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RESEARCH

Influence of an ice hockey game on power and speed-strength abilities of professional ice hockey players

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Abstract

Purpose Given the high density of the competition schedule, the importance of injury prevention and development of athletes' fitness levels has led coaches to implement training sessions following the end of ice hockey games. However, the influence of physical activity during the game on the expression of physical abilities and training effectiveness remains unclear. Studying this subject will help increase the efficacy of the training process and reduce the occurrence of injuries.
Aim Investigation of the influence of physical activity during the ice hockey game on speed–strength abilities and power of professional ice hockey players. Comparison of speed–strength abilities and power of professional ice hockey players during training days and game days in the competition period.
Methods 1. Literature review. 2. Testing. 3. Survey. 4. Descriptive statistics. 5. Statistical analysis. Subjects: 30 professional ice hockey players aged 20.1 ± 4.5 years, height 184.1 ± 5.0 cm, body mass 86.2 ± 8.1 kg.
Results An increase ($p < 0.01$) in squat jump height (+ 11.77%) and power (+ 5.76%), as well as in countermovement jump height (+ 9.92%) and power (+ 4.77%) of professional ice hockey players was recorded post-game. Indicators of speed–strength abilities and power of professional ice hockey players were superior ($p < 0.01$) on the game days compared to the training days.
Conclusion The period following the end of the game is optimal for the development of speed-strength abilities and power of professional ice hockey players.

Keywords Ice hockey · Power · Speed · Strength · Testing

Introduction

One of the Winter Olympic sport disciplines, ice hockey is a popular team sport. Every year, 82 national teams participate in the IIHF World Championship; many of these countries hold their own club championships. The result of the high spectator interest and its monetization by top professional hockey leagues is an extreme density of games that players participate in. For instance, players in the NHL (the top hockey league in the world) compete in 82 regular season games spread over 7 months, with the Stanley Cup playoffs taking place afterward. Similar game density is seen in other elite leagues, with the KHL and the AHL recording 68 and 72 games in 6 months, respectively. The need for injury prevention and the development of the physical fitness of athletes necessitated the search for optimal windows for various physical qualities training. Practitioners found the solution in a post-game training, which became popular among hockey strength and conditioning coaches [1, 2]. Studying the efficacy of the post-game training becomes necessary because hockey players experience significant external and internal loads from physical activity during the game. Ice hockey is played at a high intensity: on average, during the game, players complete 15 "shifts", each one 45–90 s long [3], performing 5.38 accelerations and 5.36 decelerations per minute [4], and athletes' working heart rate is > 90% of maximal values for 20% of the total game time [5], resulting in average in-game blood lactate values of 8.2 mmol/L and reaching up to 13.7 mmol/L [6].

Despite the fact that the internal and external load of hockey players during games has been well studied, its effect

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on the manifestation of physical qualities has been investigated insufficiently. So far, influence of activity during a hockey game only on manifestations of balance and strength has been examined. Cameron and colleagues revealed a significant increase in balance errors in the single leg stance of NCAA athletes following a 60-min on-ice game simulation [7]; Zankavets showed no change in submaximal strength expression post-game in male professional hockey players [8], indicating the possibility of training strength right after the competition. It is unclear how playing hockey affects athletes' speed, speed–strength, anaerobic and aerobic endurance, and flexibility, all of which are crucial for hockey players. With research on this topic, the effectiveness of the training process will be enhanced, and the likelihood of injuries will decrease.

Because of the complexity of the issue, the influence of the ice hockey game on each physical quality should be examined separately. This study aims to investigate how playing ice hockey impacts the speed–strength abilities and power of professional players. This topic was chosen because the development of speed–strength is crucial for success in ice hockey: higher-level players have greater power output [9] and better jump performance [10]. The skating speed of ice hockey players is strongly correlated with their vertical jump performance [11], and it can even predict a player's potential [12]. Without the optimal training stimuli, the speed–strength abilities of professional ice hockey players may decrease throughout the season [13], leading to a reduction in skating speed [11] by the start of the play-offs, which is the most important stage of the competition period.

Methods

Study design

Longitudinal study. Following methods were used in this research: literature review, testing, survey, descriptive statistics, statistical analysis.

Subjects

A total of 30 healthy men aged 23.1 ± 4.5 years (the age range 16–32 years), height 184.1 ± 5.0 cm (height range 173.0–195.0 cm), body mass 86.2 ± 8.1 kg (body mass range 69.5–98.9 kg). All of them are professional ice hockey players. 1 subject is a goaltender, 8 play defense, and 21 play forward. All the subjects underwent a medical examination on July 15, 2022.

The risks of the study were explained to the subjects before participation; each subject signed an informed consent document before participation in the investigation, which was approved by the Local Ethics Committee of Sechenov Moscow State Medical University (Protocol No. 05–21, March 10, 2021) and by the ice hockey club "Yugra" Khanty-Mansiysk, the Russian Federation. Additionally, a parental consent document for 2 ice hockey players under the age of 18 was obtained. The subjects were familiarized with all testing procedures before the start of the testing.

Duration of the study

All the procedures were performed from July 15, 2022 to October 15, 2022.

Phases of the study

Phase 1. The effect of back-to-back games that are played on 2 consecutive days on the vertical jump performance of the ice hockey players during the preparation period was studied. The schedule and timing of the vertical jump testing are reflected in Table 1.

A total of 17 subjects participated, with 8 hockey players being tested pre- and post-games on August 11 and 12, and 12 players being tested on August 26 and 27 (3 players were tested in both time frames). The team lost the first two games and won the last two games, which were all played away.

Phase 2. The dynamics of the vertical jump performance during the competition period 4-game series were investigated. The schedule and timing of the vertical jump testing are reflected in Table 2.

A total of 16 subjects participated, with 13 players being tested from September 25 to October 3 during a home game series and 14 players being tested from October 7 to October 15 during a road trip (11 players were tested in both time frames). The team won all the games except the second one, with the first 4 games being played at home and the last 4 games being played away.

Literature review

The literature review played an important role in demonstrating the significance of speed–strength abilities and power in hockey, identifying contemporary methods for their enhancement, and establishing the testing protocol.

Table 1 The vertical jump testing scheme during the back-to-back games

Pre-game 1	Post-game 1	Pre-game 2	Post-game 2
August 11		August 12	
12:15–12:30 pm	4:30–4:45 pm	4:15–4:30 pm	8:30–8:45 pm
August 26		August 27	
10:15–10:30 am	2:30–2:45 pm	1:45–2:00 pm	6:00–6:15 pm

Table 2 The vertical jump testing scheme during two 4-game series

2 days before game 1	1 day before game 1	Pre-game 1	Day off	Pre-Game 2	Day between games 2 and 3	Pre-Game 3	Day between games 3 and 4	Pre-Game 4
September 25	September 26	September 27	September 28	September 29	September 30	October 1	October 2	October 3
10:15–10:30 am	9:15–9:30 am	5:15–5:30 pm		5:15–5:30 pm	10:45–11:00 am	11:15–11:30 am	10:15–10:30 am	5:15–5:30 pm
October 7	October 8	October 9	October 10	October 11	October 12	October 13	October 14	October 15
9:45–10:00 am	9:45–10:00 am	3:15–3:30 pm		5:15–5:30 pm	4:15–4:30 pm	4:45–5:00 pm	4:15–4:30 pm	3:15–3:30 pm

Testing

Anthropometry

Each participant visited a laboratory between 8:00 am and 10:00 am on July 15, 2022. Body weight (kg) and standing height (cm) measurements were taken by a trained anthropometrist.

Standing height: a wall-mounted stadiometer and set square were used [14]. The subjects stood with their heels together and their backs against the wall, not wearing any shoes. In order to make measurements, the set square was placed on the top of the head against the wall-mounted stadiometer. The nearest 0.2 cm from the highest point on the top of the head was measured [14]. Test–retest reliability, calculated using the Pearson product-moment correlation coefficient, is 0.98.

Body weight: measured with a calibrated beam-type balance and recorded to the nearest 0.1 kg [14]. The subjects stood in shorts without footwear and a t-shirt. Test–retest reliability is 0.98.

Body composition

Six skinfold fat measurements (chest, triceps, subscapular, suprailiac, abdomen, and front thigh) were taken on the right side of the body of the subject (with the exception of the abdominal skinfold) using the Seko USA large skinfold caliper [14]. The assessment was made by an experienced tester on the same day as anthropometry. Using the formula [14] below, the percentage of body fat was determined:

$\%\ \text{body fat} = [(\boldsymbol{\Sigma}\ \text{of 6 skinfolds}) \times 0.097] + 3.64$ 1.1

Test–retest reliability is 0.96.

Vertical jumps

Due to its ease of use and minimal fatigue associated with the test, the vertical jump is widely used as an indicator of lower limb power and speed–strength abilities, neuromuscular fatigue, and athletes' current status and readiness to perform a certain type of training [15]. Since the results indicate a correlation with on-ice skating performance [11], it is also very informative for ice hockey.

Every day, each participant engaged in a jumping protocol 1–15 min prior to the team's off-ice warm-up. It was not permitted to warm up before the test. Post-game, the jumping protocol was finished within 10–25 min after the end of the game.

The protocol included two squat jumps (SJ) from a freely chosen knee angle with hands on hips. There was a 2-s pause at the bottom and a 10-s rest interval in between the attempts. Following a 30-s rest period, the participants performed two countermovement jumps (CMJ) from a freely chosen knee angle with hands on hips, separated by a 10-s rest interval [16]. The subjects were required to land on the take-off point with straight legs. It was not permitted to bend the knees, kick the legs forward, or land flat-footed. The tester closely observed all movements. The best attempt at each type of jump was recorded. Using the contact platform Chronojump Boscosystem (Barcelona, Spain), which has been used in earlier scientific research involving team sports athletes [17], jump height and jump power were computed. The high reproducibility [18], validity, and reliability [19] of the platform were demonstrated in prior studies. The subjects were familiar with the testing protocol before its execution.

Test–retest reliability is 0.91 for SJ and 0.90 for CMJ, respectively.

Survey

The rating of perceived exertion (RPE) during a hockey game was assessed using the Category-Ratio (CR10) scale (Table 3) [20]. According to Rago and colleagues, RPE is a valid and reliable tool that may be used as a global indicator of hockey players' physical load [21]. 10–25 min after the end of each game before vertical jump assessment, each subject was individually verbally surveyed.

Table 3 Category-ratio (CR10) scale

Quantitative meaning	Expression
0 - Nothing at all	
0.5 - Very, very weak	
1 - Very weak	
2 - Weak	
3 - Moderate	
4 - Somewhat strong	
5 - Strong	
6	
7 - Very strong	
8	
9	
10 - Very, very strong	

Table 4 The Chaddock scale for interpretation of correlation analysis results

Absolute Value of Correlation	Interpretation
0.00 – 0.30	Negligible correlation
0.30 – 0.50	Weak correlation
0.50 – 0.70	Moderate correlation
0.70 – 0.90	Strong correlation
0.90 – 1.00	Very strong correlation

Descriptive statistics

The individual time on ice per game played (TOI) was obtained using the Angles Software (Fulcrum Technologies, Bellevue, USA).

Statistical analysis

The methods of statistical analysis were selected in accordance with the recommendations, designed for pedagogical sciences [22]. Analysis was performed using the SPSS Statistics v.23.0 software (IBM).

To determine whether the data matches the characteristics of a normal distribution, the Kolmogorov–Smirnov test of normality was used. As all the data in this study are distributed normally ($p > 0.05$), the significance of differences between vertical jump performance on the training and game days, as well as before and after the end of back-to-back games, was determined using the paired samples t-test. A two-way repeated ANOVA was applied to compare variations in SJ_{height}, SJ_{power}, CMJ_{height}, and CMJ_{power} during the 4-game series. The Bonferroni correction with the significance level set at $p < 0.05$ was used for the post hoc test. Partial eta-squared values (η^2_p) for repeated measures were calculated as the effect size.

The relationship between variables was determined using the Pearson product-moment correlation coefficient. For interpretation of correlation analysis results, the Chaddock scale was used (Table 4) [23].

The data are reported as the means ± confidence interval. The standard deviation in the graphs is reported as the error bars.

Results

Phase 1. The effect of back-to-back games

The vertical jump performance before and after the end of back-to-back games is shown in Fig. 1.

Both post-game SJ_{height} (40.35 ± 1.43 cm post-game 1; 40.35 ± 1.78 cm post-game 2) and CMJ_{height} (41.68 ± 1.54 cm post-game 1; 41.88 ± 2.22 cm post-game 2) were significantly superior ($p < 0.01$) compared to the values for pre-game SJ_{height} (35.46 ± 1.71 cm pre-game 1; 36.74 ± 1.51 cm pre-game 2) and CMJ_{height} (37.55 ± 1.53 cm pre-game 1; 38.47 ± 1.73 cm pre-game 2). Likewise, SJ_{power} after the game (1207.89 ± 46.14 W post-game 1; 1206.60 ± 45.03 W post-game 2) and CMJ_{power} (1227.38 ± 47.04 W post-game 1; 1227.86 ± 45.71 W post-game 2) were significantly higher ($p < 0.01$) compared to the pre-game SJ_{power} (1130.75 ± 42.39 W pre-game 1; 1152.15 ± 47.84 W pre-game 2) and CMJ_{power} (1164.78 ± 45.59 W pre-game 1; 1178.79 ± 47.50 W pre-game 2) values.

In summary, post-games SJ_{height} (40.35 ± 1.13 cm) is 11.77% superior ($p < 0.01$) than pre-games SJ_{height} (36.10 ± 1.14 cm), and post-games CMJ_{height} (41.78 ± 1.33 cm) is 9.92% superior ($p < 0.01$) than pre-games CMJ_{height} (38.01 ± 1.15 cm). Post-games SJ_{power} (1207.24 ± 31.82 W) is 5.76% higher ($p < 0.01$) than pre-games SJ_{power} (1141.45 ± 31.73 W), and post-games CMJ_{power} (1227.62 ± 32.37 W) is 4.77% higher ($p < 0.01$) than pre-games CMJ_{power} (1171.78 ± 32.57 W).

On average, the participants rated perceived exertion during the games as 7.07 ± 1.11, with the average time on ice being 14:16 ± 2:52 min:sec. Correlation analysis revealed a weak inverse relationship between individual time on ice and the pre- to post-game difference in CMJ_{height} ($r = -0.32$) and CMJ_{power} ($r = -0.32$). No statistically significant correlation was found between the other indicators.

Phase 2. The dynamics of the vertical jump performance during the 4-game series

The dynamics of the vertical jump performance during the competition period 4-game series are reflected in Fig. 2.

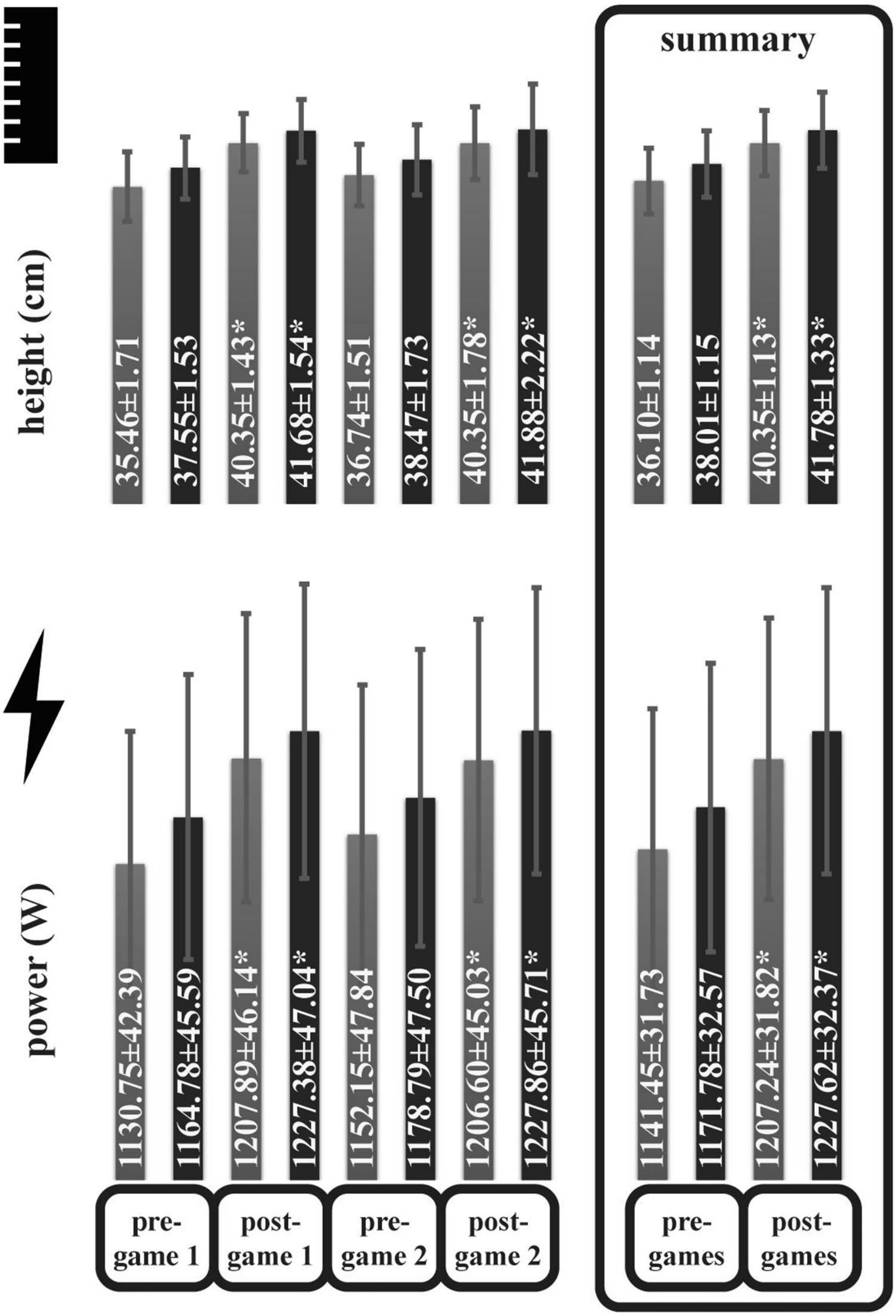

Fig. 1 The vertical jump performance before and after the end of back-to-back games. Squat jump performance is in gray, countermovement jump performance—in black. $^*p < 0.01$ = significantly different from pre-game

The results of the two-way repeated ANOVA are presented in Table 5.

According to the Bonferroni post hoc test, performance two days pre-game 1 was inferior to one day pre-game 1 ($p < 0.01$). On the day of the game 1, vertical jump indicators were significantly higher compared to the training day two days before this game ($p < 0.01$), but no difference was found compared to the training day one day before the game 1. No significant difference was observed between pre-game 1 and pre-game 2 indicators. In the same way, no difference was registered between pre-game 2, the day between games 2 and 3, and pre-game 3 values. At the same time, vertical jump performance on the day between games 2 and 3 was significantly lower than on the day of game 1 ($p < 0.01$). After remaining on the same level on the day between games 3 and 4, performance increased on the day of game 4 ($p < 0.01$).

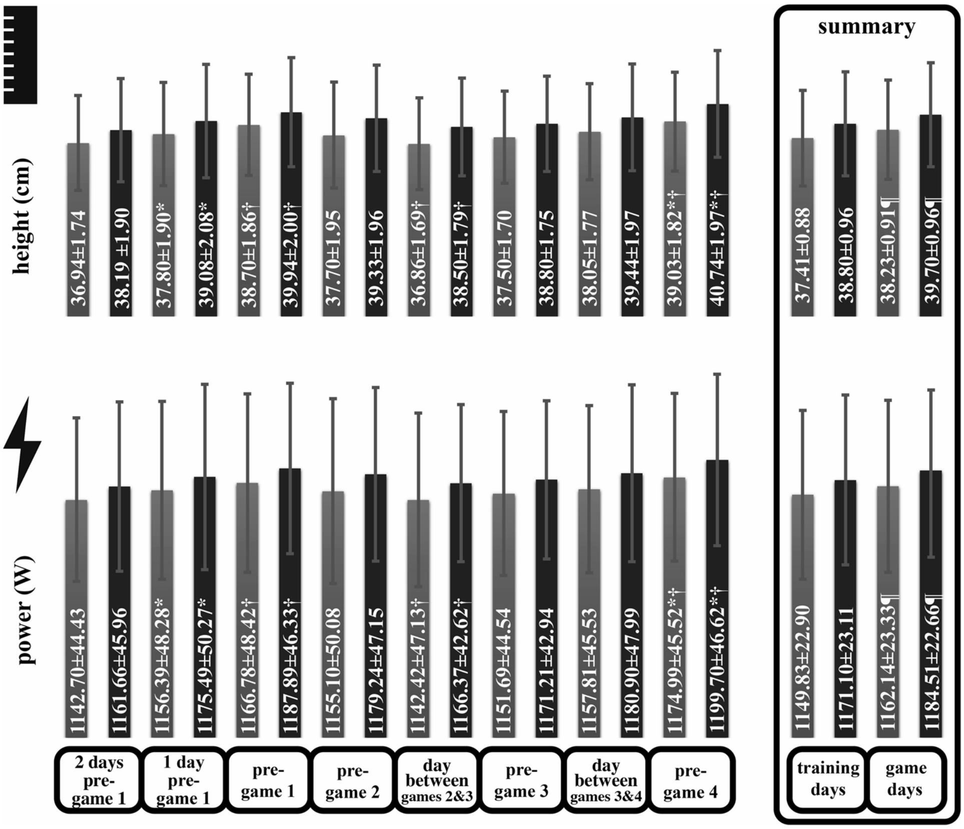

Fig. 2 The vertical jump performance during the 4-game series. Squat jump performance is in gray, countermovement jump performance—in black. $^*p < 0.01$ = significantly different from the previous day. $^\dagger p < 0.01$ = significantly different from the day before last. ¶$p < 0.01$ = significantly different from training days

Table 5 The variations in vertical jumps during the 4-game series

Factor	p	η^2_p
Day (2 days pre-game 1, 1 day pre-game 1, pre-game 1, pre-game 2, day between games 2 and 3, pre-game 3, day between games 3 and 4, pre-game 4)	< 0.01	0.11
Vertical jump (SJ_{height}, SJ_{power}, CMJ_{height}, CMJ_{power})	< 0.01	0.98
Day × vertical jump	< 0.01	0.09

In summary, SJ_{height} on the game days (38.23 ± 0.91 cm) was 2.19% higher ($p < 0.01$) than on the training days (37.41 ± 0.88 cm), and CMJ_{height} on the game days (39.70 ± 0.96 cm) was 2.32% higher ($p < 0.01$) compared to the training days (38.80 ± 0.96 cm). SJ_{power} on the game days (1162.14 ± 23.33 W) was 1.07% higher ($p < 0.01$) than on the training days (1149.83 ± 22.90 W), and CMJ_{power} on the game days (1184.51 ± 22.66 W) was 1.15% higher ($p < 0.01$) compared to the training days (1171.10 ± 23.11 W).

Discussion

The ratio of positive and negative effects determines the type of impact that game-related activities will have on physical quality (Fig. 3).

The main positive effects of playing ice hockey are an increase in body and muscle temperature, post-activation potentiation, and psychological arousal. In common, a sharp increase of muscle temperature is seen in the first 3–5 min after beginning of a motor activity, plateau occurs after 10–20 min [24]. A 1-degree increase in muscle temperature is associated with a 2–5% improvement in athletic performance [25]. It reduces muscle viscosity [26], increases joint and ligament flexibility [27], the speed of neural impulse transmission [28], the rate of muscle fiber contraction-relaxation [25], and the rate of force development [25]. Temperature may remain elevated for approximately 10 min after a moderate-intensity activity and up to 20 min after a high-intensity task [29]. In addition, high-intensity physical activity by itself improves nervous system function and leads to an improvement in subsequent athletic performance. This mechanism has been referred to

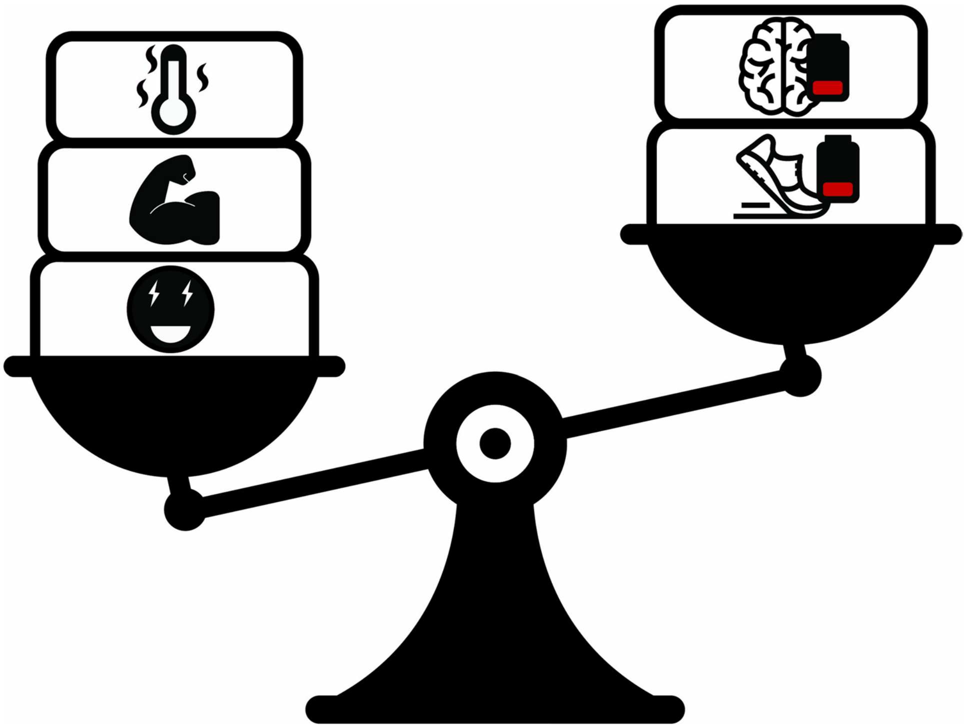

Fig. 3 The ratio of positive and negative effects that playing the ice hockey game places on the players' speed–strength ability and power manifestation

as post-activation potentiation [25, 29]. This effect begins to manifest 5 min after the end of activity and disappears completely 20 min after exercise [25]. The third effect is associated with high psychological arousal and changes in hormone levels related to anticipation of competition [30]. This is the main difference between training and game days [31]. Moderate hormone elevations before a competition are considered by scientists to be physically beneficial: they pool resources needed for the upcoming activity, have a positive effect on cognitive processes and attention control, and help regulate other stress-sensitive systems [32]. In addition, it causes stimulation of the sympathetic nervous system, which remains excited [33]. Psychological arousal leads to an improvement in speed [34], speed-strength [35], and strength [36] abilities. Hormone volume remains elevated 3–4 h after the hockey game [37].

The negative effects include the degree of central and peripheral fatigue. According to the narrative review by Tornero-Aguilera with colleagues, "central fatigue is defined as a deficient drive of motor cortical output attenuating performance or even stopping the activity, whereby inhibitory and excitatory processes are affected" [38]. Biomechanical alterations brought on by the buildup of extracellular serotonin or other molecules like glutamate, dopamine, or gamma-aminobutyric acid are the cause of this [38]. On the other hand, peripheral fatigue is characterized by alterations in the muscle's metabolism and biochemistry as well as a decrease in the neuromuscular junction's effectiveness [38]. The accumulation of metabolites in the bloodstream derived from reactive oxygen species, such as inorganic phosphates, calcium ions, lactate, ADP, magnesium, and the depletion of glycogen deposits, is a factor that breaks homeostasis [38]. Reduced muscle force production results from acidosis with low pH levels, which creates the metabolic conditions for the development of central and peripheral fatigue [38]. In addition to these physiological alterations, fatigue causes mechanical, neuromuscular, and metabolic effects in muscle cells. These can be attributed to three main factors: (1) inefficiency in the contraction coupling mechanism due to an impairment in the number or functionality of the actin and myosin cross-bridges; (2) failure in energy metabolism as the myocyte cannot continue resynthesizing ATP; (3) metabolic acidosis caused by the intramuscular accumulation of inorganic phosphates and hydrogen ions [38].

Based on the results obtained in this study, it can be assumed that, in terms of power output and speed-strength ability expression, the positive effects of playing ice hockey outweigh the negative ones. An ice hockey game, on average, does not cause severe fatigue, as evidenced by RPE values obtained in the current study (7.07 ± 1.11) as well as in a previous investigation (6.9 ± 1.3), where the effects of a game on professional ice hockey players were studied [39]. This assumption is supported by Rago and colleagues, who reported the absence of clear signs of fatigue at the end of the ice hockey game in the top Danish division [40]. Similarly, soccer matches are not stressful enough to induce a decline in referees' vertical jump performance, even though they cover a total distance of 9989.1 ± 454.8 m, including

Table 6 The post-game training protocol with vertical emphasis

Exercises	Repetitions	Circles	Rest
1A. Squat jump 1B. Push up jump 2A. Vertical hop 2B. Push up jump	5	2–4	> 60 s

2872.8 ± 422.4 m at high-intensity (> 13 km/h) [41]. Similar post-competition vertical jump performance enhancements are observed in other team sports [42] and combat sports [43]. At the same time, a player's individual psychological and physical condition before the game, his playing time, and the intensity of the game can change this balance.

Given that athletes' power output and vertical jump performance are significantly higher on competition days, particularly after the end of games, than on training days, a well-founded training program should be developed. As most official ice hockey games are scheduled in the evening, a plyometric training session in the morning can serve as a priming method [44]. According to the review made by Holmberg and colleagues, 3 sets of 5 optimally loaded CMJ with 1 min rest between sets is an effective performance-enhancing strategy [44].

The next task is to find optimal post-competition training means and load volumes that would contribute to the development of speed–strength abilities. From a practical point of view, the post-game training program is influenced by the venue of the competition. In most cases, the opportunity to train after away games is limited. On the road, hockey players often have to train on concrete, ceramic tiles, or other slippery surfaces, and external weights are often not available. Vertical jumping is the safest option in this situation (Table 6).

At the end of home games, more variety can be provided. Horizontal jumps, bounds, and hops can be performed on a non-slip floor (Table 7), which have a superior effect on sprint performance compared to vertical jumps [45, 46].

Additionally, low-load, high-velocity training should be performed as its effectiveness in maximizing power output is superior to other training methods [47] (Table 8).

Conclusion

The period following the end of the game is optimal for the development of speed-strength abilities and power of professional ice hockey players.

Table 7 The post-game training protocol with horizontal emphasis

Exercises	Repetitions	Circles	Rest
1A. Horizontal bound 1B. Horizontal pull up 2A. Lateral bound 2B. Horizontal pull up	5	2–4	> 60 s

Table 8 The post-game low-load high-velocity training protocol

Exercises	Repetitions	Circles	Rest
1. Dumbbell split squat vertical jump 2. Smith machine bench press throw 3. Sled push/sprint 4. Resistance pull up	5	2–4	> 60 s

An external weight for each exercise can be calculated depending on the results of the strength testing [80]. Dumbbell split squat vertical jump = 26% of barbell split squat; Smith machine bench press throw = 30% of barbell bench press; sled push/sprint = 30% of body weight; resistance pull-up = 30% of resistance pull-up

Future research

A training session cannot lead to the elevation of psychophysiological variables to the same level as an official competition does [31]. Theoretically, immediately after the end of the game, regardless of the result [48], an optimal window for the development of various physical qualities may appear. This assumption is supported by the results of the current research. In the sequel, the influence of the ice hockey game on speed abilities as well as on anaerobic and aerobic endurance should be studied.

Limitations

Despite the fact that the construction of the jumping platform is rigid, different properties of concrete and rubber, as well as differences in the surrounding environment during road trips, could have an impact on the results.

Author contributions Uladzislau Zankavets wrote the whole manuscript text.

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Data availability The anonymized data generated during the current study is available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare no competing interests.

Ethical approval The study was conducted in accordance with the Declaration of Helsinki. The study complies with Helsinki declaration. It was approved by the Local Ethics Committee of Sechenov Moscow State Medical University (Protocol No. 05–21, March 10, 2021) and by the ice hockey club "Yugra" Khanty-Mansiysk, the Russian Federation.

Informed consent All participants provided informed consent prior to their participation. The study complies with Helsinki declaration.

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