Morphological, Physiological and Skating Performance Profiles of Male Age-Group Elite Ice Hockey Players

by
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The purpose of this study was to describe the evolution of morphological, physiological and skating performance profiles of elite age-group ice hockey players based on repeated measures spread over one season. In addition, the results of fitness tests and training programs performed in off-ice conditions and their relationship with skating performance were analyzed. Eighteen high level age-group ice hockey players (13.1 ± 0.6 years) were assessed off and on-ice at the beginning and at the end of the hockey season. A third evaluation was also conducted at the beginning of the following hockey season. The players were taller, heavier, and showed bone breadths and muscle girths above the reference population of the same age. Muscular variables improved significantly during and between the two hockey seasons ($p < 0.05$). However, maximal aerobic power improved only during the off-season. All skating performance tests exhibited significant enhancements during the hockey season, but not during the off-season where some degradation was observed. Finally, weak observed variances (generally <20% of the explained variance) between physiological variables measured off-ice and on-ice skating performance tests indicated important gaps, both in the choice of the off-ice assessment tools as well as in training methods conventionally used. The reflection on the best way to assess and train hockey players certainly deserves to be continued.

Key words: ice hockey, elite players, skating performance, off-ice assessment, training.

Introduction

The pursuit of sporting excellence is a long and complex process that must take into account several factors. From a physical perspective, high-level performance manifests itself differently according to the sport. Indeed, technical, physiological and morphological characteristics proper to each sport make it necessary to develop assessment tools and training methods that take into account these differences. Thus, to better evaluate sport performance and ultimately prescribe the correct training program, it is essential to get access to reliable and accurate assessment tools.

In some more complex sports such as ice hockey, the challenge is even greater given the many bioenergetic systems that are sought (Cox et al., 1995; Montgomery, 1986, 2006; Nightingale et

al., 2013). In fact, ice hockey is a sport that requires high-intensity bouts of intermittent efforts, which implies that players must develop diversified physical capacities. Skating skills, however, remain the most sought quality to achieve success. It is therefore quite legitimate that hockey specialists are trying to optimize training and assessment strategies that enhance, as much as possible, these fundamental competencies inherent to the hockey game. In this regard, several tests and training methods have been proposed with the aim to either assess (Burr et al., 2008; Potteiger et al., 2010; Vescovi et al., 2006) or possibly enhance (Bracko and George, 2001; Ebben et al., 2004; Falinger and Fowles, 2008; Green et al., 2006) skating potential of the players via off-ice interventions. However, the

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interest created by obtaining the results of such tests is mixed as their value in terms of predicting sporting success is controversial (Burr et al., 2008; Nightingale et al., 2013; Vescovi et al., 2006).

Thus, the aim of this study was threefold: 1. To present physiological, morphological and skating performance profiles of age-group elite ice hockey players; 2. To follow the longitudinal course (repeated measures) of these variables; and 3. To present limitations in the relevance of commonly used off-ice testing and training programs.

Methods

Participants

A total of 18 male youth elite hockey players took part in this study. For reasons of consistency, only forward players were selected for this project. All participants (N = 18) were in their first year in the elite Bantam age-group category (aged 13-14 years old). The players were assessed off and on-ice on three testing sessions. The first assessment was completed at the beginning of the hockey season in September, the second at the end of the hockey season in March and the third at the beginning of the next hockey season (September) that allowed covering two consecutive beginning hockey seasons (September of the first year to September of the second year). All players were recruited into a special sports-study hockey program. The players came from different elite Bantam hockey teams from the Montreal area, but trained (off and on-ice) together for an average of 15 hours/week during at least nine months/year (age 13.1±0.6 year at testing session 1). Prior to the beginning of the study, each participant's parent had signed an informed consent form since it was required from the hockey direction board for the student/player to be authorized to participate in the hockey program. The project was approved by the institutional ethical committee of the Université du Québec à Montréal.

Training program

Between September and March, which represents the hockey season, each player trained on-ice 5 days/week for 2 hours/day and played 2-3 games/week for their respective team. Also, the participants trained off-ice 3 days/week for 90 min/day. The off-ice training consisted essentially of resistance training (3 sets of 8-10 repetitions),

aerobics (2 x 10 minutes of high intensity intervals), and plyometrics (2 sets of 8-10 repetitions). The terms of the training program were applied according to the recommendations of the elite development program of the Quebec Hockey Federation (Hockey Quebec, 2013). Even if the hockey season was over, all players continued to train off and on-ice during April and May. In June, all sporting activities were stopped to allow players to prepare for their school exams. From July to mid-August, the participants trained off-ice 4 days/week for 90 min/day following the same training program as previously described.

The summer training program was prepared by the Quebec Hockey Federation and was the same for those 18 players that were monitored (aerobic-anaerobic interval training, flexibility, plyometric and resistance training with free weights and/or machines). During this period, the players trained mostly individually. The last two weeks of August represented the selection camp for the different hockey organizations. All players who made their respective team were invited to join the hockey program for another year.

Off-ice assessment

The anthropometric characteristics of the players are reported in Table 1. Body height (BH), body mass (BM), body composition, and body mass index (BMI) were measured using standardized instruments (Lafayette stadiometer, precision of 0.1 cm; Detecto weight scale, precision of 0.1 kg and Harpenden skinfolds calliper, precision of 0.1 mm, respectively). The percentage of body fat (PBF) was estimated from the total of ten subcutaneous adipose skinfolds (TSAS) at the following sites: triceps, calf, abdominal, suprailiac, subscapular, midaxillary, pectoral, suprapatellar, cheek, and chin (Allen et al., 1956). The three components of the somatotype, endomorphy (Endo), mesomorphy (Meso), and ectomorphy (Ecto) were calculated accordingly to the Heath and Carter method (Carter, 1980). The epicondyles breadth of the humerus and femur (Lafayette anthropometric caliper) and the circumferences of the biceps and calf (Gulick anthropometric tape), which are needed for the estimation of the somatotype, were recorded with precision of 0.1 cm. All anthropometric measurements were performed using standardized techniques (Lohman et al.,

1988).

The physiological fitness test battery included 3 muscular endurance tests and 1 maximal aerobic test (Table 2). Muscular endurance was assessed by push-ups (Pup; 50 rep/min), sit-ups (Sup; 40 rep/min), and burpees (Bur; 25 rep/min) at an imposed cadence (maximum of 100 repetitions) as suggested by Leone and Léger (1985). Maximal aerobic power (MAP) was measured on a treadmill at a speed of 10 km·h^{-1}, with an increase in grade of 2.5% every 3 minutes until exhaustion (Leone et al., 2002). Oxygen and carbon dioxide concentrations were measured by a breath-by-breath metabolic analyzer (Sensormedics model 2900c, Anaheim, CA). All of the measurements were performed at all the 3 testing sessions.

On-ice assessment

On-ice performance was evaluated in agreement with the procedures recommended by Larivière et al. (1991), that comprised 5 skating tests (Table 2): a forward skating speed (FSS) test, a backward skating speed (BSS) test, a skating agility with the puck (SAP) test, a skating agility without the puck (SAWP) test, and a skating anaerobic power (SAnP) test. The FSS and BSS tests consisted of skating as fast as possible in a straight line over a distance of 30 m. The SAP test consisted of skating at maximal velocity back and forth on an 18 m course. During the test, the player needed to skate in a straight line, make abrupt stops and tight turns around pylons while controlling a puck for a total distance of 108 m (6 x 18 m). The same procedure was followed for the SAWP test, although without a puck. Finally, the SAnP test consisted of skating back and forth on an 18 m course at maximal speed with abrupt stops at each end. The player had to complete 12 consecutive 18 m courses that totalled 216 m. In order to assess the overall skating agility of each player, a new variable called an overall skating index (OSI) was created by calculating the average time (s) of the 5 on-ice tests.

Performances of all tests were recorded on videotape in order to obtain the final elapsed time of each test. The time was calculated by viewing individually and frame-by-frame each player for all 5 tests. As reported by Leone et al. (2006), this procedure presents several advantages: 1) it is easy to determine the exact moment of the beginning and/or ending of each test; 2) it

eliminates a part of the variability produced by the tester's or the player's reaction time that reduces the internal and external error of measurement; 3) the level of precision is good (0.017 s), which is important, especially when assessing time short distances; 4) it is possible to reassess each test as many times and at any time as necessary; and 5) video cameras are nowadays readily available.

Statistics

Descriptive statistics are presented as means and standard deviations (means ± SD). The Shapiro-Wilk test for normality was conducted for all variables. Comparisons of means were calculated using the Friedman non-parametric test for repeated measures. Correlations were calculated using the Spearman coefficient test. The level of significance was set at $p \leq 0.05$. All statistical analyses were performed using SPSS software package (Version 21.0).

Results

Table 1 presents means and standard deviations for all anthropometric variables for each of three measurement sessions. The level of significance between sessions of measurement is shown as *p*-value. Generally speaking, most of the anthropometric variables changed significantly over the year except for the somatotype, the PBF and the TSAS that remained relatively stable during all three measurement sessions.

Table 2 shows changes in physical, physiological and skating characteristics (means ± SD) of the three testing sessions. Most off-ice muscular variables improved significantly between each of the three measurement sessions. However, one should note an important exception considering maximal aerobic power expressed in ml·kg^{-1}·min^{-1}, which was maintained throughout the hockey season, but improved during the off-season. All skating performance variables improved significantly during the hockey season (SN1 and SN2) and most variables between the two hockey seasons (SN1 and SN3). On the other hand, none of these variables improved significantly after the off-season (SN2 and SN3) except for the backward skating.

Finally, Table 3 shows Spearman correlation coefficients (r) between the skating performance tests (s) and anthropometric measurements, on the one hand, and between the

physiological off-ice fitness values on the other hand.

Among all these variables, very few were reasonably correlated with skating performance tests. Furthermore, correlation coefficients did not show improvement over time, even though the values originated from repeated measures. One can, however, note that PBF, Σ10 skinfolds, endomorphic (Endo), and ectomorphic (Ecto) components of the somatotype were generally negatively related with skating performance (positive correlation with skating time means negative impact), while mesomorphy (Meso) was positively associated. Yet, the correlation coefficients were generally low and mostly non-significant. A similar situation was observed regarding the physiological fitness tests. Actually, we noted that correlation coefficients between skating performance tests and off-ice physiological measures were usually low and non-significant ($p > 0.05$).

Table 1

Anthropometric characteristics of Bantam elite hockey players

Variables	Session 1	Session 2	Session 3	*p*-values		
				a	b	c
Players (N = 18)						
Age (yr)	13.1 ± 0.6	13.6 ± 0.6	14.2 ± 0.6	0.000	0.000	0.000
Body mass (kg)	50.5 ± 5.9	54.2 ± 5.5	58.6 ± 6.0	0.000	0.000	0.000
Body height (cm)	161.3 ± 5.8	165.3 ± 5.4	168.8 ± 4.7	0.000	0.000	0.000
BMI (kg·m^{-2})	19.4 ± 1.5	19.8 ± 1.4	20.5 ± 1.8	0.005	0.001	0.005
∑ 10 skinfolds (mm)	78.4 ± 17.1	74.8 ± 17.2	78.2 ± 20.0	0.637	0.157	0.346
Body fat (%)	14.7 ± 3.3	12.9 ± 3.0	13.3 ± 3.7	0.225	0.637	0.808
Elbow breadth (cm)	6.62 ± 0.28	6.80 ± 0.24	6.92 ± 0.22	0.000	0.000	0.001
Knee breadth (cm)	9.43 ± 0.41	9.68 ± 0.33	9.74 ± 0.32	0.000	0.000	0.008
Calf girth (cm)	33.2 ± 2.1	34.2 ± 2.1	34.7 ± 2.5	0.000	0.000	0.003
Biceps girth (cm)	26.3 ± 2.1	27.2 ± 1.8	28.2 ± 2.1	0.000	0.000	0.000
Endomorphy	2.34 ± 0.66	2.14 ± 0.57	2.16 ± 0.62	0.157	0.157	0.637
Mesomorphy	4.68 ± 0.81	4.83 ± 0.69	4.70 ± 0.85	0.005	0.637	0.018
Ectomorphy	3.54 ± 0.71	3.43 ± 0.75	3.30 ± 0.99	0.467	0.637	0.157

Means and standard deviation (means ± SD); p-values: a) testing session 1 vs testing session 2; b) testing session 1 vs testing session 3; c) testing session 2 vs testing session 3. Significant difference at p ≤ 0.05.

Table 2

Physical, physiological and skating characteristics of Bantam elite hockey players.

Variables	Session 1	Session 2	Session 3	*p*-values a	b	c
Physiological characteristics (N = 18)						
Cadence push-ups (nb)	27.5 ± 8.3	35.8 ± 9.5	39.4 ± 9.5	0.000	0.000	0.005
Cadence sit-ups (nb)	36.7 ± 11.5	40.6 ± 9.0	48.2 ± 12.9	0.225	0.008	0.012
Cadence burpees (nb)	40.4 ± 22.7	62.2 ± 27.7	81.4 ± 26.0	0.008	0.000	0.050
MAP (ml·kg^{-1}·min^{-1})	52.7 ± 2.4	52.1 ± 3.5	53.6 ± 3.0	0.637	0.018	0.003
MAP (l·min^{-1})	2.66 ± 0.36	2.83 ± 0.35	3.14 ± 0.33	0.000	0.000	0.000
Skating characteristics (N = 18)						
Forward skating (s)	5.25 ± 0.41	5.12 ± 0.45	5.21 ± 0.38	0.000	0.346	0.090
Backward skating (s)	6.67 ± 0.48	6.42 ± 0.54	6.52 ± 0.62	0.018	0.157	0.012
Agility with a puck (s)	28.27 ± 2.81	27.07 ± 2.88	27.09 ± 3.12	0.005	0.005	0.617
Agility without a puck (s)	27.20 ± 2.45	25.90 ± 2.54	25.95 ± 2.69	0.000	0.000	0.617
Anaerobic skating (s)	57.29 ± 4.85	54.22 ± 4.93	54.08 ± 5.11	0.000	0.000	0.467
On-ice 5 tests average (s)	24.94 ± 2.12	23.75 ± 2.23	23.75 ± 2.34	0.000	0.000	0.808

Means and standard deviation (means ± SD); p-values: a) testing session 1 vs testing session 2; b) testing session 1 vs testing session 3; c) testing session 2 vs testing session 3. Significant difference set at p≤0.05.

Table 3

Spearman correlation coefficients between skating performance tests (s) and anthropometric and physiological fitness tests (off-ice) for each of the corresponding assessment sessions.

	Assessment session 1					
Variables	FSS	BSS	SAP	SAWP	SAnP	OSI
Age (yrs)	-0.103	-0.181	-0.246	-0.437	-0.362	-0.448
BH (cm)	-0.119	-0.187	-0.009	-0.247	-0.086	-0.178
BM (kg)	-0.383	-0.028	-0.158	**-0.501***	**-0.514***	-0.411
BMI (kg/m²)	-0.428	-0.007	-0.133	-0.447	**-0.544***	-0.374
Σ10SF (mm)	-0.060	**-0.491***	0.337	-0.009	-0.157	0.135
PBF (%)	0.137	**0.550***	0.351	0.105	-0.067	0.218
Endo	0.213	**0.558***	0.454	0.128	-0.064	0.250
Meso	-0.423	-0.128	-0.337	-0.546	**-0.626***	**-0.532***
Ecto	0.253	0.007	0.179	0.271	0.377	0.293
Pup (nbr)	0.089	0.053	-0.028	-0.134	-0.438	-0.253
Sup (nbr)	0.420	-0.021	0.026	0.24	0.016	-0.002
Bur (nbr)	-0.462	-0.324	-0.263	-0.327	-0.256	-0.336
MAP (ml·kg⁻¹·min⁻¹)	-0.336	-0.412	-0.237	-0.305	-0.332	-0.383
	Assessment session 2					
Variables	FSS	BSS	SAP	SAWP	SAnP	OSI
Age (yrs)	-0.349	-0.292	-0.439	-0.453	-0.459	**-0.513***
BH (cm)	-0.170	-0.172	-0.143	-0.148	-0.315	-0.292
BM (kg)	**-0.507***	-0.159	-0.311	-0.409	-0.369	-0.370
BMI (kg/m²)	-0.433	-0.135	-0.220	-0.366	-0.240	-0.222
Σ10SF (mm)	0.140	0.364	0.306	0.261	**0.481***	0.446
PBF (%)	-0.160	0.362	0.332	0.285	**0.500***	**0.470***
Endo	0.346	0.453	0.418	0.377	**0.569***	**0.523***
Meso	**-0.500***	-0.272	**-0.514***	**-0.546***	-0.365	-0.400
Ecto	0.301	0.185	0.185	0.298	0.131	0.112
Pup (nbr)	-0.053	-0.058	-0.166	-0.156	-0.092	-0.091
Sup (nbr)	-0.022	-0.245	-0.319	-0.241	-0.371	-0.371
Bur (nbr)	-0.159	**-0.579***	-0.164	-0.253	-0.178	-0.154
MAP (ml·kg⁻¹·min⁻¹)	-0.190	-0.286	-0.026	-0.046	-0.356	-0.187
	Assessment session 3					
Variables	FSS	BSS	SAP	SAWP	SAnP	OSI
Age (yrs)	**-0.471***	-0.225	**-0.509***	**-0.575***	-0.390	**-0.524***
BH (cm)	-0.046	-0.058	0.011	-0.108	-0.255	-0.154
BM (kg)	-0.401	-0.201	-0.346	-0.219	-0.396	-0.372
BMI (kg/m²)	**-0.540***	-0.413	**-0.580***	-0.401	**-0.476***	**-0.519***
Σ10SF (mm)	-0.013	0.112	0.069	0.226	0.265	0.209
PBF (%)	0.019	0.126	0.127	0.254	0.326	0.258
Endo	-0.011	0.093	0.088	0.248	0.224	0.203
Meso	**-0.490***	-0.307	-0.446	-0.273	-0.335	-0.383
Ecto	**0.534***	0.432	**0.578***	0.377	0.428	**0.474***
Pup (nbr)	-0.039	0.118	-0.185	-0.086	-0.015	-0.055
Sup (nbr)	-0.073	-0.062	-0.144	-0.184	-0.184	-0.228
Bur (nbr)	-0.382	-0.154	-0.431	-0.302	-0.222	-0.321
MAP (ml·kg⁻¹·min⁻¹)	-0.152	-0.284	-0.154	-0.197	-0.263	-0.231

BH = Body height; BM = Body mass; BMI = Body mass index; Σ10SF = Sum of 10 skinfolds; PBF = Percentage of body fat; Endo = Endomorphy; Meso = Mesomorphy; Endo = Endomorphy; Pup = Push-up; Sup = Sit-up; Bur = Burpee; MAP = Maximal aerobic power; FSS = Forward skating speed; BSS = Backward skating speed; SAP = Skating agility with puck; SAWP = Skating agility without puck; SanP = Skating anaerobic power; OSI = Overall skating index: Bold = significant at p ≤ 0.05.

Discussion

This study is certainly one of the few, if any, to present anthropometric, physiological, and on-ice skating performance profiles from repeated measures in elite age-group hockey players. Despite some limitations (limited age-group categories, number of participants, and player position that included only forwards), the results presented reveal several interesting findings.

Morphological profile

Based on data from the Canada Fitness Survey, the body mass and height of elite hockey players in this study were higher than the values observed in the general population. The same observation can be made for bone breadths and muscle girths (Table 1) where higher values were found in hockey players than those defined for individuals of the same age (Docherty, 1996). This is more or less surprising considering that ice hockey is a contact sport that requires some morphological sturdiness. As meaning, scouts often tend to recommend the selection of the most massive players. In our study, TSAS, BMI, and PBF tended to drop during the hockey season (Table 1) and were similar to values for elite hockey players presented elsewhere (Green et al., 2006; Potteiger et al., 2010).

Physiological profile

During the hockey season (September to March), all physiological variables improved significantly except for the MAP expressed in ml·kg^{-1}·min^{-1} that remained rather at the same level (Table 2). MAP has been shown to explain approximately 10% of the common variance in the ability to repeat on ice sprints (Peterson et al., 2015). Thus, aerobic capacity appears to be used for recovery and utilization of lactate between ice shifts, and ice shifts appear to be mostly anaerobic in nature (Peterson et al., 2016). Nonetheless, the improvement in physical qualities such as muscular endurance during the hockey season can be explained notably in two particular ways. First, such improvement is caused by the normal evolution resulting from the physical maturation process that occurs during adolescence. Indeed, most of these physical qualities improve with age during adolescence, even in individuals who are not particularly athletic (Baquet et al., 2006; Gerber et al., 2014).

Second, since the players also trained off-ice during the hockey season, the combination of these two events largely explains the observed gains. Nevertheless, this is not the case for the MAP expressed relatively to body mass, which tends to remain stable during a hockey season. This point is particularly interesting since aerobic training was considerably reduced during this period. The summer training during which a greater number of hours was devoted to the oxidative system development perhaps allowed players to reach a sufficient level to complete the hockey season with a suitable aerobic reserve (Table 2). In addition, the intermittent nature of the game, which is punctuated by repeated bouts of high-intensity efforts, seems to be sufficient to maintain fairly stable MAP throughout the hockey season.

As for MAP, all physiological variables improved significantly during the summer period, mainly due to the much greater time spent on off-ice physical fitness. Intensive physical training prior to the selection camps (July-August) certainly contributed to accelerating the improvement of players in relation to the specific physical qualities trained during this period.

Skating performance profile

During the hockey season, all skating variables improved significantly (Table 2). Considering that training sessions were focused primarily on exercises that involved skating situations, this improvement does not appear surprising. Nonetheless, what is more astounding is the fact that some skating variables did not improve between the beginnings of the two consecutive hockey seasons (Table 2). In fact, according to the data presented by Larivière et al. (1991), the expected improvement of the forward and backward skating performance tests between 13 and 14 years old should be approximately 6.5% (0.8% and 2.3% for forward and backward skating, respectively, in the present study). This gain was, however, reported for players of a much lower level than those of the present study. Therefore, it becomes more difficult to detect greater increases of performance in a more homogeneous elite group which is, in addition, at a level that is much closer to the expected maximum values. It should be also noted that these two skating tests are those that require the least amount of technical skills since they do not require puck control, stops or changes of the direction. These aforementioned reasons may

explain why elite players in these two skating techniques reach more easily a high performance level, or at least show a much slower progression especially considering that they have already achieved an excellent level of skating (less room for improvement).

During the off-season, none of the skating performance improved although the players trained intensively with the aim to improve their lower limb strength during several weeks. In fact, the backward skating test showed significant performance deterioration during this period. This suggests that the summer off-ice training programs such as those currently designed by many hockey organizations, fail to contribute to the improvement of fundamental skills such as skating ability. These training programs will, at best, maintain the level reached at the end of the previous season which is not sufficient considering that at this age and at this level, it is expected that the progression should continue throughout the year. For some skating skills less exploited during the hockey season such as backward skating by forward players for example, the summer training sessions do not even allow to maintain the level previously reached. It is therefore not surprising to hear hockey players often complain of not being "game shape" during the first weeks of on-ice practices although they train hard off-ice throughout the summer.

The lack of specificity of the off-ice training session may be an explanation of the absence of on-ice improvement, even for young players in progression. The proposed exercises should be as close as possible to the muscular and cardiorespiratory requirements observed during a hockey game. The many training aids actually available that can raise the level of specificity could be further exploited. It also appears important to include a certain number of on-ice structured skating exercises during the summer camps. Designing an off-ice training program with specific exercises together with skating sessions probably would better prepare players for the upcoming hockey season. This finding is in fact also supported by other recent works (Farlinger and Fowles, 2008; Lee et al., 2014).

On-ice performance versus morphological characteristics and physiological testing

As shown in Table 3, most anthropometric variables are poorly correlated with the results of skating tests. The presence of a highly homogeneous group of players clearly explains this situation. The variables that best correlated within the conducted skating tests were age, BM, BMI and Meso. This is not particularly surprising since older players are usually heavier. In addition, since body fat of players was relatively low (≈13.5%), we can assume that the difference in body mass was caused by greater muscle mass that ultimately would result in a greater skating speed. This possibility is also indirectly confirmed by the fact that the index of mesomorphy which reflects the rate of muscularity was also positively correlated with skating speed tests.

As expected, the somatotype of players showed a clear mesomorphic trend that was typically positively associated with skating performance variables (Table 3). A more surprising finding, however, was the importance of the ectomorphic component in these players. Indeed, an important ectomorphic component is often negatively related to athletic performance. Likewise, this is only true in individuals with too scanty muscle mass (Watson, 1988), which is not the case of hockey players in our study. In these circumstances, a relatively strong ectomorphic component does not hinder hockey performance. Finally, the endomorphic component was negatively related with performance variables, which is typically the case, even in the non-athletic population (Bale, 1986; Bale et al., 1984).

In this project, we used off-ice assessment tests similar to those often recommended to evaluate high-level hockey players (Burr et al., 2008). This type of testing is still regularly employed to help scouts from different hockey organizations to select players. The National Hockey League (NHL), which is the strongest worldwide professional hockey league, uses similar tests at their annual entry draft combine (Burr et al., 2008; Vescovi et al., 2006). However, it is quite clear from this study that most of the variables measured off-ice are not, or at least are very poorly associated with on-ice performance. Similar results were also reported by others in older elite hockey players with a percentage of explained variance that rarely exceeded 20% (Behm et al., 2005; Peyer et al., 2011; Vescovi et al., 2006). When the assessment is intended for less homogeneous groups, it is possible that the

predictive value of such tests increases. Leone et al. (2002) demonstrated that based on similar anthropometric and physiological measurements, it was possible to discriminate young elite athletes from different sports. However, it is noteworthy that already in high performance age-group athletes, there are specific families of physiological and morphological profiles that characterize athletes according to the sport practiced. In this context, athletes were compared based on their respective sport from a very heterogeneous group and therefore, more easily distinguishable.

As for training methods, this type of off-ice physical tests is not sensitive enough to accurately reflect the specific demands to play hockey. It is necessary to move towards physical tests much more related to the task. For example, Leone et al. (2007) recently showed with a group of elite players of the same age as those in the present study that values of VO$_2$max measured during a shuttle running test (Léger et al., 1988) underestimated by 6.2 ml·kg^{-1}·min^{-1} (12.9%) the energetic cost measured during a similar shuttle skating on-ice test. Likewise, Noonan (2010) showed great intra and inter-individual variability in the production of blood lactate during a hockey game. These results clearly show that the use of tests performed outside the specific context of performance fail to accurately translate the real physiological requirements of the game.

What does this article add?

This study is one of the first to present repeated measures, which describe the evolution of morphological, physiological, and skating performance variables of high-level ice hockey players over a complete hockey season. This cohort represents a sample of players competing at the highest level in Canada in their age group (13-14 years old). This age group is particularly interesting as it constitutes a turning point in their hockey career. Indeed, the best players will be promoted to the AAA level, which brings them closer to the major Canadian junior leagues. Since most players from this study will reach this level, these data represent somewhat of an ideal profile of a player that is likely to reach the highest level of performance, at least with regard to forward hockey players. Thus, the descriptive data presented, as well as their evolution over a period of 12 months, provide an important source of information for countries that aspire to compete against the best nations in the world in this sport. Finally, this study encourages a reflection on the best means (tools) and ways (methods) to assess and/or train off-ice youth hockey players by taking a critical look at currently employed methods.

Conclusions

To our knowledge, this is the first study that has documented the evolution of the morphological, physiological and on-ice performance profiles of elite age-group hockey players over a period of 12 months. Based on the data presented in this paper, this information can certainly be a useful benchmark mainly for emerging ice hockey countries, especially because this period is crucial for the remainder of the player's career. We also showed that there was a poor relationship between anthropometric and off-ice physiological variables versus on-ice performance. Furthermore, this research reveals the importance of carefully choosing training methods and testing protocols in order to better monitor and then improve on-ice performance. Based on repeated measures over a complete hockey season, this study highlighted the importance of using more specific assessment tests and training methods, particularly with a homogeneous group of young elite athletes.

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