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ORIGINAL ARTICLE

Influence of an ice hockey game on strength abilities of professional ice hockey players

Influence d'un match de hockey sur glace sur les capacités de force des joueurs professionnels de hockey sur glace

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KEYWORDS
Strength;
Testing;
Ice hockey

Summary
Purpose. — Evaluation of strength abilities of professional ice hockey players before and immediately after the game.
Methods. — Twenty-three professional ice hockey players aged 20.5 ± 2.8 years, height 183.8 ± 5.8 cm, body mass 86.5 ± 9.3 kg.
Results. — No significant difference was found in three-repetition maximum (3-RM) barbell split-squat and barbell bench press in pre- and post-game testing ($p \geq 0.05$). A significant improvement in number of pull-ups performed post-game was found ($p \leq 0.05$). The correlation analysis revealed a moderate relationship between the individual time on ice per game (TOI) and the pre- and post-game testing results difference in the pull-up test (R = 0.52) and a weak relationship between the rating of perceived exertion (RPE) and the pre- and post-game testing results difference in the barbell split-squat test (R = −0.31).
Conclusions. — the results of this study indicate that the activity during an ice hockey game does not lead to a change in the expression of strength abilities of ice hockey players. In these conditions, execution of a post-game resistance training session could be an efficient approach for strength abilities development/maintenance and injury prevention.

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MOTS CLÉS
Hockey sur glace ;
Évaluations ;
Entraînement en force

Résumé
Objectif. — Évaluation des capacités de force des joueurs professionnels de hockey sur glace avant et immédiatement après un match.
Méthodes. — Vingt-trois joueurs professionnels de hockey sur glace âgés de 20,5 ± 2,8 ans, taille 183,8 ± 5,8 cm, poids 86,5 ± 9,3 kg.
Résultats. — Aucune différence significative n'a été trouvée pour les tests sous maximaux (3-RM) avec haltères concernant le *split-squat* et le développé couché dans les évaluations pré- et postmatch ($p \geq 0,05$). Une amélioration significative du nombre de tractions effectuées après le match a été constatée ($p \leq 0,05$). L'analyse de corrélation a révélé une relation modérée entre le temps individuel passé sur la glace durant le match (TOI) et la différence des résultats des évaluations avant et d'après le match pour le test de tractions (R = 0,52). Une faible relation est observée entre l'indice de perception de la difficulté de l'effort (RPE) et la différence des résultats des tests d'avant et d'après match pour le *split-squat* avec haltères (R = −0,31).
Conclusions. — Les résultats de cette étude indiquent que l'activité pendant un match de hockey sur glace n'entraîne pas de modifications de l'expression des capacités de force des joueurs de hockey sur glace. Dans ces conditions, l'exécution d'une séance d'entraînement en résistance après le match pourrait être une approche efficace pour le développement/maintien des capacités de force et la prévention des blessures durant la saison.

1. Introduction

Success in sports is based on an efficient preparation in many areas. Physical fitness is a cornerstone in many sports disciplines. The level of physical preparedness has not only a direct impact on sport results, but also affects other aspects such as correct execution of the tactics [1], mental health [2], well-being, quality of life, decreases anxiety, stress [3] and risk of injuries [4], which also contribute to success. It is well documented, that muscle strength is one of the most important components of physical fitness of athletes, as it affects throwing speed [5], acceleration velocity [6], sprint speed [7], jumping performance [8], running speed over long distances [9] and wrestling performance [10].

Ice hockey in not an exception. Muscle strength is a main component of preparedness of a modern professional hockey player [11—13]. In a previous study, moderate correlations between isometric strength and 5 m acceleration skating forward (R = −0.55), 27.5 m sprint skating forward (R = −0.64), 5 m acceleration skating backwards (R = −0.52), 27.5 m sprint skating backwards (R = −0.63) of 65 professional ice hockey players from Belarusian top division (aged 16—33 years) were observed [14]. Bezak and Pridal reported a moderate relationship between upper-body strength and wrist shot speed (R = 0.61) in 20 male professional and semiprofessional ice hockey players (mean age 23.3 ± 2.4 years) [15]. Nevertheless, a game by itself does not provide enough stimuli for strength abilities maintenance [16], which is true for many team sports such as rugby union [17], Australian football [18], baseball [19], cricket [20], soccer [21], and ice hockey [22]. The strength level, in the absence of a sufficient stimulus, begins to decrease quickly. For example, a significant decrease in strength and power of the NCAA Division I ice hockey players after 21 weeks of the season was found by Webster [23]. The rate of declination depends on the training experience of a person: the higher is the level, the faster negative consequences occur [24]. Thus, Hakkinen and Komi reported more than 15% decrease in strength of Olympic weightlifters [25]. Signs of decrease in strength abilities in the first 2—12 weeks of detraining can be recorded using electromyography [24]. After 2 weeks of insufficient muscle stimulation a decrease in strength may be accompanied by a decrease in muscle mass [26]. In particular, Hortobagyi et al. reported a statistically significant decrease in muscle mass of the type II muscle fibers of football players and weightlifters after 14 days of detraining [27]. On the contrary, in recreationally-trained people strength abilities remain at the same level after 6 weeks of absence of training sessions [24]. An interesting fact is that in representatives of any categories, the rate of decrease of muscle mass after detraining is lower than the rate of its gain [24,26].

The aforesaid means that optimal volume and intensity of training sessions during the season for strength abilities maintenance of team sports athletes must be found. The study by Fleck and Kraemer over the entire season revealed that stimulus from 2 strength-training sessions per week was sufficient to maintain strength abilities of football players at the same level for 14 weeks [28]. This is probably the reason why most NHL strength and conditioning coaches use an average of 2 strength-training sessions per week during the regular championship [29]. In agreement with before mentioned, strength and conditioning coaches of other ice hockey leagues use the same frequency of workouts [12]. At the same time, for successful strength maintenance, training intensity is the cornerstone: if frequency of workouts is reduced, intensity should remain at the same level [26,30].

An individual approach to training process of professional hockey teams planning makes it possible to achieve statistically significant increase in strength abilities even during the regular season [31]. One of the most common approaches to individualization of training stimulus in professional hockey is calculation of weights as percentage of one repetition maximum, based on the testing results [29,32,33].

In the practical setting, the difficulty of utilization of strength workouts lies in an extreme density of a game

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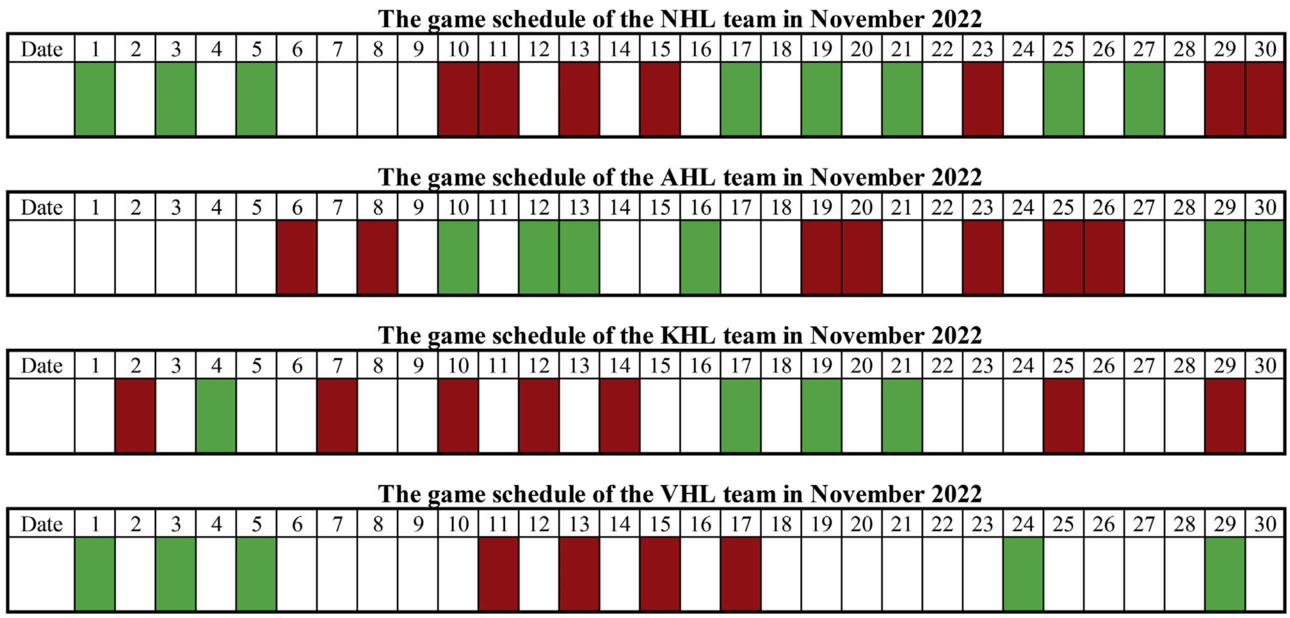

Figure 1 The game schedule of one of the NHL, AHL, KHL and VHL teams. Home games are in green, away games — in red. The NHL is the top ice hockey league of North America, the AHL is the second division. The KHL is the top ice hockey league of Russia, the VHL is the second division.

schedule in modern professional leagues, including ice hockey (Fig. 1).

Density of the modern professional leagues schedules makes post-game workouts an objective necessity for ice hockey players' muscle mass and strength maintenance, as well as injury prevention. In situations when games are scheduled every other day, a post-game workout enables to achieve both goals while providing approximately a 45-hour interval for recovery before the next game. However, this approach to training process requires objective knowledge about impact of a hockey game on strength abilities of ice hockey players. Training stimulus that does not correspond to operational state of a hockey player at best will be ineffective, at worst it can lead to overtraining syndrome or an injury [23,31]. To the best of our knowledge, influence of a game on strength abilities of ice hockey players has not been researched yet. Thereby, the purpose of this study is pre- and post-game examination of dynamics of the expression of strength abilities in professional ice hockey players.

2. Methods

2.1. Experimental approach to the problem

To achieve the purpose of the study, we selected professional ice hockey players of the ''Yugra'' Khanty-Mansiysk hockey team from the VHL, the second division of Russian hockey.

Following methods were used in this research:

- literature review;
- testing;
- monitoring;
- survey;
- descriptive statistics;
- statistical analysis.

2.2. Literature review

Literature review helped to describe the importance of strength for ice hockey players, the modern approaches to its maintenance and development used in professional ice hockey, made it possible to formulate the purpose of the study, and develop the testing protocol.

2.3. Subjects

The subjects consisted of 23 healthy men aged 20.5 ± 2.8 years (the age range 16—26 years), height 183.8 ± 5.8 cm, body mass 86.5 ± 9.3 kg. All of them are professional ice hockey players. Each person had been training consistently from childhood. Nine of them play on position of a defenceman, 14 on position of a 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'' from Khanty-Mansiysk, the Russian Federation. Additionally, a parental signed consent document for 2 ice hockey players under the age of 18 years was obtained. The subjects were familiarized with all testing procedures before the start of the testing. The study was conducted in accordance with the Declaration of Helsinki.

Figure 2 The barbell split-squat test.

2.4. Testing

A strength-testing was carried during the preparatory phase (lasting from the 17th of July 2022 to the 2nd of September 2022) in the gym of the sports complex ''Kurganovo'' (Kurganovo village, Sverdlovsk region of the Russian Federation) on the 26th and 27th of July 2022 before and right after friendly games the team had played. The pre-game testing on July 26 was carried out in 2 groups, consisted of 7 subjects each. The testing of the subjects of the first group started at 9:00 am local time, the testing of the subjects of the second group started at 10:45 am. The game started at 5:00 pm, consisted of 3 periods of 20 minutes of play, 5 minutes overtime, shootouts, and ended at 7:15 pm. The post-game testing started at 7:30 pm. The pre-game testing on July 27 started at 10:45 am, the game — at 5:00 pm. The scrimmage consisted of 3 periods of 20 minutes of play and ended at 7:00 pm. The post-game testing started at 7:15 pm. On July 27, 9 ice hockey players, who did not participate in the game the day before, were tested. Players who played both games, did not participate in the testing on the second day.

The following tests were chosen in order to assess strength abilities of the ice hockey players: the three-repetition maximum (3-RM) barbell split-squat, the 3-RM barbell bench press and the stick pull-up. It is well documented that lower body strength of hockey players has a moderate correlation (R = 0.60—0.64) with on-ice sprint [14,34]. Accordingly to Virgile, lower body strength is one of the best indicators of on-ice performance and success in ice hockey [35]. The split-squat test had been employed and investigated in a previous study by Urquhart with colleagues [36]. It allows not only to measure strength level, but also reveal unilateral leg strength symmetry. This information is valuable for practitioners from rehabilitation and injury prevention standpoint [36]. The 3-RM testing protocol was selected because of similar level of reliability for trained men and women as 1-RM protocol (men: R = 0.97 and R = 0.98; women: R = 0.94 and R = 0.99) [37], and lower risk of injury [38]. Barbell bench press and pull-up seem to be the most classical tests for upper-body strength of ice hockey players assessment, that are used both by scientists [39—41], as well as ice hockey practitioners during the NHL Combine [42]. Additionally, hockey performance practitioners view the results of the pull-up test as an indicator of health of the posterior shoulder girdle of players [43].

2.5. Testing procedures

To evaluate maximal strength of lower body the barbell split-squat test was used [33]. The initial position of the barbell was on one 25 kg weight plate 10 cm wide (each side) between the legs of a testee. The goal of the subject was to stand up with the barbell, lower it back by touching the weight plates on the floor and perform 3 repetitions (Fig. 2). After 1 minute of resting, the same was done with the second leg. If attempt was successful, rest till full recovery was given (> 3 minutes) and the weight of the barbell was increased: set 1—60 kg, set 2—80 kg, set 3—100 kg, set 4—110 kg, set 5—120 kg, set 6—130 kg, set 7—140 kg. 3-RM protocol was used in order to reduce the risk of injury [12]. Test—retest reliability, calculated using the Pearson product-moment correlation coefficient, is 0.82.

To evaluate maximal strength of upper body, the barbell bench press test was used [33]. The goal of the subject was to fully extend the arms with the barbell, lower it back by touching the chest and perform 3 repetitions. If attempt was successful, rest till full recovery was given (> 3 minutes) and the weight of the barbell was increased: set 1—60 kg, set 2—70 kg, set 3—80 kg, set 4—90 kg, set 5—100 kg, set 6—110 kg. If attempt was unsuccessful, the weight was decreased by 5 kg and the other set after rest was made. 3-RM protocol was used in order to reduce the risk of injury [12]. Test—retest reliability, calculated

Figure 3 The pull-up test.

using the Pearson product-moment correlation coefficient, is 0.95.

To evaluate strength endurance of upper body the stick pull-up test was used [33]. A hockey stick was placed on thighs of the subject after he had grasped the overhead bar with an overhand grip. The goal of the subject was to pull-up the body while bending arms so the chin raises above the bar, then to return to the position with the arms fully extended, and to perform as many repetitions as possible (Fig. 3). The test was finished as soon the stick fell down. Test—retest reliability, calculated using the Pearson product-moment correlation coefficient, is 0.90.

2.6. Monitoring

During both friendly games, the subjects were prone to wear Activio Sport System heart rate monitors (Activio AB, Stockholm, Sweden). These monitors were used in previous studies conducted by different authors [44,45]. In order to objectively assess the internal load of the games the subjects participated in, the training impulse (TRIMP) was estimated. Ulmer et al. reported moderate reliability of TRIMP for the internal load of ice hockey players assessments [46]. The following equation was used [47]:

$$TRIMP = D \times \left(\frac{HR_{ex} - HR_{rest}}{HR_{\max} - HR_{rest}} \right) \times Y \qquad (1)$$

where D is the duration of the game in minutes, HR_{ex} is the average heart rate during the game in beats per minute, HR_{rest} is the resting heart rate, HR_{max} is the maximal heart rate, and Y is the weighting factor, which is 1.92 for men and 1.67 for women.

2.7. Survey

In order to measure subject's perception of exertion during the ice hockey game, the rating of perceived exertion (RPE) scale was used [48]. On this scale, rating of 0 represents no effort, i.e. rest, and a rating of 10 represents maximal effort, i.e. the most stressful exercise performed.

2.8. Descriptive statistics

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

2.9. Statistical analyses

The methods of statistical analyses were selected in accordance with the recommendations, designed for pedagogical sciences [49]. Analysis was performed using the SPSS Statistics v.23.0 software (IBM, New York, USA).

The significance of differences between the mean values of the samples obtained in the same group was determined using the Wilcoxon signed-rank test.

The significance of differences between two independent samples was determined using the Mann-Whitney U test.

The relationship between variables was determined using the Pearson product-moment correlation coefficient. For

Table 1 The Chaddock scale for interpretation of the 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

The statistical significance condition chosen in this study was $p \leq 0.05$. Data are reported as the means ± standard deviation (SD).

interpretation of the correlation analysis results the Chaddock scale was used (Table 1) [50].

3. Results

The pre- and post-game strength-testing results, as well as its correlation with the time on ice, internal load and perceived exertion during the game are presented in Table 2. On average, the subjects spent 14:23 ± 2:47 minutes on ice during the game and rated perceived exertion at 6.9 ± 1.3 points. The internal load of the subjects during the games is reflected in Table 3. No statistically significant difference was found between forwards and defencemen. A negligible correlation between the rating of perceived exertion and the individual time on ice per game (R = −0.18), as well as the internal load during the game (R = −0.08) was registered. Furthermore, a weak relationship between the internal load and time on ice during the game (R = 0.44) was found.

4. Discussion

In the barbell split-squat test the subjects demonstrated quite homogeneous results. The maximal weight which the subjects were able to lift for 3 repetitions with each leg varied in the range from 110 to 140 kg. In the barbell bench press and pull-up tests, the range of results was wider. In the first case, the subjects were able to perform 3 repetitions of the exercise with weights in the range from 70 to 120 kg. In the second case, the range of repetitions varied from 1 to 19. This can probably be explained by the fact that leg strength of ice hockey players, generated off-ice, has higher levels of ''transfer'' to on ice performance [35]. Accordingly, this leads to greater attention from players and ice hockey coaches to lower body strength development. The more experience of training in any exercise, the less difference in results between athletes of comparable level. In the current study, the subjects were team-mates.

One of the assumptions was that the defference between the pre- and post-game testing results would be influenced by the load of the game. The latter was evaluated objectively by monitoring the heart rate of the subjects, using descriptive statistics and subjectively using the survey. On average, the ice hockey players spent 14:23 ± 2:47 minutes on ice during the game, the extreme values varied in the range from 9:26 to 19:43 minutes. The subjects rated perceived exertion during the game at 6.9 ± 1.3 points, the extreme values varied in the range from 5 to 10 points. The peak values of heart rate of the subjects were even higher comparing to a previous study, where the internal load of the players of the National U-20 team Belarus during an international tournament was observed (184 versus 176 bpm) [51].

Table 2 The strength-testing results and its correlation with the time on ice, internal load and perceived exertion during the game.

Test	$\bar{x}_1 \pm SD\bar{x}$	$\bar{x}_2 \pm SD\bar{x}$	$D_{\bar{x}_1-\bar{x}_2}$, %	$P_{\bar{x}_1-\bar{x}_2}$	$R_{TOI\text{-}D}$	$R_{TRIMP\text{-}D}$	$R_{RPE\text{-}D}$
Barbell split-squat, 3-RM (kg)	122.17 ± 7.95	124.35 ± 10.80	1.87 ± 7.32	≥0.05	0.27	0.22	−0.31
Barbell bench press, 3-RM (kg)	88.26 ± 11.44	87.83 ± 11.56	−0.44 ± 4.28	≥0.05	0.25	0.21	0.01
Pull-up (repetitions)	8.64 ± 4.72	9.41 ± 4.85	18.22 ± 40.56	≤0.05	0.52	0.18	−0.18

Note: $\bar{x}_1$: the mean value of the pre-game testing; $\bar{x}_2$: the mean value of the post-game testing; SD: the standard deviation; $D_{\bar{x}_1-\bar{x}_2}$: the difference between the pre-game and post-game testing; $P_{\bar{x}_1-\bar{x}_2}$: the level of statistical significance between the pre-game and post-game testing; $R_{TOI\text{-}D}$: the absolute value of the correlation between the individual time on ice per game played and the difference between the pre-game and post-game testing; $R_{TRIMP\text{-}D}$: the absolute value of the correlation between the training impulse and the difference between the pre-game and post-game testing; $R_{RPE\text{-}D}$: the absolute value of the correlation between the rating of perceived exertion during the game and the difference between the pre-game and post-game testing.

Table 3 The internal load of the subjects during the games.

	July 26, 2022	July 27, 2022	Summary, mean values
Peak heart rate (beats per minute)	185 ± 6	183 ± 7	184 ± 7
Mean heart rate (beats per minute)	137 ± 10	133 ± 13	135 ± 11
Duration (minutes)	94	88	91
TRIMP	113 ± 9	103 ± 14	109 ± 11

TRIMP: training impulse.

Table 4 The post-game strength-training protocols.

Interval between games	Intensity	Goal repetitions	Sets[a]	Rest	Exercises
Back-to-back games (≈ 21 hour)	No strength-training session is planned				
1 day (≈ 45 hours)	3-RM/ 93% of 1-RM	3	2	> 120 s	Barbell split-squat Barbell bench press Barbell hip thrust
2—3 days (≈ 69—93 hours)	5-RM/ 87% of 1-RM	5	2	> 120 s	Weighted neutral grip pull-up
> 4 days (≈ 117 hours and more)	8—10-RM/ 70—80% of 1-RM	8—10	3	30—90 s	Dumbbell ''Bulgarian'' split-squat Dumbbell single leg ''Romanian'' deadlift Dumbbell incline bench press Dumbbell bent-over row

[a] These assignments do not include warm-up sets.

The above is evidence of high intensity of the games studied in this research.

Nevertheless, comparison of the pre- and post-game results indicates the absence of significant differences ($p \geq 0.05$) in the barbell split-squat test (1.87%) and the barbell bench press test (−0.44%, Table 2). Based on this data, it can be assumed that the load of a hockey game (even though it is usually higher comparing to practices [52]) does not significantly affect the level of upper and lower body strength of ice hockey players. This presumption is supported by a negligible relationship between TRIMP and the pre- and post-game testing results difference in all strength tests (R = 0.22, 0.21, 0.18). Another explanation for the absence of the changes in the strength level may be a submaximal nature of the testing (the 3-RM testing protocol was carried out). Theoretically, a 1-RM testing protocol could lead to more pronounced changes of results.

Unexpectedly, statistically significant increase in the results of the pull-up test was found (18.22%, $p \leq 0.05$, Table 2). The Pearson product-moment correlation analysis revealed a moderate relationship between the pre- and post-game testing results difference in the pull-up test and TOI during the game (R = 0.52). The correlation between the pre- and post-game testing results difference in two other tests and TOI is negligible (R = 0.27 and R = 0.25). It is possible that physical activity during an ice hockey game does not require a high level of strength endurance expression by the muscles involved in pull-up action. At the same time, activity during an ice hockey game induces a rise of body and working muscles temperature, which, as is known, in absence of high CNS fatigue, local muscle fatigue and in presence of a sufficient amount of energy resources, leads to performance improvement [53]. Thus, McGowan et al. reported 2—5% performance improvement caused by 1% increase in muscle temperature [54].

The correlation analysis revealed a weak relationship between the pre- and post-game testing results difference in the barbell split-squat test and RPE during the game (R = −0.31). The correlation between the pre- and post-game testing results difference in two other tests and RPE is negligible (R = 0.01 and R = −0.18). It can be assumed that the workload, the subjects faced during the game, was not high enough to cause more significant changes. The subjective nature of RPE survey could be another reason. Because ice hockey players involved in the study are young, they may not accurately enough assess their workload during a game.

Then, it seems that RPE, TRIMP and TOI data are not an informative indicator for correction of individual weights at a strength-training session after an ice hockey game.

4.1. Limitations

In the present study, general trends in the level of strength qualities changes after an ice hockey game were revealed. At the same time, adaptation of every player is individual and related to his condition (physical and psychological), just as demands of each game are unique. It will depend on age, professional experience, level of current preparedness, volume and intensity of the game, and presence of injuries. The testing in this study was conducted at the beginning of preseason phase (day 10 and 11). Likely, most of the players were not in their top physical form yet, as athletes usually possess the highest level of preparedness at the end of preseason phase or at the mid-season [17]. Thereby, results may vary during in-season depending on intensity of the game schedule, associated with it fatigue and influence of other factors.

4.2. Future research and practical applications

Future research could focus on means for optimizing post-game training sessions. In continuation of the current investigation, influence of an ice hockey game on speed, speed-strength, and coordination abilities, as well as on anaerobic and aerobic endurance could be studied.

Based on the results of our study, which show that the strength capacities of both lower and upper limbs are not modified by the intensity of an ice hockey game, it would be possible to plan post-game strength-training sessions with the following guidelines (Table 4) [55].

4.3. Intensity, volume and rest intervals

The type of the post-game strength-training protocol should depend on the games schedule.

As Gamble recommends to include hypertrophy training sessions in-season to maintain body mass [56], this type of workout (i.e. 8—10 RM or 70—80% of 1-RM × 8—10 repetitions × 3 sets [55]) can be implemented in cases when the next game is planned not earlier than in 4 days (for example, Monday and Saturday, approximately 117 hours for recovery is remaining). A long interval until the upcoming game is required due the fact that hypertrophic lifting leads to a significantly higher blood lactate concentrations comparing to a maximal strength loading [57] and even without the use of prolonged eccentric contractions can cause delayed onset muscle soreness (DOMS) lasting up to 96 hours [58], peaking from 24 to 48 hours [59].

In cases when the upcoming game is scheduled 2 or 3 days after (for instance, Monday and Thursday or Friday, approximately 69—93 hours for recovery is remaining), a 5 RM lifting protocol (i.e. 87% of 1-RM × 5 repetitions × 2 sets [55]) can be executed. The choice can be explained by the fact that corresponding training program requires up to 72 hours to fully resolve neuromuscular fatigue [60].

If the next game is planned in a day (as example, Monday and Wednesday, approximately 45 hours for recovery is remaining), a 3-RM lifting protocol (i.e. 93% of 1-RM × 3 repetitions × 2 sets [55]) can be executed. Accordingly to Kotikangas, such load leads to a complete recovery of neuromuscular parameters in 48 hours [57].

When back-to-back games are scheduled (for example, Monday and Tuesday, approximately 21 hours for recovery is remaining), no strength-training session must be planned after the end of the first game. All attention must be focused on recovery of the ice hockey players.

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Disclosure of interest

The authors declare that they have no competing interest.

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