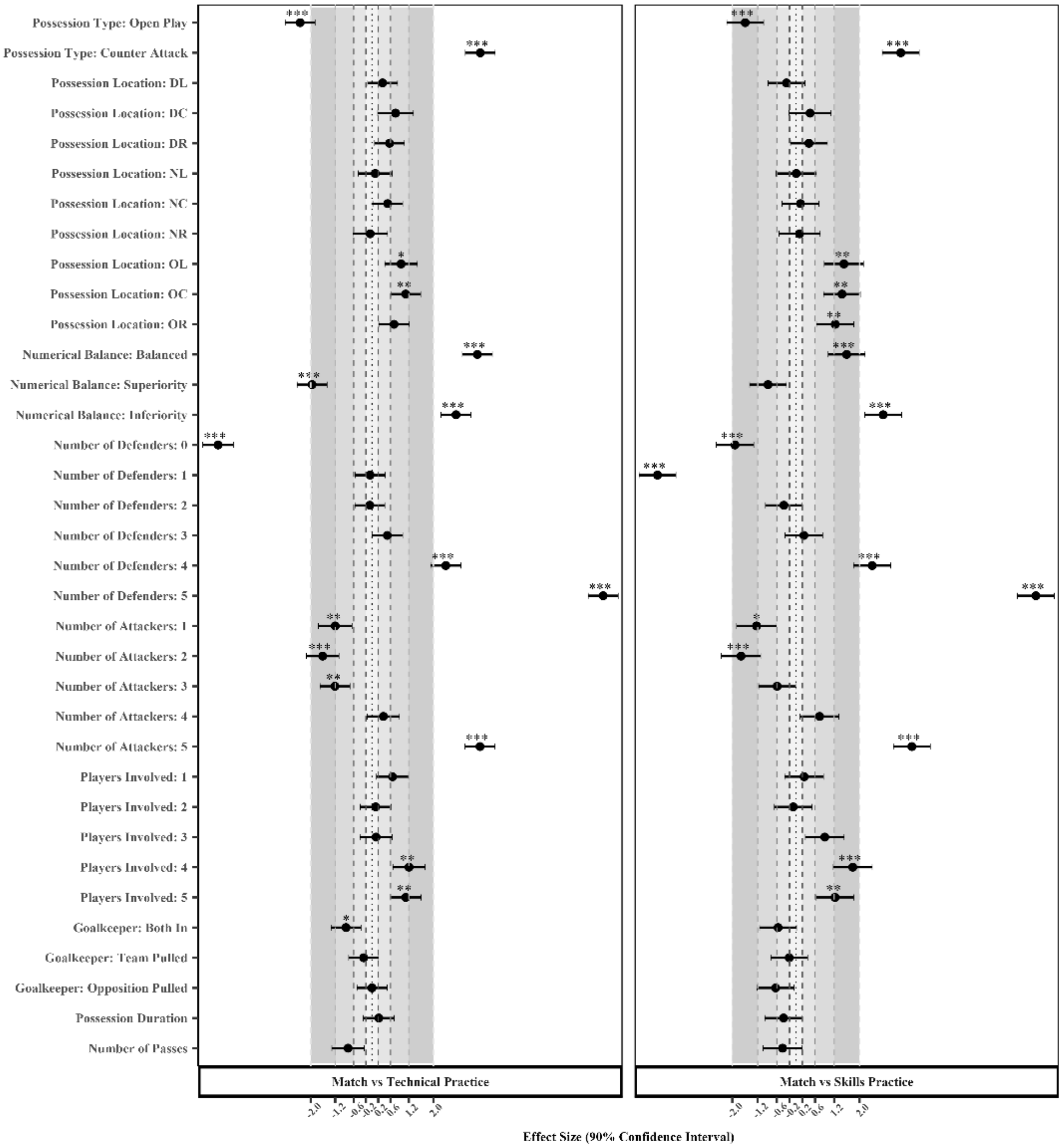

Figure 4.1. Effect size (± 90% CI) of differences in estimated mean statistical significance of possession-based variables of shooting events between match-play and training/practice state activities. *Statistically significant difference (p < 0.05*, p < 0.01**, p <0.001***).

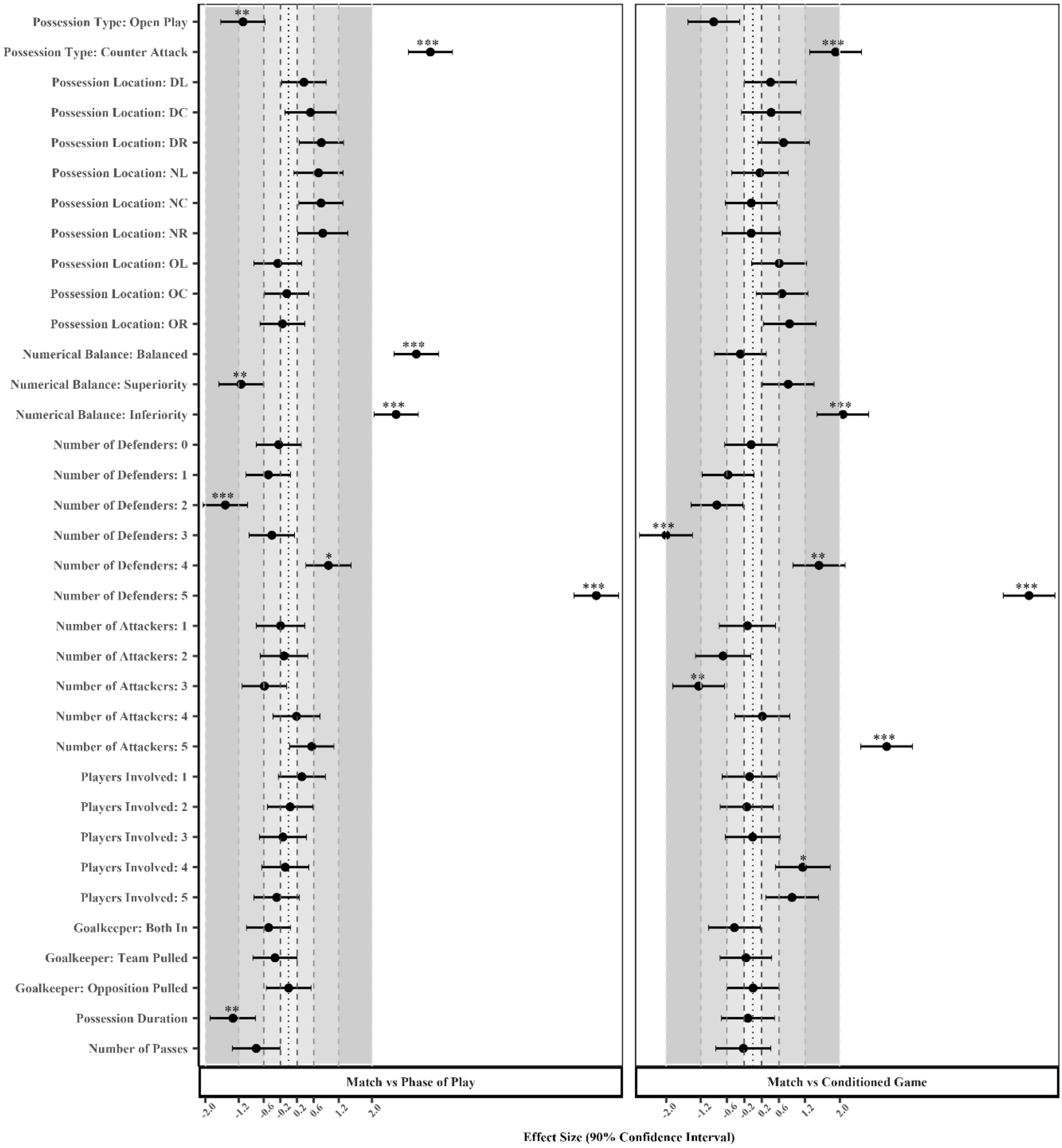

Figure 4.2. Effect size (± 90% CI) of differences in estimated mean and statistical significance of possession-based variables of shooting events between match-play and playing state activities. *Statistically significant difference (p < 0.05*, p < 0.01**, p <0.001***).

4.3.2 Shot-Based Variables

The shot-based variables according to match and training activity are presented in Table 4.3. The comparisons (statistical significance and ES) between matches and respective training activities are presented in Figures 4.3 (practice/training state activities) and 4.4 (playing state activities).

Table 4.3. Estimated marginal means (±SE) of shot-based variables during shooting events across training sessions and matches

	Match	*Practice/Training State*		*Playing State*	
		Technical Practice	**Skills Practice**	**Phase of Play**	**Conditioned Game**
Preceding Action (n)					
Pass	0.59 ± 0.76	0.29 ± 0.37	0.15 ± 0.65	1.86 ± 0.52	1.27 ± 0.70
Dribble	0.23 ± 0.61	1.96 ± 0.31	2.82 ± 0.52	0.22 ± 0.43	0.17 ± 0.56
Regain	0.16 ± 0.63	<0.01 ± 0.28	<0.01 ± 0.53	0.04 ± 0.42	0.08 ± 0.56
Individual Possession Duration (s)	2.45 ± 0.30	3.21 ± 0.15	3.99 ± 0.25	2.30 ± 0.21	2.37 ± 0.27
Pre-Shot Movement (n)					
In Motion	0.75 ± 0.36	6.97 ± 0.16	3.91 ± 0.30	1.65 ± 0.24	0.68 ± 0.32
Stationary	0.28 ± 0.51	<0.01 ± 0.23	0.01 ± 0.43	0.60 ± 0.34	0.28 ± 0.46
Shot Location (n)					
D	<0.01 ± 0.32	<0.01 ± 0.17	<0.01 ± 0.27	<0.01 ± 0.23	<0.01 ± 0.29
NL	<0.01 ± 0.32	<0.01 ± 0.14	<0.01 ± 0.27	<0.01 ± 0.21	0.02 ± 0.28
NC	<0.01 ± 0.43	<0.01 ± 0.19	<0.01 ± 0.36	<0.01 ± 0.28	0.03 ± 0.38
NR	<0.01 ± 0.36	<0.01 ± 0.16	<0.01 ± 0.31	<0.01 ± 0.24	0.01 ± 0.33
OL	0.32 ± 0.79	0.13 ± 0.36	0.14 ± 0.67	0.22 ± 0.53	0.04 ± 0.71
OC	0.37 ± 0.47	3.65 ± 0.21	2.59 ± 0.40	1.23 ± 0.31	0.07 ± 0.42
OR	0.30 ± 0.69	0.51 ± 0.31	0.22 ± 0.58	0.42 ± 0.46	0.01 ± 0.62
Shot Type (n)					
Slap Shot	0.21 ± 0.76	0.01 ± 0.36	0.01 ± 0.64	0.17 ± 0.52	0.11 ± 0.69
Wrist Shot	0.77 ± 0.29	6.55 ± 0.13	3.61 ± 0.24	1.96 ± 0.19	1.87 ± 0.26
Backhanded	0.02 ± 0.71	0.01 ± 0.31	0.04 ± 0.60	0.04 ± 0.60	0.05 ± 0.63
Shot Outcome (n)					
Goal	0.07 ± 0.66	0.40 ± 0.29	0.14 ± 0.56	0.16 ± 0.44	0.13 ± 0.59
Saved	0.57 ± 0.29	4.48 ± 0.13	2.32 ± 0.24	1.52 ± 0.19	1.47 ± 0.26
Blocked	0.18 ± 0.60	<0.01 ± 0.26	0.02 ± 0.51	0.09 ± 0.40	0.01 ± 0.54
Missed	0.18 ± 0.49	1.02 ± 0.22	0.81 ± 0.41	0.22 ± 0.33	0.16 ± 0.44

Shots In Possession (n)					
Single	0.87 ± 0.23	7.32 ± 0.10	3.90 ± 0.19	2.04 ± 0.15	1.95 ± 0.20
Multiple (Rebound)	0.08 ± 0.77	0.01 ± 0.34	0.01 ± 0.65	0.05 ± 0.51	0.06 ± 0.69
Multiple (Retention)	0.08 ± 0.44	<0.01 ± 0.20	<0.01 ± 0.37	0.10 ± 0.29	0.01 ± 0.39

Shot location: D = defensive. NL = neutral left. NR = neutral right. NC = neutral centre. OL = offensive left. OR = offensive right. OC = offensive centre.

No differences were observed between match-play and training activities in the frequency of shots following a pass. However, shots following a dribble were more frequent in technical (1.73 $n \cdot min^{-1}$; $p<0.05$; moderate ES: 1.00 ± 0.32) and skills practice (2.59 $n \cdot min^{-1}$; $p<0.05$; moderate ES: 1.17 ± 0.38) activities, whilst shots following a regain were less frequent in the practice/training state activities (technical practice: 0.16 $n \cdot min^{-1}$; $p<0.001$; large ES: 1.69 ± 0.29; skills practice: 0.16 $n \cdot min^{-1}$; $p<0.001$; large ES: 1.70 ± 0.35). The individual possession duration (1.55 s; $p<0.01$; large ES: 1.46 ± 0.37) of the shooting player was longer during skills practice compared to match-play.

The frequency of shots with the shooter in motion were more frequent in both technical practice (6.23 $n \cdot min^{-1}$; $p<0.001$; large ES: 1.68 ± 0.29) and skills practice (3.16 $n \cdot min^{-1}$; $p<0.01$; large ES: 1.24 ± 0.35) whilst shots with a stationary shooter were less frequent (technical practice: 0.28 $n \cdot min^{-1}$; $p<0.001$; very large ES: 2.67 ± 0.29; skills practice: 0.27 $n \cdot min^{-1}$; $p<0.001$; large ES: 1.77 ± 0.35), when compared to match-play.

Shots were taken more frequently (0.01 – 0.03 $n \cdot min^{-1}$; $p<0.05$ – $p<0.001$; moderate - large ESs: 1.10 – 1.94) from neutral zones (NL, NC, NR) and less frequently from the offensive right zone (OR: 0.29 $n \cdot min^{-1}$; $p<0.01$; large ES: 1.46 ± 0.37), during conditioned games. Shots taken from the offensive central zone (OC) occurred more frequently during technical practice (3.28 $n \cdot min^{-1}$; $p<0.001$; large ES: 1.32 ± 0.30) and skills practice (2.22 $n \cdot min^{-1}$; $p<0.05$; moderate ES: 1.12 ± 0.35). There were no differences in the number of shots observed from the defensive (D) or offensive left (OL) zones during competition and training.

Slap shots occurred less frequently in technical practice (0.20 $n \cdot min^{-1}$; $p<0.01$; moderate ES: 1.04 ± 0.30) and skills practice (0.20 $n \cdot min^{-1}$; $p<0.05$; moderate ES: 1.10 ± 0.36), whilst wrist shots were more frequent during technical practice (5.78 $n \cdot min^{-1}$; $p<0.001$; large ES: 1.98 ± 0.29) and skills practice (2.84 $n \cdot min^{-1}$; $p<0.01$; large ES: 1.43 ± 0.35) activities. There were no differences between competition and training activities in the frequency of backhanded shots taken.

There were no differences in the number of goals observed during competition and training. However, a greater number of saves were observed during technical practice

(3.90 $n \cdot min^{-1}$; $p<0.001$; large ES: 1.92 ± 0.29) and skills practice (1.75 $n \cdot min^{-1}$; $p<0.01$; large ES: 1.31 ± 0.35), whilst blocked shots occurred less frequently during technical (0.17 $n \cdot min^{-1}$; $p<0.001$; very large ES: 2.01 ± 0.29) and conditioned games (0.16 $n \cdot min^{-1}$; $p<0.05$; moderate ES: 1.15 ± 0.36), and missed shots were more frequent (0.83 $n \cdot min^{-1}$; $p<0.05$; moderate ES: 0.93 ± 0.29) during technical practice, compared to competition.

Possessions that resulted in a single shot occurred more frequently during technical practice (6.46 $n \cdot min^{-1}$, $p<0.001$; very large ES: 2.52 ± 0.29), skills practice (3.03 $n \cdot min^{-1}$, $p<0.001$; large ES: 1.77 ± 0.35), and phase of play (1.09 $n \cdot min^{-1}$; $p<0.05$; moderate ES: 1.01 ± 0.32). There were no differences in the frequency of possessions that produced multiple shots via a rebound. However, possessions that generated multiple shots via retained possession after the initial attempt occurred less frequently during technical and skills practice (0.08 $n \cdot min^{-1}$; $p<0.001$; very large ESs: 2.50 – 2.64).

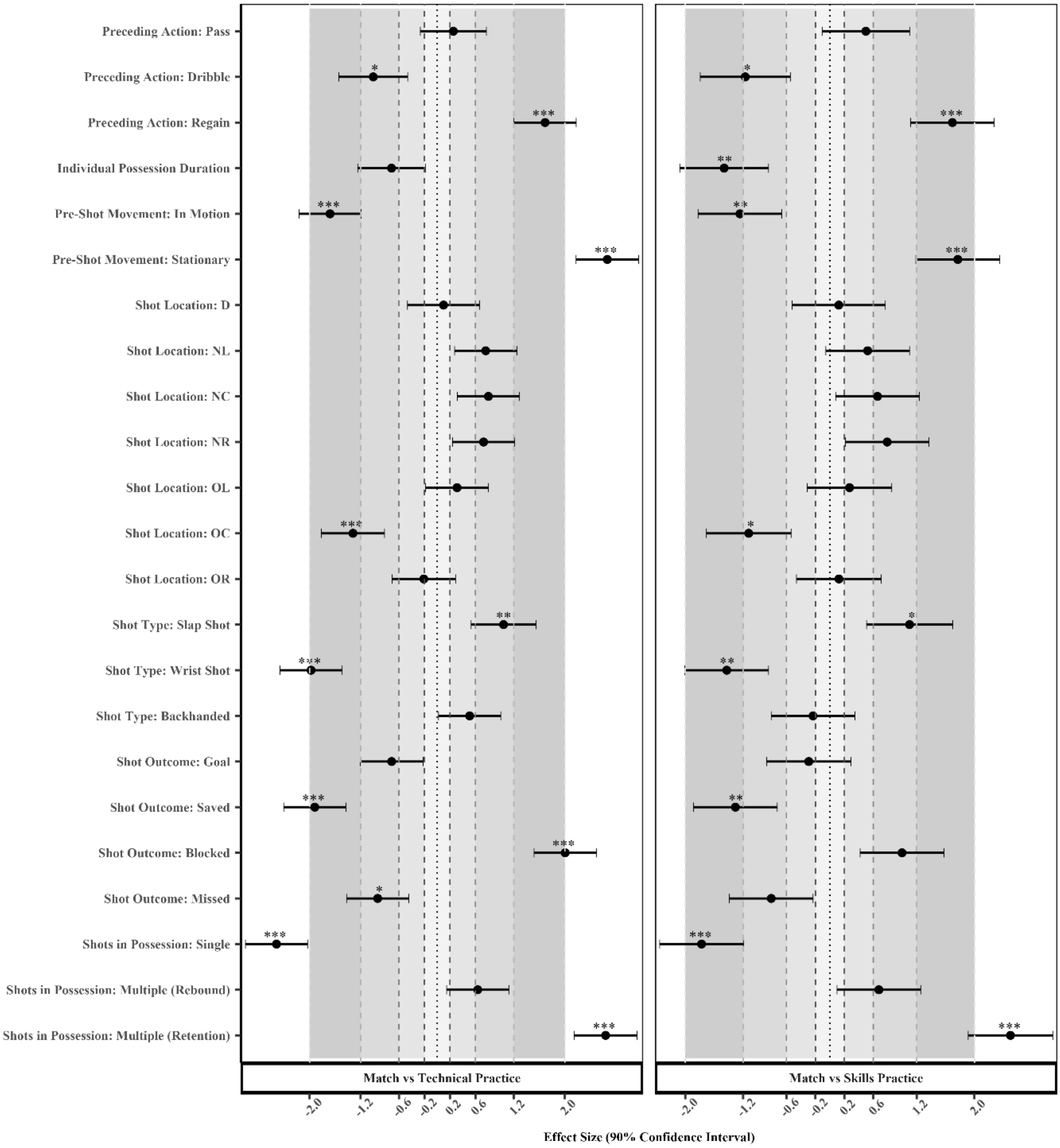

Figure 4.3. Effect size (± 90% CI) of differences in estimated mean and statistical significance of shot-based variables of shooting events between match-play and training/practice state activities. *Statistically significant difference ($p < 0.05$*, $p < 0.01$**, $p < 0.001$***).

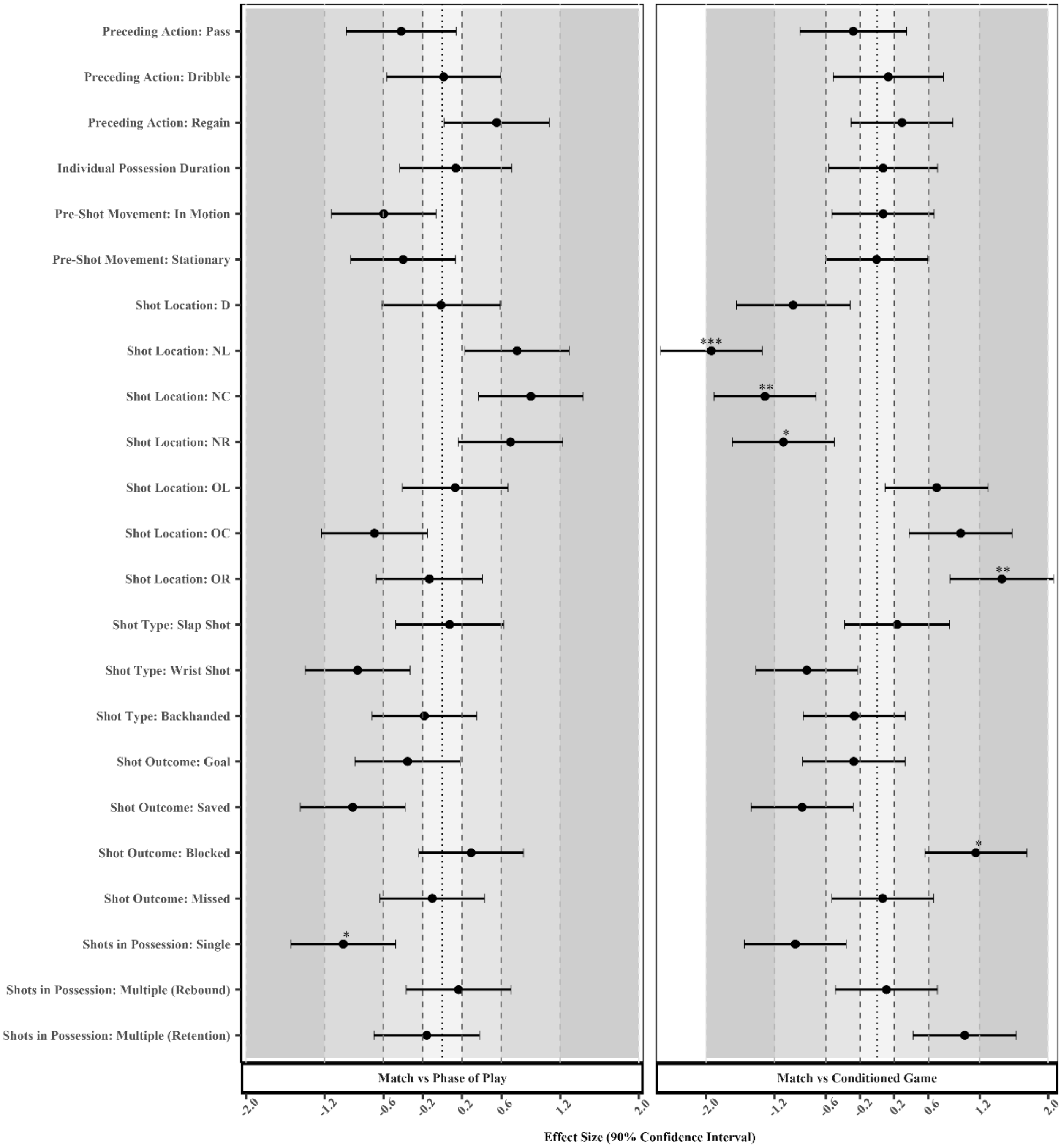

Figure 4.4. Effect size (± 90% CI) of differences in estimated mean and statistical significance of shot-based variables of shooting events between match-play and playing state activities. *Statistically significant difference (p < 0.05*, p < 0.01**, p <0.001***).

4.4 Discussion

This chapter quantified and compared the technical-tactical characteristics of shooting during competition and training activities in senior men's domestic ice hockey. This study provides a novel and comprehensive examination of representativeness, utilising a comparatively large dataset, and incorporates multiple activity types (Chapter 2). It also presents the first direct comparison of match and training demands in ice hockey, and the first analysis of how shooting behaviours emerge across different training activities within an under-examined competitive context (Chapter 2). By describing the structure and sequencing of training activities, this study offers coaches insight into how practice environments can shape the conditions athletes experience. This level of detail directly supports more intentional planning and reflection, enabling coaches access to empirical data of their training and the ability to evaluate whether their training activities genuinely prepare athletes for the demands of competition. Overall, the findings demonstrate that training activities did not reproduce the conditions that shape shooting behaviour in competition. Further, specific variables varied due to the structural design (i.e., number of players prescribed, or configuration of the playing surface) of each activity (e.g., possession location and number of defenders in technical practice). These findings highlight the need for coaches to evaluate how training activities and their constraints can shape shooting outcomes to create training environments that genuinely support the behaviours in which they intend to develop.

Set-play and counter-attack shots contributed only a small proportion of goals in matches (n=8; 11.4% of all goals), with a 2.7% and 12.8% conversion rate for set-plays and counter attacks, respectively. However, these values should be interpreted cautiously as match inter- and intra-rater match reliability was poor within possession type (Appendix 4.3), limiting the strength of any conclusions regarding possession types. Previous research has shown that faceoffs can influence short-term scoring probabilities, particularly when won in the offensive or defensive zones.[255, 256] Similarly, counter attacking situations (otherwise known as fastbreaks,[257, 258] offensive transitions[241, 259] or rush[35]) are widely recognised across invasion sports,[240, 260, 261] including ice hockey,[245] as valuable goal scoring opportunities.

Although these possession types appear beneficial in existing research, this pattern was not observed in this study. One explanation may be due to the difference in competitive standard between this sample and the elite contexts examined in previous work (e.g., National Hockey League (NHL),[255] Svenska HockeyLiigan,[35] NCAA[256]) or due to the poor reliability for possession types (Appendix 4.3). Acknowledging this limitation, the absence of set-play and counter-attacking shots within training activities suggest that players may have relatively little exposure to these potentially advantageous situations. It is unclear, however whether these situations are under-represented in training because they occur infrequently in competition, or whether they occur infrequently in competition because players have limited opportunities to practise them. Further research is warranted which investigates how training design, training behaviours and match behaviours may interact.

When analysing the shot itself, saved shots and goals were more frequent in conditioned games (66.4% and 14.7%, respectively), both exceeding match values (56.2% and 7.1%). This may be a consequence of the proportionally less frequent number of blocked shots in conditioned games (Table 4.3), suggesting reduced defensive engagement or pressure, rather than increased attacking effectiveness.[35, 262] Blocked shots were also less proportional in technical practice (0.8%) compared to matches (18.2%). This aligns with principles of RLD, particularly functionality,[26] as reducing defensive pressure removes key informational aspects that comprise the perceptual-cognitive demands of shooting in competition.[28] A similar pattern was observed for shot type, with slap shots substantially less proportional in all training activities, most notably in technical (3.5%) and skills practice (3.3.%) compared to matches (21.9%). This suggests the situations in which players typically perform slap shots in competition were largely absent from training activities. Evidence highlights how slap shots involve a greater preparatory movement, when compared to the more accurate wrist shots.[263, 264] Although defensive pressure was reduced in training, the specific situations which typically produced slap shots in competition (e.g., longer range shooting)[263] were largely absent. As a result, players more frequently selected wrist shots, which appeared as the more functional choice. As a result, clearer understanding of the contexts in which different shots emerge would help coaches design training activities that more effectively elicit match-relevant behaviours.

The number of passes in possession also differed, with 63.1% of match possessions resulting in a shot featuring one pass or fewer, whereas training, particularly practice/training states, had a higher proportion of multi-pass sequences (≥2 passes: technical practice = 64.4%, skills practice = 55.9%, match = 36.8%). These distributions indicate that shots in training were more frequently preceded by extended possession sequences compared to match-play. Together these patterns indicate that the constraints and informational cues available in training shaped shooting behaviour in ways that differed from the affordances present in match-play. Training not only simplified offensive sequences but also reduced functionality, demonstrating a lack of representativeness relative to competition.[26, 28] For coaches, these findings illustrate how constraints embedded into training activities shape the informational cues which directly influences the representativeness of shooting behaviours, and emergent possession structures. By examining the possession structures within training activities, coaches can identify where players may be afforded too much (or too little) time for structural build-up, resulting in possession structures that differ from those typically observed in matches (i.e., minimal passes per possession). This provides a practical basis for coaches to review the possession structures embedded within training activities, particularly the number of passes preceding shots, and adjust task constraints to better reflect the demands of competition.[22]

Both technical practice and skills practice produced greater possessions with one or no defenders, consistent with their definitions (Table 4.1) as activities focused on isolated technical execution under limited or controlled pressure.[152] By design, technical practice is decontextualised to the demands of match-play, with reduced functionality and action fidelity, which may be less representative than other more contextualised training activities (i.e., phase of play, conditioned game). A similar pattern was observed in conditioned games, where the only variables that differed from match-play were those that naturally emerged from the task constraints within the activity. For example, counter-attacks occurred far less frequently in conditioned games compared to match observations. This was likely due to the utilisation of predictable restarts (i.e. the coach feeding to the same team) or stoppages following a turnover, which stabilised possession and limited opportunity for rapid transitions. These structural features were observed during data collection but were not formally coded, as they fell outside the scope of the analysis. Phase of play activities also showed expected structural differences, such as longer possession durations, and more frequent open-play sequences, reflecting their emphasis on structured attacking pattern, characterised by multiple passes and more stable possessional build up. Recognising how different task constraints shape the behaviours that emerge allows coaches to adjust those constraints to create the situations they want their players to experience. Together, these observations reinforce the value of pairing drill-based and game-based activities, as each fulfils a different function (i.e., technical practice aims to isolate and develop technical skills) and contributes uniquely to player development.[106, 214]

As in any research, there are limitations which should be acknowledged. Firstly, this study had a single-team sample. Future research should adopt a multi-club sample to ensure findings are representative of the wider population (i.e., senior men’s domestic ice hockey). Secondly, data were collected over a single season, and due to logistical challenges (e.g., delay in institutional ethical approval, mismatch between the start of the season and start of the lead researcher’s postgraduate studies), some training sessions (~28%) and matches (~68%) were not collected during this season. Further, the match sample predominantly consisted of home matches. Due to the potential influence of match location on technical-tactical performance during competition, and indeed wider contextual variables (e.g., team and opposition quality,[44, 236] crowd hostility,[265] match-to-match variability[142, 266, 267]), future research should capture a greater number of matches over a greater time period to account for such variability within performances, and should examine the match-to-match variability of shooting performance, and consequently, the session-to-session variability of representativeness of training activities. Lastly, the quality of the recorded footage (i.e. restricted positioning and limited elevation within the rink due to access and venue dimensions) prevented a more detailed notational analysis process (e.g., number of touches, defender and goalkeeper interactions). This constraint also likely contributed to the lower inter- and intra-rater reliability observed in this study (Appendices 4.3 and 4.4). Future research should aim to facilitate data collection procedures which enable further detailed and comprehensive analysis processes.

4.5 Conclusion

This research provides an in-depth examination of the representativeness of shooting during training activities in senior men's domestic ice hockey. First, the research reported that set-play and counter-attacking shots contributed only a small proportion of goals in matches. Their limited presence in training suggests that players have fewer opportunities to develop these advantageous situations. Second, defensive pressure was consistently reduced across training activities, reflected in fewer blocked shots and a lower proportional use of slap shots compared to matches. This indicates that key informational and contextual demands of match shooting were often absent in practice. Third, possession frequently began in different locations in training than in match-play, with predefined restarts creating more stable and predictable attacking conditions. These starting points shaped the subsequent attacking sequences, highlighting the importance of deliberately planning the starting points of training activities to support representativeness. Together, these findings contribute population-specific insights into how training design shapes shooting behaviours in domestic men's ice hockey, a context widely underrepresented in research. This further provides practitioners with clear, evidence-informed considerations for creating more representative training environments, particularly regarding the inclusion of transitional situations, and the deliberate design of the starting points of drills. Future research should examine the alignment between coach intentions and the behaviours that training activities actually elicit. Understanding whether discrepancies arise from planning decisions or from challenges in executing session goals would strengthen the evidence base for representative session design. Additionally, expanding research across broader teams and competitive levels would help establish whether the patterns observed here a consistent across the sport or specific to this sample, thereby supporting the development of more generalisable guidance for ice hockey practitioners.

CHAPTER 5: GENERAL DISCUSSION

The purpose of this chapter is to summarise and synthesise the findings of this thesis, discuss practical applications for different stakeholders, highlight the limitations of this thesis and provide recommendations for further research.

5.1 Summary of Findings

This thesis aimed to understand the representativeness of training structures within a British, senior, domestic ice hockey setting.

Firstly, a systematic review was conducted of the scientific literature evaluating the representativeness of training activities in sports (Objective 1; Chapter 2). The research identified methodological inconsistencies, limited evidence base and included studies typically observed a lack of representativeness within training activities. The review also highlighted that studies typically analysed representativeness of training activities in relation to the whole-match, with only two studies analysing specific moments or discrete phases of play (I-50 entries,[33] disposals[81]). The findings from Chapter 2 revealed no studies evaluating the representativeness of training activities in ice hockey, and therefore highlighted an area for future research.

Prior to evaluating the representativeness of training activities in ice hockey, an understanding of which training activities are typically implemented within ice hockey was firstly required. Therefore, the distribution and organisation of training activities within a senior men's domestic ice hockey team across a competitive season were described (Objective 2; Chapter 4). The research revealed a dominance of technical practice and focus on shooting, alongside a consistent 'part-whole-part' within-session structure, illustrating how training session are structured across a season. With this understanding of the frequency and organisation of training activities, the research could progress to analysing the representativeness of a specific moment prominent during training (i.e., shooting) in relation to match environments.

Finally, to evaluate the representativeness of training activities, the technical-tactical characteristics of shooting during competition and training activities was quantified and compared (Objective 3; Chapter 4). This demonstrated that certain segments of play (e.g., possessions leading to shots) were less representative of match-play, even in contexts designed to elicit representative shooting situations. Set-play and counter attacking shots (typically associated with higher scoring probabilities in the wider literature) occurred infrequently in training and did not produce greater scoring efficiency. Alongside this, defensive pressure was lower than match situations across training activities, reflected in fewer blocked shots and a reduced utilisation of slap shots compared to match-play. Finally, possession frequently began in different locations within training activities, likely due to pre-defined start points within training that created more stable and predictable attacking conditions. Together, these findings prompt coaches to critically reflect on the possession structures that emerge in training and how the design and starting points of their training activities can be manipulated to enhance representativeness.

5.2 Synthesis of Findings

This thesis offers several novel contributions to the wider literature. Firstly, it demonstrates that training activities often assumed to be representative (i.e., match simulations) frequently fall short of reproducing match-like demands. Secondly, it presents the first detailed synthesis of within-session sequencing of training sessions, revealing consistent structural patterns. Finally, the thesis delivers the first in-depth analysis of training structure and representativeness within ice hockey and expands the evidence base available to practitioners operating beyond elite contexts.

Chapter 3 provided the first analysis of within-session activity sequencing in ice hockey, showing that training within this sample followed a consistent part-whole-part structure. Sessions typically opened with technical activities (e.g., skills practice), progressing into playing state tasks (e.g., phase of play), which offer higher representativeness,[61] before returning to similar technical activities in the latter stages of training. Alongside this, the consistency of these sequencing patterns may have become habitual[206] rather than intentionally aligned with performance demands.[111, 201] When considered alongside Chapter 4’s finding that some training activities are inherently less representative by design,[152] it suggests that coaches may not always prioritise adjusting or refining these activities to improve their representativeness. Knowledge of within-session training activity sequencing allows practitioners to identify where representative training occurs within a session and how these patterns shape the opportunities afforded to players.[98] Understanding where (within a training session) and how these training activities are prescribed is therefore critical. Coaches need to judge whether each drill's outcomes genuinely align with performance demands, and to be clear about when tasks should be representative and when not. Maintaining this clarity ensures that training design reflects competitive performance rather than defaulting to habit.[206]

Chapters 3 and 4 highlighted the prominence of shooting within both training prescription and during matches. As previously discussed, shooting is a key determinant of match outcome,[35, 220, 221, 244] however, the constituent elements of shooting situations differed considerably between training and competition (e.g., number of defenders: 4 and 5, numerical balance: inferiority, possession type: counter-attack; Tables 4.2 and 4.3). The discrepancies between the two environments are particularly notable given that shooting is one of the most frequent technical actions in ice hockey,[35, 268] and was the most prominent primary skill observed within this dataset (Table 3.2). Despite this, the possession characteristics of these shots (e.g., possession location and players involved) often differed substantially from match observations. This was further highlighted by low conversion rates from high success environments (set-play[255, 256] and counter-attack;[245] Section 4.4). Collectively, these findings indicate the importance of coaches reflecting on whether key technical actions are being practice under conditions that genuinely reflect performance demands they are intended to develop.

When task constraints differ between training and competition, changes in one variable may have consequential impacts on others, and therefore, implications for the actions of players. For example, match-like defensive numbers (four and five) were consistently under-represented in training activities (Chapter 4), and when combined with a low frequency of blocked shots, this suggests reduced defensive pressure within training environments. Together, these factors indicate a change in the type and complexity of informational cues[79] and functionality of the task.[26] Such changes can influence shot quality, as lower task difficulty can lead to decreased individual effort[269] and diminish quality of technical actions.[270]

Chapter 3 showed distinct trends in how sessions are structured, with notable consistency across the season. Such consistency aligns with research suggesting that aspects of training design can become habitual[206] rather than intentionally linked to performance demands. At the same time, some training activities (e.g., technical practice) are expected to be less representative by design.[152] This is particularly relevant when routine (i.e. habitual) structures risk limiting the development of activities as they are assumed to be 'non-representative'. Coaches therefore need to reflect on whether the outcome of each activity genuinely aligns to performance demands. Maintaining clarity about when tasks should be representative and when they should not, so that training design reflects competitive performance rather than defaulting to habit.

Amateur ice hockey offers a unique environment in which several broader issues in representative training research become more pronounced (e.g., examples without underpinning data, overly technical language which is not coach-friendly, relying on data from a singular performance environment, such as, match-only observations). Both observational studies (Chapter 3 and 4) in this thesis directly address gaps identified in Chapter 2, methodological limitations of existing work, and the lack of research involving diverse populations. By providing detailed descriptions of training structures and the most comprehensive analysis of shooting representativeness to date within an amateur setting, the thesis contributes both methodological precision and greater population diversity to the academic field. Importantly, the combined findings demonstrate that the challenges previously reported of representative training also appear in amateur environments. This suggests that these issues are not confined to specific performance levels or sporting cultures but instead reflect wider systematic issues within coaching planning and delivery.

5.3 Practical applications

5.3.1 England Ice Hockey (National Governing Body)

Aligned with England Ice Hockey's 2023-2032 strategic goal to "increase and develop coaches",[107] the findings of this thesis offer several insights that can support the organisation's wider ambitions. The following practical applications outline how England Ice Hockey can draw on this evidence to strengthen coach education provision and embed representative design principles across the sport.

1. <u>Develop and deliver coach education programmes that emphasise session design (i.e., activity sequencing and representative training activities).</u>

Throughout Chapter 3, distinct patterns emerged in how training was structured within sessions (e.g., consistent distributions of practice states and playing states, and sequences of three technical practice activities starting session). As the first study to quantify within-session structures in ice hockey, these findings highlight the practical importance of deliberate planning and how sequencing influences both training demands and the representativeness of practice. These findings reveal the value in coach-education programmes teaching practitioners how to design sessions with purposeful sequencing, including when to taper or increase training demands, balancing practice- and playing-state activities, and how to structure sessions to achieve targeted outcomes. Given that playing-state activities tend to be more physically demanding than practice states[136] improved understanding of within-session load management would further support safer[158] and more effective practice design. As all coaches are required to hold a recognised England Ice Hockey coaching qualification,[271] integrating guidance on activity sequencing and within-session organisation into these programmes would ensure that practitioners develop a consistent evidence-based foundation for planning and delivering training.

Chapter 4 highlighted a clear lack of representativeness across the observed training activities, providing strong rationale for embedding explicit instruction on representative design within England Ice Hockey's coach-education pathways. It is well established that exposing athletes to environments that replicate competitive demands supports decision-making,[27] and skill development,[26] yet the findings of this thesis demonstrate that current training structures (regardless of sport) do not consistently provide these opportunities. This gaps suggests that coaches may rely on habitual planning[111] or limited knowledge regarding how representative training is designed.[115] Therefore, coach-education programmes should include practical guidance on how to design, deliver and review representative tasks, including how to manipulate constraints to replicate match-play demands and how to evaluate whether an activity genuinely reflects competitive demands. Providing coaches with concrete examples, design principles and opportunities to practise constructing representative activities would broaden their repertoire of training prescription and ensure that training environments more accurately represent match conditions.

2. <u>Engage in collaborative research with higher education institutions to develop the evidence-base within ice hockey</u>

Throughout the thesis it became clear that wider research within ice hockey is needed to strengthen the evidence base available to coaches and practitioners. Chapters 2 and 4 highlighted that training activities were frequently not representative of competition, and that little research has examined these issues within ice hockey specifically. As the first study to quantify both within-session structures, the distribution of training activities across a season and the representativeness of shooting behaviours in this sport, this thesis demonstrates the value of further investigation into how training is designed and delivered. Given that training practices vary according to coach philosophy[80] and competitive standard,[136] collaborative research with higher education institutions would help identify broader patterns across teams, age groups and genders, and establish whether certain approaches to representative training are associated with more effective coaching outcomes. Such research would also address a common limitation in the current thesis regarding single-team samples within studies enabling league-wide or multi-club research practices. Further, embedding researchers within these applied environments would aid data-collection processes, streamline the flow of information and make large-scale (and time-consuming) research opportunities more feasible. Expanding this evidence base will require longer-term organisation-level investment, but supporting further research of this nature would help England Ice Hockey identify broader patterns and strengthen understanding of how representative training is being delivered across the sport.

5.3.2 Coach Educators

To ensure that coaches receive accurate and evidence-informed guidance, it is essential that coach educators are familiar with emerging research on training structures and representativeness within ice hockey. Three recommendations are outlined to support coach educators in strengthening the quality, accuracy and relevance of the information they deliver.

1. <u>Provide targeted training for coach educators on representative practice design.</u>

Before representative structures can be embedded within formal coach education programmes, coach educators themselves must require a clear understanding of the principles underpinning representativeness and how these can be applied in practice. Representativeness does not simply emerge because an activity resembles gameplay (i.e., match simulations). Chapter 2 revealed that many training activities expected to be representative did not align with competition demands, emphasising the need for coaches to assess the full environment, through a data-informed approach and not just subjective interpretation of how a representative a training activity looks. This consists of analysing; the technical action being performed, the possession structure or build up to the action (Chapter 4), and its contextual constraints (e.g., time pressure, defensive presence, spatial constraints), all of which affect their decision making.[59] Chapter 4 further showed that manipulating one constraint may inevitably have implications other (e.g., reduced defensive engagement, increases goals scored), often due to changes in functionality and action fidelity.[89] These trade-offs are not inherently negative, however, coaches must understand how constraint interactions influence the learning environment and whether these changes support the intended objective of the activity. Targeted training for coach educators would equip them to deliver this level of analysis, enabling them to guide coaches in designing purposeful, and representative aligned training activities.

2. Embedding critical discussions into coach education practice relating to when representative training is appropriate and when it is not

While representative training is valuable for promoting game-like behaviours, it is not necessary (or desirable) for every activity within a session to replicate competition demands. Coach educators therefore need to possess, and later provide, clear guidance on when representativeness may be appropriate and when more isolated, non-representative practice may be better suited to the activity or session objectives. Technical or skill-focused activities, for example, would lose their purpose if performed under full game-representative conditions. Alternatively, activities such as match simulations are essential to maintain the contextual and cognitive information observed in matches, to promote decision making[169] and match-like behaviours.[138] Chapter 3 highlighted that playing-state activities, designed to replicate match-like behaviours more closely,[61, 79] tended to occur in greater proportion at distinct points in the season when fixture-dense or high-importance fixtures approached, illustrating how coaches (whether knowingly or not) naturally balance representative and non-representative practice across a season. To support this, coach educators should support coaches to reflect upon their own practice, critically evaluating whether individual activities maintain the informational constraints that drive performance in matches (e.g., time pressure,[96] defensive pressure[272]) and to critically evaluate whether deviations from these constraints are intentional or appropriate. This assists coaches in recognising the purpose of activities and how to manipulate constraints to make them representative to matches. By embedding this understanding within coach-education content, coaches can make informed choices about when to prioritise representativeness and when to focus on isolated skill development.

3. Integrate existing evidence-base into coach education programmes

Using real training examples can strengthen the quality and relevance of coach education material. This thesis offers a data-driven account of how training is structured across a season (Chapter 3) and how specific activities (i.e., shooting) compared to match contexts (Chapter 4). By drawing on these findings, coach educators can embed concrete real-world examples into their delivery materials, helping coaches visualise what representative and non-representative activities may look like in practice. These examples can also be used to contextualise and translate complex concepts such as activity sequencing and representative design. In doing this, content may be easier for coaches to understand and implement. Incorporating evidence-based training and match structures in coach-education content therefore provides a practical bridge between research and applied coaching.

5.3.3 Coaches and Practitioners

Finally, the findings of this thesis also offer practical guidance for coaches and practitioners. Building on these insights, three recommendations are presented to support coaches in designing training environments that more effectively prepare players for performance.

1. Implement deliberate planning and reflective processes into their practice

Chapters 2 and 4 highlighted how training activities frequently failed to replicate competition demands, reinforcing the need for coaches to adopt deliberate planning and reflective processes within their practice. Given the inherently complex and dynamic nature of coaching,[97, 108, 109] effective planning requires coaches to set clear goals, design activities to match these goals,[113] and to make informed decisions about when representative and non-representative practice is appropriate (in this context). Equally, reflection must move beyond informal conversations between practitioners[109] and instead incorporate empirical evidence surrounding player behaviour, and how constraints shaped performance (Section 2.1). By engaging with these two processes, coaches can become more aware of the outcomes and environments they are creating, allowing coaches to refine their practice. From this, training environments can be designed to more effectively prepare athletes for performance.

2. Utilise match data to inform training design

Using match data to guide training design enables coaches to create environments that more accurately reflect the demands of competition. This thesis provides novel insight into the representativeness of training activities, showing clear misalignment between training and match behaviours (Chapters 2 and 4). Further the thesis highlights the value of using objective match data to inform practice (Chapter 4). Coaches can draw on physical data (Section 2.3.5.3) to replicate the intensity and work-rest ratios experienced in games,[36] ensuring that training loads mirror competitive demands. Information regarding possession structures (Section 4.3.1) can be used to design activities that recreate tactical patterns players encounter in matches. Technical data (Sections 2.3.5.1 and 4.3.2), including shot types, shot location, and the number of passes, can help coaches manipulate, adapt or constrain specific training scenarios to promote game-relevant behaviours. By embedding these forms of match data into training design, coaches can ensure that the constraints, informational cues and movement demands present in practice align with those that shape performance in competition. While the level of detail available in elite environments (e.g., NHL teams) may not be feasible within the domestic context examined in this thesis, basic form of match-derived information (e.g., common shot locations, typical possession structures) can still be utilised by coaches to inform activity design.

3. Plan and structure training, considering the distribution of training activities within and between sessions

Chapter 3 revealed clear and consistent pattern in how training sessions were structured, with coaches typically following a part-whole-part progression (Chapter 3). While macro-cycle (year-long) trends aligned with expected shifts in training emphasis (as important or fixture-dense periods approached)[66, 228], the within-session sequencing was more notable, showing that the coach naturally scaffolded learning moving from isolated technical practice into playing state activities. By reflecting on these patterns and planning sessions with this structure in mind, coaches can ensure that activities build and progress logically toward the training session outcomes they want to achieve. Embedding this level of planning encourages coaches to design sessions that are purposeful, progressive, and aligned with the behaviours they want athletes to develop.

5.4 Limitations

Whilst this thesis makes a valuable contribution to the limited evidence-base regarding representativeness of training activities, there are several limitations which should be acknowledged. Firstly, only a single team was examined across the observational studies (Chapters 3 and 4). This occurred primarily due to practical constraints, including limited access to clubs (e.g., geographical location, institutional resources and training schedules) and poor alignment between the start of the competitive season (September) and the start date of the lead researcher's postgraduate studies (October). These factors meant that expanding the sample beyond one team was not feasible for this project. Consequently, the findings may not be generalisable to the wider senior men's domestic ice hockey population, as differences in coaching philosophies, training schedules, and team-specific strategies may lead to other teams exhibiting different training structures and match outcomes.

Secondly, both observational studies (Chapters 3 and 4) captured only a partial season of data. This restricts the extent to which findings can be generalised across a full competitive season. Within the sample, only ~72% of training sessions and ~32% of matches were recorded across the season. Seasonal[234-236] and match-to-match variation[142, 266, 267] are well established in other invasion sports, meaning that examining a partial, singular season presents difficulty when determining whether the patterns observed here would persist across multiple seasons. In addition, contextual factors such as home-field advantage,[31, 46, 253, 265] and variation in opposition tactics[45] and quality[44, 236] were not considered within each chapter. This is especially pertinent given that ~86% of the observed matches were home fixtures. Together, these factors limit the extent to which findings can be applied across teams, seasons or other competitions, and highlight the need for future research to examine multiple seasons and more complete samples (i.e., a complete season).

Thirdly, this thesis only captured a partial representation of the wider coaching and training landscape. The observational studies focused exclusively on-ice training and match-play, meaning that off-ice preparation (such as strength and conditioning, warm-ups or cool-downs) was not included. This limits the extent to which the findings represent the full scope of the team's preparation, as important components of the training process (e.g., physiological benefits[219] and recovery[273, 274]), were not analysed. As such, the present findings offer a novel insight into the on-ice structures of an amateur ice hockey team, but they should not be interpreted as a complete account of the team's overall training programme.

Lastly, the quality of the recorded footage presented a clear limitation across Chapters 3 and 4. Restricted filming angles and limited rink access reduced the precision of the notational analysis and constrained the range of variables that could be captured, contributing to the lower reliability observed (Appendices 4.3 and 4.4). This limits the extent to which the findings can be compared across contexts or aligned with existing literature which used more comprehensive observational setups.[32] As a result, the findings should be interpreted with caution, and future research would benefit from improved data collection procedures to enable more detailed and consistent analyses.

5.5 Future research

Throughout this thesis, several areas and recommendations for future research have been suggested in respective chapters. Firstly, improving the reporting of data collection procedures and methodological rigour would strengthen the evidence base available to coaches and practitioners (Chapter 2). Secondly, greater attention should be directed toward within-session activity sequencing to understand how the ordering of tasks shapes representativeness and player engagement (Chapter 3). Third, future work should broaden the examination of how constraints interact, moving beyond analysis which considers variables in isolation (Chapter 4). Collectively, these recommendations aim to advance understanding of representative training design and support coaches in planning and reflecting on their practice.

The absence of data capturing coaches' intended outcomes in Chapter 4 highlights a critical avenue for future research. Research examining coach intention in relation to session design is limited,[275] yet understanding what a coach aims to elicit from a drill (e.g., minimum number of passes before a shot)[96] is essential for evaluating representativeness. Without capturing a coach's intended outcomes, it becomes impossible to evaluate whether a training activity reflects effective planning, or whether discrepancies from intended and actual performance outcomes reflect poor design and execution or simply differing aims. Existing research comparing coaches' intended session RPE with athletes' actual perceptions consistently shows disagreement between the two.[275-277] This highlights the value of future research examining whether similar discrepancies exist between the environments coaches *intend* to create in training compared to the environment they *actually* create. This is reinforced by findings in Chapter 2, whereby activities labelled as match simulations often failed to reproduce the competitive demands they were assumed to produce. Rather than reliably mirroring match conditions, a substantial proportion of variables differed between training and competition, raising important questions about how closely such activities align with the demands they are intended to represent. Capturing coach intention alongside observed training demands would offer a more complete understanding of coaching practice and support coaches in refining the delivery and design of practice tasks.

The prominence of management/transition states observed in Chapter 3 highlights an important avenue for future research. These periods, often comprising rest periods[218] and coaching interactions,[80, 218] are known to play a critical role in shaping learning opportunities for athletes.[217] In the present sample, management/transition states accounted for over a quarter of total training time (27.2%). Although the present thesis did not analyse the content of these states, existing work (utilising the CAIS)[217, 218] shows that coaches often utilise the primary behaviours of questioning athletes and management style behaviours (i.e. explaining how to execute a drill) during these transitional periods.[217] Examining the structure and function of management/transition states in ice hockey could therefore provide valuable insight into how coaches could scaffold learning, and regulate intensity[278] across a session. Future research should therefore aim to quantify and interpret the coach behaviours and content during these management/transition states. Analysing these behaviours would help clarify how coaches use transitional moments to scaffold learning, regulate physical demands and maintain session sequencing (i.e., rest periods to allow for recovery within training)[80]. Such insights would enable practitioners to better structure these periods to maximise athlete engagement and ensure that the intended learning opportunities are consistently supported throughout a session.

Another direction for future research includes the integration of physical data (e.g., distance covered, heart rate) into analyses of representative training design. To date, no research has examined the representativeness of training activities in ice hockey in relation to physical demands. Evidence from other invasion sports shows that a substantial proportion of physical variables differ significantly between training and competition (57.0 ± 25.2% of variables differing significantly; Chapter 2), indicating that representativeness within training activities cannot be assumed. Conducting similar work in ice hockey would offer important insight into how closely training activities replicate the physical demands of match-play and would support coaches in designing sessions that more accurately reflect competitive environments.

Ice hockey is played under a wide range of rules, constraints, and competitive structures across the world. Variations in rink size, overtime formats and league scheduling create distinct training environments,[252, 279] and the number of fixtures can differ substantially between competitions (e.g., 82 regular-season games in the NHL, compared to 37 in the present sample). These structural differences influence how much time teams have available for practice (e.g., NHL teams have half the amount of strength and conditioning sessions during in-season periods compared to off-season periods)[280] creating implications for how coaches need to adapt to effectively structure their training practices. Similar contextual differences (e.g., geographical, competitive standard) have been documented in other invasion sports (football,[281] rugby union,[282] basketball[283, 284]), indicating that training and match outcomes are shaped by the competitive and cultural environment in which teams operate. In addition to contextual variation, population-specific differences (i.e., between genders) are also well established,[140, 141] yet remain largely unexplored in ice hockey. Future research should therefore develop population-, gender- and context specific evidence by examining representative design across different leagues, nations and competitive structures. A multi-club approach would allow researchers to compare how contextual constraints influence coaching practice and to identify patterns unique to particular competitive environments. This would also provide coaches with clearer guidance on how to adapt practice design to the demands of their own competitive environment.

Chapter 3 highlighted the limitations of analysing a single-season sample, while Chapter 2 reinforced this by highlighting that small sample sizes were common across the wider literature in both training and match contexts. Although multi-season analyses exist for physical demands[19, 272] and injury epidemiology[285] in ice hockey, no study has yet examined how training structures evolve across multiple seasons (in any sport). Evidence from other invasion sports (e.g., football,[286, 287] basketball[288, 289]) show that between season variation in performance outcomes can occur due to factors such as changes in match congestion,[286] evolving coach knowledge,[288] and rule modifications.[289] A multi-season analysis of training structures in ice hockey would therefore provide valuable insight into how coaches adapt practice design over time, the stability (or variability) of training patterns and highlight shifts in representativeness across multiple seasons. Such work would also offer insight into how coaches' understanding of representativeness develops over time, and how their planning processes develop based on the new knowledge they possess. Future research should prioritise multi-season sampling to build a more robust understanding of training design within the sport.

5.6 Personal Reflections

Following a singular ice hockey team's training and match structures across a season offered a rare opportunity to understand how an amateur coach structures training and prepares their team for competition. The practical realities of data collection also shaped my development as a researcher. Training sessions routinely took place between 10pm-12am, and the rink was a 45-minute drive away from where I was based at the time. During data collection, I did not have access to a car, and it initially seemed unlikely that I would be able to capture the footage required for this thesis. After discussing these challenges with the research team, we arranged for the team's strength and conditioning coach to film all training sessions, and a second volunteer later agreed to record the match footage. This required weekly coordination to exchange cameras, upload footage to the secure cloud storage platform and ensure that all recordings were usable. Managing this process demanded consistent communication, organisation and time management, giving me first-hand insight into the collaborative and logistical demands that performance analysts navigate in applied environments. It was a process (though at times stressful) I genuinely enjoyed and reinforced my desire to pursue performance analysis beyond this degree. This experience helped me appreciate that applied research rarely occurs exactly as planned and emphasised the commitment of amateur athletes. Further, it became apparent that effective collaboration is often as important as methodological rigour and precision.

Initially, the sheer volume and variability of the footage felt overwhelming, and it became clear that my original coding approach, overly granular, meticulous (i.e., analysing the shot to the frame in which it took place) and was too slow to be feasible. The entire dataset comprised over 55 hours of footage and the process took significantly longer than I have anticipated (over a month), requiring me to be flexible, reorganise my timelines, and manage the workload in a way that ensured major deadlines were still met. Recognising these challenges forced me to critically evaluate how I was working. I streamlined my coding categories, became more familiar with the coding and performance analysis tools, and reorganised my working timetable to maintain consistency without compromising rigour. Importantly, this experience taught me how to make pragmatic methodological decisions (i.e., learning when precision added value and when precision was counterproductive) resulting in judgements that shaped the remainder of the thesis. At the same time, conducting the systematic review (Chapter 2) and narrowing 1,357 initial studies to just 18 eligible papers made me aware of the methodological inconsistencies within representative design. The process drove the recommendations for interpretation with caution emphasised throughout Chapter 2 and informed further methodological choices (i.e., ensuring transparent reporting of operational definitions and reliability assessments) made in Chapters 3 and 4. Together, these processes taught me to be more critical and efficient in how I approached the subsequent chapters, and helped me develop a clearer sense of the methodological rigour needed in practice.

Finally, halfway through the degree I transitioned from in-person research, with daily access to supervisors and a structured campus environment to working entirely remotely. I moved to the opposite side of the country, away from my usual support network and the routines that had previously shaped my working environment. This shift depicted a significant change in both lifestyle and working conditions. Initially, my productivity dropped below the standards I expected of myself, and it became clear that the self-directed nature of postgraduate research (compounded with pressing deadlines) required me to amend this as soon as possible. Adapting to remote work forced me to improve my ability to structure and the frequency of my email communication, making better use of online meetings, and engage more proactively with support available to me. It also required a more deliberate effort to maintain a consistent 9-5 working schedule. Moving from a university environment with bult-in structure (through lectures, meetings and informal interactions), to a setting entirely dependent on self-motivation, tested both my discipline and time-management skills. Over time, this experience strengthened my ability to work independently, maintain productivity without external structure and to communicate efficiently in a remote research environment.

5.7 Conclusions

The aim of this thesis was to understand and evaluate the representativeness of training structures within a British, domestic ice hockey setting. To do so, the objectives of this thesis were to: 1) systematically review the scientific literature evaluating the representativeness of training activities across multiple sports, 2) describe the distribution of training activities within an amateur, senior men's domestic ice hockey team across a competitive season, and 3) quantify and compare the technical-tactical characteristics of shooting during competition and training activities. To address the first objective, a systematic review summarised study characteristics and all variables (technical, tactical and physical) used to evaluate representativeness (Chapter 2), highlighting a distinct lack of research in amateur settings and the absence of any work in ice hockey. To contextualise this gap, Chapter 3 quantified the between-session and within-session structures of an amateur ice hockey team, providing the first description of how training is organised within this population (Objective 2). Building on this foundation, Chapter 4 examined the representativeness of shooting characteristics within the same training landscape, comparing these to match-play demands to determine how closely training activities reflected competitive environments (Objective 3).

This thesis has highlighted key inconsistencies in how research investigating the representativeness of training activities has been conducted and provides recommendations to improve the rigour and quality of future research in this field. Alongside this, several practical implications are presented for coaches regarding how the plan and reflect on their training activities. The findings also emphasise the need for future research within representative design and within ice hockey specifically, where empirical evidence remains limited. Overall, this thesis offers a novel insight into the training structures, shooting behaviours, and representativeness of a senior domestic men’s ice hockey team, contributing both a detailed account of a performance environment and applied value to researchers and practitioners working within invasion sports.

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Appendices

Appendix 2.1. Criteria for assessing methodological quality of studies[128]

Criteria	Description	Clarification
Reporting		
1	Is the hypothesis/aim/ objective clearly stated?	
2	Are the main outcomes to be measured clearly described in the introduction or methods?	If they are outcomes are first mentioned in the results, answer no.
3	Are the characteristics of the patients included in the study clearly described?	In cohort studies and trials, inclusion and/or exclusion criteria should be given. In case-control studies, a case-definition and the source for controls should be given.
5	Are the distributions of principle confounders in each group of subjects to be compared clearly described?	A list of principle confounders is provided.
6	Are the main findings of the study clearly described?	Simple outcome data (including denominators and numerators) should be reported at all major findings so that the reader can check the major analyses and conclusions.
7	Does the study provide estimates of the random variability in the data for the main outcomes?	In non-normally distributed data, the inter-quartile range of results should be reported. In normally distributed data the SE, SD or 95%CI should be reported. If the distribution of data is not described, it must be assumed that the estimates used were appropriate and the question should be answered yes.
10	Have the actual probability values been reported (0.035 and not <0.05) except where value = <0.001?	
External validity		
11	Were the subjects in the study asked to participate in the study representative of the entire population from which they were recruited?	Study must identify source populations for patients and describe how they were selected. Random sampling is only feasible where a list of all members of the relevant population exists. Where a study does not report the proportion of the source population from which patients are derived, the question should be answered as unable to determine.
Internal validity - Bias		

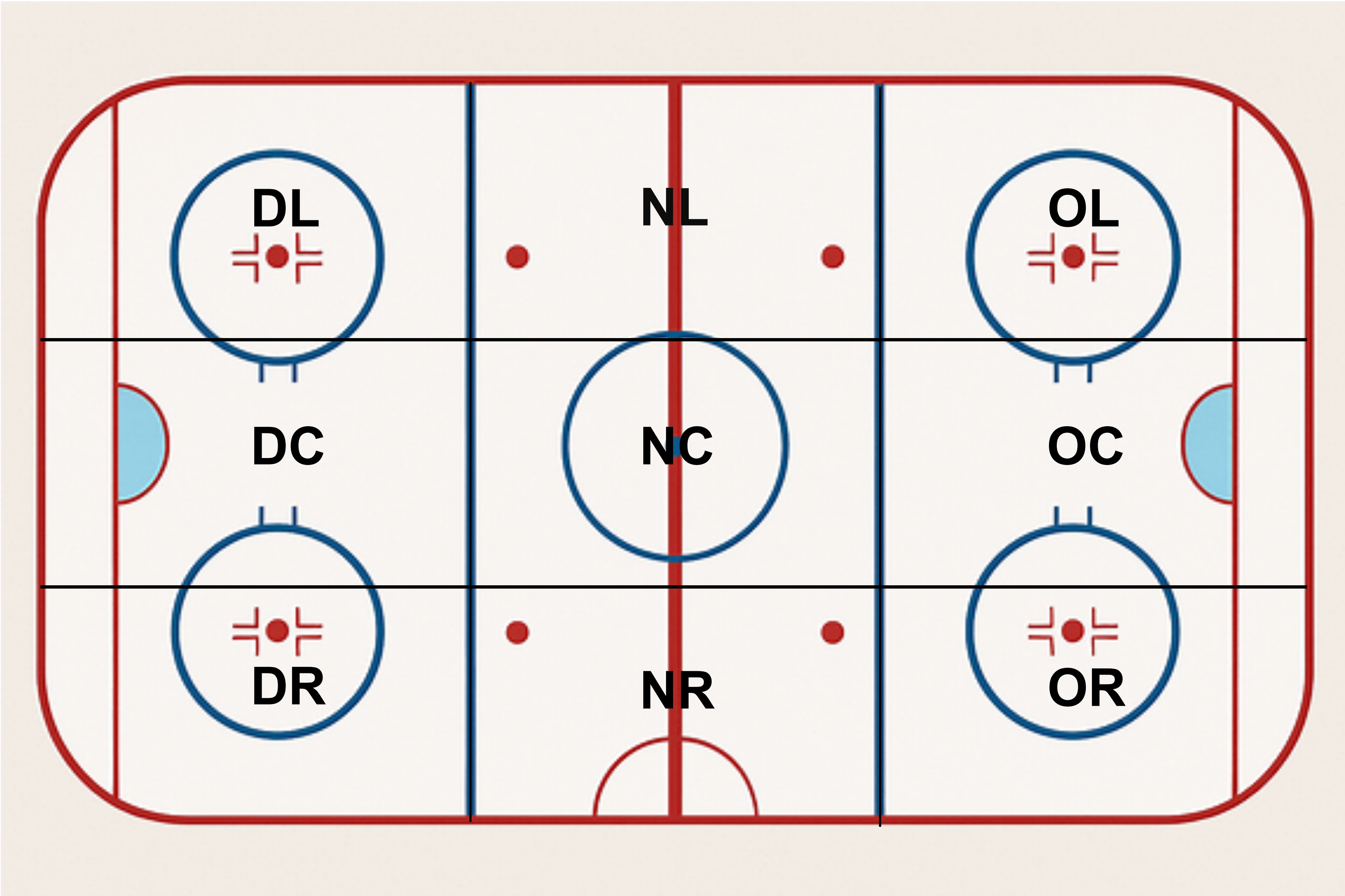
18	Were the statistical tests used to assess the main outcomes appropriate?	The statistical techniques used must be appropriate for the data. E.g. non-parametric methods should be used for small sample sizes. Where little statistical analysis has been undertaken but there is no evidence of bias, question should be answered yes. If distribution of data is not described it must be assumed that estimates were appropriate, the question should be answered yes.
20	Were the main outcome measures used accurate (valid and reliable)	For studies where the outcome measures are clearly described the question should be answered yes. For studies which refer to other work or that outcome measures are accurate, the question should be answered as yes.
Internal validity - Confounding		
25	Was there adequate adjustment for confounding in the analyses from which the main findings were drawn?	

Appendix 3.1. Outputs from intra- and inter-operator reliability assessments

	Nominal	Continuous			
Session	**Kappa**	**Mean event difference**	**TE**	**$SD_{measure}$**	**STE**
Intra-rater Reliability					
Session 1	1.00 (Perfect)	5.77	7.53	158.68	<0.05 (Trivial)
Session 2	1.00 (Perfect)	-26.65	77.39	195.12	0.40 (Small)
Mean	*1.00 (Perfect)*	*18.87*	*42.46*	*176.90*	*0.22 (Small)*
Inter-rater Reliability					
Session 1	0.92 (Very Good)	0.33	60.67	158.68	0.33 (Small)

TE = Typical Error. STE = Standardised typical error. $SD_{measure}$ = Standard deviation of the measure

Appendix 4.1. Diagram depicting the zonal markings for the analysis of shooting events



Appendix 4.2. Breakdown of individual shooting events according to match and training environments

	Match (n; %)	Training (n; %)	Technical Practice (n; %)	Phase of Play (n; %)	Skills Practice (n; %)	Conditioned Game (n; %)	Included in analyses? (Y/N)
Totals	973	2997	1526 (64.7)	732 (24.6)	379 (12.7)	360 (12.1)	Y
Match Status							
Winning	569 (58.5)	-	-	-	-	-	N
Drawing	192 (19.7)						
Losing	212 (21.8)						
Attackers in Front							
0	346 (35.6)	1969 (65.7)	1370 (89.9)	155 (21.2)	268 (70.7)	176 (48.9)	N
1	248 (25.5)	499 (16.6)	112 (7.3)	171 (23.4)	108 (28.5)	108 (30.0)	
2	196 (20.1)	284 (9.5)	40 (2.6)	173 (23.6)	3 (0.8)	68 (18.9)	
3	147 (15.1)	171 (5.7)	4 (0.2)	160 (21.9)	0 (0.0)	7 (1.9)	
4	36 (3.7)	74 (2.5)	0 (0.0)	73 (1.0)	0 (0.0)	1 (0.3)	
Attackers Behind							
0	209 (21.5)	1726 (57.6)	1163 (76.2)	232 (31.6)	219 (57.8)	112 (31.1)	N
1	312 (32.1)	866 (28.9)	335 (22.0)	237 (32.4)	151 (39.8)	143 (39.7)	
2	293 (30.1)	280 (9.3)	28 (1.8)	149 (20.4)	8 (2.1)	95 (26.4)	
3	126 (12.9)	99 (3.3)	0 (0.0)	88 (12.0)	1 (0.3)	10 (2.8)	
4	33 (3.4)	26 (0.9)	0 (0.0)	26 (3.6)	0 (0.0)	0 (0.0)	
Attackers Inactive							
0	274 (28.2)	1551 (51.7)	428 (28.1)	592 (80.9)	244 (64.4)	287 (79.7)	N
1	323 (33.2)	898 (29.9)	597 (39.2)	110 (15.0)	128 (33.8)	63 (17.5)	
2	254 (26.1)	538 (18.0)	495 (32.4)	28 (3.8)	7 (1.8)	8 (2.2)	
3	103 (10.6)	9 (0.3)	5 (0.3)	2 (0.3)	0 (0.0)	2 (0.6)	
4	19 (2.0)	1 (<0.1)	1 (<0.1)	0 (0.0)	0 (0.0)	0 (0.0)	
Defenders in Front							
0	142 (14.6)	1993 (66.5)	1507 (98.8)	141 (19.3)	180 (47.5)	165 (45.8)	N
1	143 (14.7)	461 (15.4)	9 (0.6)	150 (20.4)	195 (51.5)	107 (29.7)	

2	206 (21.2)	347 (11.6)	9 (0.6)	291 (39.8)	2 (0.5)	45 (12.5)	
3	162 (16.6)	117 (3.9)	1 (<0.1)	73 (10.0)	2 (0.5)	41 (11.4)	
4	187 (19.2)	79 (2.6)	0 (0.0)	77 (10.5)	0 (0.0)	2 (0.6)	
5	133 (13.7)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Defenders Behind							
0	290 (29.8)	2266 (75.6)	1518 (99.5)	438 (59.8)	247 (65.2)	63 (17.5)	N
1	167 (17.2)	341 (11.3)	8 (0.5)	134 (18.3)	124 (32.7)	75 (20.8)	
2	191 (19.6)	214 (7.1)	0 (0.0)	104 (14.2)	7 (1.8)	103 (28.6)	
3	153 (15.7)	153 (5.1)	0 (0.0)	38 (5.2)	1 (0.3)	114 (31.7)	
4	112 (11.5)	22 (9.7)	0 (0.0)	18 (2.5)	0 (0.0)	4 (1.1)	
5	60 (6.2)	1 (<0.1)	0 (0.0)	0 (0.0)	0 (0.0)	1 (0.3)	
Defenders Inactive							
0	616 (63.3)	2866 (95.6)	1526 (99.9)	685 (93.6)	368 (97.1)	288 (80.0)	N
1	260 (26.7)	77 (2.6)	1 (<0.1)	15 (2.1)	10 (2.6)	51 (14.2)	
2	71 (7.3)	49 (1.6)	0 (0.0)	28 (3.8)	1 (0.3)	20 (5.1)	
3	25 (2.6)	4 (0.1)	0 (0.0)	3 (0.4)	0 (0.0)	1 (0.3)	
4	0 (0.0)	1 (<0.1)	0 (0.0)	1 (0.1)	0 (0.0)	0 (0.0)	
5	1 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Number of Attackers							
1	0 (0.0)	292 (9.7)	213 (14.0)	10 (1.4)	67 (17.7)	2 (0.6)	Y
2	0 (0.0)	839 (28.0)	548 (35.9)	6 (0.8)	203 (53.5)	82 (22.7)	
3	5 (0.5)	1137 (38.0)	663 (43.4)	159 (21.7)	106 (28.0)	209 (58.1)	
4	36 (3.7)	323 (10.8)	81 (5.3)	188 (25.7)	3 (0.8)	51 (14.2)	
5	932 (95.8)	406 (13.5)	21 (1.4)	369 (50.4)	0 (0.0)	16 (4.4)	
Number of Defenders							
0	0 (0.0)	1556 (51.9)	1498 (98.2)	13 (1.8)	45 (11.8)	0 (0.0)	Y
1	0 (0.0)	392 (13.1)	16 (1.0)	1 (0.1)	315 (83.1)	7 (1.9)	
2	0 (0.0)	489 (16.3)	11 (0.7)	200 (27.3)	16 (4.1)	83 (23.1)	
3	14 (1.4)	295 (9.8)	1 (<0.1)	84 (11.5)	4 (1.0)	206 (57.2)	
4	145 (14.9)	248 (8.3)	0 (0.0)	379 (51.8)	0 (0.0)	48 (13.3)	
5	814 (83.7)	17 (0.5)	0 (0.0)	55 (7.5)	0 (0.0)	16 (4.4)	

Numerical Balance							
Superiority	142 (14.6)	2520 (84.1)	1524 (99.9)	683 (93.3)	293 (77.3)	20 (5.6)	Y
Balanced	806 (82.8)	474 (15.8)	2 (0.1)	48 (6.6)	86 (22.7)	338 (93.8)	
Inferiority	25 (2.6)	3 (0.1)	0 (0.0)	1 (0.1)	0 (0.0)	2 (0.6)	
Players Involved							
1	300 (30.8)	504 (16.8)	220 (14.4)	101 (13.8)	87 (21.4)	96 (26.6)	Y
2	343 (35.3)	1187 (39.6)	583 (38.2)	248 (33.9)	205 (54.1)	151 (41.9)	
3	216 (22.2)	1030 (34.4)	630 (41.3)	221 (30.2)	86 (22.7)	93 (25.8)	
4	96 (9.9)	204 (6.8)	72 (4.7)	115 (15.7)	1 (0.3)	16 (4.4)	
5	18 (1.8)	72 (2.4)	21 (1.4)	47 (6.4)	0 (0.0)	4 (1.1)	
Shot Location							
D	1 (0.1)	52 (1.7)	10 (0.7)	1 (0.1)	0 (0.0)	41 (11.4)	Y
NC	7 (0.7)	130 (4.3)	2 (0.1)	0 (0.0)	17 (4.5)	111 (30.8)	
NL	6 (0.6)	30 (1.0)	0 (0.0)	0 (0.0)	2 (0.5)	28 (7.8)	
NR	6 (0.6)	44 (1.5)	1 (<0.1)	1 (0.1)	0 (0.0)	42 (11.7)	
OC	353 (36.3)	1658 (55.4)	979 (64.2)	370 (50.5)	252 (66.5)	57 (15.8)	
OL	311 (32.0)	471 (15.7)	200 (13.1)	160 (21.9)	51 (13.5)	60 (16.7)	
OR	289 (29.7)	612 (20.4)	334 (21.9)	200 (27.4)	57 (15.0)	21 (5.8)	
Possession Location							
DC	67 (6.9)	321 (10.7)	184 (12.1)	60 (8.2)	52 (13.7)	25 (6.9)	Y
DL	54 (5.5)	373 (12.4)	191 (12.5)	26 (3.6)	133 (35.1)	23 (6.4)	
DR	76 (7.8)	273 (9.1)	190 (12.5)	29 (4.0)	39 (10.3)	15 (4.2)	
NC	49 (5.0)	181 (6.0)	90 (5.9)	11 (1.5)	26 (6.9)	54 (15.0)	
NL	51 (5.2)	365 (12.2)	224 (14.7)	17 (2.3)	70 (18.5)	54 (15.0)	
NR	40 (4.1)	347 (11.6)	238 (15.6)	12 (1.5)	32 (8.4)	65 (18.1)	
OC	128 (13.2)	216 (7.2)	53 (3.5)	131 (17.9)	4 (1.1)	28 (7.8)	
OL	273 (28.1)	448 (14.9)	151 (9.8)	227 (31.0)	7 (1.8)	63 (17.5)	
OR	235 (24.1)	473 (15.8)	205 (13.4)	219 (30.0)	16 (4.2)	33 (9.1)	
Possession Type							
Open Play	855 (87.9)	2987 (99.7)	1526 (100.0)	731 (99.9)	378 (99.7)	352 (97.8)	Y
Counter-attack	47 (4.8)	10 (0.3)	0 (0.0)	1 (0.1)	1 (0.3)	8 (2.2)	

Set Play	71 (7.3)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Preceding Action							
Dribble	227 (23.3)	1348 (45.0)	874 (57.3)	128 (17.5)	259 (68.4)	87 (24.2)	Y
Pass	566 (58.2)	1527 (51.0)	635 (41.6)	546 (74.6)	113 (29.8)	233 (64.7)	
Regain	180 (18.5)	122 (4.0)	17 (1.1)	58 (7.9)	7 (1.8)	40 (11.1)	
Number of Passes							
0	298 (30.6)	504 (16.8)	220 (14.4)	101 (13.8)	87 (23.0)	96 (26.6)	Y
1	316 (32.5)	725 (24.2)	323 (21.2)	200 (27.3)	80 (21.1)	122 (33.9)	
2	189 (19.4)	571 (19.1)	246 (16.1)	150 (20.5)	111 (29.3)	64 (17.8)	
3	84 (8.6)	428 (14.3)	236 (15.5)	110 (15.0)	49 (12.9)	33 (9.2)	
4	37 (3.8)	354 (11.8)	267 (17.5)	55 (7.5)	15 (4.0)	27 (7.5)	
5	21 (2.2)	122 (4.1)	68 (4.5)	43 (5.9)	4 (1.1)	7 (1.9)	
6	15 (1.5)	105 (3.5)	45 (2.9)	27 (3.7)	25 (6.6)	8 (2.2)	
7	8 (0.8)	59 (2.0)	35 (2.3)	21 (2.9)	1 (0.2)	2 (0.6)	
8	3 (0.3)	42 (1.5)	31 (2.0)	5 (0.7)	6 (1.6)	0 (0.0)	
9	0 (0.0)	42 (1.5)	34 (2.2)	8 (1.1)	0 (0.0)	0 (0.0)	
10	2 (0.2)	25 (0.8)	20 (1.3)	4 (0.5)	1 (0.2)	0 (0.0)	
11	0 (0.0)	5 (0.2)	1 (0.1)	3 (0.4)	0 (0.0)	1 (0.3)	
12	0 (0.0)	2 (0.1)	0 (0.0)	2 (0.3)	0 (0.0)	0 (0.0)	
14	0 (0.0)	2 (0.1)	0 (0.0)	2 (0.3)	0 (0.0)	0 (0.0)	
15	0 (0.0)	1 (<0.1)	0 (0.0)	1 (0.1)	0 (0.0)	0 (0.0)	
Shot Type							
Backhanded	42 (4.3)	116 (3.9)	39 (2.6)	34 (4.6)	20 (5.3)	23 (6.4)	Y
Slap Shot	213 (21.9)	218 (7.2)	54 (3.5)	118 (16.1)	12 (3.3)	33 (9.2)	
Wrist Shot	718 (73.8)	2663 (88.9)	1433 (94.0)	580 (79.2)	346 (91.4)	304 (84.4)	
Shot Outcome							
Blocked	177 (18.2)	121 (4.0)	12 (0.8)	78 (10.7)	17 (4.5)	14 (3.9)	Y
Goal	70 (7.2)	393 (13.1)	208 (13.6)	75 (10.2)	47 (12.4)	53 (14.7)	
Missed	178 (18.3)	548 (18.3)	327 (21.4)	99 (13.5)	78 (20.6)	44 (12.2)	
Saved	547 (56.2)	1935 (64.6)	979 (64.2)	480 (65.6)	237 (62.5)	239 (66.4)	
Disallowed	1 (0.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	

Shots In Possession							
Single	813 (83.6)	2741 (91.5)	1483 (97.2)	66 (9.0)	17 (4.5)	27 (7.5)	Y
Multiple (Retention)	88 (9.0)	104 (3.5)	1 (<0.1)	85 (11.6)	3 (0.8)	15 (4.2)	
Multiple (Rebound)	72 (7.4)	152 (5.0)	42 (2.8)	581 (79.4)	359 (94.7)	318 (88.3)	
Pre-Shot Movement							
In Motion	681 (70.0)	2598 (86.7)	1513 (99.1)	498 (68.0)	367 (96.8)	220 (61.1)	Y
Stationary	292 (30.0)	399 (13.3)	13 (0.9)	234 (32.0)	12 (3.2)	140 (38.9)	
Goalkeeper							
Both in	976 (100.0)	2937 (98.0)	1487 (97.4)	722 (98.6)	369 (97.4)	359 (99.7)	Y
Team Pulled	0 (0.0)	59 (2.0)	39 (2.6)	10 (1.4)	9 (2.4)	1 (0.3)	
Opposition Pulled	0 (0.0)	1 (<0.1)	0 (0.0)	0 (0.0)	1 (0.2)	0 (0.0)	

Possession/Shot location: D = defensive. DL = defensive left. DR = defensive right. DC = defensive centre. NL = neutral left. NR = neutral right. NC = neutral centre. OL = offensive left. OR = offensive right. OC = offensive centre. Goalkeeper Presence: GK = goalkeeper. Included in analyses?: N = no. Y = yes.

Appendix 4.3. Raw outputs of categorical variables from reliability assessments.

Shot-Based Characteristics							
Session	Preceding Action	Pre-Shot Movement	Shot Location	Shot Type	Shot Outcome	Shots in Possession	**Mean**
Intra-Rater Reliability							
Match 1	0.325 (Fair)	0.564 (Moderate)	0.417 (Moderate)	0.556 (Moderate)	0.377 (Fair)	0.901 (Very Good)	0.523 (Moderate)
Session 1	0.526 (Moderate)	0.257 (Fair)	0.577 (Moderate)	0.346 (Fair)	0.633 (Good)	0.116 (Poor)	0.410 (Moderate)
Session 2	0.931 (Very Good)	0.259 (Fair)	0.653 (Good)	0.267 (Fair)	0.613 (Good)	0.421 (Moderate)	0.524 (Moderate)
Inter-Rater Reliability							
Match 1	0.675 (Good)	0.393 (Fair)	0.088 (Poor)	0.707 (Good)	0.838 (Very Good)	0.522 (Moderate)	0.510 (Moderate)

Possession-Based Characteristics									
Session	Possession Type	Possession Location	Numerical Balance	Number of Defenders	Number of Attackers	Players Involved	Goalkeeper	Number of Passes	**Mean**
Intra-Rater Reliability									
Match 1	0.143 (Poor)	0.302 (Fair)	0.627 (Good)	1 (Perfect)	1 (Perfect)	0.118 (Poor)	NaN	0.348 (Fair)	0.505 (Moderate)
Session 1	NaN	0.606 (Good)	1 (Perfect)	1 (Perfect)	1 (Perfect)	0.660 (Good)	NaN	0.686 (Good)	0.825 (Very Good)
Session 2	NaN	0.508 (Moderate)	NaN	1 (Perfect)	1 (Perfect)	0.347 (Fair)	NaN	0.661 (Good)	0.703 (Good)
Inter-Rater Reliability									
Match 1	0.103 (Poor)	0.04 (Poor)	0.034 (Poor)	0.115 (Poor)	0.008 (Poor)	0.363 (Fair)	NaN	0.338 (Fair)	0.100 (Poor)

NaN = Not a Number

Appendix 4.4. Raw outputs of all nominal variables from all reliability assessments.

Session	**Possession Duration**			**Individual Possession Duration**		
	TE	$SD_{measure}$	STE	TE	$SD_{measure}$	STE
Intra-Rater Reliability						
Match 1	5.00	4.84	1.03 (Moderate)	1.24	1.14	1.08 (Moderate)
Session 1	4.25	5.11	0.83 (Moderate)	1.10	1.35	0.80 (Moderate)
Session 2	4.80	4.19	1.14 (Moderate)	1.88	1.50	1.25 (Large)
Inter-Rater Reliability						
Match 1	5.69	5.01	1.14 (Moderate)	0.63	1.17	0.54 (Small)

TE = Typical Error. STE = Standardised typical error. $SD_{measure}$ = Standard deviation of the measure

Appendix 4.5a. Confusion matrix for possession-based characteristics within intra-operator match outputs.

Match			Operator 2: Possession Type – Counter-Attack	Open Play	Possession Location – DC	DL	DR	NC	NL	NR	OC	OL	OR	Numerical Balance – Advantage	Balanced	Disadvantage	Number of Defenders – 1	2	3	4	5	Sum
Operator 1	Possession Type	Counter-Attack	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
		Open Play	3	48	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51
	Possession Location	DC	0	0	2	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	4
		DL	0	0	0	0	1	1	0	1	1	0	0	0	0	0	0	0	0	0	0	4
		DR	0	0	0	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	0	4
		NC	0	0	2	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	5
		NL	0	0	1	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	4
		NR	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
		OC	0	0	0	0	0	0	2	0	6	2	0	0	0	0	0	0	0	0	0	10
		OL	0	0	0	0	0	1	0	1	2	7	3	0	0	0	0	0	0	0	0	14
		OR	0	0	1	0	0	2	0	1	1	1	5	0	0	0	0	0	0	0	0	11
	Numerical Balance	Advantage	0	0	0	0	0	0	0	0	0	0	0	3	3	0	0	0	0	0	0	6
		Balanced	0	0	0	0	0	0	0	0	0	0	0	2	47	0	0	0	0	0	0	49
		Disadvantage	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	2
		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2

	Number of Defenders	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	550
		3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	0	6
		5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	51	51
Sum			3	51	6	1	3	5	4	5	12	12	9	5	50	2	0	0	0	6	51	

Possession location. DL = defensive left. DR = defensive right. DC = defensive centre. NL = neutral left. NR = neutral right. NC = neutral centre. OL = offensive left. OR = offensive right. OC = offensive centre

Appendix 4.5b. Confusion matrix for possession-based characteristics within intra-operator match outputs.

Match			Operator 2																				Sum
			Number of attackers					Players Involved					Goalkeeper Presence			Number of Passes							
			1	2	3	4	5	1	2	3	4	5	Both In	Team Pulled	Opposition Pulled	0	1	2	3	4	5	6	
Operator 1	Number of Attackers	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		4	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
		5	0	0	0	0	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55
	Players Involved	1	0	0	0	0	0	12	3	1	2	0	0	0	0	0	0	0	0	0	0	0	18
		2	0	0	0	0	0	4	5	5	1	0	0	0	0	0	0	0	0	0	0	0	15
		3	0	0	0	0	0	4	7	1	3	0	0	0	0	0	0	0	0	0	0	0	15
		4	0	0	0	0	0	2	1	3	2	1	0	0	0	0	0	0	0	0	0	0	9
		5	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1
	Goalkeeper Presence	Both In	0	0	0	0	0	0	0	0	0	0	51	0	0	0	0	0	0	0	0	0	51
		Team Pulled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Opposition Pulled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Number of Passes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13	3	1	0	1	0	0	18
	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	5	3	1	0	0	1	13
	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	8	1	1	0	0	12
	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	1	1	0	0	6
	4	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	3
	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0	3
	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	2
Sum		0	0	0	4	110	22	16	10	9	1	51	0	0	20	10	14	6	5	0	2	

Appendix 4.6. Confusion matrix for all shot-based variables within the intra-operator match outputs.

Match			Operator 2																						Sum
			Preceding Action			Pre-Shot Movement		Shot Location							Shot Type			Shot Outcome				Shots In Possession			
			Dribble	Pass	Regain	In Motion	Stationary	D	NL	NC	NR	OL	OC	OR	Backhanded	Slap Shot	Wrist Shot	Blocked	Goal	Missed	Saved	Instinctive	Retention	Single	
Operator 1	Preceding Action	Dribble	3	5	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
		Pass	4	23	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	34
		Regain	0	4	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	13
	Pre-Shot Movement	In Motion	0	0	0	44	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	45
		Stationary	0	0	0	1	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7
	Shot Location	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		NL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		NC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		NR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		OL	0	0	0	0	0	0	1	0	0	5	3	2	0	0	0	0	0	0	0	0	0	0	11
		OC	0	0	0	0	0	0	0	0	0	4	23	5	0	0	0	0	0	0	0	0	0	0	32
		OR	0	0	0	0	0	0	0	0	0	1	4	9	0	0	0	0	0	0	0	0	0	0	14
	Shot Type	Backhanded	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	0	0	0	0	0	0	4
		Slap Shot	0	0	0	0	0	0	0	0	0	0	0	0	0	6	4	0	0	0	0	0	0	0	10
		Wrist Shot	0	0	0	0	0	0	0	0	0	0	0	0	1	4	38	0	0	0	0	0	0	0	43
	Shot Outcome	Blocked	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	1	0	3	0	0	0	12
		Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	1	2	0	0	0	5
		Missed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	3	0	0	0	0	7
		Saved	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	6	21	0	0	0	33
		Instinctive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	4

	Shots in Possession	Retention	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		Single	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	51	52
Sum			7	32	18	45	7	0	1	0	0	10	30	16	4	10	43	16	5	10	26	5	1	51	

Shot location. D = defensive. NL = neutral left. NR = neutral right. NC = neutral centre. OL = offensive left. OR = offensive right. OC = offensive centre

Appendix 4.7a. Confusion matrix for possession-based variables within the aggregated intra-operator training outputs

Training			Operator 2																			Sum
			Possession Type		Possession Location									Numerical Balance			Number of Defenders						
			Counter-Attack	Open Play	DC	DL	DR	NC	NL	NR	OC	OL	OR	Advantage	Balanced	Disadvantage	0	1	2	3	4	5	
Operator 1	Possession Type	Open Play	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Counter-Attack	0	286	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	286
	Possession Location	DC	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3
		DL	0	0	0	12	2	0	2	0	0	6	1	0	0	0	0	0	0	0	0	0	23
		DR	0	0	1	1	9	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	15
		NC	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
		NL	0	0	0	7	0	0	48	14	0	2	1	0	0	0	0	0	0	0	0	0	72
		NR	0	0	0	0	0	0	14	43	0	1	2	0	0	0	0	0	0	0	0	0	60
		OC	0	0	1	0	1	0	0	0	6	2	3	0	0	0	0	0	0	0	0	0	13
		OL	0	0	5	5	6	0	2	1	8	35	3	0	0	0	0	0	0	0	0	0	65
		OR	0	0	0	1	0	0	0	1	1	5	25	0	0	0	0	0	0	0	0	0	33
	Numerical Balance	Advantage	0	0	0	0	0	0	0	0	0	0	0	261	0	0	0	0	0	0	0	0	261
		Balanced	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0	0	0	25
		Disadvantage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Number of Defenders	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	1	0	0	3	0	154
		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	30	0	0	0	0	31
		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	58	0	0	0	58
		3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	43	0	43

		5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum			0	286	9	26	18	2	66	59	16	53	37	261	25	0	151	31	58	0	46	0	

Possession location. DL = defensive left. DR = defensive right. DC = defensive centre. NL = neutral left. NR = neutral right. NC = neutral centre. OL = offensive left. OR = offensive right. OC = offensive centre

Appendix 4.7b. Confusion matrix for possession-based variables within the aggregated intra-operator training outputs

Training			Operator 2: Number of Attackers					Players Involved					Goalkeeper Presence			Number of Passes															Sum
			1	2	3	4	5	1	2	3	4	5	Both in	Team Pulled	Oppo Pulled	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
Operator 1	Number of Attackers	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		2	0	102	2	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	107
		3	0	1	112	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	115
		4	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
		5	0	0	0	0	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60
	Players Involved	1	0	0	0	0	0	16	6	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	286
		2	0	0	0	0	0	6	109	11	13	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	141
		3	0	0	0	0	0	2	18	62	8	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	92
		4	0	0	0	0	0	1	3	4	6	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	18
		5	0	0	0	0	0	1	0	4	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
	Goalkeeper Presence	Both In	0	0	0	0	0	0	0	0	0	0	286	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	286
		Team Pulled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Opposition Pulled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Number of Passes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	19	3	1	0	1	1	1	0	0	0	0	0	0	0	0	26
		1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	27	2	11	3	1	0	0	0	0	0	0	0	0	0	47
		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	30	3	0	0	1	0	0	0	0	0	0	0	0	46
		3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	1	54	2	2	0	0	0	0	0	0	0	0	0	64

4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	56	2	0	0	0	0	0	0	0	0	0	61
5	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	6	17	0	0	0	1	0	0	0	0	0	26
6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	0	0	0	4
7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	0	0	0	4
8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	2
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
Sum	1	103	114	5	63	26	136	82	31	11	0	0	0	24	48	35	71	69	24	4	3	0	1	2	2	0	0	1	

Appendix 4.8. Confusion matrix for all shot-based variables within the aggregated intra-operator training outputs

Training			Operator 2																						Sum
			Preceding Action			Pre-Shot Movement		Shot Location							Shot Type			Shot Outcome				Shots In Possession			
			Dribble	Pass	Regain	In Motion	Stationary	D	NL	NC	NR	OC	OL	OR	Backhanded	Slap Shot	Wrist Shot	Blocked	Goal	Missed	Saved	Instinctive	Retention	Single	
Operator 1	Preceding Action	Dribble	119	17	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	138
		Pass	13	116	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	132
		Regain	7	2	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	16
	Pre-Shot Movement	In Motion	0	0	0	239	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	250
		Stationary	0	0	0	27	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36
	Shot Location	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		NL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		NC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		NR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		OC	0	0	0	0	0	0	0	0	0	73	9	10	0	0	0	0	0	0	0	0	0	0	92
		OL	0	0	0	0	0	0	0	0	0	19	90	6	0	0	0	0	0	0	0	0	0	0	115
		OR	0	0	0	0	0	0	0	0	0	7	12	55	0	0	0	0	0	0	0	0	0	0	74
	Shot type	Backhanded	0	0	0	0	0	0	0	0	0	0	0	0	6	2	7	0	0	0	0	0	0	0	15
		Slap Shot	0	0	0	0	0	0	0	0	0	0	0	0	2	7	16	0	0	0	0	0	0	0	25

		Wrist Shot	0	0	0	0	0	0	0	0	0	0	0	0	6	15	225	0	0	0	0	0	0	0	246
	Shot Outcome	Blocked	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	4	6	0	0	0	14
		Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	29	3	8	0	0	0	41
		Missed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	36	11	0	0	0	50
		Saved	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6	10	6	159	0	0	0	181
	Shots in Possession	Instinctive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	1	5	9
		Retention	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	6	9
		Single	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	7	252	268
Sum			139	135	12	266	20	0	0	0	0	99	111	71	14	24	248	12	41	49	184	12	11	263	

D = defensive. NL = neutral left. NR = neutral right. NC = neutral centre. OL = offensive left. OR = offensive right. OC = offensive centre

Appendix 4.9a. Confusion matrix for possession-based variables within inter-operator reliability match outputs.

Match			Operator 2																		Sum
			Possession Type		Possession Location									Numerical Balance			Number of Defenders				
			Counter-Attack	Open Play	DC	DL	DR	NC	NL	NR	OC	OL	OR	Advantage	Balanced	Disadvantage	1	2	3	4	5	
Operator 1	Possession Type	Counter-Attack	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
		Open Play	13	31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	44
	Possession Location	DC	0	0	2	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	4
		DL	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
		DR	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
		NC	0	0	1	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	4
		NL	0	0	1	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4
		NR	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
		OC	0	0	1	0	0	1	0	2	2	3	1	0	0	0	0	0	0	0	0	10
		OL	0	0	0	0	0	0	3	2	0	2	5	0	0	0	0	0	0	0	0	12
		OR	0	0	0	0	2	0	4	0	2	2	0	0	0	0	0	0	0	0	0	10
	Numerical Balance	Advantage	0	0	0	0	0	0	0	0	0	0	0	3	1	1	0	0	0	0	0	5
		Balanced	0	0	0	0	0	0	0	0	0	0	0	6	17	20	0	0	0	0	0	43

		Disadvantage	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	2
	Number of Defenders	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5
		5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	7	11	13	11	44
Sum			13	33	6	1	6	3	9	5	6	7	7	9	20	21	2	7	11	18	11	

Possession location. DL = defensive left. DR = defensive right. DC = defensive centre. NL = neutral left. NR = neutral right. NC = neutral centre. OL = offensive left. OR = offensive right. OC = offensive centre

Appendix 4.9b. Confusion matrix for possession-based variables within inter-operator reliability match outputs.

Match			Operator 2																					Sum
			Number of attackers					Players Involved					Goalkeeper Presence			Number of Passes								
			1	2	3	4	5	1	2	3	4	5	Both In	Team Pulled	Opposition Pulled	0	1	2	3	4	5	6	7	
Operator 1	Number of Attackers	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		4	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
		5	1	10	22	3	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	47
	Players Involved	1	0	0	0	0	0	8	5	0	2	1	0	0	0	0	0	0	0	0	0	0	0	16
		2	0	0	0	0	0	3	5	4	0	0	0	0	0	0	0	0	0	0	0	0	0	12
		3	0	0	0	0	0	0	1	10	2	1	0	0	0	0	0	0	0	0	0	0	0	14
		4	0	0	0	0	0	0	0	4	3	1	0	0	0	0	0	0	0	0	0	0	0	8
		5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Goalkeeper Presence	Both In	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	50
		Team Pulled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		Opposition Pulled	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Number of Passes	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	3	1	1	0	1	0	1	14
		1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	3	0	1	0	0	0	9
		2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	7	0	2	1	0	0	11
		3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	1	0	0	5
		4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2
		5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	3
		6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	2
		7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sum			1	12	22	3	11	11	11	18	7	3	50	0	0	10	6	14	5	4	5	1	1	

Appendix 4.10. Confusion matrix for all shot-based variables within inter-operator reliability match outputs.

Match			Operator 2																						Sum
			Preceding Action			Pre-Shot Movement		Shot Location							Shot Type			Shot Outcome				Shots In Possession			
			Dribble	Pass	Regain	In Motion	Stationary	D	NL	NC	NR	OL	OC	OR	Backhand	Slap Shot	Wrist Shot	Blocked	Goal	Missed	Saved	Instinctive	Retention	Single	
Operator 1	Preceding Action	Dribble	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
		Pass	1	23	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	26
		Regain	2	4	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12
	Pre-Shot Movement	In Motion	0	0	0	39	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40
		Stationary	0	0	0	6	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9
	Shot Location	D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		NL	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		NC	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		NR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		OL	0	0	0	0	0	0	0	0	3	0	0	7	0	0	0	0	0	0	0	0	0	0	10
		OC	0	0	0	0	0	0	0	1	2	1	19	4	0	0	0	0	0	0	0	0	0	0	27
		OR	0	0	0	0	0	0	0	0	2	8	2	0	0	0	0	0	0	0	0	0	0	0	12
	Shot Type	Backhanded	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0	4
		Slap Shot	0	0	0	0	0	0	0	0	0	0	0	0	0	8	1	0	0	0	0	0	0	0	9
		Wrist Shot	0	0	0	0	0	0	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0	0	32
	Shot outcome	Blocked	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	1	0	0	0	10
		Goal	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	5
		Missed	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	5	0	0	0	0	6
		Saved	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	26	0	0	0	29
	Shots in possession	Instinctive	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	4
		Retention	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1
		Single	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	40	45
Sum			12	27	8	45	4	0	0	1	7	9	21	11	0	8	37	10	5	8	27	6	3	41	

Shot location. DL = defensive left. DR = defensive right. DC = defensive centre. NL = neutral left. NR = neutral right. NC = neutral centre. OL = offensive left. OR = offensive right. OC = offensive centre