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Evaluating the representativeness of shooting during training activities in senior men's domestic ice hockey

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ABSTRACT

Designing and delivering representative training environments is important for skill development and transfer into competition. Therefore, understanding the demands of, and information present in competition and training is essential for enabling representative environments. The aim of this study was to quantify and compare the technical-tactical characteristics of shooting during competition and training activities within senior men's domestic ice hockey. Data were collected during 14 matches and 21 training sessions, totalling 901 shots during matches and 2997 shots from 147 training activities. Linear mixed models estimated possession-based and shot-based technical-tactical characteristics and determined differences in the relative frequency and proportion of variables between training activities and competition. Overall, the representativeness of shooting differed according to training activity, with similar trends in the representativeness (e.g., more/less frequent, higher/lower proportions) of possession- and shot-based technical-tactical variables observed between and within training state (i.e., technical activities, skills activities) and playing state (i.e., phase of play, conditioned game) activities. Shooting situations with numerical superiority were typically over-represented during training activities, and numerical balance or inferiority under-represented, with the starting location of possessions, number of defenders and attackers typically lacking representativeness. Further, the action preceding a shot, shooter's pre-shot movement, shot location, shot type, shot outcome and number of shots in the possession (single, multiple-rebound, multiple-retention) also lacked representativeness across training activities. This is the first study to evaluate representativeness of training activities in relation to shooting and within ice hockey. Whilst results are limited to the respective team and season, there are practical implications for informing training design and coaching practices regarding shooting within ice hockey.

1. Introduction

Designing and delivering training activities which are representative of competition (i.e., contain key information and movement demands present in competition, whereby information regulates action, perception and action remain coupled, and comparable affordances are available to player(s)) [1] can enhance learning and skill transfer between environments [1,2]. This is an important challenge for coaches and practitioners working across applied sport environments. To create representative training environments, coaches must have an evidence-based understanding of the demands of, and information present within, both competition and training, and how these environments compare. Whilst research has comprehensively investigated match demands across a variety of sports, quantifying physical, technical and tactical performance [3–8], and evaluated training demands [9], either at a whole-session level [10–12] or for specific training activities (e.g., small-sided games; SSGs) [13–16], there is however, relatively limited literature evaluating the representativeness of training directly comparing competition and training environments [17].

Beyond the limited scientific literature, there are also several key limitations within the body of evidence evaluating representativeness which limit the application of findings for coaches and practitioners working within applied sport environments [17]. Firstly, research evaluating the representativeness of training has predominantly focussed upon Australian rules football [18–23]. Whilst similarities exist between invasion sports (e.g., internal logic: the aim of the sport, similar moments of the game) [24], we cannot assume the evidence derived from one sport would be applicable in others due to differing

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constitutive rules which define the sport, and therefore, impact how athletes and teams within respective sports may approach such moments of the game (e.g., in possession, out of possession, offensive transition, defensive transition, set-pieces) [25]. Secondly, this is compounded by the homogeneity of participants within the research, typically professional senior male populations [17]. Given the population-specific differences (e.g., physiological, biomechanical) and contextual differences (e.g., competition schedules, training experience, sport science and medicine provision) which may exist between sporting populations (e.g., male vs female; senior vs youth; professional vs amateur), informing applied practice using evidence derived from another population may be inappropriate [26]. Thirdly, research has predominantly evaluated the representativeness of single training activities [17], with research focussing on assessing match simulations (or full-sided games) [18,22,23,27] or small-sided games [19,21,28,29]. Coaches utilise a range of training activities (e.g., technical practice, skills practice, phase of play, conditioned games) [30] for different purposes (e.g., to elicit specific performance outcomes, to facilitate session aims, or focus on individual player development), and therefore, understanding how representativeness may vary across training activities is important for informing the planning, delivery and review of coaching practices. These activities can be grouped as training state activities (technical and skills practice), in which skills are practised with no or limited opposition, and playing state activities (phase of play and conditioned games), which retain attacker-defender interactions and elements of the game [30]. Opposition, decision coupling, time-space pressure and task uncertainty would therefore be expected to increase from technical practice to conditioned games. This taxonomy is grounded in observation of coaching practice [30] and, unlike broader classifications (e.g., isolated, opposed, game-based), distinguishes between game-based activities with differing scoring structures. Lastly, research typically assesses representativeness through comparing whole training activities against whole-competition observations (i.e., aggregates of physical, technical or tactical variables for the whole activity and whole-match) [23,28,29,31]. This aggregated approach misses important contextual information (e.g., information surrounding actions, players, team-mates or opposition), which would be essential for informing the design of training activities which preserve key informational cues and movements which may be experienced during competition [1]. Therefore, there is a need to consider the representativeness of specific moments of the game, to ensure the capture of important contextual information at a moment-level (as opposed to whole-match-level) which can inform the design of respective training activities.

Where research has investigated the representativeness of moments of the game, this has again, predominantly focussed on specific phases within Australian rules football, evaluating disposals [20], inside-50 entries [18], and high-pressure contested phases [21]. Acknowledging the aforementioned limitations and implications for informing coaching practice from other sports and populations, consideration must also be given to which specific moments of the game are important to understand. Given the aim of invasion sports is grounded on maximising goal (or point) scoring (whilst minimising the opponents goal/point scoring), the ability of teams and individual players to create and take advantage of goal scoring opportunities is fundamental for success within the respective sport. Whilst research has investigated goal scoring opportunities during competition and the influence of situational and contextual factors (e.g., possession type, pitch location, match status, match time, competition type, team/opposition quality) [32–36], research has primarily focussed upon football and importantly, is yet to evaluate the representativeness of shooting within training activities within any invasion sport. Within training, task constraints (e.g., number of players, area, scoring rules) shape attacker-defender-goalkeeper interactions and the affordances available to the shooter [1], which emerge as observable possession and shot characteristics that can be compared with competition. Therefore, research is warranted which investigates the representativeness of shooting during training activities, to understand what key contextual information is present (or not) and therefore, may need to be considered when designing, delivering and manipulating training activities intended to represent goalscoring opportunities during competition to enhance skill transfer between environments.

In contrast to the evidence-base investigating goalscoring opportunities in football, relatively limited research exists within ice hockey [37–42]. Due to the sport-specific constraints of ice hockey (e.g., spatial; playing area, boards and continuous boundaries, goal dimensions), there is a need to develop sport-specific research. Further, research has investigated goal scoring within international or professional ice hockey leagues, such as the National Hockey League (USA). As previously highlighted, due to population-specific differences and contextual differences (e.g., roster stability, tactical understanding, coaching resource; rink size, temporal structure of matches, rules relating to specific infractions) [43] between ice hockey populations, evidence derived from this population and applied to others may not be appropriate. Furthermore, not only is there a need to develop a sport- and population-specific evidence-base evaluating representativeness, but also for future research to evaluate representativeness: across training activities rather than single training activities, and of (phases within) moments of the game within training activities as opposed to a whole-match-level. This approach can inform the design, delivery and review of training activities intended to represent those of competition and enhance skill transfer between environments. Given the above, the aim of this study is to quantify and compare the technical-tactical characteristics of shooting during competition and training activities within senior men's domestic ice hockey.

2. Methods

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. The team participated in regional league and cup competitions, with one or two 60-minute rink-based (56 m x 26 m) training sessions per week, and off-rink strength and conditioning provision. The head coach, assistant coach and all players (n = 25; age = 25.7 ± 5.5 years) representing the club were recruited. The head coach had 14 years of experience at and above the team's current competitive level, held an England Ice Hockey Level 2 Team Coach qualification (the highest level of domestic coaching qualification) and acted as an Instructor on England Ice Hockey Level 1 and 2 coaching qualifications. Written informed consent (or assent and player/guardian consent) was collected prior to participation. This study was approved by the University of Essex Research Ethics Committee (ETH2425-2089; November 2024).

2.2. Sample size estimation and justification

No formal sample size estimation was performed for this study, rather the sample was limited by practical challenges associated with data collection in this population (e.g., unfeasible travelling distance/time to and from the research institution to respective club training and match venues for data collection, compounded by the typical training times of this population (starting after ~22:00)) [44].

2.3. Procedures

An observational study design was conducted, in which data were collected from 14 matches and 21 training sessions during the 2024/25 competitive season (October 2024 to April 2025). The match sample included league (n = 10) and cup (n = 4) competitions, home (n = 12) and away (n = 2) fixtures, and win (n = 10), draw (n = 2) and loss (n = 2) match outcomes. All training sessions were scheduled for a 60-min duration (mean = 55.2 ± 4.8 min). Overall, the sample represents

~72% of the club's training sessions and 32% of competitive fixtures during the respective season.

Home matches were recorded using a video camera (Hero 4, GoPro, USA) 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; one match was recorded from an elevated, central sideline position set back from the rink, and 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 recorded using a video camera (n = 4 sessions: HDR-CX625, Sony, Japan; n = 17 sessions: Hero 4, GoPro, USA) from a fixed position; 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. Match and training recordings were imported into Metrica PlayBase (v.2.23; Metrica Sports, Spain) and analysed using a customised coding panel. Firstly, the training sessions were analysed to identify training activities and the primary observed skill within each activity; these methods (e.g., categorisation, operational definitions) have been detailed previously [45]. Training activities which had shooting as their primary skill (i.e., aiming to score a goal against a goalkeeper) were included for subsequent 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 operational definitions for included training activities are presented in Table 1. Secondly, matches (regulation-time only) and training activities were analysed to quantify the technical-tactical characteristics of shooting. The variables (possession-based n = 9; shot-based n = 13) quantified and respective operational definitions are presented in Tables 2 and 3. Operational definitions were developed by the research team drawing upon sport (SQ) and performance analysis (AHA) expertise, refined through an iterative process led by (CF) which also included engaging with and drawing upon wider performance analysis research. A total of 2997 training shots (143 ± 33.9 shots per training session) and 973 match shots (66.1 ± 12.7 shots per match) were analysed. Only the team's shots were analysed during matches with no opposition data contributing to analysis. The dataset characteristics for shots during matches and training are presented in Supplementary Table S1.

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

Table 1
Training activities included within the study.

Training Activity Grouping	Training Activity	Definition [45]
Practice/ training state activities	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)
Playing state activities	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 (e.g., attackers score in a main regulation goal and the other team runs the puck out of play through some marker cones/over a line, or by outletting the puck to a feeder/ coach)
	Conditioned game	Restrictions/variations to rules, goals or area of play, but with teams scoring in the same way

Table 2
Technical-tactical characteristics and operational definitions.

Variable Grouping	Variable	Level (if categorical)	Definition
Possession-Based	Possession Location	(see Figure S1)	The zone on the rink (Supplementary Material Figure S1; relative to the team's direction of attack) 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
	Numerical Balance	Balanced	Equal players on the ice for each team (5v5, 4v4)
		Superiority	The shooting team has more players on the ice compared to the opposing team (5v4, 5v3)
		Inferiority	The shooting team has fewer players on the ice compared to the opposing team (4v5, 3v5)
	Number of Defenders (n)	Defenders	The total number of outfield opposition players on the ice
	Number of Attackers (n)	Attackers	The total number of outfield players on ice for the shooting team
	Players Involved (n)	N/A	The number of players from the shooting team who touched the puck (i.e. pass) throughout the possession
	Goalkeeper Presence	Both in	Both teams' goalkeepers are on the ice
		Team Pulled	The shooting team's goalkeeper has been substituted for an outfield player
		Opposition Pulled	The opposing team's goalkeeper has been substituted for an outfield player
	Possession Duration (s)	N/A	The duration of the shooting 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 the possession to the shot being taken
Shot-Based	Preceding Action	Pass	The shooting player received a pass from another player before taking the shot
		Dribble	The shooting player carried the puck forward before taking the shot
		Regain	The shooting player regathered the puck (e.g., after a saved or blocked shot, or loose puck) before taking the shot
		Other	Any other action the shooting player made before taking the shot
	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 shooting player is in motion at the point in which the puck is struck

(*continued on next page*)

Table 2 (*continued*)

Variable Grouping	Variable	Level (if categorical)	Definition
		Stationary	The shooting player is stationary at the point in which the puck is struck
	Shot Location	(See Figure S1)	The zone on the ice where the shot is taken from (Supplementary Material Figure S1)
	Attackers In Front (n)	N/A	The number of teammates between the shooter and attacking goal line when the shot is taken
	Attackers Behind (n)	N/A	The number of teammates behind the puck and in front of the goal line when the shot is taken
	Attackers Inactive (n)	N/A	The number of teammates behind the goal line or in the neutral zone when the shot is taken
	Defenders In Front (n)	N/A	The number of opponents between the shooter and attacking goal line when the shot is taken
	Defenders Behind the Shooting Player (n)	N/A	The number of opponents behind the puck and in front of the goal line when the shot is taken
	Defenders Inactive (n)	N/A	The number of opponents behind the goal line or in the neutral zone when the shot is taken
	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 intervention from a goalkeeper or defender
		Blocked	An opponent (excluding the goalkeeper) intercepts or deflects the shot from reaching the goal frame or preventing a goal
		Disallowed	A goal that is initially scored but subsequently nullified due to a rule infringement or violation
	Shots in Possession	Single	One shot taken within the possession
		Multiple (Rebound)	Multiple shots attempted within the possession, with a subsequent shot taken immediately after the shooting team regains possession
		Multiple (Retention)	Multiple shots attempted within the possession, with a shot taken after the shooting team retains possession to create a structured shooting opportunity

2997 shots from training activities (*technical practice*: n = 1526; 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 (Supplementary Table S1). Alongside this, specific variables were excluded due to a high proportion of zero-observations within respective levels of these categorical variables within training activities (e.g., number of defenders/attackers; in front, behind, inactive) or heavily imbalanced observations within levels of variables (e.g., goalkeeper presence). The final variables included (and excluded) for data analysis are detailed in Supplementary Table S1.

Shot-level data were aggregated to create observation-level data for each match and training activity. For each observation, two datasets were quantified. Firstly, to gain insight into the representativeness of the density of technical-tactical characteristics [19,21–23], 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., $n \cdot min^{-1}$). Secondly, to gain insight into the representativeness of the overall structure of technical-tactical characteristics [21], the proportion of each level within categorical variables was quantified (i.e., relative to the respective variable).

2.4. Reliability assessment

All notational analyses were conducted by the lead researcher (CF). The reliability assessment of the training activities and the primary observed skill have been described elsewhere [45]. To determine intra-operator reliability of the technical-tactical characteristics of shots, one match (n = 97; 6.8%) and two training sessions (n = 300; 9.5%) were randomly selected and reanalysed approximately five weeks after initial analyses were completed. Categorical variables had moderate agreement (κ=0.54) for match shots and good agreement for training shots (κ=0.72) [46], whilst possession duration and individual possession duration had moderate disagreement for match (standardised typical error: possession = 1.03 s; individual possession = 1.08 s) and training (standardised typical error: possession = 0.99 s; individual possession = 1.03 s) shots [47]. The intra-operator reliability for categorical variables are presented in Supplementary Table S2.

2.5. Data 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 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 (± 95% CI) were derived from the model for each technical-tactical variable (emmeans package). Frequency-based variables were log-transformed for inclusion in the model, and the estimates back-transformed. 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.

Table 3
Estimated marginal means (±95% CI) of possession-based variables during shooting events across matches and training activities.

Variable	Match		Practice/Training State Activities				Playing State Activities			
			Technical Practice		Skills Practice		Phase of Play		Conditioned Game	
	(n·min^{-1})	%	(n·min^{-1})	%	(n·min^{-1})	%	(n·min^{-1})	%	(n·min^{-1})	%
Possession Location										
DL	0.04 ± 0.03	6.19 ± 11.88	**0.01 ± 0.01**	11.74 ± 5.32	0.10 ± 0.08	**29.49 ± 9.95**	**0.01 ± 0.01**	4.77 ± 7.89	**0.01 ± 0.01**	6.43 ± 10.52
DC	0.08 ± 0.06	7.94 ± 10.44	**0.01 ± 0.00**	11.48 ± 6.98	0.02 ± 0.02	12.87 ± 8.78	**0.02 ± 0.01**	7.14 ± 7.91	0.02 ± 0.02	13.91 ± 9.27
DR	0.09 ± 0.07	9.16 ± 11.49	**0.01 ± 0.01**	12.34 ± 5.42	**0.02 ± 0.02**	13.04 ± 9.70	**0.01 ± 0.00**	5.22 ± 7.78	**0.01 ± 0.01**	5.66 ± 10.34
NL	0.06 ± 0.05	5.91 ± 9.68	0.04 ± 0.03	**14.93 ± 4.92**	0.06 ± 0.04	**16.93 ± 8.21**	**0.01 ± 0.00**	2.36 ± 6.71	0.04 ± 0.03	11.67 ± 8.81
NC	0.03 ± 0.03	5.15 ± 8.22	**0.01 ± 0.00**	6.86 ± 3.62	0.02 ± 0.02	7.56 ± 6.87	**< 0.01 ± 0.00**	1.55 ± 5.43	0.04 ± 0.03	**14.69 ± 7.25**
NR	0.03 ± 0.03	4.07 ± 9.53	0.04 ± 0.02	**16.03 ± 4.83**	0.02 ± 0.02	10.78 ± 8.08	**< 0.01 ± 0.00**	2.02 ± 6.06	0.04 ± 0.03	**13.63 ± 8.67**
OL	0.26 ± 0.20	25.42 ± 9.54	**0.02 ± 0.01**	**9.77 ± 4.29**	**< 0.01 ± 0.00**	**1.90 ± 8.00**	0.53 ± 0.34	30.22 ± 6.35	**0.05 ± 0.04**	23.31 ± 8.46
OC	0.13 ± 0.10	13.16 ± 6.17	**0.01 ± 0.00**	**4.73 ± 2.78**	**< 0.01 ± 0.00**	**1.42 ± 5.18**	0.15 ± 0.09	16.74 ± 4.11	**0.02 ± 0.02**	**7.43 ± 5.48**
OR	0.23 ± 0.19	23.00 ± 8.87	**0.03 ± 0.01**	**11.61 ± 4.11**	**0.01 ± 0.00**	**8.42 ± 7.47**	0.36 ± 0.24	**29.21 ± 5.96**	**0.02 ± 0.01**	**8.91 ± 7.94**
Numerical Balance										
Balanced	0.87 ± 0.56	84.58 ± 12.52	**< 0.01 ± 0.00**	**1.42 ± 5.52**	**0.04 ± 0.02**	**34.49 ± 10.48**	**< 0.01 ± 0.00**	**9.48 ± 8.28**	1.52 ± 0.90	85.00 ± 11.04
Superiority	0.11 ± 0.07	13.00 ± 12.37	**7.03 ± 2.75**	**98.58 ± 5.45**	**0.71 ± 0.43**	**65.51 ± 10.35**	**1.25 ± 0.66**	**90.33 ± 33.00**	**0.02 ± 0.01**	13.92 ± 10.91
Inferiority	0.01 ± 0.00	2.42 ± 0.72	**< 0.01 ± 0.00**	**< 0.01 ± 0.32**	**< 0.01 ± 0.00**	**< 0.01 ± 0.60**	**< 0.01 ± 0.00**	**0.02 ± 0.47**	**< 0.01 ± 0.00**	**1.08 ± 0.63**
Number of Defenders										
0	< 0.01 ± 0.00	< 0.01 ± 8.48	**7.01 ± 2.47**	**97.87 ± 4.01**	**0.03 ± 0.02**	**18.41 ± 7.16**	< 0.01 ± 0.00	2.56 ± 5.74	< 0.01 ± 0.00	1.09 ± 7.63
1	< 0.01 ± 0.00	< 0.01 ± 8.32	< 0.01 ± 0.00	0.59 ± 4.12	**1.54 ± 0.81**	**72.19 ± 7.05**	**< 0.01 ± 0.00**	**5.71 ± 5.72**	**< 0.01 ± 0.00**	3.22 ± 7.55
2	< 0.01 ± 0.00	< 0.01 ± 13.5	< 0.01 ± 0.00	0.36 ± 6.05	**< 0.01 ± 0.00**	5.49 ± 11.32	**0.04 ± 0.02**	**36.47 ± 8.97**	**0.01 ± 0.00**	**24.52 ± 11.97**
3	< 0.01 ± 0.00	1.22 ± 13.33	**< 0.01 ± 0.00**	1.18 ± 6.24	< 0.01 ± 0.00	4.43 ± 11.24	**0.01 ± 0.00**	**17.56 ± 9.00**	**0.16 ± 0.10**	**51.09 ± 11.97**
4	0.11 ± 0.07	13.17 ± 13.00	**< 0.01 ± 0.00**	**0.03 ± 13.00**	**< 0.01 ± 0.00**	**0.24 ± 10.92**	**0.02 ± 0.01**	**37.33 ± 8.68**	**0.01 ± 0.00**	12.75 ± 11.57
5	0.88 ± 0.33	85.62 ± 4.6	**< 0.01 ± 0.00**	**< 0.01 ± 4.60**	**< 0.01 ± 0.00**	**< 0.01 ± 3.86**	**< 0.01 ± 0.00**	**0.19 ± 3.07**	**< 0.01 ± 0.00**	**7.77 ± 4.09**
Number of Attackers										
1	< 0.01 ± 0.00	< 0.01 ± 13.45	**0.03 ± 0.02**	**16.78 ± 6.60**	**0.04 ± 0.03**	**27.95 ± 11.39**	< 0.01 ± 0.00	3.12 ± 9.23	< 0.01 ± 0.00	< 0.01 ± 12.19
2	< 0.01 ± 0.00	< 0.01 ± 18.52	**0.17 ± 0.10**	**34.04 ± 8.8**	**0.24 ± 0.19**	**44.34 ± 15.64**	< 0.01 ± 0.00	2.31 ± 12.57	**0.01 ± 0.01**	**19.87 ± 16.69**
3	< 0.01 ± 0.00	0.02 ± 20.15	**0.15 ± 0.09**	**42.05 ± 8.89**	**0.01 ± 0.01**	**27.32 ± 16.86**	**0.01 ± 0.01**	**15.93 ± 13.33**	**0.17 ± 0.14**	**53.16 ± 17.77**
4	0.01 ± 0.01	3.46 ± 12.52	**0.01 ± 0.00**	4.37 ± 6.07	**< 0.01 ± 0.00**	0.57 ± 10.59	0.01 ± 0.01	**18.42 ± 8.55**	0.01 ± 0.01	**17.43 ± 11.32**
5	1.00 ± 0.63	96.34 ± 12.16	**< 0.01 ± 0.00**	**2.53 ± 5.36**	**< 0.01 ± 0.00**	**< 0.01 ± 10.17**	**0.35 ± 0.17**	**60.54 ± 8.04**	**< 0.01 ± 0.00**	**7.72 ± 10.72**
Players Involved										
1	0.28 ± 0.22	28.54 ± 14.57	**0.04 ± 0.02**	**17.10 ± 7.08**	0.13 ± 0.10	31.96 ± 12.33	0.10 ± 0.07	**14.29 ± 9.96**	0.35 ± 0.27	22.40 ± 13.19
2	0.37 ± 0.30	35.75 ± 17.44	0.25 ± 0.14	35.98 ± 8.39	0.48 ± 0.36	47.08 ± 14.75	0.33 ± 0.22	28.3 ± 11.89	0.57 ± 0.45	38.89 ± 15.76
3	0.24 ± 0.20	23.58 ± 17.28	0.16 ± 0.09	**40.9 ± 8.15**	**0.01 ± 0.01**	20.57 ± 14.58	0.38 ± 0.27	26.80 ± 11.69	0.25 ± 0.20	30.53 ± 15.54
4	0.09 ± 0.06	10.26 ± 7.65	**0.01 ± 0.00**	**3.42 ± 3.86**	**< 0.01 ± 0.00**	**0.09 ± 6.49**	0.11 ± 0.06	**21.74 ± 5.30**	**0.01 ± 0.00**	6.92 ± 6.96
5	0.01 ± 0.01	1.86 ± 6.15	**< 0.01 ± 0.00**	2.47 ± 3.1	**< 0.01 ± 0.00**	0.60 ± 5.22	0.01 ± 0.01	**9.07 ± 4.25**	**< 0.01 ± 0.00**	0.49 ± 5.59
Possession Duration (s)	6.52 ± 1.17		6.04 ± 0.54		**7.37 ± 0.99**		**9.44 ± 0.79**		6.77 ± 1.05	
Number of Passes (n)	1.48 ± 0.94		**2.80 ± 0.48**		**2.19 ± 0.80**		**2.79 ± 0.65**		1.85 ± 0.86	

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. **Bold:** statistically significant p-value ($p < 0.05$) and/or substantial effect size (>0.2).

3. Results

3.1. Possession-based variables

The possession-based variables according to match and training activity are presented in Table 4, and comparisons (statistical significance and ES) between matches and respective training activities are presented in Supplementary Material Figures S2 (relative frequency of variables; S2A: training state activities; S2B: playing state activities) and S3 (proportion of variables; S3A training state activities; S3B playing state activities).

3.1.1. Competition vs technical practice

Technical practice had lower: frequency of possessions (resulting in a shot) starting in all defensive zones and NC zone (small – moderate ESs: 0.34 – 0.77), frequency and proportion starting in all offensive zones (moderate ESs: 0.72 – 1.10), and a greater proportion starting in NL and NR zones (small – moderate ESs: 0.52 – 0.70). Further, a lower frequency and proportion of possessions with numerical balance and inferiority ($p < 0.001$; large - very large ESs: 1.78 – 3.51), and greater frequency and proportion of numerical superiority ($p < 0.001$; large – very large ESs: 1.96 – 3.65). Technical practice had a greater frequency and proportion of possessions with no defenders ($p < 0.001$; very large ESs: 5.02 – 6.25), and lower: frequency with three defenders (small ES: 0.50 ± 0.49), and frequency and proportion with four and five defenders ($p < 0.001$; small - very large ESs: 0.54 – 9.88). Further, a greater: frequency and proportion of possessions with one, two and three attackers (moderate – large ESs: 0.69 – 1.61), and frequency with four attackers (small ES: 0.37 ± 0.52), and lower frequency and proportion with five attackers ($p < 0.001$; very large ESs: 3.52 – 4.07). Technical practice had a lower: frequency and proportion of possessions with one and four players involved (small – large ES: 0.43 – 1.20), frequency of five players involved ($p < 0.001$; moderate ES: 1.10 ± 0.50), and higher proportion of three players involved (small ES: 0.54 ± 0.50). There was no difference in possession duration, but technical practice had a higher number of passes (moderate ES: 0.78 ± 0.53).

3.1.2. Competition vs skills practice

Skills practice had lower: frequency of possessions (resulting in a shot) starting in the DR zone (small ES: 0.41 ± 0.58), and frequency and proportion starting in all offensive zones (moderate – large ESs: 0.88 – 1.51), but higher proportion starting in DL and NL zones (moderate ESs: 0.54 – 1.04). Further, lower frequency and proportion of possessions with numerical balance and inferiority ($p < 0.001$; large – very large: 1.59 – 2.74), and greater frequency and proportion of possessions with numerical superiority (moderate – very large ES: 0.88–2.24). Skills practice had a greater: frequency and proportion of possessions without and one defender(s) ($p < 0.05$; moderate – very large ESs: 1.18 – 4.81), and frequency of two defenders (small ES: 0.38 ± 0.58), and a lower frequency and proportion of possessions with four and five defenders (small - very large ESs: 0.53 – 9.89). Further, greater frequency and proportion of possessions with one, two and three attackers (small – large ESs: 0.58 – 1.30), and lower: frequency of four attackers (moderate ES: 0.74 ± 0.61), and frequency and proportion of five attackers ($p < 0.001$; very large ESs: 3.64 – 4.18). Skills practice had a greater: frequency of three and five players involved (moderate – large ESs: 0.91 – 1.23), and frequency and proportion of four players involved (moderate – large ESs: 0.74 – 1.78). Skills practice had longer possessions and a greater number of passes (small ESs: 0.39 – 0.42).

3.1.3. Competition vs phase of play

Possessions during phase of play started more frequently from the defensive and neutral zones (small – moderate ESs: 0.37 – 0.82), whilst a greater proportion started from the OR zone (small ES: 0.38 ± 0.54). Further, a lower frequency and proportion of possessions with numerical balance and inferiority ($p < 0.001$; large – very large ESs: 1.64 – 3.17), and a greater frequency and proportion with numerical superiority ($p < 0.01$; moderate – very large ESs: 1.15 – 3.30). Phase of play had a greater: proportion of possessions with four defenders ($p < 0.05$; 0.99 ± 0.54), and frequency and proportion with one, two, and three defenders (small – large ESs: 0.41 – 1.52), but a lower frequency with four defenders ($p < 0.05$; moderate ESs: 0.95 ± 0.54), and frequency and proportion with five defenders ($p < 0.001$; very large ESs: 7.49 – 9.86). Phase of play had a greater: frequency and proportion of possessions with three attackers (small ESs: 0.41 – 0.59), and proportion with four attackers (moderate ES: 0.65 ± 0.56), and lower frequency and proportion of five attackers (small – large ESs: 0.29 – 1.55). Phase of play had a lower proportion of possessions with one player involved (small ES: 0.54 ± 0.56), but higher proportion of four and five players involved (moderate ESs: 0.65 – 0.84). Phase of play had longer possessions ($p < 0.01$; large ES: 1.34 ± 0.54) and a greater number of passes (moderate ES: 0.78 ± 0.57).

3.1.4. Competition vs conditioned game

Conditioned games had a lower: frequency of possessions starting from DL, DR and OL zones (small – moderate ESs: 0.41 – 0.70), and frequency and proportion from OC and OR zones (small – moderate ESs: 0.49 – 0.85), and greater proportion starting from NC and NR (small – moderate ESs: 0.56 – 0.61). Further, a lower: frequency of possessions with numerical superiority (moderate ES: 0.81 ± 0.59), and frequency and proportion with numerical inferiority (moderate – very large ES: 0.99 – 2.07). Conditioned games had a greater: frequency of possessions with one defender (small ES: 0.57 ± 0.59), and frequency and proportion of two and three defenders (moderate – very large ES: 0.83 – 3.03), but a lower: frequency with four defenders ($p < 0.001$; large ES: 1.52 ± 0.60), and frequency and proportion of five defenders ($p < 0.001$; very large ESs: 6.36 – 8.98). Further, a greater: frequency and proportion of possessions with two and three attackers (small – large ESs: 0.58 – 1.39), proportion of four attackers (moderate ES: 0.61 ± 0.62), and lower frequency and proportion of five attackers ($p < 0.001$; very large ESs: 3.08 – 3.85). Conditioned games had a lower frequency of four and five players involved in possession (moderate ESs: 0.90 – 1.15). There was no difference in possession duration or number of passes.

3.2. Shot-based variables

The shot-based variables according to match and training activity are presented in Table 4. The comparisons (statistical significance and ES) between matches and respective training activities are presented in Supplementary Material Figures S4 (relative frequency of variables; S4A: training state activities; S4B: playing state activities) and S5 (proportion of variables; S5A: training state activities; S5B: playing state activities).

3.2.1. Competition vs technical practice

Technical practice had a greater frequency and proportion of shots with a dribble as the preceding action ($p < 0.05$; moderate – large ES: 1.00 – 1.44), lower: proportion of shots preceded by a pass (moderate ES: 0.75 ± 0.60), and frequency and proportion of shots preceded by a regain ($p < 0.001$; large – very large: 1.69 – 2.71). Further, the shooting player had longer individual possession (moderate ES: 0.72 ± 0.53). Technical practice had a greater frequency and proportion of shots where the shooter was in motion ($p < 0.001$; large ESs: 1.44 – 1.68) and lower frequency and proportion where the shooter was stationary ($p < 0.001$; large – very large ESs: 1.44 – 2.67). Further, a lower: frequency of shots occurred in the neutral zones (moderate ESs: 0.73 – 0.76), frequency and proportion in the OL zone (small – moderate ESs: 0.31 – 1.13), and proportion in the OR zone (small ES: 0.47 ± 0.50), but a higher frequency and proportion in the OC zone ($p < 0.01$; moderate – large ESs: 1.14 ± 1.32). Technical practice had a greater frequency and proportion of wrist shots ($p < 0.001$; large ESs: 1.42 – 1.98), and lower frequency and proportion of slap shots and backhanded shots (small –

Table 4
Estimated marginal means (±95% CI) of shot-based variables during shooting events across matches and training activities.

Variable	Match		Practice/Training State Activities				Playing State Activities			
			Technical Practice		Skills Practice		Phase of Play		Conditioned Game	
	(n·min^{-1})	%	(n·min^{-1})	%	(n·min^{-1})	%	(n·min^{-1})	%	(n·min^{-1})	%
Preceding Action										
Pass	0.59 ± 0.46	57.99 ± 15.75	0.29 ± 0.15	**38.72 ± 9.06**	**0.15 ± 0.11**	**25.81 ± 13.38**	**1.86 ± 1.20**	**75.16 ± 11.36**	1.27 ± 0.94	60.32 ± 14.35
Dribble	0.23 ± 0.16	23.81 ± 15.43	**1.96 ± 0.91**	**60.05 ± 8.83**	**2.82 ± 1.81**	**71.43 ± 13.11**	0.22 ± 0.13	18.16 ± 11.11	0.17 ± 0.12	30.15 ± 14.06
Regain	0.16 ± 0.12	18.19 ± 3.32	**< 0.01 ± 0.00**	**1.17 ± 1.46**	**< 0.01 ± 0.00**	**2.81 ± 2.78**	**0.04 ± 0.02**	**6.61 ± 2.20**	0.08 ± 0.05	**9.81 ± 2.93**
Individual Possession Duration (s)	2.45 ± 0.59		**3.21 ± 0.30**		**3.99 ± 0.50**		2.30 ± 0.41		2.37 ± 0.54	
Pre-Shot Movement										
In Motion	0.75 ± 0.38	72.14 ± 9.42	**6.97 ± 1.86**	**97.89 ± 4.15**	**3.91 ± 1.74**	**96.47 ± 7.88**	**1.65 ± 0.561**	68.11 ± 6.23	0.68 ± 0.31	**62.18 ± 8.31**
Stationary	0.28 ± 0.18	27.86 ± 9.42	**< 0.01 ± 0.00**	**2.11 ± 4.15**	**0.01 ± 0.01**	**3.53 ± 7.88**	**0.60 ± 0.29**	31.89 ± 6.23	0.28 ± 0.17	**37.82 ± 8.31**
Shot Location										
D	< 0.01 ± 0.00	0.15 ± 6.22	< 0.01 ± 0.00	1.08 ± 3.57	< 0.01 ± 0.00	1.13 ± 5.28	< 0.01 ± 0.00	1.31 ± 4.48	**< 0.01 ± 0.00**	**7.99 ± 5.67**
NL	< 0.01 ± 0.00	0.66 ± 1.44	**< 0.01 ± 0.00**	< 0.01 ± 0.62	**< 0.01 ± 0.00**	0.31 ± 1.17	**< 0.01 ± 0.00**	< 0.01 ± 0.93	**0.02 ± 0.01**	**6.63 ± 1.24**
NC	< 0.01 ± 0.00	0.85 ± 6.98	**< 0.01 ± 0.00**	1.42 ± 3.18	**< 0.01 ± 0.00**	2.81 ± 5.86	**< 0.01 ± 0.00**	0.03 ± 4.67	**0.03 ± 0.02**	**22.42 ± 6.22**
NR	< 0.01 ± 0.00	0.71 ± 2.31	**< 0.01 ± 0.00**	0.07 ± 1.02	**< 0.01 ± 0.00**	< 0.01 ± 1.93	**< 0.01 ± 0.00**	0.11 ± 1.53	**0.01 ± 0.01**	**8.90 ± 2.03**
OL	0.32 ± 0.25	31.57 ± 8.95	**0.13 ± 0.06**	**12.34 ± 3.95**	0.14 ± 0.10	**14.71 ± 7.49**	0.22 ± 0.14	**19.11 ± 5.92**	**0.04 ± 0.03**	**23.92 ± 7.90**
OC	0.37 ± 0.22	36.62 ± 12.24	**3.65 ± 1.25**	**62.66 ± 5.63**	**2.59 ± 1.40**	**67.17 ± 10.30**	**1.23 ± 0.57**	**56.01 ± 8.21**	**0.07 ± 0.04**	**21.94 ± 10.94**
OR	0.30 ± 0.22	29.44 ± 8.26	0.51 ± 0.24	**22.28 ± 3.81**	0.22 ± 0.15	**14.89 ± 6.95**	0.42 ± 0.25	24.36 ± 5.55	**0.01 ± 0.01**	**6.37 ± 7.39**
Shot Type										
Slap Shot	0.21 ± 0.17	21.4 ± 6.18	**0.01 ± 0.01**	**4.96 ± 2.77**	**0.01 ± 0.01**	**4.82 ± 5.18**	0.17 ± 0.11	**17.24 ± 4.11**	0.11 ± 0.08	**9.14 ± 5.47**
Wrist Shot	0.77 ± 0.33	74.06 ± 6.79	**6.55 ± 1.46**	**92.34 ± 2.99**	**3.61 ± 1.37**	**89.72 ± 5.68**	**1.96 ± 0.62**	77.91 ± 4.49	**1.87 ± 0.74**	**84.31 ± 5.98**
Backhanded	0.02 ± 0.02	4.54 ± 3.04	**0.01 ± 0.00**	**2.70 ± 1.37**	0.04 ± 0.03	5.48 ± 2.55	0.04 ± 0.02	4.86 ± 2.02	0.05 ± 0.03	6.50 ± 2.70
Shot Outcome										
Goal	0.07 ± 0.05	7.68 ± 6.04	**0.40 ± 0.18**	**14.85 ± 2.72**	0.14 ± 0.09	10.50 ± 5.07	**0.16 ± 0.09**	10.76 ± 4.02	0.13 ± 0.09	**16.13 ± 5.36**
Saved	0.57 ± 0.25	55.66 ± 7.57	**4.48 ± 0.99**	**63.69 ± 3.34**	**2.32 ± 0.88**	58.92 ± 6.33	**1.52 ± 0.48**	**61.70 ± 5.01**	**1.47 ± 0.58**	**67.64 ± 6.68**
Blocked	0.18 ± 0.12	18.01 ± 3.28	**< 0.01 ± 0.00**	**0.74 ± 1.45**	**0.02 ± 0.01**	**5.57 ± 2.74**	0.09 ± 0.05	**11.62 ± 2.17**	**0.01 ± 0.01**	**4.61 ± 2.89**
Missed	0.18 ± 0.11	18.65 ± 6.28	**1.02 ± 0.35**	20.76 ± 2.98	**0.81 ± 0.45**	**24.75 ± 5.30**	0.22 ± 0.11	15.87 ± 4.26	0.16 ± 0.09	**11.54 ± 5.65**
Shots In Possession										
Single	0.87 ± 0.31	83.71 ± 3.94	**7.32 ± 1.31**	**97.42 ± 1.74**	**3.90 ± 1.22**	**96.29 ± 3.29**	**2.04 ± 0.52**	**80.93 ± 2.60**	**1.95 ± 0.64**	**87.91 ± 3.47**
Multiple (Rebound)	0.08 ± 0.06	7.67 ± 2.80	**0.01 ± 0.01**	**2.55 ± 1.23**	**0.01 ± 0.01**	**3.24 ± 2.34**	0.05 ± 0.03	7.67 ± 1.85	0.06 ± 0.04	8.24 ± 2.47
Multiple (Retention)	0.08 ± 0.04	8.62 ± 2.66	**< 0.01 ± 0.00**	**0.03 ± 1.20**	**< 0.01 ± 0.00**	**0.46 ± 2.23**	0.10 ± 0.04	**11.41 ± 1.77**	**0.01 ± 0.01**	**3.85 ± 2.36**

Shot location: D = defensive. NL = neutral left. NR = neutral right. NC = neutral centre. OL = offensive left. OR = offensive right. OC = offensive centre. **Bold**: statistically significant p-value ($p < 0.05$) and/or substantial effect size (>0.2).

large ES: 0.32 – 1.41). Further, a greater: frequency and proportion of goals and saves (small – large ESs: 0.56 – 1.92) and frequency of misses ($p < 0.05$; moderate ES: 0.93 ± 0.48), and lower frequency and proportion of blocks ($p < 0.001$; very large ES: 2.00 – 2.78). Technical practice had a greater frequency and proportion of single shots in a possession ($p < 0.001$; large – very large ESs; 1.84 – 2.52), and lower frequency and proportion of multiple shots through rebound and retention (moderate – very large ESs: 0.97 – 2.64).

3.2.2. Competition vs skills practice

Skills practice had a higher frequency and proportion of shots preceded by a dribble ($p < 0.05$; moderate – large ESs: 1.17 – 1.89), and lower frequency and proportion of shots preceded by a pass or regain (small – very large ESs: 0.50 – 2.45). Individual possession duration was longer during skills practice ($p < 0.01$; large ES: 1.46 ± 0.61). Skills practice had a greater frequency and proportion of shots where the shooter was in motion ($p < 0.01$; large ESs: 1.24 – 1.36), and lower frequency and proportion of shots where the shooter was stationary ($p < 0.01$; large ESs: 1.36 – 1.77). Further, a lower: frequency of shots were taken in the neutral zones (small – moderate ESs: 0.52 – 0.79) and proportion of shots in OL and OR zones (moderate ESs: 0.95 – 0.99), and greater frequency and proportion of shots in OC zone ($p < 0.05$; moderate – large ESs: 1.12 – 1.33). Skills practice had a greater frequency and proportion of wrist shots ($p < 0.01$; large ESs: 1.22 – 1.43) and lower frequency and proportion of slap shots ($p < 0.05$; moderate – large ESs: 1.10 – 1.42). Further, a greater: frequency of saves ($p < 0.001$; large ES: 1.31 ± 0.58) and frequency and proportion of misses (small – moderate ESs: 0.53 – 0.81), and lower frequency and proportion of blocks ($p < 0.05$; moderate – very large ESs: 1.00 – 2.00). Skills practice had a greater frequency and proportion of single shots in a possession ($p < 0.001$; large ESs; 1.69 – 1.78), and lower frequency and proportion of multiple shots through rebound and retention (moderate – very large ESs: 0.68 – 2.50).

3.2.3. Competition vs phase of play

Phase of play activities had a greater frequency and proportion of shots preceded by a pass (small – moderate ESs: 0.42 – 0.67) and lower frequency and proportion preceded by a regain (small – large ESs: 0.55 – 1.84). Phase of play activities had a greater frequency of shots where the shooter was in motion and stationary (small ESs: 0.40 – 0.60). Further, a lower frequency of shots taken in the neutral zones (moderate ESs: 0.69 – 0.90) and proportion of shots taken in the OL zone (moderate ES: 0.73 ± 0.53) and greater frequency and proportion of shots taken in the OC zone (moderate ESs: 0.69 – 0.85). Phase of play had a greater frequency of wrist shots (moderate ES: 0.86 ± 0.53) and lower proportion of slap shots (small ES: 0.36 ± 0.53). Further, a greater frequency of goals (small ES: 0.35 ± 0.54) and frequency and proportion of saves (small - moderate ESs: 0.42 – 0.91) and lower proportion of blocked shots ($p < 0.05$; moderate ES: 1.03 ± 0.53). Phase of play activities had a greater frequency ($p < 0.05$; moderate ES: 1.01 ± 0.53) but lower proportion (small ES: 0.37 ± 0.53) of single shots in a possession, and a greater proportion of multiple shots through retention of possession (small ES: 0.55 ± 0.53).

3.2.4. Competition vs conditioned game

Conditioned games had a lower proportion of shots preceded by a regain ($p < 0.01$; large ES: 1.33 ± 0.59) and where the shooter was in motion (small ES: 0.56 ± 0.59), and a greater proportion where the shooter was stationary (small ES: 0.56 ± 0.59). Further, a greater frequency and proportion of shots taken in the defensive (moderate ESs: 0.77 – 0.98) and neutral zones ($p < 0.05$; moderate – large ESs: 1.10 – 2.24). Conditioned games had a greater frequency and proportion of wrist shots (moderate ESs: 0.80 – 0.82), and lower frequency of slap shots ($p < 0.05$; moderate ES: 1.05 ± 0.59). Further, a greater: proportion of goals (moderate ES: 0.74 ± 0.59) and frequency and proportion of saves (moderate ESs: 0.84 – 0.88), and lower: frequency and proportion of blocked shots ($p < 0.05$; moderate – very large ESs: 1.16 – 2.16) and proportion of missed shots (moderate ES: 0.61 ± 0.61). Conditioned games had a greater frequency and proportion of single shots in a possession (small – moderate ESs; 0.56 – 0.96), and lower frequency and proportion of multiple shots through retention of possession (moderate ESs: 0.95 – 1.03).

4. Discussion

This study quantified and compared the technical-tactical characteristics of shooting during competition and training activities in senior men's domestic ice hockey. There are several novelties of this study, including evaluating the representativeness of shooting during training activities in any sport, evaluating the representativeness of training activities in ice hockey, and conducting match and/or training analysis of shooting within this population (amateur senior men's domestic ice hockey). Further, the comparatively large dataset (~4000 shots) and comprehensive notational analysis process to evaluate representativeness of training activities are key strengths of this study [17]. Overall, the representativeness of shooting differed according to training activity. Similar trends in the representativeness (e.g., more/less frequent, higher/lower proportions) of possession- and shot-based technical--tactical variables were observed between and within training state (i.e., technical activities, skills activities) and playing state (i.e., phase of play, conditioned game) activities. The findings highlight the need for coaches to evaluate how training activities, and their inherent constraints, shape shooting performance and wider performance. Specific consideration should be given to what, and the extent of, informational cues and movement demands are present in competition. This detail could support the development and transfer of skills between training and competition environments. Lastly, and importantly, an activity may preserve some features of competition (e.g., attacker-defender relations) whilst intentionally altering others (e.g., shot location, repetition density); a lack of representativeness in specific variables is therefore not necessarily a shortcoming of the activity.

During competition, possessions resulting in a shot predominantly had numerical balance between the attacking and defending team (84.6% of shots), with five attackers (85.6%) and five defenders (96.3%). In contrast, during training activities, possessions resulting in a shot predominantly had numerical superiority (technical practice = 98.6%; skills practice = 65.5%; phase of play = 90.33%) with only conditioned games having a similar proportion of numerical balance (85.0%). Further, training activities with five defenders (<0.01 – 7.8%) and five attackers (<0.01 – 60.5%) were under-represented across all training activities. This lack of (or low) representativeness to competition may be expected within training state activities (i.e., technical practice, skills practice), as by their definition, focus on technical execution under limited or controlled pressure [30]. Therefore, technical practice is by design, decontextualised to the demands of match-play, with reduced functionality and action fidelity, which may ultimately have reduced transfer to competitive environments [1]. However, training activities which are more contextualised (i.e., phase of play, conditioned game), surprisingly also lacked key informational cues present in competition. Moreover, creating possessions with numerical superiority and a lower number of defenders, will impact the informational cues and movement demands relating to attacker-defender interactions (e.g., defensive pressure, player positioning and decision-making), likely providing the player in possession and their teammates greater time and spatial affordances within training activities [48]. Further, the lower number and proportion of shots blocked across all training situations would indicate less defensive pressure on the shooter, and the higher frequency and proportion of goals and saved shots within specific training activities, suggest greater opportunity to create and convert goal scoring opportunities [33,49]. Considering the combination of these findings, training activities (training state or playing state) appear to represent limited information

and demands of competition, which may limit the development and transfer of shooting [1]; however, as learning and transfer were not measured, this requires empirical investigation. Nonetheless, technical practice afforded a far greater density of shooting repetitions than competition (e.g., single shots: 7.32 vs 0.87 $n \cdot min^{-1}$) under reduced pressure, which may benefit players developing a skill, with task complexity progressively increased as proficiency improves [50,51]. Coaches should therefore balance repetition and representativeness when designing shooting practice.

When considering the attacking team, it is also important to acknowledge that training activities may fail to represent the informational cues, and movement demands present in competition for defenders and the goalkeeper, and therefore, may have skill transfer implications to competition. For example, (assuming similarities within other teams or across the population) the majority of shots during competition were taken from offensive zones (97.6%), yet shots from the OC zone was over-represented and OL and OR zones under-represented across technical practice, skills practice and phase of play activities, whilst all offensive zones were under-represented in conditioned games. The location the shot is taken from, will have wider implications on the execution of the shot (e.g., trajectory, type: wrist-shots typically over-represented across training activities) [52], and defenders' (e.g., distance, body orientation) and goalkeeper's (e.g., depth, width, angle) positioning and decision-making (e.g., defensive intervention, save technique). Further, in addition to the lack of possession-based representativeness in the build-up to the shot, and the shot itself, training activities typically had an over-representation of single shots in possession and under-representation of multiple shots (rebound and retention). Consequently, training activities may lack the contextual information, and movement demands present for the next action or phase of the possession; either securing the puck to defend (or attack) instinctively through a rebound or to retain possession for a further attack, or if a turnover in possession, transition to attack [25]. This may therefore impact skill transfer (execution and decision-making) into competitive environments. Coaches should therefore consider not only the representativeness of the shot or the possession which leads to it, but also the phase(s) after, when designing and delivering training activities intended to represent key informational cues and movement demands present in competition. Additionally, future research should adopt a sequential analysis approach to explore the representativeness of shooting, considering the sequence and order of events which occur within the possession, shot, and the phase(s) after; moving beyond an aggregated approach would further facilitate the design and of coaching activities.

Notably, there were several variables which were excluded from analyses due to a high proportion of zero-observations within respective levels of categorical variables within competition and/or training activities, including number of attackers in front, behind, and inactive, and number of defenders in front, behind and inactive. Consequently, the absence of such observations within either training and/or competition, demonstrates a lack of representativeness within the respective variables. For example, both goalkeepers were present for all shots during competition, and therefore, shots during training which had either the team or opposition goalkeeper pulled, lacks representativeness to competition. Therefore, coaches and practitioners may not only draw insights from the presented analyses of this study, but also the frequency and distribution of the underpinning shots during competition and training, which are presented in the supplementary material.

As is the nature of applied observational research, the research team had no contribution or involvement in the planning, delivery and review of training sessions, or indeed, the tactics and strategies adopted in competition. Further, the team had no understanding of the decision-making or considerations impacting the choice of training activities implemented or approaches within competition. Consequently, the context surrounding respective training activities are unknown. The role of the coach may therefore be fundamental in aiding interpretations of training activities in relation to representativeness. For example, understanding: the intentions and decisions relating to training activity and design within the session (e.g., pedagogical approaches, learning outcomes, specific task constraints, increasing or decreasing challenge, isolating skills, trialling specific combinations of players) [50,53,54], beyond the session (e.g., training curricula, periodisation and training load management) [51,53,55] or the performance expectations upon players (e.g., "success looks like…", coach/club philosophies or principles of play) [56–58]. Therefore, future research should aim to capture and consider the intentions of the coach and key decisions informing match strategy and training design and delivery, to contextualise performance and inform interpretations. For example, were coaches conceding representativeness in specific variables (e.g., starting location of possession in this study typically not representing competition) to focus on development of others, and if so, which variables should be prioritised, and how would they approach creating more or less representative environments (e.g., which constraints would they implement, what are the expected impact on performance?). Further, research could engage in critical reflections with the coach to understand whether their intentions (e.g., planned session) matched the reality (e.g., performance; did the intention of creating representative environments align with observed behaviours?). Coaches within applied environments are encouraged to reflect upon coaching practices (during planning, delivery and review) where training activities are intended to be representative; how the design may facilitate (or not) representativeness, what interventions (e.g., task constraints, coach behaviours) may create more or less representative environments, and the rationale and considerations contributing to their decision-making processes. For example, coaches could: 1) identify the intended learning outcome; 2) identify the features of competition most relevant to it (e.g., numerical balance, number of defenders, shot location); 3) select the activity and constraints that preserve these; 4) decide which features may be conceded (e.g., for repetition density); and 5) review observed performance against competition.

Whilst this study provides novel and comprehensive insights into the representativeness of shooting during training activities in ice hockey, there are limitations which should be acknowledged. Firstly, this study utilised a single-team sample due to the practical challenges associated with data collection in this population (e.g., unfeasible travelling distance/time to and from the research institution to respective club training and match venues for data collection, compounded by the typical training times of this population (starting after ~22:00)). Consequently, the number of matches and training observations, and therefore, training activities and shots were limited. Future research should aim to increase the number of observations (e.g., whole season or across multiple seasons) to increase the sensitivity of analyses to reliably detect statistically significant differences in effects of smaller magnitudes. Furthermore, future research should adopt a multi-club data collection approach (across multi-seasons) to investigate potential differences in representativeness between-teams/clubs, and to facilitate greater generalisability of findings for the wider population (i.e., senior domestic men's ice hockey). Secondly, spatial constraints within the venues (e.g., venue dimensions, access or viewing points) had implications for the camera location, and therefore the recordings of matches and training sessions (e.g., angle, height, distance) and notational analysis process pertaining to shots. Consequently, it was not possible to conduct a more detailed analysis process (e.g., number of touches, goalkeeper-related variables, distance-based measures (e.g., defensive pressure)). Future research may consider alternative data capture approaches (e.g., multiple camera angles) to facilitate such analyses (acknowledging the practical challenges associated with data collection in applied sport environments). Thirdly, this study compared training activities (i.e., technical practice, skills practice) without understanding of the coaches' intentions and consideration of the characteristics within training activities. Given that task constraints may influence performance (physical, technical and tactical) [9,59,60], it is therefore

important that future research, at a minimum, describes task-constraints for training activity observations, but also aims to explore the potential influence of task constraints on the representativeness of training activities [17]. Further, learning, retention and transfer were not measured; implications for skill transfer are therefore theoretically informed and require testing through intervention research. Lastly, a linear mixed model approach was adopted, utilising data aggregated to the activity-level. Consequently, the random effect (observation ID) had uneven number of observations; whilst included to account for dependence within the data (i.e., between training activities within training sessions), this contributed limited information to the estimation of random-effect variance. Additionally, an alternative distribution-specific generalised linear mixed model may provide a more appropriate means of modelling the distinct characteristics of count (e.g., Poisson or negative-binomial distributions), proportion (e.g., binomial or multinomial distributions) and duration (e.g., Gamma distribution) variables. Future research could adopt alternative statistical approaches to evaluate representativeness of activities, and at differing levels of analysis (i.e., shot-level).

5. Conclusion

This research provides a novel and comprehensive assessment of the representativeness of shooting during training activities in senior men's domestic ice hockey. Overall, the representativeness of possession-based and shot-based technical-tactical characteristics for shooting differed according to the training activity. Across training activities, shots typically lacked possession-based representativeness; for the starting location of possessions, with numerical superiority over-represented and numerical balance and inferiority under-represented, and consistently fewer defenders and attackers than present in competition, therefore, the possessions leading up to shots appear to lack key informational and contextual demands present in competition. Additionally, the differences between competition and training activities surrounding the shot (action preceding the shot, shooter's pre-shot movement, location the shot was taken from, type of shot, outcome of the shot and number of shots in the possession) would further suggest that key informational and contextual demands present in competition are not present within training activities. However, it is important for coaches to consider representativeness as a spectrum (i.e., more or less representative), understanding how different training activities may allow more or less representative shooting performance to emerge, with consideration of specific technical-tactical characteristics. Understanding which possession-based and shot-based variables may be more or less representative across training activities can inform the design, delivery and review of coaching practice (e.g., focussing on the development or transfer of a particular skill and therefore, the representativeness of a specific variable). Rather than viewing representativeness as an inherent quality of a training activity, these findings suggest that coaches should deliberately align the informational and contextual demands of shooting practice with the intended learning outcome, whether this is technical refinement, decision-making under pressure, or transfer to competition. Therefore, future research should examine the alignment between coach intentions and performance which occurs during training activities (i.e., intention vs reality), and importantly, how (the manipulation of) task constraints may influence the representativeness of training activities. Lastly, future research should adopt a multi-club approach over multiple seasons to explore between-team/club differences and the generalisability of representativeness to the wider population.

Ethical considerations

This study was approved by the University of Essex Research Ethics Committee (ETH2425-2089) in November 2024.

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Consent to participate

Written informed consent (or assent and player/guardian consent) was collected prior to participation.

CRediT authorship contribution statement

Conrad Fletcher: Writing – original draft, Validation, Software, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Simon Quick:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Emily Cushion:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Alice Harkness-Armstrong:** Writing – review & editing, Visualization, Validation, Supervision, Software, Methodology, Formal analysis, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

The authors report generative AI was not used in their research or preparation of this manuscript.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.tss.2026.100033.

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