Physiological profile of professional hockey players — a longitudinal comparison

David L. Montgomery

Abstract: This paper examines the size, strength, and aerobic fitness of players from a professional hockey team. Beginning in 1917, data on body size were obtained from historical records of the Montreal Canadiens. Body composition, strength, and $VO_{2\ max}$ were obtained through physiological testing of Canadiens players between 1981 and 2003. Compared with players in the 1920s and 1930s, current players were an average of 17 kg heavier and 10 cm taller, with BMI increased by 2.3 kg/m^2. The gain in BMI was not attributed to added fat mass, since percent body fat remained unchanged over the past 22 years. From 1992 to 2003, upper body strength was assessed using a bench press test. Predicted 1 repetition maximum (1 RM) for the 17- to 19-year-old group was 107.0 kg with the highest values attained by the 25- to 29-year-old age group (128.1 kg). Gains in body mass were associated with an increase in upper body strength. $VO_{2\ max}$ was measured annually on a treadmill between 1992 and 2003 with annual mean values ranging between 54.6 and 59.2 mL·(kg·min)$^{-1}$. Compared with values from players in the early 1980s, $VO_{2\ max}$ has increased with the improvements independent of body mass; however, given the variability in the data, we are hesitant to infer that $VO_{2\ max}$ has increased significantly during the 1990s.

Key words: physiological assessment, strength, aerobic power, professional hockey players.

Résumé : Cette étude évalue le gabarit, la force et la condition physique aérobie d'une équipe professionnelle de hockey sur glace. On se sert des données sur le gabarit des joueurs prélevées dans les fichiers des Canadiens de Montréal et remontant jusqu'en 1917. On utilise aussi d'autres données sur composition corporelle, la force musculaire et le $VO_{2\ max}$ prises chez les joueurs des Canadiens de Montréal entre 1983 et 2003. Comparativement aux joueurs des années 20 et 30, les joueurs d'aujourd'hui pèsent 17 kg de plus et mesurent 10 cm de plus; l'IMC a augmenté de 2,3 kg/m^2. L'augmentation de l'IMC n'est pas due au surplus de gras, car le pourcentage de gras n'a pas augmenté au cours des 22 dernières années. De 1992 à 2003, la force du haut du corps a été évaluée par une épreuve de développé-couché des bras. Le maximum sans répétition (1 RM) chez les 17 à 19 ans est estimé à 107,0 kg et à 128,1 kg chez les 25 à 29 ans. On attribue les gains de masse corporelle à l'amélioration de la force du haut du corps. De 1992 à 2003, les valeurs moyennes du $VO_{2\ max}$ ne varient pas plus de 4,6 mL·(kg·min)$^{-1}$ (de 54,6 à 59,2 mL·(kg·min)$^{-1}$). En comparaison avec le début des années 80, les données du $VO_{2\ max}$ ont augmenté indépendamment des gains de la masse corporelle; compte tenu de la variabilité des résultats, nous hésitons à dire que le $VO_{2\ max}$ a augmenté de façon significative au cours des années 90.

Mots clés : évaluation fonctionnelle, force musculaire, puissance aérobie maximale, joueurs de hockey professionnel.

[Traduit par la Rédaction]

Introduction

Baseball, basketball, and football players have improved performance by increasing in size (Neyer 2001); however, they are not the only athletes benefiting from a "the bigger the better" philosophy. Observations of today's professional hockey athletes would suggest that they are not only bigger, but also stronger and faster than the players from the first decade of the National Hockey League (NHL). The development in size, strength, and speed has both positive and negative consequences.

The risk of injury in any sport relates to the nature of the sport, the rules and regulations that govern playing conditions, environmental conditions, the quality of the equipment, and the physical and physiological characteristics of the athletes. The NHL monitors the injury patterns associated with playing professional hockey. Injuries in hockey are on the rise and are not the result of a single causative variable.

Ice hockey is played at a high tempo with frequent body contact resulting in injuries. Azuelos et al. (2004) reviewed the causes of injury from 39 studies between 1950 and 2000. The subjects in these studies played at the junior level or higher. An injury was defined as an event occurring during a hockey game or practice that caused the player to miss a minimum of one game. Ten factors were examined as sources of injury: (*i*) collisions with other players, (*ii*) collisions with

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the boards, (*iii*) ice and (or) falls, (*iv*) being struck by the puck, (*v*) being struck by a stick, (*vi*) contact with a skate, (*vii*) an injury incurred during a goal, (*viii*) fighting, (*ix*) non-contact and (or) overuse injuries, and (*x*) other causes. Azuelos et al. (2004) concluded that the major cause of injury was collisions with other players. The data also showed a trend for an increasing proportion of the injuries to result from collisions with other players. Does size contribute to this trend? It is logical to assume that a larger mass is being propelled at a greater speed owing to the increased strength and power of the athletes. The increased force on impact is probably a factor contributing to injuries during collisions.

The purpose of this paper was to examine the physiological profile of players from one professional team in the NHL and to document changes in size, strength, and aerobic fitness.

Materials and methods

The data included in this longitudinal study were primarily obtained from two sources. Information on body size was obtained from historical records of the Montreal Canadiens. Season guides were examined at the Communications Department of the Canadiens. Claude Mouton's book, *The Montreal Canadiens: A Hockey Dynasty* (1980), provided a historical perspective on each player. The NHL (2001) *Official Guide and Record Book* provided comprehensive statistical coverage on each player. These data were checked against statistics from the NHL player's association Web site and the historical statistics section at http://www.faceoff.com. The information on body composition, strength, and $VO_{2\ max}$ were obtained from physiological testing of the Montreal Canadiens at McGill University over the past 22 years. Each year during the first day of training camp, players performed a battery of tests including body composition analysis, aerobic endurance, anaerobic endurance, strength, muscular endurance, power, and flexibility.

The sample for body size analysis included all athletes playing for the Montreal Canadiens. Although the Montreal Canadiens hockey club was formed in 1909, the NHL's first season of play was not until 1917. Beginning in 1917 and ending in 2003, the rosters for the team were compared each year, with a total of 87 teams and 2291 players in the sample. For each team, the following data were examined: height, mass, and body mass index (BMI), was used to compare mass (kg) relative to height (m) and calculated using the formula weight/height^2.

A player was included in the sample in a given year if he appeared in at least 1 game for the team during that season. In 1917, 19 players appeared in at least 1 game, and clubs played a 22-game schedule in the premiere season of the NHL. For the next 7 seasons, 1918–1925, only 11–13 players made up the sample size. In comparison, during the 2000–2001 season, 39 players appeared in at least 1 game, with the season consisting of 82 games.

Percent body fat was estimated using the Yuhasz equation (1966) for the period 1981–2003. Sources of variability associated with estimation of body fatness include the investigator conducting the measurements, the calipers used, the number of sites measured, and the regression equation used for calculation (Lohman et al. 1984). Variability in the longitudinal data was minimized, since the same person took all measurements with one set of Harpenden calipers throughout this 22 y period. In addition, the same 6 skinfold sites (triceps, subscapula, suprailiac, chest, abdomen, and medial thigh) were used to predict percent fat from the sum of these 6 skinfolds. Each site was measured twice in non-sequential order. If the 2 measurements differed by 1 mm, a third measurement was taken.

Upper body strength was assessed using a bench-press test during the years 1992–2003. The bench-press exercise was part of the resistance-training program that was given to each player during the summer months. Since the technique is relatively easy to master, it was assumed that the players were prepared to perform a maximum effort at the start of training camp without risk of injury. The players performed as many repetitions as possible with 200 lbs (90.9 kg). If this mass could not be lifted, then 150 lbs (68.2 kg) was used. Each athlete was allowed as much time as desired for a warm up before the lift. A spotter was used to lift the bar from the support racks. During the lifts, the athlete was in a supine position on the bench, with both feet on the floor. The buttocks maintained contact with the bench throughout the lifts. Both hands were positioned in an overhand grip without specification to the width of the grip. The bar was lowered slowly to the chest, then returned to the fully

Fig. 1. Height (cm) for the Montreal Canadiens hockey team from 1917 to 2003.

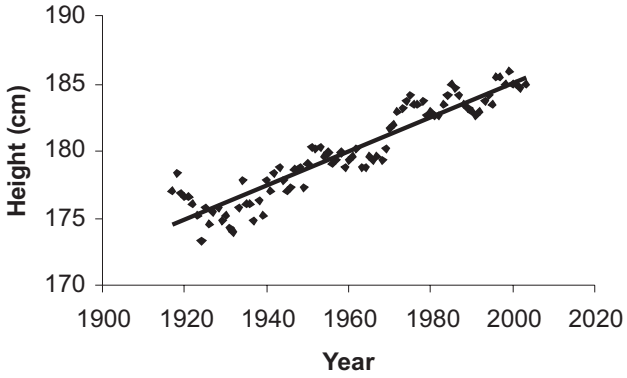


Fig. 2. Body mass (kg) for the Montreal Canadiens hockey team from 1917 to 2003.

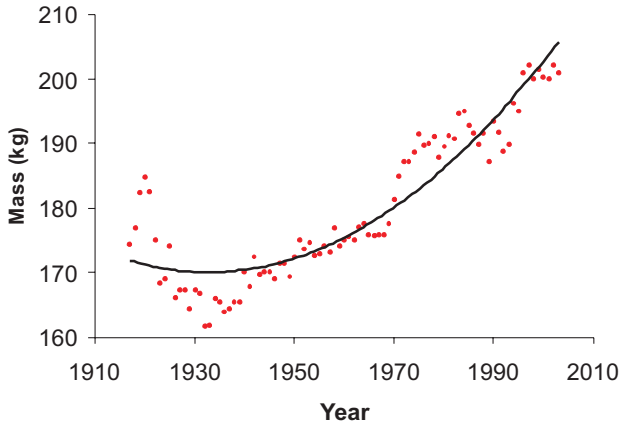


Table 1. Body composition (% fat) of Montreal Canadiens (1982–2003).

Year	*n*	Mean	Standard deviation
1981	27	12.4	1.9
1982	30	9.7	1.6
1992	24	8.3	2.6
1993	63	12.4	4.1
1994	41	9.8	1.3
1995	65	11.5	2.4
1996	59	11.2	1.7
1997	24	10.4	1.7
1998	58	10.4	1.9
1999	52	10.2	1.8
2000	48	10.2	1.8
2001	52	10.0	1.4
2002	53	10.3	1.6
2003	39	10.4	1.4

extended position. The 1 repetition maximum (1 RM) was predicted using regression equations as follows:

(*a*) 1–10 repetitions: Brzycki (1993),

(*b*) 11–20 repetitions: Lombardi's equation (Whisenant et al. 2003),

(*c*) >20 repetitions: Wathen (1994).

The basis of these formulas is the strong association between 1 RM and the number of repetitions needed to reach fatigue (LeSeur et al. 1997).

Aerobic power was assessed using an incremental treadmill test. The protocol for the test has been the same for the last 12 y. Treadmill grade was set at 5% at the beginning of the test and remained constant. The initial speed was 134 m·min^{-1} (5 miles/h) and increased by 13.4 m·min^{-1} (0.5 miles/h) each minute until volitional fatigue. The test duration ranged from 8 to 13 min. Three metabolic carts were used to analyze the expired air and $VO_{2\ max}$ was recorded from the highest 60 s sample. In the 1981 and 1982 seasons, aerobic power was measured using a continuous cycle ergometer test with an initial power output of 120 W and increasing increments of 30 W every 2 min. Players remained seated throughout the cycling test. For both ergometers (treadmill and cycle), $VO_{2\ peak}$ was determined using the classic $VO_{2\ max}$ criteria of a plateau with increasing workloads.

Results and discussion

Figure 1 compares the changes in height from 1917 to 2003. In the 1920s, the average height of a player was approximately 1.75 m. In 2003, the average height was 1.85 m. Figure 1 suggests that players will continue to gain in height, as the trend appears to be linear over the period 1917 to 2003.

Figure 2 illustrates the changes in body mass from 1917 to 2003. In the 1920s, the average body mass was approximately 75 kg. In 2003, the average mass was 92 kg. This increase of 17 kg represented a 23% gain in mass that appears to be in the form of muscle tissue. There are no historical records to confirm this statement, since body composition of the Montreal Canadiens has only been estimated using skinfold measurements during the past 22 years. Table 1 shows that percent body fat has remained relatively unchanged with mean values ranging from 8% to 12% body fat. Furthermore, the reported increase in height (Fig. 1) may also add to the explanation of some of the gains in body mass (Fig. 2).

Fig. 3. BMI (kg·m^2) for the Montreal Canadiens hockey team from 1917 to 2003.

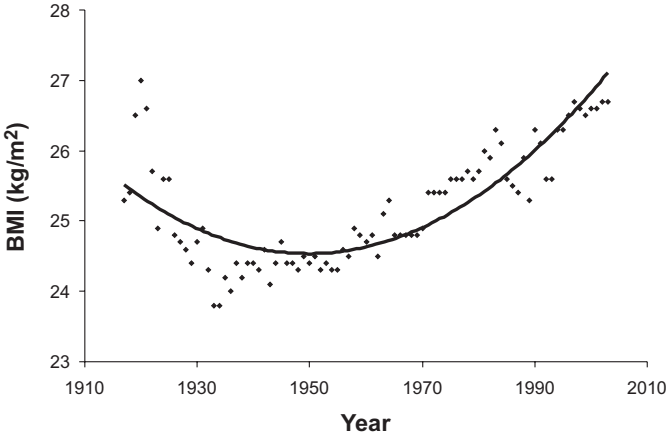


Figure 3 plots the changes in BMI from 1917 to 2003. In the 1920s and 1930s, the sample size for each year was small compared with later years and sometimes one athlete could influence the mean value for that year. As an example, only 12 athletes were included in the sample for the year 1919. The mean for 1919 was significantly influenced by the data for one large player — Howard McNamara. His mass was 109 kg and his stature was 1.83 m, resulting in a BMI of 32.6 kg/m^2. In the 1930s, the BMI averaged 24.3 kg/m^2. By 2000, the mean BMI had increased to 26.6 kg/m^2. The gain of 2.3 kg/m^2 shows that current players are not just larger, but that they are larger relative to their height compared with players in the 1930s and later decades.

There are many factors contributing to the increasing size of the players. Teams are drafting larger players. The NHL funds a central scouting bureau whose mandate is to evaluate amateur prospects for the annual NHL entry draft. Players are assessed by scouts on 10 task requirements (Renger 1994) with size and (or) strength and aggressiveness and (or) toughness being part of the selection process. Other factors include increased time spent in training, particularly strength training. In recent years, teams have added fitness and strength specialists to the coaching staff. Most NHL teams, including the Canadiens, have in-house facilities containing excellent equipment for physical development of the players. Nutrition is also a factor contributing to larger players. During games and workouts, players consume specialized beverages and products that facilitate their recovery. In recent years, some players have used supplements like creatine that result in a small weight gain (Juhn 2004).

The predicted 1 RM bench-press scores are shown in Table 2. Only 6% of the players could not lift 200 pounds and thus used 150 pounds. The 575 players that were tested between 1992 and 2003 were placed into 4 age groups.

Table 2. Predicted 1 RM bench press of professional hockey players (n = 575).

Age group (y)	n	Mass (kg, mean ± SD)	1 RM bench press (kg, mean ± SD)	Range (kg)
17–19	136	86.8±7.5	106.95±19.9	68.18–172.72
20–24	274	89.2±6.6	117.45±18.5	70.0–181.81
25–29	126	91.9±8.0	128.09±19.7	72.27–181.81
>30	39	91.9±7.8	125.31±18.8	75.0–172.72

Note: Data presented in Table 2 are collapsed pre-season testing data from 1992–2003 seasons.

Table 3. $VO_{2\ max}$ (mL·(kg·min)$^{-1}$) of Montreal Canadiens (1982–2003).

Year	n	Mean	Standard deviation
1981	27	55.6	—
1982	29	51.9	—
1992	24	55.8	6.1
1993	61	55.1	3.6
1994	40	58.1	4.7
1995	65	55.4	5.2
1996	59	55.3	4.2
1997	58	54.2	4.9
1998	50	54.4	3.4
1999	42	55.5	3.0
2000	60	53.7	4.4
2001	52	57.7	3.1
2002	52	57.7	3.1
2003	61	59.0	3.5

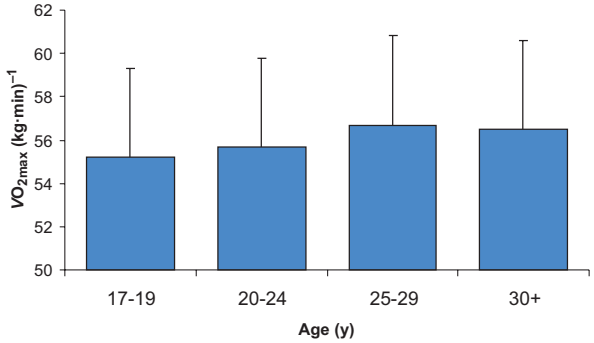
Note: In the 1981 and 1982 seasons, aerobic power was measured using a continuous cycle ergometer test; for all other years, aerobic power was measured using an incremental treadmill test.

During this period, the Canadiens had a full-time strength and fitness coach that prepared resistance training programs for the developmental players (junior- and minor-league professionals) and the NHL players. Resistance training was an integral part of the physical conditioning program. Weight training was included in both the summer program and the competitive season program. The Canadiens' weight-training facility is adjacent to their locker room, which facilitates supervised training sessions. With an increased emphasis on resistance training, the youngest group, as well as the 3 older groups, were stronger than the players on the 1981 and 1982 Canadiens teams (Montgomery and Dallaire 1986). The players on these 2 teams (n = 57) had an average 1 RM for the bench press of 203.5 lbs. In comparison, the 25–29 y group (see Table 2) was 16% stronger.

Hockey players are drafted by NHL teams at approximately 18 years of age. They continue to gain in body mass until about 25 years in age. On average, the players gain 5 kg in body mass over this period of time. The predicted 1 RM bench press for the youngest group was 107.0 kg, with the highest bench-press mean ocurring in the 25–29 y group (128.1 kg). The gain in body mass was associated with an increase in bench press of 21 kg.

Mean $VO_{2\ max}$ of elite hockey players has ranged from 52 to 63 mL·(kg·min) $^{-1}$ (Montgomery 2000). Table 3 summarizes the treadmill $VO_{2\ max}$ results for the years 1992 to 2003. During these 12 years, the means differed by only 4.6 mL·(kg·min) $^{-1}$ (54.6 to 59·2 mL·(kg·min)$^{-1}$). These high values are impressive, given that body mass has also increased during these years. Figure 4 displays $VO_{2\ max}$ results (n = 531 players) for the years 1992–2003 with the sample divided into 4 age groups (n = 89 for the 17–19 y group; n = 253 for the 20–24 y group; n = 134 for the 25–29 y group; and n = 55 for the 30+ y group). The 4 groups had similar $VO_{2\ max}$ values even though the older groups were higher in body mass.

Fig. 4. $VO_{2\ max}$ (mL·(kg·min)$^{-1}$) for 4 age groups.



Given the trend in these data, despite the highest values occurring in the last 2 years, we are hesitant to infer that $VO_{2\ max}$ has increased during the 1990s. Cox et al. (1995) summarized $VO_{2\ max}$ scores for NHL players from 1980 to 1991. Their lowest mean $VO_{2\ max}$ occurred in 1980 (54.0 mL·(kg·min)$^{-1}$; n = 38) with the highest mean occurring in 1991 (62.4 mL·(kg·min)$^{-1}$; n = 55). The latter data set were players from Team Canada who were recruited for the 1991 Canada Cup. These athletes were the NHL's most-skilled players. Since 1980, the frequency distribution for $VO_{2\ max}$ among NHL players has shifted to a higher mean and median (Cox et al. 1995). The improvements in aerobic power are independent of body mass and probably represent greater emphasis on cardiovascular training and more consistent selection of players (Cox et al. 1995). More specifically, beginning in 1993, the NHL adopted centralized physiological testing for NHL entry draft players (Gledhill and Jamnik 1994). The physiological results are available to all teams before player selection. In the weeks following the draft, the Canadiens bring each player to Montreal for development training camps. At that time, the fitness and strength coach works with each player on a summer training program in preparation for the upcoming hockey season.

Conclusions

Compared with players in the 1920s and 1930s, current players for the Montreal Canadiens are 17 kg heavier and 10 cm taller. Their body mass index has increased by 2.3 kg/m^2. It is unlikely that the gain in weight relative to

height reflects added fat mass, since values for percent fat have remained relatively unchanged over the past 22 years. The increase in body size has resulted in stronger players. Upper body strength was assessed using a bench-press test with either 150 or 200 lbs on the bar. Only 6% of the players could not lift 200 lbs. The 575 players tested between 1992 and 2003 were placed into 4 age groups. The predicted 1 RM bench press for the youngest group was 107.0 kg, with the highest value occurring in the 25–29 y age group (128.1 kg). The gain in body mass was associated with an increase in bench press of 21 kg. $\dot{V}O_{2\ max}$ was measured on a treadmill between 1992 and 2003, and mean values differed by only 4.6 mL·(kg·min)$^{-1}$ (54.6 to 59·2 mL·(kg·min)$^{-1}$). In comparison, $\dot{V}O_{2\ max}$ testing in 1982 was conducted on a cycle ergometer and revealed a single low mean score of 51.9 mL·(kg·min)$^{-1}$ for the Canadiens team. Therefore, compared with the early 1980s, there are higher relative $\dot{V}O_{2\ max}$ scores with larger body masses in more recent years, suggesting that aerobic power may have increased slightly.

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