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Dynamics of training and competition demands in top-class male rink hockey: a case study of a rink hockey European Championship

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ABSTRACT

This study aimed to investigate the training load through external and internal load dynamics across the preparation and competition of a top-level national team during a Rink Hockey European Championship. A non-experimental descriptive method was developed. A two-way mixed design ANOVA and a Spearman correlation test were used to compare and understand the relationship between players' external and internal load across microcycles during training sessions and competitive matches. Results revealed significantly higher values between training match day −3 to training match day −1 for player load ($p \leq 0.05$), distance covered, and high-speed skating ($p \leq 0.001$). Competition weeks exposed significantly higher values in comparison with training weeks. Interestingly, during competition, high impacts ($p \leq 0.001$, $r = 0.64$) and decelerations ($p \leq 0.001$, $r = 0.43$) had a greater influence on players' session RPE than in training weeks. Different external and internal load dynamics were observed in the competition and training weeks, with high impacts and decelerations appearing to create a physiological impact on players, but the same does not occur in the training sessions. Results highlight the need to understand the competitive dynamics of each sport and the use of the most appropriate metrics to monitor the preparation process.

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Indoor team sports; performance; load monitoring; local position system; fatigue

1. Introduction

In team sports such as rink hockey, monitoring athletes' training load (TL) and competition load (CL) is important for understanding whether they are adapting to training programmes as well as to determine their responses to competition

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(Halson, 2014; Rago et al., 2020). Therefore, it is important to monitor TL to appropriately adjust between stress and recovery during training microcycles (Rago et al., 2021) and minimise the risk of developing non-functional overreaching (Halson, 2014).

In TL, the external load (EL) is the work accomplished by the players to achieve a certain goal (i.e. distance, accelerations, decelerations, change of directions, or sprints, among others) during the training or competitive contexts (Fernández et al., 2021; Rago et al., 2021), the internal load (IL) represents the physiological stress imposed by the stimulus for training/competition-induced adaptation. Accordingly, EL may be classified into three main categories: *(1)* Kinematics, which quantifies overall movement during exercise; *(2)* Mechanical, which describes the player's overall load during exercise; and *(3)* Metabolic, which quantifies overall movement energy expenditure during exercise (Impellizzeri et al., 2019). The internal load is usually measured through direct measures such as heart rate (HR) or indirectly through the rating of perceived exertion (RPE) (Rossi et al., 2018). In order to manage athlete fatigue and ensure peak performance during short concentrated competitions, it is crucial to assertively adjust the microcycles and modify the dynamics of training load to promote optimal responses to specific stimuli (Halson, 2014). In that sense, analysing the relationship between EL and IL is key for monitoring player fatigue and readiness for competition (Halson, 2014). Thus, further research is expected to identify the variables that better characterise the dynamics of training weeks and competitive weeks and the specific strategy of tapering before the competition.

Rink hockey is a team sport that is played by four field players and one goalkeeper, and official games have two periods of 25 min each (Hoppe et al., 2015). The game is performed on a court like futsal and handball, but with railings around the rink perimeter (Yagüe et al., 2013), promoting fewer interruptions compared to other indoor team sports (Fernández et al., 2021). Additionally, the use of quad roller skates facilitates the movement of the players on the court, making it easier to cover large distances. It is, in fact, a high-intensity intermittent sport in which non-continuous actions of different speed levels are followed by incomplete recovery periods, requiring a well-developed metabolism for short and long-duration efforts (Vona, 2009). It is also characterised by high-intensity actions such as accelerations, decelerations, sprints, and changes of direction (Fernández et al., 2021). Additionally, intra- and inter-muscular and neuromuscular coordination are determinants for skating, ball mastery, and control using the stick (Ferraz et al., 2020). Despite rink-hockey popularity, research is still scarce; however, in the last years, some studies have been conducted related to elite players, such as the analysis of the goalkeeper activity (Sousa et al., 2018), body composition and conditional profile (Ferraz et al., 2022), training, and competition demands (Fernández et al., 2021)

The availability of tracking technology provides an opportunity to increase the understanding of game and player demands in indoor sports such as rink hockey. To date, only four studies have been conducted regarding the characterisation of physical demands in elite rink hockey (Fernández et al., 2020, 2021, 2023) Notwithstanding such studies, no research has been conducted to investigate the relationship between the impact of EL variables on the IL of players in a short and concentrated international competition such as the rink hockey European Championship. That is, what is the relationship between the structure of the training and the competition regarding the type of work developed (EL variables) and the stress imposed on the players (IL) in a short, concentrated competition such as the rink hockey European Championship? Is there any relationship between EL and IL between training and competition weeks, suggesting that the training process represents the competition's demands?

Therefore, the aim of this research was to understand the dynamics of external and internal load across the training sessions of the 2 weeks of preparations and the competition week of the European Championship (three matches in a row). Consequently, we defined two specific goals: *(1)* to understand the dynamics and compare the EL and IL of training sessions and the competition weeks; *(2)* to understand the relationship between EL and IL in training sessions and competition matches EL.

2. Material and methods

2.1. Ethics statement

Data collections were carried out according to the international ethical standards with humans based on the Declaration of Helsinki (Harriss et al., 2019) after approval by the Ethics committee of the University of Beira Interior (CE-UBI-Pj-2019–053:ID1519). All participants were informed about the aims, the protocol and the procedure, and provided signed written informed consent. Participation was voluntary, and each participant could withdraw at any time. To ensure player confidentiality, all data were anonymised prior to the analysis.

2.2. Participants

A total of nine top-level Portuguese male rink hockey players (five defenseman/midfielder and four forwards; age = 29.89 ± 3.41 years old, height = 175.7 ± 4.21 cm, body mass = 80.03 ± 8.33 kg, BMI = 25.94 ± 2.64 kg/m^2) competing at the 2021 Rink Hockey European Championship participated voluntarily in the study. These world-class athletes compete in the main teams of the most prestigious rink hockey leagues (Arboix-Alió et al., 2021). Goalkeepers were not included. The inclusion criteria for participants in the study were as follows: *(1)* the player had no injury or limitation during the period of analysis; *(2)* the player had completed the entire training session or game; and *(3)* the player participated in the competitive games at the 2021 Rink Hockey European Championship.

2.3. Study design

An observational study was carried out during the preparation and competition phases at the 2021 Rink Hockey European Championship from the 1^{rst} until the 20th of November 2021 (Figure 1). A non-experimental descriptive method was used to characterise the training sessions and training matches during the two (2) concentrated pre-season weeks (TW-2 - two training weeks preceding the competition and TW-1 - one week before the competition) and the competitive games of the competition week (CW). Each preparation week included two cycles of three training sessions (TMD-3, TMD-2, TMD-1) followed by one training match

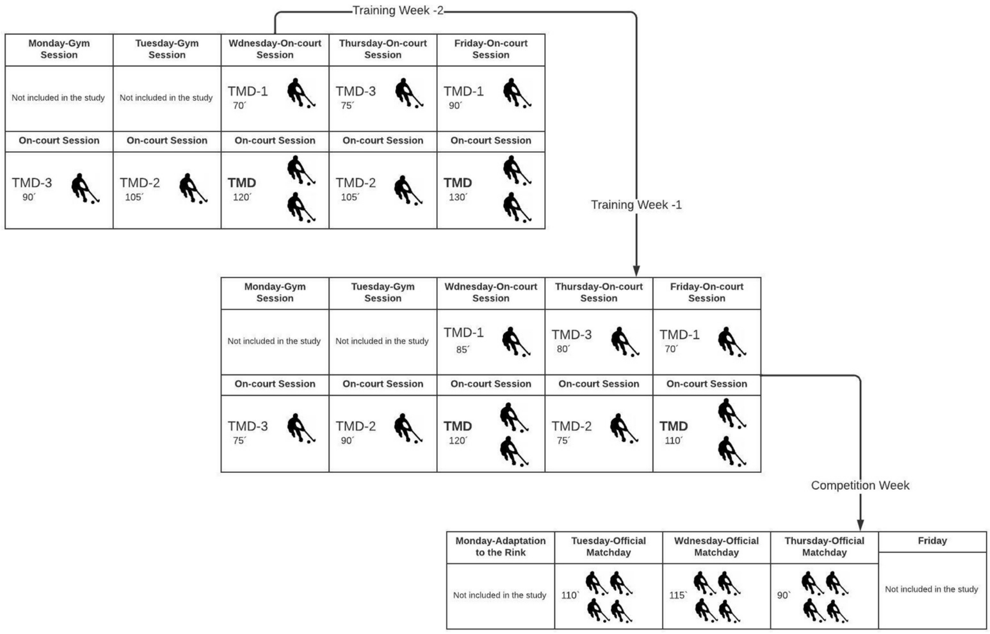

Figure 1. Flow chart of training sessions and official match days of the reported weeks.

(TMD). In total, the players participated in 12 rink training sessions, 4 training matches, and 3 international competitive games during the 3 weeks of the study. To monitor players' load in their training context, no information was given about the research design to the technical staff throughout the data collection period.

2.4. External Load variables (EL)

Data collection related to player's activity during in-court sessions with skates was carried out with Inertial Movement Units (IMUs) using an ultra-wideband (UWB) local positioning system (LPS) technology from WIMU PRO^{TM} (Realtrack Systems SL, Almeria, Spain) and downloaded using its corresponding software (SPRO^{TM}, Realtrack Systems SL, version 986). The WIMU PRO^{TM} is equipped with four 3D accelerometers (full-scale out output ranges are ±16 g, ±16 g, ±32 g and 400 g; 100 Hz sample frequency), three gyroscopes (8000°/s full-scale out output range; 100 Hz sample frequency), a 3D magnetometer (100 Hz sample frequency), a Global Positioning System (GPS; 10 Hz sample frequency), and a UWB (18 Hz sample frequency) (Fernández et al., 2021; Impellizzeri et al., 2004). The devices were turned on 10–15 min before the warm-up began and placed in the upper part of the athlete's back, in a tight-fitting harness. Six antennas with UWB technology were fixed ±5 m to the court. The LPS system operates using triangulations between the antennas and the LPS unit devices and derives the unit's position (X and Y coordinates) using one of the antennas as a reference. Although training sessions and official games occurred in two different courts, to decrease possible technical differences, WIMU devices were calibrated according to the specific court design and

Table 1. EL variables recorded in this study.

Type	Variable	Sub-variable	Unit	Description
Kinematics	Distance covered		DT (m)	Total distance skated in meters
		Moderate-Speed Skating	(12.1–12 km/h) MSS (m)	Total distance skated between 12.1 and 18 km/h
		High-Speed Skating	(18.1–30 km/h) HSS (m)	Total distance skated between 18.1 and 30 km/h
Mechanicals	High-intensity Impacts	Total	HImpt (n)	Total number of impacts recorded between 8 and 10 *g*
	Player Load	Total	PL (a.u.)	Accumulated accelerometer load in the three axes of movement
	Accelerations	Total	ACC/[3 10]m/s^2 (n)	Total number of positive speed changes
	Decelerations	Total	DEC/[−10–3]m/s^2 (n)	Total number of negative speed changes

antenna positions. The accuracy and reliability of the WIMU devices have been previously reported and validated (Bastida-Castillo et al., 2019).

From the collected positional data, the following variables were calculated in absolute terms to describe EL (Table 1): distance travelled (DT; m); medium speed skating (MSS (12.1–18 km/h);/m); high-speed skating (HSS (18.1–30 km/h);/m); number of high-intensity impacts (HImpt (8–100 G); n); number of high-intensity accelerations (ACC [3 10] m/s^2); n); number of high-intensity decelerations (DEC [−3–10]m/s^2); n); and Player Load (PL; au). High-intensity impacts were included in line with previous research in rink hockey (Yagüe et al., 2013). Training sessions and official game data were expressed in absolute values (load) – to translate and compare the demands of the official match sessions total load and the training routines.

2.5. Internal Load variables (IL)

Individual players' rating of perceived exertion (RPE) was collected using a visual Borg category (0–10) scale, obtained approximately 30 min after each in-court training and official game session, ensuring that the perceived effort reflected the whole session and not the most intense exercise (Impellizzeri et al., 2004). The overall TL was described by the session-RPE, which was calculated by multiplying the RPE score (0–10 AU) by the individual session's duration (in minutes, excluding game warm-up) (Foster et al., 2001) in line with previous research on elite male Rink Hockey athletes (Fernández et al., 2021).

2.6. Statistical analysis

All statistical analyses were conducted using IBM SPSS Statistics for Windows (Version 20.0. Armonk, NY: IBM Corp.) Descriptive statistics (range, mean, standard error of the mean and standard deviation) were calculated for the overall sample. Training and games were grouped by weeks (microcycles) according to previous descriptions (TW-2; TW-1 and CW). Also, training sessions were grouped according to the days distancing the training matches during the TW-2 and the TW-1 (e.g. TMD-3; TMD-2; TMD-1, and TMD). Data normality was tested by the Shapiro–Wilk test. To compare the differences between EL and IL across the weeks and the training days, a two-way mixed design analysis of variance (ANOVA) was conducted. The Bonferroni method was used for multiple pairwise comparisons. The Kruskal–Wallis test was performed for variables with non-normally distributed data. Additionally, Cohen's *d* effect size analysis was used to determine the magnitude of effect, whenever the ANOVA test was used and was interpreted based on the following criteria: 0–0.20, trivial; 0.21–0.60, small; 0.61–1.20 moderate; 1.21–2.00, large; >2.00, very large (Hopkins et al., 2009). In cases where the Kruskal–Wallis test was used, η^2 was obtained and the interpretation of the effect size was based on the following criteria: <0.01 no effect, <0.0–0.05 small effect, 0.06–0.13 moderate effect, and ≥0.14 large effect (Fritz et al., 2012). In the presented results, the effect size was reported only where significant ($p \leq 0.05$) differences were found. Finally, to understand the relationship between players' EL and IL during training sessions and competitive matches, a Spearman correlation test was performed.

3. Results

The analysis of training weeks revealed a general decrease in all the variables from TMD-3 to TMD-1. Significant differences ($p \leq 0.05$) were also observed between TMD-3 and TMD-2 in comparison with TMD-1 for PL. Further, significant differences ($p \leq 0.05$) were observed between TMD-3 and TMD-1 for DT and HSS (Table 2).

The comparison between training matches (TMD) and training sessions (TMD-3 to TMD-1) during the weeks TW-2 and TW-1 revealed that the total duration of the session (DS) and all EL and IL variables of TMD were significantly ($p \leq 0.05$) higher than in TMD-3, TMD-2 and TMD-1 (Table 2).

The analysis between training (TW-2 and TW-1) and competition (CW) weeks revealed significant differences ($p \leq 0.05$) in all metrics with higher values for CW when compared to both TW-2 and TW-1. TW-2 revealed higher significant values ($p \leq 0.05$) in IL metrics RPE and s-RPE and in the EL metric (DT) in comparison with the TW-1 (Table 3). In opposition, TW-1 revealed higher significant values ($p \leq 0.05$) in EL metric ACC in comparison with the TW-2 (Table 3). No other differences were observed in EL variables between TW-2 and TW-1.

The analysis of the correlations between EL and IL variables (Table 4) revealed different relations for TW-2 and TW-1 in comparison with CW. While TW-2 and TW-1 revealed significant correlations between all EL variables and the IL (s_RPE), the CW only revealed significant correlations between HImpt and DEC (Table 4). Additionally, HImpt demonstrated lower correlations with s-RPE in TW-2 and TW-1 when compared to CW. Interestingly, CW also revealed a tendency to have negative correlations ($p \geq 0.05$) between DT, MSS, HSS, and s-RPE.

4. Discussion

The present study aimed to understand the dynamics of external and internal load across the training sessions of the 2 weeks of preparations and the competition week of the male 2021 Rink Hockey European Championship. According to our expectations, during the training weeks, the management of the training load was developed with reference to the TMD, both in TW-2 and TW-1, with a wavy dynamic. Also, while TW-2 was characterised by high levels of RPE, s-RPE, and DT, TW-1 was characterised by high levels of

Table 2. External load and IL metrics between training sessions and training matches (TMD) across TW-2 and TW-1.

Variable	TMD-3 (*n* = 35) Value [95%CI]	TMD-2 (*n* = 32) Value [95%CI]	TMD-1 (*n* = 39) Value [95%CI]	TMD (*n* = 34) Value [95%CI]	*Effect Size* Value	*Effect Size* Qual.
DS (min)	84 ± 7.46	85.78 ± 12.19	74.49 ± 23.31	119.71 ± 7.17	**#** $0.86^{\S2}$	large
	[81.44–86.56]	[81.39–90.18]	[66.93–82.04]	[117.20–122.21] **# ** ϴ**	** $0.84^{\S2}$	large
					ϴ $1.07^{\S2}$	large
DT (ms)	7,586.59 ± 1,113.74	7,122.66 ± 1,894.09	6,221.13 ± 1,590.34	9,055 ± 874.72	**#**$0.65^{\S2}$	large
	[7,195.88–7,977.30] **ϴ**	[6,439.77–7,805.55]	[5,705.60–6,736.66]	[8,749.79–9,360.21] **# ** ϴ**	**$0.84^{\S2}$	large
					ϴ$1.09^{\S2}$	large
MSS (m)	1,898.32 ± 635.55	1,594.89 ± 1,067.58	1,571.39 ± 596.85	2,145.63 ± 408.26	**α** $0.69^{\S1}$	moderate
	[1,680.01–2,116.64]	[1,209.98–1979.79]	[1,375.21–1,767.58]	[2,003.18–2,288.08] **α β**	**β** $1.11^{\S1}$	moderate
HSS (m)	452.54 ± 123.87	413.81 ± 244.81	281.13 ± 185.10	573.30 ± 162.70	**ϴ** $1.08^{\S1}$	moderate
	[409.98–495.09] **ϴ**	[325.54–502.07]	[221.12–341.13]	[516.52–630.06] **α ϴ**	**α** $0.77^{\S1}$	moderate
					ϴ $1.67^{\S1}$	big
HImpt (n)	0.40 ± 0.65	0.47 ± 0.88	0.46 ± 0.85	3.12 ± 2.53	*$0.45^{\S2}$	large
	[0.93–1.93]	[0.70–1.49]	[0.85–2.07]	[3.30–6.06] *** ** ϴ**	** $0.50^{\S2}$	large
					ϴ $0.48^{\S2}$	large
PL (a.u.)	35.68 ± 6.37	35.06 ± 8.97	29.79 ± 7.59	45.49 ± 5.81	**β** $0.84^{\S1}$	moderate
	[33.49–37.87] **β**	[31.82–38.29] **β**	[27.33–32.26]	[43.47–47.52] **# ** ϴ**	**β** $0.64^{\S1}$	moderate
					# $1.61^{\S1}$	big
					** $1.39^{\S1}$	big
					ϴ $2.30^{\S1}$	very big
ACC (n)	116 ± 31.19	102.59 ± 40.27	89.08 ± 40.90	157.59 ± 54.84	*$0.37^{\S2}$	large
	[105.28–126.72]	[88.08–117.11]	[75.82–102.33]	[138.45–176.72] *** ** ϴ**	** $0.48^{\S2}$	large
					ϴ $0.65^{\S2}$	large
DEC (n)	77.43 ± 23.71	70.03 ± 32.22	57.38 ± 31.67	104.15 ± 31.77	*$0.96^{\S1}$	moderate
	[69.28–85.57]	[58.42–81.65]	[47.12–67.65]	[93.06–115.23] *** ** ϴ**	** $1.07^{\S1}$	moderate
					ϴ $1.48^{\S1}$	big
Declared RPE (0–10 scale)	5.71 ± 1.82	5.19 ± 2.48	4.87 ± 1.96	7.24 ± 1.37	***** $0.36^{\S2}$	large
	[5.09–6.34]	[4.29–6.08]	[4.24–5.51]	[6.76–7.71] *** α ϴ**	**α** $0.45^{\S2}$	large
					ϴ $0.56^{\S2}$	large
s-RPE (a.u)	485.29 ± 175.72	468.75 ± 271.63	392.31 ± 228.47	868.82 ± 182.84	**#** $0.64^{\S2}$	large
	[424.92–545.65]	[370.82–566.68]	[318.25–466.37]	[805.03–932.62] **# ** ϴ**	** $0.67^{\S2}$	large
					ϴ $0.82^{\S2}$	large

**Significantly higher than TMD-3 ($p \leq 0.05$); # significantly higher than TMD-3 ($p \leq 0.001$); α significantly higher than TMD-2 ($p \leq 0.05$); **significantly higher than TMD-2 ($p \leq 0.001$); β Significantly higher than TMD-1 ($p \leq 0.05$); ϴ Significantly higher than TMD-1 ($p \leq 0.001$);* §1 – Cohen's *d*; §2 - η^2.

DS, total duration of the session; DT, distance travelled; MSS, moderate-speed skating; HSS, high-speed skating; HImpt, number of high-impacts; PL, Player Load; ACC, high-intensity accelerations; DEC, high-intensity decelerations; RPE, rating of perceived exertion; s-RPE, sessional-RPE; TMD-3, 3 training sessions before the training game; TMD-2, 2 training sessions before the training game; TMD-1, 1 training sessions before the training match; TMD, training match day..

Table 3. Comparison of the average metrics for the EL and IL during the preparation and competition weeks.

Variable	Total ($n = 165$) Value [95%CI]	TW-2 ($n = 63$) Value [95%CI]	TW-1 ($n = 77$) Value [95%CI]	CW ($n = 25$) Value [95%CI]	*Effect Size* Value	*Effect Size* Qual.
DS (min)	92.64 ± 21.82	98.57 ± 19.49	83.77 ± 22.61	105 ± 12.24	**#** 0.31^{§2}	large
	[89.28–95.99]	[93.66–103.48] **#**	[78.63–88.90]	[99.94-110-06] **#**	**#** 0.44^{§2}	large
DT (ms)	7,675.48 ± 1,825.40	7,504.5 ± 1,556.47	7,417.50 ± 1,907.91	8,900.20 ± 1,769.87	***β*** 0.40^{§2}	large
	[7,394.89–7,956.08]	[7,112.51–7,896,50]	[6,984.70–7,850.78]	[8,169.72–9,630.67] ***β*** *****	* 0.33^{§2}	large
MSS (m)	1847.14 ± 721.62	1,831.12 ± 535.02	1,774.19 ± 872.87	2,111.54 ± 553.06	-	-
	[1,735.87–1,958.40]	[1,695.25–1,966.99]	[1,576.07–1,972.31]	[1,883.25–2,339.84]		
HSS (m)	463.65 ± 229.93	431.97 ± 209.07	419.77 ± 212.29	678.65 ± 220.63	***θ*** 1.16^{§1}	moderate
	[428.31–499]	[379.32–484.63]	[371.59–467.96]	[587.58–769.72] **Θ #**	# 1.21^{§1}	big
HImpt (n)	3.70 ± 5.29	2.44 ± 2.97	1.94 ± 2.55	11.24 ± 7.08	***θ*** 0.67^{§2}	large
	[2.89–4.52]	[1.68–3.19]	[1.35–2.52]	[9.19–15.37] **Θ #**	#0.64^{§2}	large
PL (a.u.)	37.81 ± 9.85	37.28 ± 8.91	35.46 ± 9.41	46.40 ± 9.08	***θ*** 1.02^{§1}	moderate
	[36.30–39.33]	[35.04–39.53]	[33.33–37.60]	[42.67–50.16] **Θ #**	**#** 1.18	moderate
ACC (n)	126.53 ± 55.36	102.25 ± 44.33	126.40 ± 52.92	188.12 ± 46.52	***β*** 0.22^{§2}	large
	[118.02–135.04]	[91.84–112.66]	[114.39–138.41] **β**	[168.92–207.32] **Θ ***	***θ*** 0.69^{§2}	large
					***** 0.47^{§2}	large
DEC (n)	83.47 ± 37.58	70.24 ± 35.38	81.88 ± 32.84	121.68 ± 31.85	***β*** 1.49^{§1}	big
	[77.69–89.24]	[61.33–79.15]	[74.43–89.34]	[108.53–134.83] ***β*** *****	*1.22^{§1}	big
Declared RPE (0–10)	5.92 ± 2.20	6.24 ± 2.12	5.31 ± 2.04	7 ± 2.34	*0.21^{§2}	moderate
	[5.58–6.26]	[5.70–6.77] *****	[4.85–5.78]	[6.03–7.97] *****	*0.35^{§2}	large
s-RPE (a.u)	579.42 ± 294.67	637.30 ± 282.12	476.30 ± 265.91	579.42 ± 294.67	***** 0.27^{§2}	small
	[534.13–624.72]	[566.25–708.35] *****	[415.94–536.65]	[627.25–875.15] **#**	**#** 0.39^{§2}	small

**Significantly higher than TW-1 ($p \le 0.05$); # significantly higher than TW-1 ($p \le 0.001$) β Significantly higher than TW-2 ($p \le 0.05$); θ Significantly higher than TW-2 ($p \le 0.001$); §1– Cohen's d; §2 - η2.*

DS, Total duration of the session; DT, Distance travelled; MSS, Moderate-speed skating; HSS, High-speed skating; HImpt, Number of high-impacts; PL, Player Load; ACC, High-intense accelerations; DEC, High-intense decelerations; RPE, rating of perceived exertions; s-RPE, Rate of perceived exertion xtotal duration of the session; TW-2, Two Training weeks until the competition week; TW-1, One Training week until the competition week; CW, Competition week.

Table 4. Spearman correlation matrix between EL and IL metrics from TW-2 until CW.

	TW-2	TW-1	CW
	s_RPE *r* [95% C.I]	s_RPE *r* [95% C.I]	s_RPE *r* [95% C.I]
DT (m)	0.69** [0.53–0.80]	0.67** [0.52–0.78]	−0.10 [−0.47–0.30]
MSS (m)	0.57** [0.37–0.71]	0.46** [0.26–0.62]	−0.20 [−0.55–0.21]
HSS (m)	0.49** [0.28–0.66]	0.63** [0.47–0.75]	−0.23 [−0.57–0.18]
HImpt (n)	0.35** [0.11–0.55]	0.32** [0.10–0.51]	0.64** [0.33–0.83]
PL (a.u.)	0.69** [0.53–0.80]	0.65** [0.50–0.76]	0.08 [−0.33–0.46]
ACC (n)	0.72** [0.57–0.82]	0.52** [0.34–0.67]	0.39 [−0.01–0.68]
DEC (n)	0.71** [0.56–0.81]	0.60** [0.43–0.73]	0.43* [0.04–0.70]

*$p \leq 0.05$; **$p < 0.001$.
DT, Distance travelled; MSS, Moderate-speed skating; HSS, High-speed skating; HImpt, Number of high-impacts; PL, Player Load; ACC, High-intense accelerations; DEC, High-intense decelerations; RPE, Declared rate of perceived exertions; s-RPE, Rate of perceived exertion x total duration of the session; TW, Training week; CW, Competition week.

ACC. In opposition, a different relationship was observed between EL and IL both in TW-2 and TW-1 when compared to CW, revealing that the training process seems to not sample the demands of the competitive matches. Thus, results generally support the idea that the competition week was not only more demanding but also promoted unexpectedly different kinematic and mechanical stress with impact on IL in relation to competition demands, suggesting that training also did not fully replicate the demands of competitive matches by missing specific metrics such DEC and HImpt.

In line with previous research in an elite rink hockey club (Fernández et al., 2021), results revealed that DT, PL, and HSS were higher in TMD-3 in comparison with TMD-2 and TMD-1. As observed in other sports (soccer and futsal), this decrease in kinematics (DT and HSS) and mechanical (PL) metrics before the TMD suggests a tapering strategy in which EL metrics tend to decrease as a match day approaches (Illa et al., 2020; Martín-García et al., 2018). Regarding the load dynamics of an elite rink hockey team that competes regularly, Fernández et al. (2021) have reported an inverted "*U-shape*" with higher EL and IL values on MD-3 and MD-2 during each microcycle. In this sense, and regardless of the tapering strategy, our results describe a different load dynamic than previously reported by Fernández et al. (2021). We believe that this may be related to the different structures of each championship and the strategy used to improve athletes' physiological adaptation, as suggested by Tarragó et al. (2019). Accordingly, the number of matches per week, the days between matches, and the physical condition of the team may impact the structure of the microcycle throughout a specific season (Tarragó et al., 2019).

In other indoor team sports, such as futsal (Illa et al., 2020) and soccer (Martín-García et al., 2018), MD-3 and MD-2 seem to establish a parallelism with the match day, by following the demands of training to those of the competition. Although in our study TMD-3 present higher values when compared to TMD-2 and TMD-1, they were nevertheless lower when compared to TMD values. The lack of information regarding match demands in rink hockey may contribute to such differences.

According to Halson (2014), training loads may be adjusted for each training cycle to either increase or decrease fatigue levels corresponding to a specific phase of training, such as baseline or competition. In our results, EL variables and DS presented higher values in TW-2 than in TW-1, associated with higher IL values of RPE and s-RPE, possibly revealing an attempt of tapering in the week before the competition (Fernández et al., 2021). To optimise training and competition adaptations, it is important to ensure the delay of the onset of acute and chronic fatigue development. Consequently, large dissociations between EL and IL may reveal an athlete's state of fatigue (Halson, 2014). As such, since we did not observe significant differences in EL metrics between TW-2 and TW-1, we believe that the higher values of RPE and s-RPE observed in TW-2 when compared to TW-1 and CW may have been influenced by the DS and not so much by EL variations. Moreover, we may infer that, at this stage of preparation, the volume of the training session has a higher impact on IL metrics than does intensity. With the exception of ACC, which was greater in TW-1 when compared to TW-2, statistical differences between TW-2 and TW-1 were not observed with other kinematic and mechanical metrics. Thus, it means that the possible attempt of tapering was promoted particularly based on the decrease in DS (Halson, 2014) and maintaining the intensity and structure of the training process.

As expected, CW EL and IL were significantly higher than in both TW-2 and TW-1. Once training is concerned with the planning, design, execution and control of the tasks (Tarragó et al., 2019), these results may suggest the need for training optimisation by adapting tasks to be performed in an environment that requires similar kinematics and mechanics demands as occurs in the game. There is a need to further understand the dynamics between exercises, allowing to reach high kinematic and mechanic game demands, while promoting at the same time readiness for the competition at the right time.

An additional critical finding of this study is the characterisation of demanding metrics related to an official international rink hockey match. It has been already reported that HSS, ACC, and DEC are the EL variables that better characterise the most demanding efforts in this sport (Fernández et al., 2021). Our results are aligned with that. However, it seems that PL is much higher in our study than in previous studies (Fernández et al., 2021), which may be explained by the playing time of each player, with fewer player interchange rotations than in a team that competes regularly. Thus, further research regarding this relationship may bring new insights concerning the impact of the number of player interchange rotations and playing time on athletes' fatigue development and, consequently, their performance.

One of the major findings in our study was the analysis of the relationship between EL and IL variables between training and competition weeks. Results revealed that, in opposition to the training weeks, in competitive matches, the number of HImpt presented a high value of correlation with s-RPE. To the best of our knowledge, there are no other studies that analysed HImpt in rink hockey games. This new information possibly supports the idea that the training drills used and the structure of the training sessions do not fully represent the game demands (Fernández et al., 2021). This fact corroborates the need to understand the game demands seeking to create adjusted cycles of load modification, particularly increased frequency, duration and intensity, as reported by Halson (2014). Additionally, it may also be important to understand how training drills are characterised in order to understand which drills may replicate the competition environment.

Finally, the impact of training sessions and competition matches on the EL and IL of players was analysed. Results highlighted that while in training sessions, all external load variables were related to the s-RPE, in the competition, only the number of HImpt [8–10 g] and the number of DEC were related to the s-RPE. Such differences between training and competition cycles distinguish the metrics that may be analysed to enhance players' performance. The impact of HImpt and DEC on s-RPE allows us to characterise rink hockey as a sport with high neuromuscular demand, as previously observed (Fernández et al., 2021). The influence of DEC and HImpt (>3 g) has been previously reported in a collision team sport (Australian Football) as strong predictors of post-match creatine kinase (CK) levels and consequently as strong indicators of muscle damage (Gastin et al., 2019). Thus, such variables can be used as good metrics to monitor the tapering process followed, particularly on the day before the competition. However, in this work, the fact that HImpt and DEC were not highly represented during the training process may induce in athletes additional efforts related to the neuromuscular system for this fast and explosive action (Andersen & Aagaard, 2010). This mechanical variation has already been suggested as a factor of athletes' emotional exhaustion, constraining the conventional model of training load monitoring mainly because of the game's unpredictability (Coyne et al., 2018). Consequently, it is legitim to suggest that these results may open a new perspective on the monitoring of training loads (TL). It has already been suggested that there is a need to understand the EL variables that impact athletes under training and competition constraints in order to develop a more accurate strategy to better comprehend how physiological adaptations can be promoted during training based on competition demands (Ferraz et al., 2023). According to some authors, biomechanical adaptations occur in musculoskeletal tissues due to mechanical stress (Coyne et al., 2018; Vanrenterghem et al., 2017). Therefore, as a result of the influence of HImpt on rink hockey players' IL (s_RPE) during the competition, we may consider HImpt to be a (Bio)mechanical EL variable (Coyne et al., 2018) that led to a perception of how difficult a training/competition session is. Finally, based on our findings and this monitoring approach, we can suggest that RPE likely reflects both types of IL (physiological and biomechanical stress) and should be monitored in an integrative way, defining the metrics (EL and IL) that best translate the physiological and biomechanical efforts. Notwithstanding the importance of understanding how EL and IL fluctuate and contrast across training microcycles and competitions, we acknowledge the potential limitations of the present investigation related to the sample size of players and the number of matches, which should be larger to increase the power of the results (Lupo & Tessitore, 2016). Therefore, further research should be developed considering different teams and their specific competitive context. Also, clustering EL demands per minute in training, while categorising specific rink hockey drills and comparing them to competition, could further improve the knowledge of rink hockey training actions/density and how it impacts official matches.

5. Conclusions

In this study, different load dynamics were reported during the preparation of an elite male rink hockey for an international championship, which is in accordance with tapering strategies. However, training sessions do not translate the game demands, and HImpt followed by DEC has a greater influence on s-RPE during competition. Yet, these findings offer a novel perspective on the tracking of training loads (TL).

5.1. Practical applications

The transfer of this evidence to the training process is significant; in so far as knowing the intensity of the match and which variables best characterise it, coaches can concretely manipulate and adjust the physical requirements of practice tasks during the microcycle to match demands to optimise players' performance and reduce the risk of injury. Also, our findings can underpin considerations to identify the best variables that characterise rink hockey demands for the definition of dedicated monitoring tools, as well as for strategies of benchmarking between teams of different competitive levels. Finally, if the goal is to replicate the mechanical demands of competition, rink hockey training should be reviewed, and coaches should prescribe drills that contain a greater number of HImpt and DEC efforts. These changes may be necessary in order to better prepare athletes to deal with match-play challenges.

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AF, JNR, JVS, and BT contributed to the conception and design of the study. AF and BT collected the data. AF, FY and PDM performed the statistical analysis. AF, JNR, and BT contributed to the interpretation of the results. AF, FY and BT wrote the manuscript. AF, PDM, JNR, FY, JVS and BT revised and finalised the manuscript. All authors have read and approved the final version of the manuscript, agreed with the order of presentation of the authors and approved the submitted version.

References

Andersen, J. L., & Aagaard, P. (2010). Effects of strength training on muscle fiber types and size; consequences for athletes training for high-intensity sport. *Scandinavian Journal of Medicine and Science in Sports*, *20*(SUPPL. 2), 32–38. https://doi.org/10.1111/j.1600-0838.2010.01196.x

Arboix-Alió, J., Buscà, B., Aguilera-Castells, J., Fort-Vanmeerhaeghe, A., Trabal, G., & Peña, J. (2021). Competitive balance in male European rink hockey leagues. *Apunts Educación Física y Deportes*, *145*(145), 33–38. https://doi.org/10.5672/apunts.2014-0983.es.(2021/3).145.05

Bastida-Castillo, A., Gómez-Carmona, C. D., De la Cruz-Sánchez, E., Reche-Royo, X., Ibáñez, S. J., & Ortega, J. P. (2019). Accuracy and inter-unit reliability of ultra-wide-band tracking system in indoor exercise. *Applied Sciences (Switzerland)*, *9*(5), 939. https://doi.org/10.3390/app9050939

Coyne, J. O. C., Gregory Haff, G., Coutts, A. J., Newton, R. U., & Nimphius, S. (2018). The current state of subjective training load monitoring—A practical perspective and call to action. *Sports Medicine - Open*, *4*(1). https://doi.org/10.1186/s40798-018-0172-x

Fernández, D., Cadefau, J. A., Serra, N., Carmona, G., & Oliveira, R. F. S. (2023). The distribution of different intensity demanding scenarios in elite rink hockey players using an electronic performance tracking system. *PloS One*, *18*(3), 1–13. https://doi.org/10.1371/journal.pone.0282788

Fernández, D., Moya, D., Cadefau, J. A., & Carmona, G. (2021). Integrating external and internal load for monitoring fitness and fatigue status in standard microcycles in elite rink hockey. *Frontiers in Physiology*, *12*(June), 1–10. https://doi.org/10.3389/fphys.2021.698463

Fernández, D., Varo, F., Carmona, G., & Reche, X. (2020). Quantification of external load of elite rink hockey players in official matches. *Journal of Sports Medicine and Physical Fitness*, *60*(12), 1520–1525. https://doi.org/10.23736/S0022-4707.20.11097-1

Ferraz, A., Duarte-Mendes, P. A., Sarmento, H. B., Valente-dos-Santos, J., & Travassos, B. (2023). Tracking devices and physical performance analysis in team sports: A comprehensive framework for research. Trends and future directions. *Frontiers in Sports and Active Living*, *5*, 1284086. https://doi.org/10.3389/FSPOR.2023.1284086

Ferraz, A., Valente-Dos-Santos, J., Duarte-Mendes, P., Nunes, C., Victorino, S., Coelho-E-Silva, M. J., Travassos, B., & Muazu Musa, R. (2022). Body composition and grip strength constraints in elite male rink-hockey players of contrasting ethnicity. *PloS One*, *17*(9), e0274894. https://doi.org/10.1371/journal.pone.0274894

Ferraz, A., Valente-Dos-Santos, J., Sarmento, H., Duarte-Mendes, P., & Travassos, B. (2020). A review of players' characterization and game performance on male rink-hockey. *International Journal of Environmental Research and Public Health*, *17*(12), 1–21. https://doi.org/10.3390/ijerph17124259

Foster, C., Florhaug, J. A., Franklin, J., Gottschall, L., Hrovatin, L. A., Parker, S., Doleshal, P., & Dodge, C. (2001). A new approach to monitoring exercise training. *Journal of Strength and Conditioning Research*, *15*(1), 109–115. https://doi.org/10.1519/00124278-200102000-00019

Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: Current use, calculations, and interpretation. *Journal of Experimental Psychology: General*, *141*(1), 2–18. https://doi.org/10.1037/a0024338

Gastin, P. B., Hunkin, S. L., Fahrner, B., & Robertson, S. (2019). Deceleration, acceleration, and impacts are strong contributors to muscle damage in professional Australian football. *Journal of Strength and Conditioning Research*, *33*(12), 3374–3383. https://doi.org/10.1519/JSC.0000000000003023

Halson, S. L. (2014). Monitoring training load to understand fatigue in athletes. *Sports Medicine*, *44*(S2), 139–147. https://doi.org/10.1007/s40279-014-0253-z

Harriss, D. J., Macsween, A., & Atkinson, G. (2019). Ethical standards in sport and Exercise Science Research: 2020 update. *International Journal of Sports Medicine*, *40*(13), 813–817. https://doi.org/10.1055/a-1015-3123

Hopkins, W. G., Marshall, S. W., Batterham, A. M., & Hanin, J. (2009). Progressive statistics for studies in sports medicine and exercise science. *Medicine and Science in Sports and Exercise*, *41*(1), 3–12. https://doi.org/10.1249/MSS.0b013e31818cb278

Hoppe, M. W., Freiwald, J., Baumgart, C., Born, D. P., Reed, J. L., & Sperlich, B. (2015). Relationship between core strength and key variables of performance in elite rink hockey players. *Journal of Sports Medicine and Physical Fitness*, *55*(3), 150–157.

Illa, J., Fernandez, D., Reche, X., Carmona, G., & Tarragó, J. R. (2020). Quantification of an elite Futsal Team's microcycle external load by using the repetition of high and very high demanding scenarios. *Frontiers in Psychology*, *11*(October), 1–10. https://doi.org/10.3389/fpsyg.2020.577624

Impellizzeri, F. M., Marcora, S. M., & Coutts, A. J. (2019). Internal and external training load: 15 years on training load: Internal and external load theoretical framework: The training process. *International Journal of Sports Physiology and Performance*, *14*(2), 270–273. https://doi.org/10.1123/ijspp.2018-0935

Impellizzeri, F. M., Rampinini, E., Coutts, A. J., Sassi, A., & Marcora, S. M. (2004). Use of RPE-based training load in soccer. *Medicine and Science in Sports and Exercise*, *36*(6), 1042–1047. https://doi.org/10.1249/01.MSS.0000128199.23901.2F

Lupo, C., & Tessitore, A. (2016). How important is the final outcome to interpret match analysis data: The influence of scoring a goal, and difference between close and balance games in elite soccer: Comment on lago-penas and Gomez-Lopez (2014). *Perceptual and Motor Skills*, *122*(1), 280–285. https://doi.org/10.1177/0031512515626629

Martín-García, A., Gómez Díaz, A., Bradley, P. S., Morera, F., & Casamichana, D. (2018). Quantification of a professional football team's external load using a microcycle structure. *Journal of Strength and Conditioning Research*, *32*(12), 3511–3518. https://doi.org/10.1519/jsc.0000000000002816

Rago, V., Brito, J., Figueiredo, P., Costa, J., Barreira, D., Krustrup, P., & Rebelo, A. (2020). Methods to collect and interpret external training load using microtechnology incorporating GPS in professional football: A systematic review. *Research in Sports Medicine*, *28*(3), 437–458. https://doi.org/10.1080/15438627.2019.1686703

Rago, V., Muschinsky, A., Deylami, K., Mohr, M., & Vigh-Larsen, J. F. (2021). Weekly training load in elite male ice hockey: Practice versus competition demands. *International Journal of Sports Physiology and Performance*, *17*(2), 270–277. https://doi.org/10.1123/ijspp.2021-0188

Rossi, A., Pappalardo, L., Cintia, P., Iaia, F. M., Fernàndez, J., Medina, D., & Sampaio, J. (2018). Effective injury forecasting in soccer with GPS training data and machine learning. *PloS ONE*, *13*(7), 1–15. https://doi.org/10.1371/journal.pone.0201264

Sousa, T., Sarmento, H., Harper, L. D., Valente-dos-Santos, J., & Vaz, V. (2018). Development and validation of an observational instrument tool for analysing the activity of rink hockey goalkeepers. *Journal of Sport Pedagogy and Research*, *4*(3), 16–26.

Tarragó, J. R., Massafret-Marimón, M., Seirul·lo, F., & Cos, F. (2019). Entrenamiento en deportes de equipo: el entrenamiento estructurado en el FCB. *Apunts Educación Física y Deportes*, *137*(137), 103–114. https://doi.org/10.5672/apunts.2014-0983.es.(2019/3).137.08

Vanrenterghem, J., Nedergaard, N. J., Robinson, M. A., & Drust, B. (2017). Training load monitoring in team sports: A novel framework separating physiological and biomechanical load-adaptation pathways. *Sports Medicine*, *47*(11), 2135–2142. https://doi.org/10.1007/s40279-017-0714-2

Vona, G. (2009). *Body composition of Italian female hockey players*. June 2014. https://doi.org/10.5604/20831862.890172

Yagüe, P. L., Del Valle, M. E., Egocheaga, J., Linnamo, V., & Fernández, A. (2013). The competitive demands of elite male rink hockey. *Biology of Sport*, *30*(3), 195–199. https://doi.org/10.5604/20831862.1059211