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ORIGINAL RESEARCH

Comparison of selected performance-associated parameters after off-season and two-month training preparation in professional Czech ice hockey players

Filip Neuls[1✉], Michal Botek[1], Jakub Krejčí[1], and Martin Sigmund[2]

[1]Department of Natural Sciences in Kinanthropology, Faculty of Physical Culture, Palacký University Olomouc, Czech Republic; and [2]BALUO Application Centre, Faculty of Physical Culture, Palacký University Olomouc, Czech Republic

Abstract

Background: In ice hockey, regular off-ice testing can serve as a controlling mechanism for a training program's effectiveness. **Objective:** The main aim of this study was to describe changes in selected morphological and physiological parameters, intended to be relevant for a complex ice hockey performance, after two months of pre-season training preparation following one month of an off-season period. **Methods:** The sample consisted of 22 adult male players aged 18–39 years from a top Czech ice hockey league team. Two laboratory testing procedures performed at the end of the off-season and after two months of the pre-season conditioning consisted of basic anthropometry and body composition measurements, countermovement jump (CMJ), and maximal incremental test focused on the assessment of various parameters, including maximal oxygen consumption ($\dot{V}O_2max$), maximal power output during the test (Pmax) or estimation of anaerobic threshold intensity (ANT). **Results:** After the pre-season, we found a significant decrease in body fat (13.7 vs. 11.4%, $p < .001$) and an increase in fat-free mass (74.2 vs. 76.6 kg, $p < .001$), $\dot{V}O_2max$ (relative 48.8 vs. 52.6 $ml \cdot kg^{-1} \cdot min^{-1}$ $p = .001$; absolute 4.20 vs. 4.54 $L \cdot min^{-1}$, $p < .001$), Pmax (5.26 vs. 5.44 $W \cdot kg^{-1}$, $p = .011$), power output at ANT (4.07 vs. 4.35 $W \cdot kg^{-1}$, $p < .001$), and CMJ (44.9 vs. 47.1 cm, $p = .002$). **Conclusions:** Based on our results, two months of the pre-season training program led to a significant improvement in body composition and physical performance levels in professional Czech ice hockey players.

Keywords: sports games, exercise physiology, strength, endurance, laboratory testing

Introduction

Ice hockey is a complex multidimensional sport that requires the contribution of many different components for success at the elite level (Burr et al., 2008). This sports game can be characterized by intermittent high-intensity bouts of skating requiring rapid acceleration and sudden changes in velocity and direction, the potential for high-impact body contact, and the execution of a variety of skilled skating maneuvers, stick and puck handling or interaction with teammates (Montgomery, 1988; Quinney et al., 2008; Twist & Rhodes, 1993). It involves both anaerobic and aerobic metabolism when alternating high-energy output during shifts lasting from 30 to 80 s with 2 to 5 min of recovery between shifts. A player receives 16 to 35 min of actual playing time extended over 120 min and more (Cox et al., 1995). Thus, the process of sports training in ice hockey should reflect, among others, the demands of finely trained aerobic and anaerobic energy pathways as aerobic training builds a base necessary to handle more intense anaerobic training and prepares the on-ice energy supply and recovery process (Twist & Rhodes, 1993).

A typical season in ice hockey usually has three phases corresponding with 1) off-season detraining process necessary for the elimination of fatigue and associated with a decrease in training adaptations after the termination of the preceding season; 2) pre-season conditioning including non-specific and sport-specific training stimuli aimed at regaining, improvement, and peaking of readiness for following competitive loading; and 3) in-season period with regular games and minimal training which attempts to maintain conditioning level gained earlier and game readiness (Cox et al., 1995). Specifying the pre-season training period in Czech ice hockey as the main concern of this study, it is focused on the development of determining motor abilities and the formation of a variety of motor skills. Off-ice training includes a wide spectrum of exercises targeting the improvement of speed, power, strength, non-specific and specific endurance (especially strength endurance), and coordination (Perič, 2002).

Athlete testing conducted on a planned schedule is an integral part of the training process, its monitoring and evaluation. In ice hockey, a wide variety of off-ice and on-ice testing possibilities are available (Burr et al., 2008; Nightingale et al., 2013). Routine off-ice testing procedures

✉ **Corresponding author:** Filip Neuls, e-mail filip.neuls@upol.cz, ORCID® record https://orcid.org/0000-0002-5802-1950

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can serve as a base for players' evaluation in various phases of the season. They usually include anthropometry, jumping, aerobic capacity, anaerobic power, speed, strength, and agility (Burr et al., 2008; Montgomery, 2006; Quinney et al., 2008; Tarter et al., 2009). The importance of players' morphology is confirmed by the frequent involvement of somatic parameters in the functional diagnostics of ice hockey players, along with exercise tests (Montgomery, 2006). It has been demonstrated that a higher performance level is associated with a higher level of development of basic somatic parameters (Sigmund et al., 2014). According to Burr et al. (2008), somatic predispositions are among the significant predictors of a successful game performance as they are likely associated with the full-contact nature of ice hockey. At the moment of collision during a body check or physical altercations for puck control, larger and stronger players who possess greater muscle mass will generally be at an advantage. Although some degree of fat mass may be favorable for injury protection during collisions or as added mass for inertia while hitting, muscle mass is what helps propel players across the ice, and it can stabilize joints at impact. On the other hand, higher body mass increases frictional resistance on the skates (Montgomery, 1988). For example, the players' average of the world's best ice hockey league (Canadian-American National Hockey League [NHL]) is 186.0 cm of body height and 91.7 kg of body mass (Sigmund et al., 2016). Quinney et al. (2008) published a 26-year physiological description of an NHL team in which body mass index (BMI) oscillated between 25.9 and 26.8 $kg \cdot m^{-2}$ with an increasing trend. Vescovi, Murray, and VanHeest (2006) support the use of anthropometric measurements to effectively distinguish among positions for elite-level ice hockey players.

Regarding the functional predispositions of elite ice hockey players, the optimal development of aerobic (maximal oxygen consumption [$\dot{V}O_2max$] 56–60 $ml \cdot kg \cdot min^{-1}$) and anaerobic capacity (absolute values approx. 1300–1400 W and more, relative values exceeding approx. 15 $W \cdot kg^{-1}$) is considered to be among the main predictive factors for success and performance (Heller et al., 2019; Tarter et al., 2009). The development and maintenance of these parameters are supported primarily by the conditioning sessions players are exposed to across the various phases of the season (Kutáč et al., 2017).

Various types of laboratory-tested jumps are commonly used to evaluate ice hockey players' explosive leg power, which is necessary for quick acceleration and overall skating speed (Burr et al., 2007). The vertical jump is considered to be a strong predictor of on-ice top skating speed, acceleration and short sprints (Farlinger et al., 2007; Mascaro et al., 1992; Peterson et al., 2016), and it is also highly correlated ($r > .85$) with the Wingate test (average power or peak power; Kasabalis et al., 2005) commonly used in ice hockey players to test their anaerobic capacity.

Despite the wide use of various off-ice tests, there is a controversy regarding the ambiguous degree of correlation between off-ice testing and on-ice performance. Hence, more hockey-specific testing is often preferred (Peterson et al., 2015). In the review of Nightingale et al. (2013), a majority of studies suggest that off-ice testing has limited use when testing ice hockey players. On the other hand, seasonal off-ice testing seems to be important for strength and conditioning coaches to make individualized modifications to a player's fitness regimens in an effort to improve specific physiological attributes (Green et al., 2006). Off-ice tests can also help identify strengths and weaknesses in individual physical predispositions or differentiate between otherwise similar players of interest during the selection process (Vescovi, Murray, et al., 2006). Moreover, off-ice testing is adequate when the availability of ice time is reduced during some parts of a season (Farlinger et al., 2007).

When performed on a regular basis, off-ice testing can also serve as a controlling mechanism for the effectiveness of the training intervention. Typically, such testing can be implemented in order to monitor changes in performance-associated parameters before and after pre-season conditioning (Kutáč et al., 2017) or after a specifically oriented training program (Szmatlan-Gabrys et al., 2006) but also over the course of a competitive season (Delisle-Houde et al., 2019) or even whole annual cycle (Moroščák et al., 2013).

The main aim of this study was to assess whether two months of pre-season training preparation following one month of the off-season period induced a positive response in selected morphological and performance variables in professional Czech ice hockey players.

Methods

Sample and training process

This study included 22 ice hockey players aged 25.1 ± 6.2 years (range 18–39 years). All subjects gave written informed consent in accordance with the Declaration of Helsinki and filled in the form of "Sudden cardiovascular death in sport: Lausanne Recommendations" (Bille et al., 2006). All measuring procedures have been approved by the Ethics Committee of the Faculty of Physical Culture, Palacký University Olomouc (Czech Republic).

All players were tested after the off-season and pre-season periods. The off-season period covered unspecified leisure activities and voluntary individual training activities. The pre-season period included organized training intervention which consisted of training workouts focused on anaerobic and aerobic conditioning. In general, a weekly training microcycle included two hours a day (excluding warm-up and cool-down time) of complex off-ice exercises oriented on speed, agility, dexterity, reaction, coordination, strength and power, speed endurance, endurance or various types of intermittent games, and more specific on-ice activities like shooting or stickhandling. One day of the weekly routine included arbitrary individual training on endurance activities (running, cycling, in-line skating) or racket sports (tennis, badminton, squash). The weekly microcycle also incorporated time for regeneration or compensational exercises and one day off (see Table 1 for specification).

Testing procedures

As indicated above, each player underwent two testing sessions (April and June 2019) held in the exercise physiology laboratory at the Faculty of Physical Culture. During the testing sessions, the ambient temperature (22−24 °C) in the laboratory was maintained by the air-conditioning system with relative humidity kept between 30 and 50%. The first session, including anthropometrical measurements, vertical jump test, and maximal incremental test, was performed after one month of the off-season (transitory) period. The follow-up session comprised of the same measuring procedures was implemented after two consequential months of the pre-season training preparation during the weekly microcycle focused on testing (see note in Table 1).

Anthropometrical measurement

The ice hockey players had their body height (cm) and body mass (kg) measured using the SOEHNLE 7307 (Leifheit, Nassau, Germany). The percentage of body fat and fat-free mass were determined using bioimpedance analysis (Tanita BC-418 MA, Tanita, Tokyo, Japan). BMI was calculated according to the formula: BMI = body mass/body height squared ($kg \cdot m^{-2}$). Both sessions of these measurements were performed under the same conditions. The measurements took place between 8:00–9:00 a.m. on the same day of the week (Thursday) and were led by the same laboratory assistant. The players wore only underwear during the measurements. They were instructed in advance to avoid exercise, food, caffeine, dehydration or overhydrating at least 4 hours before the body composition measurements and to drink up to two cups of water (250–500 ml) two hours prior to the testing procedure.

Vertical jump test

Subjects performed three single maximal effort countermovement jumps with arm swing (CMJ) after a warm-up (dynamic stretching of the lower limbs for 1 min and one submaximal CMJ). A 10-s rest period was provided between each CMJ. The starting position for the CMJ was an upright posture with the arms down by the sides. Participants initiated the CMJ by lowering the body and swinging the arms back (shoulder hyperextension) and then jumped up as high as possible while swinging the arms forward and upward (shoulders moving from hyperextension to flexion; Harman et al., 1990). Vertical ground reaction force was measured on a force platform (FP8, HUR Labs, Tampere, Finland) with a sampling frequency of 1000 Hz. A quiet standing period of 2 s was recorded prior to the initiation of each CMJ to ensure an initial velocity of zero and to calculate the body mass. The maximal jump height of three CMJ repetitions was considered as recorded and used for statistical analysis.

Maximal incremental testing

The maximal incremental test was performed on a bicycle ergometer Ergoline 800 (Ergoline, Bitz, Germany). The exercise protocol consisted of a 6-min warm-up period (3 min at 100 W, 3 min at 150 W; both steps with a cadence of 70 rpm) followed by a 1-min incremental steps, starting at 250 W and increasing by 35 W every minute until exhaustion. The cadence increased arbitrarily following the participants' individual needs to reach the maximum.

Breath-by-breath ventilation and gas exchange were measured (Ergostik with Blue Cherry software; Geratherm Respiratory, Bad Kissingen, Germany) during the exercise with the data averaged to 30 s for analysis. Gas and flow analyzers were recalibrated before each test using gases of known concentration and a 3-L calibration syringe. The following criteria were used to document that $\dot{V}O_2$max was achieved: 1) a lack of increase in $\dot{V}O_2$ upon an increase in work rate, and 2) respiratory exchange ratio > 1.10 (Shephard & Åstrand, 1992). $\dot{V}O_2$max was recorded as the highest $\dot{V}O_2$ value in the final 30 s of the test (Millet et al., 2003). Heart rate (HR) response was measured continuously using a chest strap (Polar Electro Oy, Kempele, Finland). Maximal HR (HRmax) was defined as the highest HR recorded during the test. The relative value of maximal power output (Pmax) was determined as the highest wattage reached and maintained during the last 30 s of the test, divided by individual body mass. The anaerobic threshold (ANT) intensity as expressed by %$\dot{V}O_2$max was estimated based on the V-slope method of detecting the gas exchange threshold (Schneider et al., 1993).

Table 1 Framework training routine in developmental weekly microcycles during the pre-season period

Day	Training content	Time (min)
Monday	speed, agility, dexterity, reaction (stadium)	40
	strength (maximal, submaximal, contrast) – upper and lower body (gym)	60
	shooting, stickhandling (ice)	20
Tuesday	speed endurance (stadium)	40
	core training, compensational exercise (gym)	35
Wednesday	explosive power, agility (gym)	25
	gymnastics and combat activities – skillfulness, coordination (gym)	25
	various games play (gym)	20
	strength (maximal, submaximal, contrast) – upper and lower body, trunk (gym)	60
Thursday	interval training, runs 200–300 m (stadium)	60
	game play (stadium)	30
Friday	strength endurance or endurance, game play (gym)	50
	regeneration	90
Saturday	fartlek/cardio, cycling, in-line, tennis, badminton, squash (individual choice)	35
Sunday	day off or individual training	

Note. Weekly microcycle aims are summarized as follows: development (1st to 3rd week), stabilization (4th week), regeneration (5th week), development (6th to 8th week), regeneration (9th week), and testing (10th week).

Statistical analysis

Data were expressed as a mean ± standard deviation. The normality of the data was verified using the Shapiro-Wilk test. Two variables (fat-free mass: $p = .016$ and HRmax: $p = .029$) were significantly different from the normal distribution, and therefore nonparametric tests were used. The statistical significance of changes after two months of the pre-season training preparation was evaluated using paired Wilcoxon test. Statistical significance was set at $p < .05$. The effect size was calculated using Wilcoxon r according to the formula $r = z/\sqrt{n}$ where the z-score was obtained from the Wilcoxon test procedure and n was the sample size (Fritz et al., 2012). Thresholds for interpreting the magnitude of Wilcoxon r were: .00–.09 trivial, .10–.29 small, .30–.49 moderate, ≥ .50 large (Fritz et al., 2012). Any value of Wilcoxon r exceeding the threshold for trivial effect size was considered practically significant. Spearman's correlation coefficient was used to assess the relationship between changes in anthropometric variables and physiological variables. Thresholds for interpreting the magnitude of the correlation coefficient were the same as for Wilcoxon r. Statistical analysis was performed using TIBCO Statistica (Version 14.0; TIBCO Software, Palo Alto, CA, USA).

Results

Values of anthropometrical and physiological variables after the off-season and two months of the pre-season training preparation are shown in Table 2. There were no significant changes in body mass ($p = .301$) and BMI ($p = .260$). However, body fat decreased significantly ($p < .001$, $r = -.73$, large effect) and fat-free mass increased significantly ($p < .001$, $r = .84$, large effect). There were significant changes in maximal incremental test outcomes, namely, a large increase in $\dot{V}O_2$max ($p = .001$, $r = .66$), large increase in Pmax ($p = .011$, $r = .53$), and a moderate decrease in HRmax ($p = .031$, $r = -.46$). Increase in $\dot{V}O_2$max expressed in the absolute unit ($L \cdot min^{-1}$) was also significant ($p < .001$, $r = .77$, large effect), while the change in respiratory exchange ratio (RER) was not significant ($p = .945$). ANT expressed as a percentage of $\dot{V}O_2$max did not change significantly ($p = .149$), but power output at ANT (P_{ANT}) increased significantly ($p < .001$, $r = .70$, large effect). There was a significant increase in CMJ ($p = .002$, $r = .64$, large effect).

On average, the change in body mass 0.4 ± 2.5 kg was not significant, but individual changes ranged from –6.7 to 4.0 kg. Individual changes in body mass were significantly correlated (Figure 1) with changes in $\dot{V}O_2$max ($r_S = -.55$, $p = .007$, large correlation), Pmax ($r_S = -.51$, $p = .014$, large correlation), and P_{ANT} ($r_S = -.44$, $p = .038$, moderate correlation). No significant correlation was found in the remaining variables (all ps ≥ .225; Table 3). The correlation coefficients calculated for changes in BMI were very close to the coefficients calculated for changes in body mass. The differences between the calculated coefficients ranged from –.02 to .01 (Table 3). On the other hand, changes in body fat did not correlate with any physiological variable (all ps ≥ .084; Table 3). Changes in fat-free mass were significantly correlated only with changes in $\dot{V}O_2$max ($r_S = -.46$, $p = .030$, moderate correlation; Table 3).

Discussion

This study aimed to quantify changes in the selected performance-related variables in the group of players from the elite Czech ice hockey league (ELH) when comparing corresponding test results at the end of the off-season and after the pre-season conditioning lasting two months.

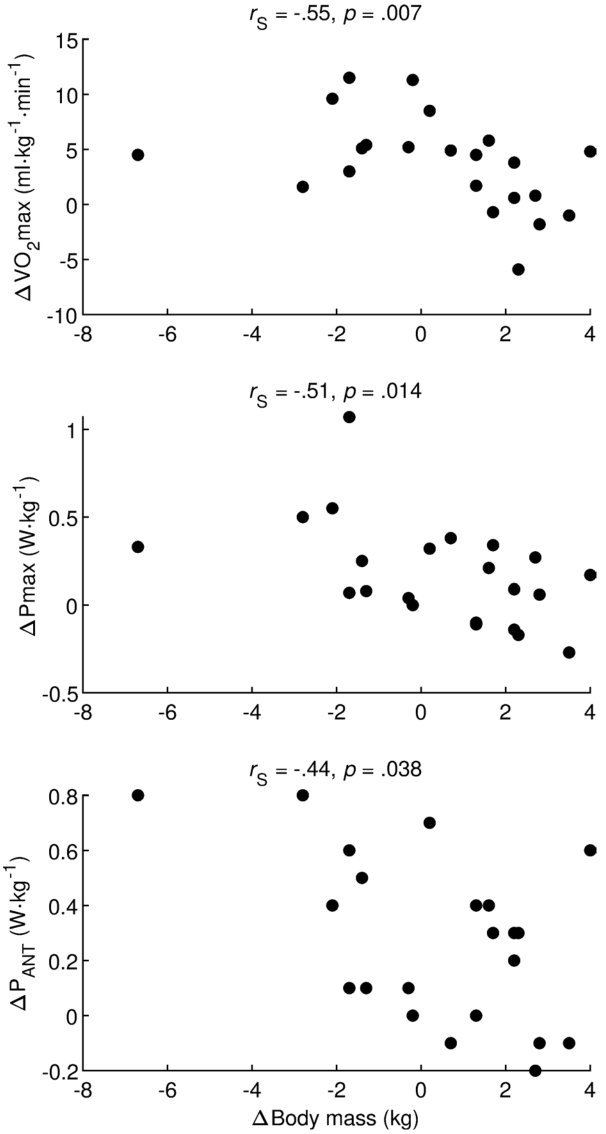
Somatic parameters of the team tested in our study (mean body height 182.9 cm, body mass 86.5 kg, and BMI 25.9 $kg \cdot m^{-2}$) are in accordance with the ELH reference values (body height 184.2 cm, body mass 87.1 kg, BMI 25.6 $kg \cdot m^{-2}$; Sigmund et al., 2015), as well as the International

Table 2 Comparison of anthropometrical and physiological variables after off-season and two-month training preparation

Variable	Off–season	Preparation	p	r
Body height (cm)	182.9 ± 3.2	–	–	–
Body mass (kg)	86.1 ± 5.9	86.5 ± 6.0	.301	.23
BMI ($kg \cdot m^{-2}$)	25.7 ± 1.5	25.9 ± 1.5	.260	.24
Body fat (%)	13.7 ± 3.4	11.4 ± 2.8	< .001	–.73
Fat-free mass (kg)	74.2 ± 4.7	76.6 ± 5.5	< .001	.84
$\dot{V}O_2$max ($ml \cdot kg^{-1} \cdot min^{-1}$)	48.8 ± 4.6	52.6 ± 4.2	.001	.66
$\dot{V}O_2$maxabs ($L \cdot min^{-1}$)	4.20 ± 0.47	4.54 ± 0.43	< .001	.77
Pmax ($W \cdot kg^{-1}$)	5.26 ± 0.40	5.44 ± 0.38	.011	.53
HRmax ($beats \cdot min^{-1}$)	188.6 ± 7.1	186.3 ± 6.2	.031	–.46
RER	1.27 ± 0.05	1.27 ± 0.08	.945	.02
ANT (%$\dot{V}O_2$max)	82.2 ± 5.0	83.9 ± 5.0	.149	.31
P_{ANT} ($W \cdot kg^{-1}$)	4.07 ± 0.38	4.35 ± 0.39	< .001	.70
CMJ (cm)	44.9 ± 3.8	47.1 ± 4.0	.002	.64

Note. SD = standard deviation; p = statistical significance of paired Wilcoxon test; r = Wilcoxon effect size; BMI = body mass index; $\dot{V}O_2$max = maximal oxygen uptake; $\dot{V}O_2$maxabs = maximal oxygen uptake in absolute unit; Pmax = maximal power output; HRmax = maximal heart rate; RER = respiratory exchange ratio; ANT = anaerobic threshold; P_{ANT} = power output at anaerobic threshold; CMJ = countermovement jump with arm swing.

Figure 1 Association of changes in maximal oxygen uptake and power outputs with changes in body mass



Note. Δ = the difference between the value after pre-season training preparation and the value after off-season; $\dot{V}O_2$max = maximal oxygen uptake; Pmax = maximal power output; P_{ANT} = power output at anaerobic threshold; r_s = Spearman's correlation coefficient; p = statistical significance of correlation coefficient.

Ice Hockey Federation Ranking of A teams (body height 183.1 cm, body mass 85.7 kg; Sigmund et al., 2014). When comparing the two testing sessions with regard to the somatic parameters, the tested players had more favorable body composition after the pre-season preparation as their body fat decreased (–2.3%) and fat-free mass increased (+3.2%) while their body mass and BMI remained invariable. We can assume that these changes in body composition are mostly related to the training program as they exceed the typical error of measurement in Tanita BC-418 MA (e.g., 0.36% for body fat when analyzing its inter-daily variability in young men; Kutáč, 2015). In a similar study, Kutáč et al. (2017) observed a decrease in body fat (from 14.7 to 12.4%) and an increase in fat-free mass (from 75.9 to 77.0 kg) without changes in body mass or BMI after an 8-week conditioning program in 25 players from another Czech ELH team. In our study, the body fat percentage at the end of the pre-season was 11.4%. In his long-term comparison within one NHL team, Montgomery (2006) shows a stable body fat percentage ranging from 10.0 to 10.4%. Burr et al. (2008) report a reference value of 9.7% in 18-year-old elite junior-level hockey players ranked by NHL central scouting as being among the top 120 players worldwide of their respective year. However, research also shows higher values, for example, 13.2% in the Polish national team and Polish league (Roczniok et al., 2016; Szmatlan-Gabryś et al., 2014) or even 16.1% in Canadian elite collegiate hockey players aged 21 to 26 years (Chiarlitti et al., 2018). In our study, fat-free mass (or lean body mass) in the players at the end of the pre-season achieved 76.6 kg. Kutáč and Sigmund (2015) found similar fat-free mass (77.5 kg) in a group of other Czech players from ELH when comparing them to a group of players from the top Russian league (81.4 kg). Available data from other studies are very inconsistent, varying probably due to different methods of body composition assessment (bioimpedance analysis, dual-energy X-ray absorptiometry or skinfold caliper) and various types of participants as the values range widely from 42.2 kg (Burr et al., 2008) to 65.5 kg (Chiarlitti et al., 2018).

Table 3 Correlation analysis between changes in anthropometrical variables and physiological variables

	ΔBody mass		ΔBMI		ΔBody fat		ΔFat-free mass	
Variable	r_s	p	r_s	p	r_s	p	r_s	p
Δ$\dot{V}O_2$max	–.55	.007	–.57	.006	–.10	.647	–.46	.030
Δ$\dot{V}O_2$maxabs	–.21	.359	–.22	.322	.13	.575	–.24	.286
ΔPmax	–.51	.014	–.51	.016	–.27	.221	–.30	.171
ΔHRmax	.27	.225	.27	.231	.28	.210	.06	.789
ΔRER	–.08	.725	–.07	.754	–.38	.084	.23	.308
ΔANT	–.09	.675	–.08	.721	.02	.920	–.12	.585
ΔP_{ANT}	–.44	.038	–.45	.038	–.22	.336	–.35	.113
ΔCMJ	.23	.297	.23	.297	.00	.992	.12	.590

Note. Δ = the difference between the values after pre-season training preparation and after off-season; BMI = body mass index; $\dot{V}O_2$max = maximal oxygen uptake; $\dot{V}O_2$maxabs = maximal oxygen uptake in absolute unit; Pmax = maximal power output; HRmax = maximal heart rate; RER = respiratory exchange ratio; ANT = anaerobic threshold; P_{ANT} = power output at anaerobic threshold; CMJ = countermovement jump with arm swing.

During an ice hockey match, on-ice heart rates are often sustained as high as 85% of HRmax and have been reported to peak high above 90% of HRmax or even exceeding the laboratory-measured maximum (Burr et al., 2015). HRmax is probably not a parameter which is strongly affected by changes in trainability (Zavorsky, 2000). On the other hand, values of HRmax obtained during the maximal incremental testing as well as heart rates corresponding with selected thresholds or zone intensities are useful for managing the training process (Stanula & Roczniok, 2014). In our study, HRmax was also used as a control variable to confirm whether both maximal tests were terminated at the comparable intensity. The observed difference is considered negligible when maximal values of the RER were also practically the same in both testing sessions.

When measured in a laboratory setting using a bicycle ergometer as the most task-specific laboratory device related to skating (Cox et al., 1995), $\dot{V}O_2$max in elite ice hockey players should generally range between 50–60 ml·kg^{-1}·min^{-1} (Montgomery, 2006) or above 60 ml·kg^{-1}·min^{-1} in forwards (Cox et al., 1995; Twist & Rhodes, 1993). Reference data by Burr et al. (2008) state a mean $\dot{V}O_2$max of 57.4 ml·kg^{-1}·min^{-1} (5.0 L·min^{-1}) in elite 18-year-old juniors with a mean body mass of 87.6 kg. According to Quinney et al. (2008), there is an increasing trend observed in $\dot{V}O_2$max through the years which is most notable for the absolute value (L·min^{-1}) as a reflection of the increased size of players since relative $\dot{V}O_2$max shows only little changes. Thus, values of $\dot{V}O_2$max should be interpreted with respect to changes in body or muscle mass. After two months of pre-season training, we detected a significant increase in the mean $\dot{V}O_2$max (+7.8%) up to 52.6 ml·kg^{-1}·min^{-1} (range from 47.4 to 61.2 ml·kg^{-1}·min^{-1}). The absolute values of $\dot{V}O_2$max increased significantly by 8.1%. Moroščák et al. (2013) observed changes during the pre-season period from 49.0 to 56.7 ml·kg^{-1}·min^{-1} (+15.7%) in 15–16-year-old players after completing a 9-week training. In their study, aerobic fitness remained at a relatively stable level up to the playoffs (55.5–57.5 ml·kg^{-1}·min^{-1}).

Although short shifts predominate in ice hockey, the physiological demands are not limited only to anaerobic pathways. Adequate aerobic capacity is responsible for recovery from high-intensity intermittent exercise or play, acting as a buffer against fatigue and a factor minimizing the attenuation of power output during subsequent shifts (Glaister, 2005). In addition, if a short bench (three lines of forwards) is used, the work-to-rest ratio might be reduced from 1:3 (typical of four lines) to 1:2 and consequently heighten the aerobic demands during shifts (Vescovi, Murray, et al., 2006). However, there are many varying views on the importance of aerobic capacity training in ice hockey training programs. Szmatlan-Gabrys et al. (2006) claim that training exercises oriented rather toward aerobic capacity can negatively affect anaerobic capacity and vice versa. Carey et al. (2007) point out that coaches and trainers probably do not need to include aerobic training in their practices because the high-intensity interval training commonly seen in ice hockey training also improves aerobic capacity. In a study by Peyer et al. (2011), aerobic fitness does not appear to be a significant predictor of player performance as measured by the +/- system (i.e., a measure of a player's goal differential: increased by one for those players on the ice for the team scoring the goal and decreased by one for those players on the ice for the team allowing the goal; power play or penalty shot goals are excluded). On the other hand, Green et al. (2006) found $\dot{V}O_2$max to be significantly related to players' net scoring chances (r = .41, p < .03). Roczniok and colleagues confirmed a significant association between selected specific on-ice tests like 6 × 9 m stops or 6 × 30 m endurance and $\dot{V}O_2$max (r > .50, p < .05; Roczniok et al., 2014) and also the importance of $\dot{V}O_2$max value among the best predictors of success in the recruitment of top-level ice hockey players (Roczniok et al., 2016). Stanula et al. (2014) found a significant correlation between $\dot{V}O_2$max and the total fatigue index for 6 sprints of 89 m (r = –.58, p = .003). Peterson et al. (2015) indicate that $\dot{V}O_2$peak measured on a sport-specific skating treadmill is associated with the repeated sprint ability of ice hockey players.

In ice hockey laboratory testing, power usually refers to anaerobic capacity evaluated by the all-out Wingate test on the specialized bicycle ergometer (Cox et al., 1995). Our testing procedure works with the highest power output as determined during the maximal incremental test. As such, it could be denoted as the final aerobic workload. According to Tarter et al. (2009), there are three main components of maximal incremental testing related to aerobic power: $\dot{V}O_2$max, final aerobic workload and test duration. In our study, the Pmax value increased significantly by 3.4% after two months of the pre-season training program. When maintaining the body mass between the first and the second testing session, improvements in Pmax are associated mostly with the longer duration of the maximal incremental test. The mean time difference between the tests was 30 s. Hence, the players were probably more resistant to fatigue caused by work at maximal intensity. Additionally, our results suggest that individual decreases (Δ) in body mass or BMI had favorable influence on positive changes in Pmax and also power output at the anaerobic threshold (P_{ANT}) after the pre-season conditioning when compared to the values at the end of the off-season.

Evaluating the explosive power of legs, the players in our study improved their performance in the countermovement jump test during the pre-season period by 4.9 % to 47.1 cm. Mascaro et al. (1992) reported that vertical-jump power was the strongest predictor of on-ice skating speed (r = –.85) in adult professional ice hockey players. Similar results were described by Farlinger et al. (2007) who found out significant correlation (r = –.71) between vertical jump (mean value 51.4 cm) and test of on-ice 35-meter sprint in competitive hockey players of diverse playing levels aged 15 to 22. Vertical jump (mean value 51.6 cm) also significantly correlated with on-ice acceleration and top speed (r = –.42 to –.59) in a study by Peterson et al. (2016) analyzing off-ice and on-ice performance in adult hockey players playing Division I, Division III, or Junior level hockey in the Minneapolis area.

With a variety of testing protocols showing limited or equivocal practical results, conditioning coaches should ensure that they are fully aware of the strengths and weaknesses of both on-ice and off-ice testing when working with a team (Nightingale et al., 2013). Regularly repeated valid and reliable testing procedures ensure longitudinal continuity of evaluating effectivity of a training process on both individual and team levels.

This study was limited to only one ELH team. The involvement of more teams would be beneficial in order to perform more extensive analyses. Another limitation refers to the current ice hockey testing profile. We assume that more complex laboratory testing (including tests of anaerobic capacity, upper body strength and power) would offer deeper insight into performance-associated variables and further improvement of training practice.

Conclusions

This research shows that two months of the pre-season training preparation program seems to be an adequate period for inducing significant adaptation responses that result in improvements in body composition and physical performance levels in professional Czech ice hockey players.

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Conflict of interest

The authors report no conflict of interest.

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