Journal of Physical Education and Sport ® (JPES), 17(3), Art 208, pp. 2059 - 2066, 2017
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Changes in selected morphological characteristics in elite ice hockey players during an eight-week conditioning program

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Published online: September 30, 2017
*(*Accepted for publication September 20, 2017
DOI:10.7752/jpes.2017.03208

Abstract:
Backround: High performance is also associated with specific ranges in somatic parameters depending on the sporting discipline. The development and maintenance of these parameters is supported primarily by the conditioning sessions players are exposed to across the various phases of the season. Objective: The aim of the study was to monitor the changes in the body composition of an entire team of elite players during a conditioning program. Method: The study included a total of 25 elite, Czech Republic, premier league (ELH) ice hockey players (24.6±5.0 years). The measured parameters included the following: body mass (BM), body fat (BF), fat free mass (FFM) and segmental analysis BF. These parameters were measured at the beginning and at the end of specific phases of the conditioning program, with four measurements taken in total. Results: Compared with the pre conditioning phase measurement, percentage of body fat decreased by 1.8 to 2.3 % ($p<.05$, $\eta2 = .06$) during the conditioning phase which was analyzer dependent. Extracellular mass decreased by 2 kg ($p<.05$, $\eta2 = .04$), while there was a 2.9 kg ($p<.05$, $\eta2 = .14$) increase in intracellular mass. There were also changes in the segmental distribution of body fat, with a decrease of 1.4 to 1.9% ($p<.05$, $\eta2 = .07$) in the lower limbs and a decrease of 2.9% ($p<.05$, $\eta2 = .07$) in the trunk. No changes were observed in the upper limbs. Conclusion: These results indicate that the conditioning program had a positive effect on the somatic parameters in the players. There was a decrease in fat mass and increase in muscle mass, which creates another precondition for further development of the strength performance.
Key words: ice hockey; conditioning; body mass; body composition; segmental analysis.

Introduction

Success in high performance sport requires the optimal development of characteristics such as motor abilities, skills and physical fitness. High performance is also associated with specific ranges in somatic parameters depending on the sporting discipline. Athletes in endurance (aerobic) disciplines have a lower body weight and a lower body fat percentage compared with athletes competing in strength or anaerobic sports. In athletics, this is documented by the values for road cyclists, middle distance and long distance runners, compared with sprinters or throwers; in skiing there are different values for downhill skiers versus cross-country skiers. The differences in body height in athletics can also be found when comparing the values of endurance runners, sprinters, jumpers and throwers. Height is also one of the most significant factors associated with sporting performance in many sport games (McArdle, Katch & Katch, 2007).

From a physiological perspective, ice hockey is an high-intensity intermittent physical activity (Mongomery, 2000). Therefore, training should focus on the development of strength, particularly explosive strength as the fundamental motor skill, together with the development of aerobic and particularly anaerobic performance including speed and agility (Brocherie, Babault, Cometti, Maffiuletti, & Chatard, 2005; MacLean, 2008; Montgomery, 2006; Quinney et al., 2008). Conditioning sessions should emphasize developing overall strength of the trunk, extensors of the hip and knee joint, hip adductors, musculus triceps brachii and musculus deltoideus (Brocherie et al., 2005; Quinney et al., 2008). The optimum development of aerobic [VO_{2max} scores ± 56–60 $mL.(kg.min)^{-1}$] and anaerobic capacity (AnC) (the total AnC in elite ice hockey players is ± 1100–1200 W; the relative AnC/kg in elite ice hockey players is ± 13 W/kg) is considered to be the main predictive factors for success and performance (Peyer, Pivarnik, Eisenmann, & Vorkapich, 2011; Potteiger, Smith, Maier, & Foster, 2010; Tarter et al., 2009). The development and maintenance of these parameters is supported primarily by the conditioning sessions players are exposed to across the various phases of the season. Together with the development of aerobic and anaerobic components of elite ice hockey players conditioning phases should also impact on specific somatic parameters. This is supported by a number of studies addressing the association between the somatic parameters and performance in ice hockey players (Barzilay, 2002; Quinney et al., 2008; Zryd, Kölliker, & Tschopp, 2009) or in studies analysing the morphological and functional parameters in elite

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ice hockey players (Canadian-American NHL, Russian KHL, Czech ELH) (Kutáč & Sigmund, 2015; Skowronek, Socha, Roczniok, & Socha, 2013; Stanula et al., 2013).

In the Czech Republic, the ELH competition period runs from Fall without any breaks until the end of Spring. Therefore, players have a limited, but a clearly defined time period, to complete intensive pre-season conditioning. This intensive conditioning is primarily performed off-ice and provides players with the opportunity to develop specific motor abilities, skills and fitness (MacLean, 2008; Sigmund, Dostálová, & Brychta, 2013). This is also a period during which changes in the somatic characteristics of the players should take place as a result of the intensive conditioning. Ideally, these changes will contribute to improved or optimal performance in the upcoming ELH competition. In the ELH, the traditional conditioning model is a joint pre-season program, with elite players participating in conditioning programs at their ice hockey club. This model has previously made it difficult to perform research examining the impacts of specific conditioning on somatic changes in elite Czech ice hockey players. Therefore, the aim of the study was to monitor the changes in the body composition of an entire team of elite players during a conditioning program.

Material & methods

Participants

Initially, the conditioning program included 30 players. Over the course of training, five players left and five new players joined the team. The study includes only those players who completed the whole training, i.e., 25 players. The age of these players was 24.6±5.0 years, height 185.1±7.3 cm and an average time of involvement in ice hockey of 19 years. These players had a valid professional contract with a Czech ice hockey club and were regular participants in EHL playoff games. Therefore, these were elite players playing in the highest professional ice hockey competition in the Czech Republic.

All participants signed an informed consent to their participation in this research. The research was approved by the Ethics Committee of the University of Ostrava and complied with the Declaration of Helsinki.

Description of the conditioning program

The pre-season program lasted 14 weeks. It started in May after the players returned from their holidays and ended at the beginning of the new competition year in September. For the present study, an eight-week off-ice period was selected that focused on intensive conditioning training. The preparation started on the 18th May and ended on the 10th July (the players then started training on the ice after a week off). The monitored conditioning program was divided into three stages. Stage I lasted 3 weeks and the players had two-phase training, three times a week (18 training units). Stage II also lasted 3 weeks. In the first week, the players participated in a four-day training camp with three-phase training (12 training units in total). In the remaining two weeks, there was two-phase training, three times a week (12 training units). Stage III lasted 2 weeks and training was two-phased, three times a week (12 training units). The total number of training units in the conditioning program was 54. The average duration of a training unit ranged from 75 to 90 minutes.

Specification of the applied load

Stage I (Week 1 – 3)

This stage included training for the development of dynamic strength of the upper and lower limbs and body – a set of 7 to 8 exercises using body weight, then with light and medium-heavy resistance, occasionally with resistance for a maximum of 7 repetition, non-maximal velocity of execution, 5 – 7 repetitions of the exercise; rest interval between exercises 1 – 2 minutes, 3 – 4 series, rest interval between the series (RIS) 45 s. Training of dynamic-strength endurance consisted of a) training of strength endurance of the upper and lower limbs, upper part of the back and stomach muscles - load intervals (LI)/rest intervals (RI) 55/5 s (five exercises); number of series 5, RIS 3 min, b) box performed with maximum intensity – LI/RI 3/1 min, number of repetitions (NR) 6. Sport games – mainly football, floorball and tennis. Aerobic-endurance continuous run in terrain. Sensomotor stimulation with balance exercises ("core" training). Training of explosive strength by the plyometric method – 4 exercises with 3 repetitions in 1 series, 4 series, RIS 2 min. Training of speed endurance – sprint with a change in direction with concurrent throws of a medicine ball, LI/RI 20/10 s, NR 6. This content was the same for all three weeks.

Stage II (Week 4 – 6)

Training for the development of the dynamic strength of the upper and lower limbs and body – identical to Stage I. Training of dynamic-strength endurance – identical to Stage I, changes in comparison with Phase II: training of strength endurance of upper and lower limbs, upper part of the back and stomach muscles LI/RI 20/20 s, 8 exercises in a series, 4 series, RIS = 2–3 min; in a box LI/RI per 1/1 min, NR 15. Sport games – same as in Stage I. Training of explosive strength by the plyometric method – changed to 7 series when compared with Stage I.

Sensomotor stimulation with balance exercises – identical to Stage I. Anaerobic-aerobic endurance running interval training – LI/RI 1/1 min, NR 10. Training of speed endurance – identical to Stage I. This content was the same for all three weeks.

Stage III (Week 7 – 8)

Training for the development of the dynamic strength of upper and lower limbs and body – identical to Stage I, or Stage II. Sport games – identical to Phase I and II. Training of dynamic-strength endurance – change in comparison with Stage II – box LI/RI 40/20 s, NR 20. Training of speed-strength ability of lower limbs – 15 m sprints pulling a sledge with a 50 kg load, RI 1 min, NR 15. Sensomotor stimulation with balance exercises – identical to Stage I and II. Explosive strength training by the plyometric method – identical to Stage II. Training of spring speed – racing sprints, LI/RI 10/60 s, NR 20. Training of speed endurance – racing sprints – identical to Stage I and II. This content was identical for both weeks of Stage III.

The volume and percentage of the type of load in the individual stages are presented in Table 1.

A detailed analysis of the dietary habits of our group of players was not performed. Typically, the system of preparation used for elite Czech players is based on a group approach, and on a training day, food is provided by their club upon agreement with the club physician. The total daily energy intake of the monitored ice hockey players during the preparatory period equals 4-5,000 kcal with a corresponding proportion of main nutrients. Nutrition recommendations respect the somatic characteristics and sports specializations of the monitored athletes (Kreider et al., 2010). Nutritional supplementation practices in the players was also not monitored monitored. In comparison with the European (Czech) approach to preparation, the preparatory period of the North American National Hockey League (NHL) players focuses on the individual preparation of each player, including nutrition and supplement management. After the final health examination at the end of the season, the players receive in their home organizations from their conditioning coaches and nutrition therapists advice about their individual preparation and nutrition, which they should follow until they meet at a training camp before the start of a new season.

Table 1. Load volume used in the conditioning program

Type of training	Stage I		Stage II		Stage III	
	min	%	min	%	min	%
Maximum strength	380	21	230	11	30	3
Dynamic strength	340	19	590	29	380	37
Explosive strength-plyometrics	90	5	150	8	130	13
Sensorimotor stimulation	120	8	140	7	100	10
Speed endurance	-	-	90	4	100	10
Short-term endurance	60	3	180	9	160	15
Medium-term endurance	160	9	180	9	-	-
Aerobic endurance	270	15	180	9	-	-
Sports games	350	19	290	14	120	12
Total	1770	100	2030	100	1020	100

Note. min-minutes, %-proportion of a particular type of training to the total volume

Procedures

The somatic measurements were carried out at the beginning of the conditioning phase and at the end of the individual conditioning phases, in the morning, and observing standardized measurement principles. All participants provided informed consent to participate in this research. The research was approved by the Ethics Committee of the University of Ostrava and complies with the Declaration of Helsinki.

The body height (BH) was measured using the A-213 Anthropometer (Trystom, Czech Republic). The body mass (BM), body fat (BF) and segmental analysis of the body fat (BF) distribution were measured using the Tanita BC 418 MA tetrapolar bioimpedance scale (Tanita corporation, Japan). This single-frequency analyser uses a bioelectric impedance method and takes measurements at a frequency of 50 kHz. The measurements were carried out in the Athletic mode. The other body composition parameters, i.e., overall body fat (BF), fat free mass (FFM), extracellular mass (ECM) and intracellular mass (BCM) were measured using the Nutriguard-MS bioimpedance analyser (DataInpud, Germany). This multi-frequency analyser uses a bioelectric impedance method and takes measurements at a frequency of 100 kHz. Both the analysers comply with the applicable European standards (93/42EEC, 90/384EEC) for use in the medical industry. One of the input parameters of this analyser is the BM because the Nutriguard does not weigh the participants; we used the values measured by the Tanita analyser for the BM. To compare the mean values of BM and BH with the mean values of the players in the Czech ELH, we used the normalization index (N_i).

$N_i = \frac{M_i - M}{SD}$, M_i = mean value of the monitored players, M = mean value of ELH players, SD of ELH players.

Statistical analysis

Outliers were identified using boxplots, and the normality of the distribution was assessed using the Shapiro-Wilk test. The data were found to be normally distributed, and therefore the assessment of the differences in average values was performed using a repeated measures analysis of variance of repeated measurements. We used Tukey's post-hoc test to determine statistically significant differences between the individual measurements. The values with statistical significance were also tested for material significance. To assess the practical material significance, we used the Eta squared (η^2). An η^2 value of 0.01 indicates a small change, 0.06 a medium change and 0.14 a large change (Pierce, Block, & Aguinis, 2004). To confirm the material significance, a threshold value of $\eta 2 \geq 0.06$ was used. For all tests, the level of statistical significance was $\alpha = 0.05$. Statistical analysis was performed using the IBM SPSS Statistic (Version 21 for Windows; IBM, Armonk, NY, USA).

Results

This section presents the interim values for the individual body composition parameters including the segmental distribution of BF and the changes after each stage across the eight weeks. The values measured at the end of the last stage represent the monitored parameters at the moment when the players completed the program (Table 2).

Table 2. *Average values of whole-body analyses*

Parameters	M1 (n=25)	M2 (n=25)	M3 (n=25)	M4 (n=25)	η^2
	M±SD	M±SD	M±SD	M±SD	
BM (kg)	90.6±8.7	90.5±9.7	90.0±8.7	90.0±8.2	-
BMI (kg/m^2)	26.4±2.8	26.4±2.5	26.3±2.4	26.3±2.5	-
BF (%)$_{A1}$*	16.2±2.7	15.7±3.0	15.2±2.6	14.4±3.2	.06
BF (kg)$_{A1}$*	14.7±3.6	14.2±4.0	13.7±3.4	13.0±3.6	.04
BF (%)$_{A2}$*	14.7±3.4	13.7±3.3	13.3±3.4	12.4±3.2	.06
BF (kg)$_{A2}$*	13.3±3.9	12.4±3.5	12.0±3.8	11.2±3.3	.04
FFM (kg) $_{A1}$*	75.9±5.8	76.3±5.9	76.3±6.1	77.0±6.1	.03
BCM (kg) $_{A1}$*	44.3±3.2	45.2±3.7	46.7±3.1	47.2±3.5	.14
ECM (kg) $_{A1}$*	31.6±3.6	31.1 ±3.7	29.6±3.9	29.8±3.7	.04
ECM/BCM*	0.71±0.08	0.69±0.07	0.63±0.08	0.63±0.08	.14

Note. BM-body mass, BMI-body mass index, FFMI-fat free mass index, BF$_{A1}$-body fat measured by the Nutriguard-MS, BF$_{A2}$-body fat measured by the Tanita BC 418 MA, FFM-fat free mass, BCM-intracellular mass, ECM-extracellular mass, M1-measurement at the beginning of Stage I, M2-measurement at the end of Stage I and beginning of Stage II, M3-measurement at the end of Stage II and beginning of Stage III, M4-measurement at the end of Stage III, n-frequency, M-mean, SD-standard deviation, *ANOVA $p<.05$, η^2-Eta squared

No statistically significant changes were identified for body mass; therefore, the material significance of the body mass was not tested. Statistically significant differences were observed in all other parameters. Based on the results of post-hoc tests, it was revealed that for the parameters BF$_{A1, A2,}$ and BCM, statistically significant differences were identified between the measurements taken at the beginning of the summer training (M1), at the end of Stage II (M3) and at the end of the summer training (M4), and also between the measurements at the end of Stage I (M2) and at the end of the conditioning program (M4). For the FFM, there were significant differences between measurements at the beginning (M1) and the end of the conditioning program (M4). For the ECM parameter and ECM/BCM index, differences were identified between the measurements taken at the beginning of the conditioning program (M1), at the end of Stage II (M3) and at the end of the conditioning program (M4), and also between the measurements at the end of Stage I (M2), at the end of Stage II (M3) and at the end of the conditioning program (M4). A medium material significance was found in the percentage of BF (η^2 = .06), while a large change was identified for BCM and the ECM/BCM index (η^2 = .14). In the other cases, material significance was not found because η^2 did not reach a value of .06.

For the segmental distribution of the BF (Table 3), statistically significant differences were found for the proportion of BF in the lower limbs and the trunk. For the decrease in the proportion of BF in the lower limbs, a medium material significance was found (η^2>.06) and high material significance was noted for the trunk (η^2=.14). Based on the results of post-hoc testing, significant differences for all segments were identified between the measurements taken at the beginning of the summer training (M1), at the end of Stage II (M3) and at the end of the conditioning program (M4).

Table 3. Average values of the segmental analysis measured by the Tanita BC 418 MA

Body segment	M1 (n=25)	M2 (n=25)	M3 (n=25)	M4 (n=25)	η^2
	M±SD	M±SD	M±SD	M±SD	
RL* (BF %)	14.0±2.6	12.7±2.7	12.4±2.4	12.1±2.6	.07
LL*(BF %)	14.1±2.5	13.1±2.5	12.8±2.3	12.7±2.4	.07
RA (BF %)	11.3±1.9	12.1±2.5	11.7±2.3	11.4±2.5	-
LA (BF %)	11.2±1.9	12.0±2.3	11.5±2.5	11.3±2.5	-
Trunk* (BF %)	14.6±3.8	13.5±4.2	13.2±3.6	11.7±3.9	.14

Note. RL-right leg, LL-left leg, RA-right arm, LA-left arm, BF-body fat, M1-measurement at the beginning of Stage I, M2-measurement at the end of Stage I and beginning of Stage II, M3-measurement at the end of Stage II and beginning of Stage III, M4-measurement at the end of Stage III, n-frequency, M-mean, SD-standard deviation, *ANOVA $p<.05$, η^2-Eta squared

Discussion

Systematic monitoring of basic body parameters in ice hockey players was already being performed in the second decade of the 20th century in North America. Specifically, beginning in 1917, Montreal players were regularly tested for basic morphological and functional parameters at the beginning of the Canadian-American National Ice Hockey League (NHL) (Montgomery, 2006). The dynamic development of ice hockey and the increasing demands on the development of morphological parameters is also documented by the positive development of height and weight in NHL players. Between the 1920s and 1930s and the present, the average height in NHL players increased by more than 10 cm. Another significant finding is that there has been a 17 kg increase in weight in current NHL players in comparison with players from the early 20th century (Montgomery, 2006). In elite Czech ice hockey players, a significant increase in body height and weight occurred in the 1970s and 1980s. A further increase in Elite Czech ice hockey players' height and mass occurred during the first decade of the 21st century, particularly with respect to player positions gaming (Sigmund, Riegerová, & Dostálová, 2012). The height, weight and body composition of the players in the present study are similar to those reported in the research by Sigmund et al. (2012). When using the normalization index N_i, the BW value was 0.22 SD and the BH value was 0.12 SD, which are mean values.

In regards to the minimal changes in the overall BM, it is likely that this result was wereprimarily related to alterations in the body composition components (e.g. percent BF and FFM) that make up the overall BM. During the conditioning program, we observed a gradual decrease in the overall proportion of BF, which was reflected by a gradual increase in the FFM values. The overall decrease in the proportion of BF by 1.8% in the case of the Nutriguard analyser (A1) and by 2.3% for the Tanita analyser (A2) were considered significant, not only because statistical and material significance were confirmed but also because these changes exceeded the values of the typical error of measurement (TE) for the devices. For the bioimpedance analysers, the TE reference values are between 0.38 and 0.83 for BF, depending on the type of analyser used (Kutáč & Gajda, 2011; Macfarlane, 2007). Therefore these differences were not the result of the analysers' measurement error, but possibly related to the conditioning program. The decrease in the overall proportion of BF was also reflected by a decrease in BF in the individual body segments. A statistically and materially significant decrease of the BF in the lower limbs and especially the trunk supports the beneficial effects of the conditioning program. To compare the size of the decrease in BF in our players, we used values obtained in players preparing for the new NHL season, who were measured at our diagnostic centre at the beginning and end of their conditioning training program. These were three players who regularly play in their primary NHL line-ups. The decrease in BF proportion measured in these players exceeded 3.5%. Similarly, in his case report, Sigmund, Brychta and Dostalova (2013) reported a greater decrease in BF compared with the present study. Sigmund et al.(2013) monitored the changes following an intensive eight-week training in a professional player (22.5 years), who was preparing for a new season in the NHL. The decrease in the proportion of BF in this player measured by the Tanita Bc 418 MA instrument was 4.5%. Similar to our players, there were only minimal changes in the total weight, but a 4 kg increase in FFM kg. The most significant morphological changes occurred in this player after the completion of Stage II of the conditioning program (after 6 weeks). A detailed analysis of our players revealed that there was a decrease in BF exceeding 3.5% in only four players (16%) as measured by the Nutriguard analyser and in three players (12%) as measured by the Tanita analyser. These differences could have been caused by a more appropriate dietary regime followed by the players preparing for the NHL. Regarding the fact that none of these players had a nutritionist or were on a special diet during the conditioning training, we tentatively suggest that the cause of the differences was the demanding nature of the conditioning training. This is reflected by the fact that in our players there was not only a smaller decrease in BF but also higher proportional values of BF at the beginning of the competition period. In elite players, the reference proportion of BF is between 8 and 12%, depending on the method used for measurement (Agre et al., 1988; Green, Pivarnik, Carrier, & Womack, 2006; Montgomery, 2006; Papapanagiotou et al., 2011). In our players, values ≤ 12% BF was only observed in 11 players (44%) when measured using the Tanita analyser and in only eight players (32%) when measured using the Nutriguard analyser. A segmental analysis revealed that even in NHL players, the largest decrease in BF proportion was in the trunk, which shows that they had a similarly focused training.

Improvements in body composition should result in an improved performance level of a player during a match, particularly in skating. Potteiger et al. (2010) reported that skating speed decreases as body fat percentage increases. Generally, there are significant differences in body weight amongst various groups of athletes that may be related to metabolism type. Especially in those sports that require a higher proportion of muscle mass (Stanula, Roczniok, Maszczyk, Pietraszewski, & Zając, 2014). Undoubtedly, ice hockey is included in this category of sports. The training and fitness demands, including position specific training/fitness demands are increasing in elite ice hockey players (Vescovi, Murray, & Vanheest, 2006).

In the present study there was a gradual decrease in the proportion of BF together with an increase in the FFM. The greatest difference between FFM was found between the beginning and the end of conditioning program, which corresponded with the differences found between the proportion of BF. From physiological perspectives, a significant increase in FFM could be link with performed specific training plan that includes particularly a high intensity training and/or resistant training that induced a muscular hypertrophy (Goldberg, Etlinger, Goldspink, & Jablecki, 1975).

The total decrease in BF measured by the Nutriguard analyser was 1.7 kg, while there was an 1.1 kg increase in the FFM during the same period, which resulted in a decrease in overall BM by 0.6 kg. Provided that skeletal muscles make up 60% of the FFM (Heymsfield, Lohman, Wang, & Going, 2005), we can assume that there was an increase in muscle mass of approximately 0.7 kg. Of note, not only was there an increase in the FFM, but there were also changes in the proportion of its individual components (ECM and BCM). During the training period, we observed a gradual decrease in the proportion of ECM and an increase in BCM; these changes are graphically presented in Figure 1. Because the BCM is a component of the FFM containing cells that are capable of utilizing oxygen, this is an FFM component that is directly involved in muscular work (Talluri, Lietdke, Evangelisti, Talluri, & Maggia, 1999). Therefore, it is proposed that when this mass increases, it may reflect a muscle that is in a better condition for performance.

To evaluate the predisposition for physical performance, the ratio of these components of the FFM (ECM/BCM) was used as an index value. A lower value for this index, i.e., a higher proportion of BCM and lower proportion of ECM, is associated with a better physical performance. In elite athletes, the reference value of the index is between 0.71 and 0.66, depending on the type of sport (Psotta, Svěráková, Bunc, Šeflová, & Hráský, 2009). In accordance with the changes in the ECM to BCM ratio during conditioning program, the index gradually decreased in our players, which means that their readiness for a physical load gradually increased. No difference between the values at the end of Stages II and III was observed, which was likely caused by the inclusion of game activities and tactics on the ice during Stage III, which were performed at the expense of fitness training as the new competition season approached.

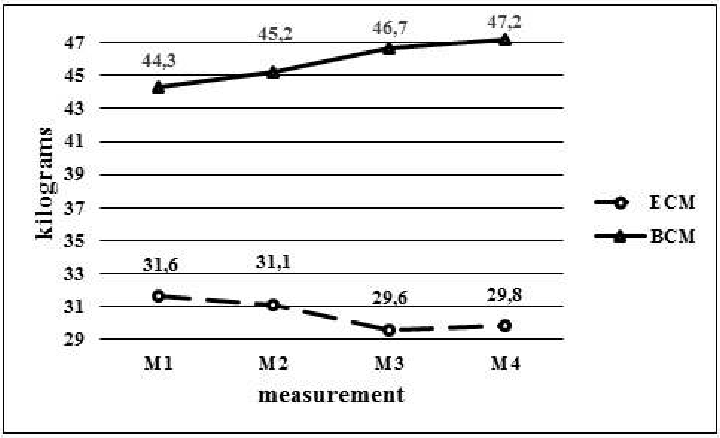

Fig.1. Changes in the FFM components during conditioning program BCM-intracellular mass, ECM-extracellular mass, M1-measurement at the beginning of Stage I, M2-measurement at the end of Stage I and beginning of Stage II, M3-measurement at the end of Stage II and beginning of Stage III, M4-measurement at the end of Stage III

Conclusion

The results of the present study suggest that an intensive 8-week pre-season, off ice conditioning program resulted in significant body composition changes in elite ice hockey players. The changes in the proportion of individual body weight fractions were consistent with the changes observed in elite players.

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