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BODY COMPOSITION OF WOMEN'S ICE HOCKEY PLAYERS: COMPARISON OF ESTIMATES USING SKINFOLDS AND iDXA

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ABSTRACT

The purpose of this study was to compare percent fat (% Fat) estimates from anthropometric equations using skinfolds (SKF) in women's ice hockey players to estimates obtained from Lunar iDXA. Data were collected on 19 elite female Swedish hockey players (mean age $\pm$ SD = 18.4 $\pm$ 2.4 y). Four skinfolds (SKF) (triceps, abdominal, suprailiac, and thigh) were measured within two hours of iDXA assessments. The % Fat estimates from iDXA and four anthropometric equations were compared using paired t-tests, and a one-way ANOVA was used to compare % Fat estimates from the anthropometric equations. Bland Altman analyses were used to assess agreement between % Fat estimates from SKF and iDXA. The significance level was set *a priori* at $p < 0.05$. The % Fat estimates from anthropometric equations were significantly lower than those from iDXA (mean $\pm$ SD: 26.85 $\pm$ 4.93%, $p = 0.000$). Bland Altman analyses indicated mean differences of -7.96 to -10.13 percentage points between anthropometric equations and iDXA. Estimates of % Fat from anthropometric equations (range: 16.72% to 18.89%) were within the range reported in earlier studies using the Sum of 7 SKF. Thus, SKF offer a reasonable alternative to iDXA for this population, but result in underestimates of % Fat relative to iDXA. Strength and conditioning coaches should use the same body composition assessment method consistently, and interpret the results with caution, as they are estimates and not true values.

KEY WORDS: women's ice hockey, female athletes, relative fatness, skinfolds, DXA

INTRODUCTION

Body composition is a topic of great interest to athletes; their coaches, trainers, and team physicians; and sport scientists as it relates to the nutritional status, health, and performance of athletes (1, 21, 22, 26). Within the context of sports, a lower percentage of body fat (% Fat) is often advantageous, as excess body fat tends have a negative effect on performance (22). However, it equally important to maintain energy availability (i.e., associated with a healthy amount of body fat) in order to avoid negative effects on health and performance (25, 35).

Body composition is one of the most commonly tested fitness variables in professional ice hockey players (6), because additional lean body mass contributes to power generation and speed (27), and reduced fat mass decreases frictional resistance during skating (24). Body composition assessments give the strength and conditioning coach important information that can be used to evaluate the effect of previous training programs and to develop individually based training and nutritional programs for the athlete. Thus, it is of great importance to assess body composition with accuracy and precision and to provide interpretations of the results with care.

As it is impossible to measure the exact body composition by direct methods *in vivo*, body composition is assessed by using indirect methods (1). Two methods that have been used to assess body composition in athletes with reasonable accuracy are dual-energy X-ray absorptiometry (DXA) and skinfold measurements (SKF).

The DXA method is based on the assumption that-bone mineral and soft tissue absorb low-dose x-rays differently and that discrimination between fat mass and fat-free mass can be made by calculated based on difference in signal attenuation (20). The method provides whole body and regional estimates of body fat and bone-free soft tissue (19, 37). A DXA scan is often considered a laboratory reference method as it is made with high accuracy and precision (low variability between tests performed on the same person within a short time-frame) (1). The average precision error (coefficient of variation) associated with whole body scans generally fall within $\pm 2\text{-}3\%$ (1). The most recent version of DXA is the iDXA where increased resolution is supposed to further increase the precision of the scan (37) and the average precision error is usually reported to be $<1\%$ (13, 16, 30). However, as DXA is a laboratory method involving expensive equipment and trained personnel, this method is not always easily available for use with athletes (7). In spite of this, DXA is increasing in popularity in the sports context as a body composition assessment method because it gives the useful additional information regarding regional distribution of lean mass (31). However, cross validation studies have revealed that that the results vary depending on what kind of DXA machine that has been used, thus, the validity of the method has yet to be established (37).

Skinfold (SKF) thicknesses are measurements of subcutaneous adipose tissue at standardized sites on the body with a skinfold caliper. Total body fat can be estimated from regression equations developed on general populations (large samples across a broad age range) or specific populations (e.g., young adult female athletes). Estimates of body composition derived from SKF measurements have been deemed an acceptable alternative to lab methods (33). SKF thus provide a simple and practical, portable and inexpensive means of estimating body composition for many populations (12, 14), including athletes in their competitive environment (7, 18, 29). While SKF measurements have numerous advantages, the accuracy of body composition estimates yielded depends on the skill and experience of the technician performing the measurements (1).

Previous studies using both SKF and DXA have shown that estimates of body fat are obtained from SKF equations tend to be lower than those obtained from DXA assessments-(3, 17, 32). However, few studies have compared body composition estimates from DXA and SKF in female athletes (23, 38) and none included women's ice hockey players. The literature on body composition in women's ice hockey players is relatively limited (8, 9, 11, 28, 29), and available data are for players of different ages at various levels of play from different countries using different assessment methods. No study to date has compared body fat estimates from DXA and SKF in this athlete population. Given the rapid growth in and increasing international popularity of women's ice hockey (29), there is a need for more data and current information regarding body composition in female ice hockey players for the purposes of designing evidence-based training programs, assessing their efficacy, and, consequently, improving performance in women's ice hockey. Thus, the purpose of this study was to compare body composition estimates for female ice hockey players derived from SKF using several anthropometric equations against iDXA as the criterion method. Based on the literature, our hypothesis was that % Fat estimates obtained from the selected anthropometric equations would be significantly lower than those obtained using iDXA and consequently, the null hypothesis was that % Fat estimates obtained from anthropometric equations would not be significantly different than those obtained from iDXA.

METHODS

Experimental Approach to the Problem

A cross-sectional study design was used to study the agreement of body composition estimates obtained from SKF and iDXA in a sample of elite female ice hockey players. The dependent variable, % Fat, was selected based on the focus in the literature, as well as in practice, of the impact of relative fatness on sports performance, particularly in female athletes. The independent variables were age, body mass, height, and four skinfolds (SKF): (triceps, abdominal, suprailiac, and thigh).

Subjects

The study protocol was designed in compliance with the Declaration of Helsinki (39) and was approved by the Regional Ethical Review Board. All participants were informed about the experimental procedure, risks and benefits associated with the study, in accordance with the use of human subjects in research policies. Signed, informed consent to participate in the study was obtained from all participants. In addition, informed assent was obtained from parents for under-aged participants (i.e., those under 18 years of age).

All of the players from one single team in the highest league for women's ice hockey in Sweden (Riksserien) were invited to participate in the study, and 19 players participated in the postseason testing (see Table 1). The players usually trained 9-10 hours per week and played 2 games per week.

Procedures

Prior to testing, the subjects completed a health questionnaire regarding general health status, assuring they were not pregnant or suffering from any illness. The subjects were instructed to refrain from heavy exercise and alcohol consumption the day prior to testing. All tests were performed in the morning. The subjects were instructed to eat breakfast as usual on the day of testing and not to use tobacco or snuff during the hour before testing. The participants were measured once, where the tests were performed in the following order: anthropometrics (body mass, height and SKF) and iDXA. Because body composition varies between days and even within a single day, the two assessments of body composition (i.e., by SKF and iDXA) were performed for each subject within a short period of time (two hours maximum, usually about 30 minutes) on the morning of the same day in the first month of the post-season.

Anthropometry

Measurements of body mass and height were performed according to ISAK standards (36). Body mass was measured to the nearest 0.1 kg while wearing light sports clothes on a standard digital scale (Fitbit Aria, WS-30; Fitbit Inc., San Francisco, CA, USA). Height was measured to the nearest 0.1 cm using a wall-mounted Harpenden Stadiometer (Holtain Limited, Crymych, Pembrokeshire, United Kingdom).

Measurements of SKF were made according to the ACSM's Guidelines for Exercise Testing & Prescription (2) by one trained technician at four sites (triceps, thigh, abdominal, and suprailium) on the right side of each participant's body. Each site was measured twice using Harpenden calipers (CE 0120, Baty International, Sussex, United Kingdom) and the mean values were calculated and recorded. If the skinfold measurements differed by >1 mm at any site, a third measurement was taken and the mean of the two closest values was recorded.

Two well-accepted and frequently used general population equations for predicting body density (D_b) from SKF in healthy females were used to estimate body density (D_b): Sum of 3 SKF (JPW3): triceps, suprailiac, and thigh (15); and Sum of 4 SKF (JPW4): triceps, abdominal, suprailiac, and thigh (15) which has been recommended for use with athletes. Percent fat was calculated from D_b estimated from JPW4 and JPW3 using Siri's equation (34). Because using Harpenden calipers results in smaller SKF measurements and, thus, in lower estimates of % Fat than those obtained using Lange calipers (10) on which the JPW3 was based, % Fat was also estimated from an equation developed by Gruber et al. (10) to correct for underestimates of % Fat from Harpenden calipers using the JPW3 equation. In addition, an anthropometric equation developed specifically for female athletes, including ice hockey players, by Warner et al. (38) using DXA as the criterion was used to predict Fat-Free mass (FFM), from which Fat Mass and % Fat were then calculated.

Intra-observer (test-retest) reliability was determined for Sum of 3 SKF and Sum of 4 SKF from duplicate SKF measurements and for resulting estimates of % Fat ($n=12$). The intraclass correlation coefficient for SKF measurements was 0.955 ($p=0.000$) and .990 ($p=0.000$) JPW3 and JPW4, respectively. The mean differences between % Fat estimates obtained from duplicate measurements were very small (range=0.11% to 0.27%). Skinfold (SKF) measurements at the four sites were subjected to Kolmogorov-Smirnov tests for normality of distribution, and all were normally distributed (all $p>0.05$). Standard error of the mean (SEE) for % Fat from iDXA was 1.13%, and SEEs for mean differences between iDXA estimates of % Fat and those obtained from anthropometric equations ranged from 0.69% for JPW4 (15), to 0.79% for Warner et al. 2004 (38).

iDXA

Body composition of the whole body was measured using dual x-ray absorptiometry with a Lunar iDXA (GE Medical Systems Lunar, WI, USA; Encore Version 14.10.022). The Lunar iDXA was calibrated each day of the testing using a standardized phantom, and there was no significant drift during the study. All body scans were performed and analyzed by the same trained technician, according to the manufacturer's instructions. The subjects wore light sports clothes and removed all metal artifacts prior to the scans. The scans were performed with the participants in the supine position, with arms placed along their sides, with palms pronated to face their thighs. A Velcro strap secured the position of the participants' feet and a slight gap between the feet ensured that there was no crossover when the different body parts were analyzed (i.e., between left and right leg, arms and trunk).

Statistical Analyses

Statistical analyses were conducted using IBM SPSS 24 (Armonk, NY: IBM Corp, 2016) and

JMP®, Version 13.1. for Macintosh, SAS Institute Inc., Cary NC, 1989-2007. The significance level was set *a priori* at $p < 0.05$.

Descriptive statistics (means and standard deviations, SDs) were run for body mass, height, Sum of 3 SKF, Sum of 4 SKF, D_b , and % Fat estimates from iDXA and the four anthropometric equations. Paired t-tests and correlations were used to make pairwise comparisons between % Fat estimates obtained from iDXA and each of the anthropometric equations to test the hypothesis that % Fat estimates obtained from the anthropometric equations would be significantly lower than those from iDXA. A one-way ANOVA was run to test for significant differences among the % Fat estimates obtained from the four anthropometric equations. Descriptives, paired t-tests, and ANOVA were run using SPSS. Bland Altman plots (4) were created to assess the agreement between estimates of % Fat from the estimates from each of the anthropometric equations and iDXA using JMP.

RESULTS

Descriptive characteristics of the participants are shown in Table 1. Mean differences, correlations and agreement between % Fat estimates obtained using iDXA and the four anthropometric equations: JPW3, Gruber et al. (1990), JPW4, and Warner et. al. (38), are shown in Table 2. Pairwise comparisons between each of the anthropometric equations and iDXA all showed significant differences in % Fat estimates and all correlations were strong, positive, and significant ($p < 0.05$). Estimates of % Fat obtained by anthropometric equations all were significantly lower than estimates obtained from iDXA by an average of 9.36 percentage points ($p < 0.05$). A one-way ANOVA revealed no significant differences among the estimates of % Fat obtained from the anthropometric equations. Thus, our null hypothesis stating % Fat estimates from anthropometric equations would not be significantly lower than those obtained from iDXA was rejected.

*Table 1 about here (attached at the end)

*Table 2 about here (attached at the end)

Bland Altman plots were created to examine the agreement between % Fat estimates from each of the anthropometric equations and % Fat estimates from iDXA (Figures 1-4). The estimates of % Fat obtained using anthropometric equations were consistently and significantly lower than those obtained from iDXA (all comparisons: $p < 0.0001$) by an average of 9.36% (range: 7.96%-10.13%).

*Figures 1-4 about here (attached at the end)

DISCUSSION

Our study showed that % Fat estimates from anthropometric equations using SKF and iDXA were highly and positively correlated; however, they were also significantly different ($p < 0.05$). The results reject our null hypothesis and support our hypothesis that estimates of % Fat obtained from anthropometric equations would be significantly lower compared to those obtained using iDXA. Estimates of % Fat from anthropometric equations were 7.96 to 10.13 percentage points lower than those obtained from iDXA, consistent with previous studies that have compared body composition estimates using these two methods (3, 17). Even though the inconsistencies in % Fat estimates between methods are considerable, it is important to remember that these methods merely estimate body composition and there is some error associated with any method used *in vivo*. Also, the anthropometric equations used in our study have reasonably low SEEs relative to underwater weighing (15) and DXA (38). The differences between results obtained from anthropometric equations using SKF and those from iDXA are indications of the inherent methodological problems within the field of body composition assessment in general (1).

As mentioned earlier, DXA has proven to have excellent precision, and provides results of both fat and lean body mass, as well as whole body and-regional estimates of body fat and bone-free soft tissue. This method for assessing body composition has increased in popularity; however, its validity has been questioned based on the fact that the results of a DXA scan are affected by the type of machine used.

Even though anthropometric equations using SKF tend to underestimate % Fat considerably relative to iDXA assessments, they seem to provide consistent estimates of % Fat for samples of women's ice hockey players across different studies with reasonable SEEs relative to underwater weighing (15) and DXA (38). Compared to hockey players in previous studies in which SKF measurements were used to obtain estimates of body composition from anthropometric equations, the elite Swedish ice hockey players in our study were slightly lighter and leaner than average than Canadian collegiate hockey players (8), slightly lighter than the U.S. hockey players competing for a spot on the U.S. Olympic team (28), and heavier than Swedish players who attended a high-performance camp organized by the International Ice Hockey Federation in 2011 (29). The players in our study were also younger, on average, which could mean some of them were still growing and not yet chemically mature (i.e., bone, muscle, and water components were still changing as percentages of fat-free mass).

The strengths of our study included high intra-observer reliability for SKF measurements and resulting % Fat estimates, and the associated SDs for % Fat estimates were within an acceptable range (1). In addition, iDXA is considered to be a high precision method, and serves as a useful criterion against which to compare estimates from anthropometric equations. The primary limitation of our study was our small sample size; however, sample

sizes in studies of athletes from a single sports team are often relatively small (7, 17, 28, 29). Smaller sample sizes may result in a greater likelihood of a Type I error (5), and samples may not be representative of the larger population from which they are drawn. However, the % Fat estimates from anthropometric equations in our study are within the range of those reported in earlier studies in which anthropometric equations using SKF were employed for female hockey players and contribute to the literature on body composition in female ice hockey players. Since the Sum of 3 SKF and Sum of 7 SKF equations (15) have been noted to yield very similar estimates of % Fat, it is reasonable to make comparisons of % Fat estimates in our study with those of previous studies in which anthropometric equations were used (8, 28, 29). What is problematic is the comparison of estimates of % Fat from anthropometric equations and iDXA, since the validity of iDXA for assessing body composition has yet to be established (37), and error associated with SKF-derived estimates of % Fat is greater than that for iDXA.

Better prediction equations using SKF to estimate body composition need to be developed for female athletes in a variety of sports in order to reduce the differences in estimates obtained from lab and field methods. Additional research is needed on body composition in women's ice hockey players to support the design of evidence-based training programs, assessment of their efficacy, and improvement of performance in women's ice hockey.

As body composition is an important fitness and performance variable, it is vital that the measurements are as accurate as possible. Whatever method is used to estimate % Fat and other components of body composition, coaches and trainers and researchers need to be aware of the differences among methods and the error associated in estimates they yield.

PRACTICAL APPLICATIONS

Our findings suggest that anthropometric equations based on SKF measurements are a reasonable alternative to iDXA for assessing body composition in women's ice hockey players when the latter is not available, affordable, or practical. However, as body composition assessments performed by anthropometry and iDXA result in significantly different results, the results from the two methods cannot be used interchangeably. Specifically, assessments made by SKF may lead to an underestimation of % Fat relative to iDXA. When tracking changes in body composition, the method used to assess body composition should be consistent over time. Strength and conditioning coaches need to interpret body composition assessments with caution, especially when comparisons with previous studies are being made.

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Table 1

Characteristics of the Participants (n=19)

Variable	Mean $\pm$ SD	Range Min – Max
Age (yrs)	18.5 $\pm$ 2.4	15.8 – 25.9
Height (cm)	169.0 $\pm$ 5.2	158.7 – 179.1
Body mass (kg)	67.3 $\pm$ 5.6	58 - 77
SKF (mm)		
Triceps	13.5 $\pm$ 3.4	6.5 – 20
Abdominal	15.5 $\pm$ 4.2	8 – 21
Suprailiac	8.9 $\pm$ 2.2	6.0 – 12.5
Thigh	18.7 $\pm$ 3.7	13.0 – 25.5
Sum of 3 SKF (mm)	41.1 $\pm$ 8.1	25.5 – 57.5
Sum of 4 SKF (mm)	56.6 $\pm$ 11.2	34.5 – 76.0

Note. SD = Standard deviation; SKF = Skinfold

Table 2

Table 2. Estimates (Mean $\pm$ SD) of percent body fat (% Fat) from iDXA and anthropometric equations using SKF, mean difference between estimates of % Fat (anthropometric equation – iDXA), and correlations between estimates obtained using different methods

Variable	% Fat Mean $\pm$ SD	Mean Difference (percentage points)	Correlation with iDXA
iDXA	26.85 $\pm$ 4.93		
JPW3 ^a	16.94 $\pm$ 2.84	-9.91	0.786*
Gruber et al. 1990 ^b	18.89 $\pm$ 2.79	-7.96	0.785*
JPW4 ^c	17.40 $\pm$ 2.81	-9.45	0.830*
Warner et al. 2004 ^d	16.72 $\pm$ 2.06	-10.13	0.816*

Note: SD = Standard Deviation

^a General population equation using the Sum of 3 SKF (Jackson, Pollock, and Ward, 1980).

^b Equation developed to correct for underestimations of body density from JPW3 resulting from using a Harpenden caliper.

^c General population equation using the Sum of 4 SKF (Jackson, Pollock, and Ward, 1980)

^d Equation developed for female athletes using DXA as the criterion.

*Correlations significant at the $p < 0.05$ level

Figure 1. Bland Altman plot of differences between % Fat estimates obtained from the JPW3 equation (15) and iDXA vs. the mean of the two % Fat estimates. The dashed lines indicate the 95% confidence interval for the mean difference and the reference diamond indicates that the range of difference is greater than half the range of the data.

Figure 2. Bland Altman plot of differences between % Fat estimates obtained from the Gruber et al. equation (10) and iDXA vs. the mean of the two % Fat estimates. The dashed lines indicate the 95% confidence interval for the mean difference.

Figure 3. Bland Altman plot of differences between % Fat estimates obtained from the JPW4 (15) equation and iDXA vs. the mean of the two % Fat estimates obtained. The dashed lines indicate the 95% confidence interval for the mean difference and the reference diamond indicates that the range of difference is greater than half the range of the data.

Figure 4. Bland Altman plot of differences between % Fat estimates obtained from the Warner et al. equation (38) and iDXA vs. the mean of the two % Fat estimates. The dashed lines indicate the 95% confidence interval for the mean difference and the reference diamond indicates that the range of difference is greater than half the range of the data.