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Abstract

Despite impressive numbers of hockey participants, there is little research examining elite female ice hockey players. Therefore, the purpose of this study was to describe the physical characteristics of elite female ice hockey players who were trying out for the 2010 U.S. Women's Ice Hockey team. Twenty-three women participated in the study and were evaluated on: body mass (kg), height (cm), age (y) vertical jump (cm), standing long jump (cm), 1 RM front squat (kg), front squat/body mass (%), 1 RM bench press (kg), bench press/body mass (%), pull ups, and body composition (% body fat). Athletes in this sample were 24.7 ± 3.1 years of age, and 169.7 ± 6.9 cm tall; on average, they weighed 70.4 ± 7.1 kg, and reported percent body fat of 15.8 ± 1.9%. Mean vertical jump was 50.3 ± 5.7 cm and standing long jump was 214.8 ± 10.9 cm. Mean 1RM for upper body strength (bench press) was 65.3 ± 12.2 kg (95.1 ± 15.5% of body mass) and 1RM for lower body (front squat) was 88.6 ± 11.2 kg (127.7 ± 16.3% of body mass). This study is the first to report physical characteristics of elite female ice hockey players from the United States. Data should assist strength and conditioning coaches in identifying talent, testing for strengths and weaknesses, comparing future teams to these indicators, and designing programs that will enhance the performance capabilities of female ice hockey athletes.

Introduction

Ice hockey is a sport that requires significant metabolic, physiological, and biomechanical skills. It is a highly variable, high intensity sport that requires speed, agility, muscular strength and endurance, and aerobic and anaerobic fitness (8, 17). Games consist of three 20 minute periods and the average length of a shift as measured in professional men's ice hockey is approximately 61 seconds (5). With the advent of Title IX, girls and women have increased participation in sports in record numbers. Specifically, women's participation in ice hockey has grown ten-fold during the past 20 years; In the 1990's, there were about 6,000 girls and women registered with USA Hockey; in 2010, over 60,000 girls and women were registered; Participation in women's collegiate hockey has grown from 15 teams in the 1990's to 37 collegiate club programs and 86 Division I and II NCAA teams (18). The 1998 gold medal performance at the Olympic games in Nagano, Japan, coupled with silver medal performances in 2002 (Salt Lake City, UT) and 2010 (Vancouver, BC) have undoubtedly helped generate increased interest in women's ice hockey.

As participation in ice hockey continues to grow, so has the need to examine the physiological and performance demands of the sport. Previous researchers have examined topics such as off-ice performance and draft status of elite male hockey players (25), positional profiling of elite male athletes (26) and psychological profiling of male junior ice hockey players (9). Another topic of recent interest is how well off-ice testing corresponds to on-ice performance. Several researchers have concluded that the 40 yd sprint (7), vertical jump (16), and standing long jump (8), are valid and reliable predictors of on-ice test performance. To examine whether off-ice tests could predict game play (versus on-ice skating performance), Green and colleagues (11) tested the relationship between player game performance (total minutes played and net scoring chances) and physical test results (VO2max, blood lactate, and percent body fat). They reported that blood lactate during a late stage of a treadmill test and percent body fat were significantly related to total minutes played and that VO2max was significantly related to scoring chances.

To date, few researchers have studied women's ice hockey. Those who have conducted research on women's ice hockey have used athletes from Canada (7, 10, 27), and topics have included bone density characteristics of female hockey players compared to their non active counterparts (22), air quality concerns in ice rinks and effects on female

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hockey players (20, 21), on-ice testing performance in elite and non-elite female hockey players (6), physical and performance differences among positions (10), development of test protocols for anaerobic fitness (27) and injuries in female hockey players (1, 2). To our knowledge, no previous published research has provided physical profile data for elite women ice hockey players from the United States. Knowing the physical profile of elite female ice hockey players will enable athletes, coaches, athletic trainers, scouts, and strength and conditioning specialists to establish athlete physical fitness expectations, design science-based training programs that will improve performance, and address any weaknesses in physical fitness identified through testing (7). Given the need to expand the available research related to women's ice hockey, and the potential benefits of knowing the test performance characteristics of elite female ice hockey players, and the potential benefits of knowing the physical profile of elite female ice hockey players, the primary purpose of this retrospective, descriptive study is to describe anthropometric and fitness characteristics of elite female ice hockey players. This information should provide additional training guidelines for individuals seeking to facilitate elite levels of performance in female hockey athletes.

Methods

Experimental Approach to the Problem.

To examine anthropometric and test performance characteristics of elite female hockey players, a series of eight tests were performed: body mass (kg), height (cm) vertical jump (cm), standing long jump (cm), 1RM front squat (kg), 1 RM bench press (kg), pull ups, and body composition. Once 1RM front squat and 1RM bench press were collected, they were divided by body mass and multiplied by 100 to reflect lower and upper body strength relative to body mass. Means, standard deviations, and ranges of the data were calculated to provide a descriptive profile of elite female hockey players in the U.S.

Subjects.

Twenty three female ice hockey players who were invited to the USA Hockey trials to complete for a spot on the Olympic Ice Hockey team participated in the study. Of the twenty three women who participated in this testing process, twenty one (91%) made the official U.S. roster for the Olympics. These women are representative of the top competitors in the sport of ice hockey in the United States. They were evaluated in August of 2009, prior to the 2010 Olympic Games in Vancouver in February of 2011. Most of the athletes have been in the pool of elite female ice hockey players for four years, training consistently on the U.S. National Team programs, and participating in national team testing (e.g., training camps, developmental camps, etc.). This study was approved by the Boise State University Institutional Review Board and consent was obtained from USA Hockey to publish these data. Identities were removed from the data and information is presented in aggregate to ensure confidentiality.

Testing Protocols and Procedures

Testing was conducted in Blaine, MN (at Herb Brooks Training Center) in August of 2009, approximately five months prior to the 2010 Olympics held in Vancouver, British Columbia. The same trained tester (the second author), an experienced and certified strength and conditioning specialist, conducted all testing sessions to ensure face validity. Reliability testing was not performed. To further standardize testing procedures, tests were conducted at the same time of day for each testing session (i.e., in the morning, after breakfast), athletes were advised to come to testing properly hydrated, and they were advised not to perform strenuous exercise 24 hours prior to testing. Anthropometric measurements (weight, height, and body composition) were collected first, followed by a standardized warm-up of 10 minutes. After the warm-up, athletes performed the tests in the following order, per NSCA recommendations (13): vertical jump, long jump, 1RM Front Squat, 1 RM Bench Press and Pull-ups. Power tests (vertical jump, long jump) were conducted on day 1 and strength tests (1 RM Front Squat, 1 RM Bench Press and Pull-ups) were conducted on day 2 with 10-15 minutes of rest between tests on each day.

These off-ice performance tests were selected based on the recommendations of previous researchers who have studied correlations between on- and off-ice performance as summarized in the introduction. Additionally, the tests are viewed by strength and conditioning professionals as practical, reliable, and valid measures of power, speed, strength and body composition (14). A full description of each testing procedure is provided below.

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Anthropometric Measures. Body mass in kilograms was collected by having the athlete step onto a calibrated digital scale without shoes and in minimal clothing (e.g., shorts and tee shirts) (3). Height was measured with a stadiometer in centimeters without shoes and at eye-level (3). Body composition (% body fat) was estimated using skinfold measurements marked and collected on the right side of the body. Each site was measured twice (to the nearest 0.2mm) with Harpenden calipers, and averaged. If the measurements differed by more than 1mm, another measure was taken and values were averaged. A 7-site test that collected standard measurements at the triceps, subscapular, axilla, chest, suprailiac, abdomen, and thigh was used and skinfold measurements were entered into the equation by Jackson et al. (15) to estimate body density. Next, body density was converted to percent body fat using the Siri equation (23).

Vertical Jump Height. A Vertec testing device (M-F Athletic Co., Cranston, Rhode Island) was used to determine vertical jump height (cm), a valid and reliable measure of lower body power (14). To complete this test, a trained tester adjusted the height of the color-coded plastic vanes so that it corresponded to the athlete's standing reach height. The vane stack was then raised a standardized distance (corresponding to the athletes' expected jump) so the athlete would not jump higher or lower than the set of vanes. Using a countermovement, the athlete flexed the ankles, knees and hips and swung the arms in an upward motion tapping the highest possible vane with the fingers of the dominant hand. Each participant took three jumps with 40-60 seconds rest between each jump. The best of three trials was recorded and used for statistical analysis.

Standing Long Jump. Standing long jump (cm) was also used to assess lower body power (14). A flat jumping area of 20 feet was marked on a gym floor. A tape measure, stretched to 10 feet, was placed next to the jumping area. Starting with toes behind the starting line, athletes performed a countermovement and jumped forward as far as possible. A marker was placed at the back edge of the athlete's heel and the best of three trials was recorded to the nearest 0.5 inch.

Lower Body Muscular Strength. A 1-RM Front Squat (kg) was used to assess lower body strength (14). Front squat is often recommended instead of back squat for ice hockey athletes because it increases quad and erector spinae (back) activation compared to the back squat (12). Athletes were reminded of proper front squat form prior to testing and they were instructed to do one warm up set of 5-10 repetitions with a light to moderate load and two heavier warm up sets of 3-5 repetitions with heavier weights. Athletes started the test by front squatting a weight that was within 95% of their most recent 1-RM and increased their load in increments until they reached the maximal weight that they could lift one time. Failure was defined as the inability to squat so that the femur was parallel to the floor, or the inability to maintain proper technique. To assess lower body strength relative to body mass, 1 RM front squat (kg) was divided by body mass (kg), multiplied by 100, and reported as a percentage.

Upper Body Muscular Strength and Endurance. A 1-RM Bench press (kg) was used to assess upper body strength (14). Athletes were reminded of proper bench press form prior to testing and they were instructed to do one warm up set of 5-10 repetitions with a light to moderate load and two heavier warm-up sets of 3-5 repetitions with heavier weights. Athletes started bench pressing a weight that was within 95% of their most recent 1-RM and increased their load incrementally until they reached a maximum weight they could lift one time. Failure was defined as the inability to lift the bar with arms extended or the inability to maintain proper technique. To assess upper body strength relative to body mass, 1 RM bench press (kg) was divided by body mass (kg), multiplied by 100, and reported as a percentage.

Upper body strength and muscular endurance were examined by asking each athlete to complete the maximum number of pullups possible. Pull-up testing was conducted on a pull up bar with an overhand grip. Athletes completed as many pull ups as possible in good form (e.g., with the chin above the bar), and only full repetitions counted toward the pull up count total.

Statistical Analysis.

To examine anthropometric and fitness characteristics of elite women ice hockey players, means and standard deviations were calculated using SPSS (Version 18.0, SPSS Inc., Chicago).

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Results

Table 1 summarizes anthropometric and fitness test results for the ice hockey athletes in this sample. The mean age of female hockey players from this sample was 24.7 $\pm$ 3.1 years and these women were heavier (kg) than previously studied elite women hockey players (10), however, the women were also very lean compared to other female athletes (14, 19). Vertical jump (cm) was higher than other elite women hockey players (10) and comparable to collegiate Division I athletes from a variety of sports (14). Standing long jump was slightly less than previously studied collegiate Division I athletes (14). Lower body strength, measured as 1-RM on a front squat and upper body strength, measured as 1-RM bench press were impressive, and higher than previously reported collegiate Division I female athletes from a variety of sports (14). Previous studies have not reported scores for pull-ups as a measure of upper body fitness, but this study reports an average of 10 pull ups for the elite female hockey players, which is impressive given that the Marine Corps would award 50 points to male cadets on their fitness test for 10 pull ups (24).

[Insert Table 1 About Here]

Discussion

To the best of our knowledge, this study is the first to describe anthropometric and fitness performance characteristics of elite female ice hockey players from the United States. The three most important findings from this study were that: (a) these elite female ice hockey athletes were heavier, yet leaner than previously studied female athletes; (b) vertical jump was within the range previously reported for female collegiate Division I athletes; (c) standing long jump was slightly below the value previously reported for female collegiate Division I athletes; and (d) upper body and lower body strength (bench press and front squat, kg, respectively) were higher than the values previously reported for female collegiate Division I athletes.

It is not surprising that these athletes were heavier than the previous sample of elite Canadian female hockey players (10) and leaner than many team sport female athletes in collegiate Division I athletics (14). Since data from other female athletes were collected and reported by Harman and Garhammer (14), many advances have been made in strength and conditioning, periodization techniques, and nutritional practices, potentially resulting in optimal levels of lean body mass and percent body fat. Clearly, today's athletes competing in the Olympics are fit, lean, and ready for competition.

The fact that vertical jump was consistent with previously tested female collegiate Division I athletes was not surprising given that women's hockey is a game of power and athletes are on the ice working very hard for relatively short periods of time. Additionally, high levels of leg power should translate to faster skating in ice hockey. The assumption is that a hockey player who can jump high can generate quick, powerful muscle contractions, which lead to fast acceleration (7).

It was interesting that the values for standing long jump were slightly lower than those previously reported data from female athletes. It is possible that ice hockey players develop significant single leg lateral or diagonal power rather than double leg frontal power (as is measured with the standing long jump) or even double leg vertical power (as measured with the vertical jump), and that a test of lateral or diagonal power might be a better indicator of ice hockey performance than either vertical or horizontal jumping power. It is also possible that female athletes might need different off-ice tests than those recommended for male athletes (8). Further research is warranted in this area.

The 1-RM upper and lower body strength values for these athletes were indicative of the level of training typically conducted by Olympic-caliber athletes. Their values were higher than those reported by female collegiate Division I athletes from a variety of sports. The need for strength in ice hockey is apparent given the physical nature of the sport, the regularity of body contact, and the fact that players skate at high speeds. Upper body strength is important to prevent shoulder injuries, more common in male athletes but still prevalent in female athletes (1), and lower body strength is important to prevent hip and groin injuries, more common in female athletes (2). It was particularly impressive that the 1RM values for front squat in ice hockey players were higher than those for other sports using back squat. Typically 1RM front squat values are lower than 1RM back squat values (12). The fact that elite ice hockey players had such strong upper and lower body strength is notable and should be a focus for strength and conditioning coaches working with elite ice hockey players.

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Despite our noteworthy findings, this study is not without limitations. Data reported were collected on a single occasion five months prior to the Olympic games. Collecting data from a larger sample of athletes or at a time closer to the Olympic games may have resulted in even higher values for the parameters tested. Additionally, these data only reflect specific off-ice fitness parameters related to upper and lower body strength, leg power, and muscular endurance. Additional factors such as anaerobic and aerobic fitness, agility, mental toughness, motivation, hockey and skating skills, genetics, coaching, and team camaraderie may also play a role in individual athlete and team success. Finally, we did not test how the off-ice testing data we collected correlated with on-ice performance and game play.

Regardless of limitations, this study is the first to report descriptive data from a sample of elite female ice hockey players from the United States. Although this was not specifically tested, it is possible that the high levels of off-ice fitness reported in this study will translate into lower injury rates and better performance under duress (e.g., penalty kills or overtime) in game situations. Future research is needed to examine the relationship between training and fitness levels, to compare on-ice performance tests with off-ice fitness test results, and to continue to examine potential positional differences in fitness parameters in female ice hockey players.

Practical Applications

Anthropometric and physical test data provide "profiling" information so athletes and coaches know what it takes to be a successful elite athlete. Other things such as past performance, skill, game play, psychological factors, and team "fit" may also determine whether or not an athlete succeeds at the elite level (8). Nevertheless, if two athletes have similar skill levels, coaches will likely give the edge to a player who is more physically fit because that athlete may be more able to resist fatigue and less likely to sustain an injury (8). Additionally, an athlete who is more fit will be better able to withstand double shifts, penalty kills, and overtime games. If athletes have deficiencies in some of the testing areas, coaches and strength and conditioning professionals can use these data to identify deficiencies, measure progress over a season or a career, or help a player return to "peak condition" following an injury (8). These updated data present information about a group of female athletes that has not been previously studied: elite female ice hockey players from the United States. Using these data as a reference, coaches and strength and conditioning specialists can compare current fitness levels with expected norms to help improve deficiencies and focus training; by designing training programs that focus on important physical fitness characteristics of previously successful players, strength and conditioning coaches can continue to improve their programs, the game, and their athletes (8).

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Table 1: Anthropometric and fitness characteristics of elite female ice hockey players

Anthropometric/Fitness Characteristics	**Elite Female Ice Hockey Players** M ± SD and Range (Low to High Value)	**Other Female Athletes**
Body Mass (kg) (n = 23)	70.4 ± 7.1 (58.5 - 85.2)	**Geithner et al. (2006)** Competitive Canadian Female Ice Hockey Athletes (n = 112)[c]**:** 66.4 ± 6.9 kg
Height (cm) (n = 21)	169.7 ± 6.9 (152.4 - 182.9)	**Geithner et al. (2006)** 167.9 ± 5.3 cm
Vertical Jump (cm) (n = 23)	50.3 ± 5.7 (41.9 - 62.2)	**Competitive College Female Athletes**[a] 44 - 53 cm **Geithner et al. (2006)** 43.1 ± 4.9
Standing Long Jump (cm) (n = 21)	214.8 ± 10.9 (198.1 - 241.3)	**90th percentile for Female College Athletes**[a] 315 cm
1 RM Front Squat (kg) (n = 20)	88.6 ± 11.2 (74.8 - 115.7)	**90th percentile for Female College Athletes (Back Squat)** [a] Basketball: 81 kg Softball: 84 kg Swimming: 66 kg Volleyball: 84 kg
Front Squat/Body Weight (%) (n = 20)	127.7 ± 16.3 (107.0 - 165.0)	
1 RM Bench Press (kg) (n = 22)	65.3 ± 12.2 (43.1 - 88.4)	**90th percentile for Female College Athletes**[a] Basketball: 56 kg Softball: 53 kg Swimming: 53 kg Volleyball: 51 kg **Baker & Fagan**[b] 24 Female Provincial Hockey Players: 53.8 kg

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Table 1 (Cont'd.)

Anthropometric/Fitness Characteristics	**Elite Female Ice Hockey Players** M ± SD and Range (Low to High Value)
Bench Press/Body Weight (%) (n = 22)	95.1 ± 15.5 (66.0 - 118.0)
Pull-Ups (repetitions) (n = 18)	10.1 ± 5.7 (2 - 26)
Body Composition (% body fat) (n = 23)	15.8 ± 1.9 (13.0 - 18.9)

Notes. Normative values obtained from Harman & Garhammer (14)[a]; Baker & Fagan (4)[b]; Geithner et al. (10)[c]