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Original Investigation

Associations between skinfold thickness, body mass index and waist-to-height ratio in elite national dance sport athletes

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Purpose: The main purpose of the study was to investigate the associations between fat mass percentage (%) assessed by skinfold thickness with body mass index (BMI) and waist-to-height ratio (WHtR).
Methods: For this observational study, we recruited 33 young dancer sport athletes who competed at international level (age = 18.70 ± 5.00 yrs, height = 172.43 ± 7.85 cm, weight = 61.88 ± 10.60 kg, BMI = 20.70 ± 2.43 kg/m2, 48.50% women). The sum of seven skinfold thicknesses (triceps, chest, subscapular, midaxillary, suprailia, abdominal, and thigh) were measured using the Harpenden® skinfold caliper on the right side of the body. Body fat % was estimated with the Jackson & Pollock equations for men and women. BMI and WHtR were calculated as weight in kg divided by height in meters squared and the ratio between waist circumference and height in cm.
Results: In men, the average values in body fat %, BMI and WHtR were 10.17±4.28%, 21.34±2.31 kg/m2 and .43±.03. Body fat % was positively and strongly correlated with BMI (R = .71, P= .002) and WHtR (R = .76, P< .001). In women, the average values in body fat %, BMI and WHtR were 12.94±3.92%, 20.02±2.45 kg/m2 and .43±.04. In comparison to men, body fat % exhibited somewhat stronger correlations with BMI (R = .83, P< .001) in women, yet the correlation with WHtR yielded lower scores (R = .69, P= .003). In the total sample, body fat % remained positively and moderately correlated with BMI (R = .60, P< .001) and WHtR (R = .68, P< .001).
Conclusions: This study shows that both BMI and WHtR are valid measures to estimate body fat % in elite dance sport athletes.

Key words: Body fat; Adiposity; Sex; Aesthetic sports; Relationship

Introduction

Dance represents a very complex and vigorous type of sport characterized by a variety of different movements to execute at a high level. These movement often include a mixture of slow and smooth figures with a fast transition to more percussive and vibratory components defined by a given music or the type of dance.[1] As part of aesthetic sports, dance often requires excellent physical fitness, comprising of adequate muscular strength, cardiorespiratory endurance, and flexibility abilities.[2] Although the above-mentioned components of physical fitness need to be achieved, the optimal body composition in terms of low fat mass percentage (%) plays an important role for achieving successful performance.[3] Evidence suggests that in dancing, the artistic and aesthetic components overcome the level of strain,[4] indicating that aesthetic goal of thinness is vastly dominant in this type of activity.

It has been well-documented that dance sport athletes pay special attention to their body size, in order to have more fluent movements throughout the performance.[5,6] This would suggest that they need to optimize their training and diet regimes to keep aesthetics optimized for further development.[6] Available literature indicates, that body composition of dance sport athletes is mainly characterized by lower fat mass %, which is believed to enhance sports execution during both preparatory and competition periods.[7] Although it has been shown that athletes from more aesthetic sport branches have lower fat mass %, the majority of previous studies aiming to examine body composition have been conducted among ballet dance sport athletes.[8-15] In ballet, performers have to pay even more attention to body appearance, due to busy schedule and constant effort.[8-10] Thus, the comparison between different measuring techniques may not be generalized to other dance sub-groups (like standard or Latin-American). Nevertheless, an objective approach to body composition assessment in dance sport athletes has yet to be investigated.

Even though different techniques for assessing body composition in dancing have been proposed previously,[3,7] the most common ones include bioelectrical impedance,[3,4,7,16,17] and dual x-ray absorptiometry (DEXA),[7,15,17] while the methodology of measuring skinfold thickness[7,15] has been less studied. Although DEXA has been referred to as a 'gold standard' for evaluating fat and lean mass, it is often described as expensive, stationary, relatively slow and not easy to use.[3,17] Skinfold thickness may serve as a good alternative, since previous data showed a high correlation with DEXA (R = .80).[15] On the other hand, fat mass % may be easily predicted by the number of skinfold thicknesses in three-, four-, or seven-component model.[18,19] Despite these advantages over DEXA, the outcome of skinfold thickness may vary considering the use of different models,[20] where three- and four-component models underestimate the true value of fat mass %.[20] Also, if using skinfold thickness to estimate fat mass %, one would need an expert to distinguish between fat and lean mass when conducting the measurement. Therefore, the use of simpler methods to establish body composition in dance sport athletes may be more feasible for coaches and health-related professionals for fast monitoring and tracking fat mass % during the season.

Recently, a systematic review by Leal *et al*.[17] aiming to evaluate cross-validity of eight predictive equations of anthropometry and twelve of bioelectrical impedance to estimate fat mass % in classic ballet dancers showed that height and weight were good indicators of fat mass % (r > .80). However, the ratio of weight and height (BMI), and waist circumference and height (WHtR) correlated to skinfold thickness method has not been examined in dance. Although evidence suggests that skinfold thickness has relatively high correlation with BMI[21] and WHtR,[22,23] most of available data have been derived from school-going children, with no information related to dance sport athletes. The necessity of using simple methods like BMI and WHtR to adequately predict fat mass % can be a good, inexpensive and fast alternative to obtain reliable and valid estimation of body composition. Moreover, dance sport athletes have significantly lower fat mass % in comparison to general population,[24,25] which may lead to different correlation strength between BMI and WHtR with skinfold thickness and the inability to generalize the findings to other sports athletes.

Therefore, the main purpose of the study was to examine the associations between fat mass % obtained by the sum of seven skinfolds with BMI and WHtR in professional dance sport athletes. Based on previous findings,[17,21-23] we hypothesized that both BMI and WHtR would yield satisfactory coefficients of correlation (r > .70) in men and women.

Materials and methods

Study participants

In this observational, cross-sectional study, we recruited 33 young men and women dance sport athletes (age = 18.70 ± 5.00 yrs, height = 172.43 ± 7.85 cm, weight = 61.88 ± 10.60 kg, BMI = 20.70 ± 2.43 kg/m^2, 48.50% women) from ten professional elite dance school. The inclusion criteria were as follows: i) men and women who dance at national and international level; ii) the minimum experience of 10 years of dancing; iii) being without locomotor and mental disorders which may prevent them to participate in the study; iv) having no injury at the time of testing; and v) completing the measurements of skinfold thickness, BMI and WHtR. After all the participants were informed about the purpose of the study, they signed a written consent form before entering into the study. The G*power sample size calculator[26] and a compromised t-test correlation analysis showed that a two-tailed significance of P< .05, effect size of f = .77 (calculated from a hypothesized coefficient of determination between skinfold thickness, BMI and WHtR), and the total sample size of n = 33 would yield a statistical power of 1–β = .98 and a critical t-value of 3.22. All procedures in the study were anonymous and in accordance with the Declaration of Helsinki.[27]

Body fat %

To assess the level of fat mass %, we used Harpenden skinfold caliper (British Indicators, West Sussex, UK) to measure skinfold thickness with a precision of .1 mm on the right side of the body.[28] We used a seven-component skinfold model as follows: i) triceps, ii) chest, iii) subscapular, iv) midaxillary, v) suprailia, vi) abdominal, and vii) thigh. All measures were taken three times, and the mean value was taken for further analysis. To calculate the estimated body fat %, we used the regression equations proposed by Jackson and Pollock for men[18] and women.[19] First, we calculated body density taking into consideration the sum of all the skinfolds and age, after which fat mass % was derived with the following formula:

Fat mass (%): [(495 / body density) x 100

The proposed regression equation from skinfold thicknesses has been previously validated to DEXA[15] as an adequate technique to estimate fat mass % in men and women.[18,19]

BMI

To assess body weight, we used portable medical balanced scale to the nearest .1 kg. All participants were in their comfortable clothing for dance. Body height was measured by an anthropometer to the nearest .1 cm (GPM; Siber-Hegner & Co., Zurich, Switzerland). To obtain BMI, we divided body weight in kg by body height in meters squared (kg/m^2).

WHtR

Waist circumference was measured in an upright position during quiet stance. An anthropometric tape was placed between the lower rib margin and the iliac crest at the end of normal expiration in a horizontal position. WHtR was calculated as waist circumference divided by the height in cm.[29]

Statistical analysis

To examine the normality of data, we used the Kolmogorov-Smirnov (K-S) test. The K-S test showed that the data for BMI (critical D = .08, P= .200), WHtR (critical D = .15, P= .068) and fat mass % (critical D = .10, P= .200) were normally distributed and no outliers were detected. Thus, basic descriptive statistics for the study participants are presented as mean and standard deviation (SD). The coefficients between fat mass % with BMI and WHtR were examined using Pearson's test of correlation with the following magnitudes: i) .00 – .10 (zero), ii) .10 – .39 (weak), iii) .40 – .69 (moderate), iv) .70 – .89 (strong), and v) ≥ .90 (very strong).[30] In addition, to examine associations between skinfold thickness with BMI and WHtR, we performed linear regression analyses with unstandardized β coefficients and 95% CI. Fat mass % derived from skinfold thickness was put as the dependent variable, and BMI and WHtR were entered separately as the independent variables. We adjusted both models for sex, and age was not entered as a potential covariate, since preliminary analyses showed no significant associations with fat mass %. All analyses were performed in Statistical Packages for Social Sciences ver. 26 (SPSS Inc., Chicago, Illinois, USA). The significance was set at P< .05.

Results

Basic descriptive statistics of the study participants are presented in table 1. Men were taller, heavier and had larger waist circumference values, compared to women ($P< .05$). Women tended to have higher triceps (+ 43.71%), abdominal (+ 22.83%) and thigh (+ 66.71%) skinfold thickness values then men. Fat mass % derived from the regression equations of Jackson and Pollock[18,19] showed that women had higher values (+ 27.24%), in comparison to men. There were no significant differences in other study variables ($P> .05$).

Table 1. Basic descriptive statistics of the study participants.

Study variables	**Total sample (n = 33)**	**Men (n = 17)**	**Women (n = 16)**	***P***
	Mean (SD)	Mean (SD)	Mean (SD)	
Age (yrs)	18.87 4.97	20.10±5.90	17.20±3.30	.090
Experience (yrs)	10.01±3.65	10.20±3.81	9.83±3.45	.456
Height (cm)	172.43±7.85	178.52±4.80	165.96±4.48	< .001
Weight (kg)	61.88±10.60	68.16±9.18	55.19±7.58	< .001
BMI (kg/m^2)	20.70±2.43	21.34±2.31	20.02±2.45	.122
Waist circumference (cm)	74.87±6.93	77.52±6.42	72.04±6.45	.020
WHtR	.43±.03	.43±.03	.43±.04	.999
Skinfold thickness				
Triceps (mm)	12.61±5.00	10.41±4.12	14.96±4.89	.007
Chest (mm)	8.93±3.13	8.01±2.54	9.91±3.47	.081
Subscapular (mm)	11.54±3.42	11.74±3.87	11.33±2.98	.731
Midaxillary (mm)	8.56±3.73	8.22±3.52	8.93±4.03	.594
Suprailia (mm)	9.68±4.24	9.12±4.36	10.27±4.16	.442
Abdominal (mm)	18.15±6.47	16.34±6.38	20.07±6.19	< .001
Thigh (mm)	19.64±5.00	14.84±5.72	24.74±4.90	< .001
Fat mass (%)*	11.51±4.28	10.17±4.28	12.94±3.92	.043

*denotes calculating fat mass % from body density using the equations from Jackson and Pollock[18,19]

Table 2 shows correlations between separate components of skinfold thicknesses with BMI and WHtR. In men, BMI was positively and strongly correlated with subscapular (P= .002), abdominal (P= .002) and total fat mass % (P= .002) and moderately correlated with triceps (P= .029), chest (P= .033), suprailia (P= .011), midaxillary (P= .003), and thigh (P= .032) skinfold thicknesses. For WHtR, positive and strong correlations with subscapular (P< .001), midaxillary (P< .001), suprailia (P< .001), abdominal (P< .001) and total fat mass % (P< .001) and moderate correlations with triceps (P= .019), chest (P= .009), and thigh (P= .026) skinfold thicknesses were observed. In women, BMI was positively and strongly correlated with triceps (P= .002), midaxillary (P< .001), suprailia (P< .001), and total fat mass % (P< .001) and moderately correlated with chest (P= .004), subscapular (P= .004), abdominal (P= .009), and thigh (P= .048) skinfold thicknesses. For WHtR, positive and strong correlations with midaxillary (P< .001), suprailia (P< .001), and abdominal (P< .001) and moderate correlations with triceps

Table 2. Correlations between skinfold thicknesses (and fat mass %) with BMI and WHtR, according to sex

Study variables	**Men (n = 17)**		**Women (n = 16)**	
	BMI (kg/m^2)	**WHtR**	**BMI (kg/m^2)**	**WHtR**
Skinfold thickness	*R* (95% CI)	*R* (95% CI)	*R* (95% CI)	*R* (95% CI)
Triceps (mm)	.53 (.11 – .76)	.56 (.25 – .81)	.71 (.52 – .88)	.68 (.39 – .89)
Chest (mm)	.52 (.22 – .77)	.61 (.35 – .81)	.67 (.04 – .89)	.63 (.25 – .87)
Subscapular (mm)	.70 (.54 – .87)	.75 (.63 – .92)	.68 (.12 – .90)	.65 (.11 – .90)
Midaxillary (mm)	.60 (.26 – .80)	.71 (.54 – .87)	.78 (.32 – .92)	.78 (.56 – .95)
Suprailia (mm)	.68 (.38 – .86)	.75 (.62 – .88)	.76 (.34 – .93)	.81 (.36 – .95)
Abdominal (mm)	.70 (.45 – .87)	.80 (.63 – .92)	.63 (.06 – .90)	.71 (.20 – .89)
Thigh (mm)	.52 (.10 – .83)	.54 (.07 – .87)	.35 (.18 – .73)	.10 (-.10 – .55)
Fat mass (%)*	.71 (.48 – .86)	.76 (.60 – .90)	.83 (.60 – .93)	.69 (.29 – .89)

*denotes calculating fat mass % from body density using the equations from Jackson and Pollock[18,19]

(P= .004), chest (P= .009), subscapular (P= .007) skinfold thicknesses, and total fat mass % (P= .003) were shown. For thigh, a low correlation with WHtR was found (P= .702).
Associations and regression equations for BMI and WHtR to predict the level of fat mass % are presented in Table 3. In model 1, BMI was positively associated with fat mass % (P< .001) and the common variance was 36.00%. When 'sex' was entered in model 2, both variables were positively associated with fat mass % (P< .001) and the common variance rose to 62.41%. WHtR was positively associated with fat mass % in model 3 (P< .001, the variance of 46.24%), and when 'sex' was entered in model 4, both variables were positively associated with fat mass % (P< .001) with the increased common variance to 56.25%.

Table 3. Associations between BMI and WHtR with fat mass %*

Study variables	*β* (95% CI)	Std. error	Significance	Equation
Model 1				
BMI	1.06 (.55 – 1.58)	.25	*R*= .60	-10.45 + 1.06 × (BMI)
Model 2				
BMI	1.32 (.90 – 1.74)	.20	*R*= .79	-22.47 + 1.32 × (BMI) + 4.50 × (sex)**
Sex	4.50 (2.50 – 6.50)	.98		
Model 3				
WHtR	87.67 (52.79 – 122.55)	17.10	*R*= .68	-26.54 + 87.67 × (WHtR)
Model 4				
WHtR	87.68 (55.90 – 119.47)	15.57	*R*= .75	-30.65 + 87.68 (WHtR) + 2.76 × (sex)**
Sex	2.76 (.69 – 4.84)	1.02		

*denotes calculating fat mass % from body density using the equations from Jackson and Pollock[18,19]
**1 for men and 2 for women

Discussion

The main purpose of the study was to examine the associations between fat mass % obtained by the sum of seven skinfolds with BMI and WHtR in professional dance sport athletes. Findings suggest that fat mass % was positively and strongly correlated with fat mass % derived from skinfold thickness. Based on these results, we are able to create the proposed regression equations, which yield satisfactory variance shared between fat mass %, BMI and WHtR.
This is one of the first studies that used simple and easy-to-use methods of BMI and WHtR to predict the level of fat mass % in dance sport athletes. Our data showed that BMI and WHtR were positively and strongly correlated with fat mass % derived from skinfold thickness equations[18,19], which is in line to previous studies.[21-23] Although BMI has been extensively used as a screening tool to define normal weight, overweight and obesity,[21] one major disadvantage is its inability to adequately distinguish between fat and lean body mass. With that in line, it has been reported that BMI is only moderately correlated with more accurate measures of body fat, like DEXA or prompt gamma in vivo neutron activation analysis.[31] A study by Taylor *et al.*[22] found that subscapular (R = .71) and abdominal (R = .66) skinfold thicknesses were moderately-to-strongly correlated with BMI, which agrees with the results of this study. Interestingly, in this study BMI was more strongly correlated with fat mass % in women (R = .83), opposed to men (R = .71), while WHtR yielded better correlation coefficients for men (R = .76) than women (R = .69). Somewhat lower correlations obtained in this study may be explained by relatively low body fat % in men and women. Specifically, the mean value of body fat % in the total sample was <12.00%, which falls within a critical and dangerous zone of essential fat between 10.00% and 14.00% for dance sport athletes.[32] It has been suggested that individuals with high BMI values are more likely to have elevated fat mass %,[33] yet BMI values towards undernutrition category represents a poor indicator of body fatness.[34] This would suggest that BMI relies only on body size parameters of height and weight, which are not reliable and valid measures to estimate fat mass %.[21] Low fat mass % also indicates an increased level of lean mass, and by using the formula: lean mass (%) = total mass (%) – fat mass (%), the mean lean mass % in our sample was 88.49%. As mentioned, low sensitivity properties in individuals with low BMI (as dance sport athletes) can cause a misclassification in body fatness, leading to poorer coefficients of correlation. On the other hand, available literature suggests that WHtR is more strongly correlated with the sum of skinfolds in boys (R = .82) and girls (R = .81).[23] When observing WHtR as an indicator of central adiposity, larger correlations in men are explained by similar waist circumference, yet taller stature, opposed to women. However, the discrepancy between the correlations may also be affected by sample size and greater heterogeneity between the study participants. This is not surprising, because previous studies have highlighted a great variability in fat mass %, ranging from 7.80% to 24.00%.[7] Unfortunately, we were unable to measure fat mass % with more objective methods, like DEXA or air plethysmography, which might have given us with different results. Nevertheless, the study showed that both BMI and WHtR were strongly correlated with fat mass %.
Since we found positive correlations between BMI and WHtR with body fat %, we were able to establish a set of regression equations to predict the level of body fatness. In general, we found that 'sex' reinforced both the regression model, but more strongly for BMI (+ 3.61%) than WHtR (+ .49%). Correlations between full models with fat mass % were .79 (BMI) and .75 (WHtR), which is comparable to previous studies.[17] When using hydrostatic weighing as the outcome measure, and anthropometrical characteristics (height, weight) as the independent variables, the coefficients of correlation ranged between .70 and .85, which is line to our findings. Interestingly,

when comparing predictive properties of BMI vs. skinfold thickness, previous studies have shown that the sum of three-component[18,19] and four-component[35,36] exhibited the strongest correlations with hydrostatic weighing, indicating that skinfold thickness may be used as a valid and reliable method to estimate fat mass %. Despite these similarities, body composition in dance sport athletes largely depends on the weekly training volume, ethnicity, age and nutritional intake, which were not evaluated in this study. Although we calculated the appropriate sample size in the G*power calculator, by conducting the study among 33 dance sport athletes, the lack of statistical power cannot be excluded.

Dance is a specific aesthetic type of sport characterized by intensive physical training, and high level of physical fitness.[1-3] To be able to perform at constantly high level, dance sport athletes have to keep their nutrient intake under control, and the mixture of vigor training and a reduced diet often leads to a normal or even undernutrition weight status.[6] Due to this characteristics, body composition of both men and women dance sport athletes tends to be lean with very low % of body fatness. This was confirmed in this study, where at the group level, fat mass % did not exceed 12.00%. Because of this 'problem', it can be difficult to monitor skinfold thickness at follow-up, making body composition assessment almost impossible to practice in everyday settings.[37] The evaluation of skinfold thickness may induce mental health problems, like anxiety and developing negative thoughts about particular sites of the body, inherent to the shape of an individual.[17] Therefore, more practical approaches to body composition measurement are necessary to: i) define nutritional status of an individual, ii) screen and track the level of body fatness over a longer period of time, iii) increase the motivation and reduce potential intrinsic or extrinsic factors that could prevent from undertaking the measurement.

Indeed, we confirmed and added to the existing literature that both BMI and WHtR were positively and strongly correlated with fat mass %, yet these findings should be taken with caution. A cross-sectional design cannot explain the causality of the correlations between fat mass %, BMI and WHtR. Second, small sample size might not be adequate enough to detect true correlations and predictive equations between BMI and WHtR with fat mass %. Although an effort was made to create predictive equations of body composition using skinfold thickness, BMI and WHtR, the G*power analysis showed that we would need a large effect size to detect differences, which could have led to type I error. Also, we only conducted a study among dance sport athletes who competed in standard and Latin-American dance styles, while other type of dancers (like ballet, tap dance etc.) were not included in the analysis. Nevertheless, this study represents a good starting point for what we can consider a preliminary investigation. Third, the measurement of skinfold thickness must be completed by an educated professional. This would imply that subcutaneous fatty tissue should be clearly distinguished from lean mass when grabbing a certain part of the body with caliper. Since fat mass % in our sample was low, it is possible that the researcher grabbed some amount of lean mass and included the value in the equation, which might have led to potential measurement error. Fourth, we failed to use more sophisticated techniques to establish body composition values, including DEXA, air plethysmography, hydrostatic weighing, total body electrical conductivity and isotope dilution.[17] The aforementioned limitations should be particularly considered, since conducting skinfold thickness measures by an unprofessional researcher might have led to a considerable measurement error. In addition, an increase in such error may be attributed with using predictive equations from skinfold thickness, which correlate well, but not perfect with more objective methods, like DEXA.[18,19] Thus, it was possible that we already decreased the validity properties of BMI and WHtR by comparing them with skinfold thickness, instead of clinically sophisticated and expensive tools. This would suggest that skinfold thickness method to assess the level of fat mass % might underestimate the true value, especially in women, where the average fat mass % was around 13.00%, which was considered low. Such possible misinterpretation may be related to the distribution of fat mass in women, while men have more lean mass and less subcutaneous fatty tissue. This implies that the measurement of fat mass % in men may be more feasible and easier to perform, while in women the same procedure needs to be done with caution with a special emphasis of recruiting a professional staff. However, this study confirmed that fat mass % derived from skinfold thickness could be relatively easy to predict using simple anthropometric indices of BMI and WHtR in dance sport athletes. Finally, the age range was relatively homogenous. Thus, future research should be conducted among larger sample sizes in a longitudinal design with more objective methods to determine validity properties of BMI and WHtR in dance sport athletes.

Practical Applications

According to the findings of this study, BMI and WHtR are valid tools to estimate fat mass % derived from the skinfold thickness equations.[18,19] Strong correlations between body fatness with BMI and WHtR suggest that both measures may be used as fast screening methods for nutritional status in dance sport athletes. Moreover, regression equations with BMI and WHtR adjusted for sex tended to explain >50.00% of the variance, making them acceptable for using in population-based settings. Thus, a simple combination of height and weight (BMI) or height and waist circumference (WHtR) can give an insight about fat mass % in aesthetic sports activity, such as dance. However, more data about different measuring techniques of body composition and reference values should be created to test multiple correlations and predictive equations of fast and easy-to-use indexes to predict the level of body fatness in competitive dance.

Conclusions

In summary, this study shows that BMI and WHtR are strongly correlated with body fatness estimated from the sum of seven skinfolds and using regression equations from Jackson and Pollock.[18,19] Newly established regression equations with BMI and WHtR adjusted for 'sex' seem to remain highly associated with fat mass %. Therefore, both measures can be implemented as components of physical fitness, as they may predict the level of fat mass % in dance sport athletes.

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Informed Consent Statement

Informed consent was obtained from all subjects involved in the study.

Ethical Committee approval

Ethical review board of the Faculty of Kinesiology, University of Zagreb approved this investigation (ethical approval code: 8/9 - 2019).

Topic

Sport Science

Conflicts of interest

The authors have no conflicts of interest to declare.

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Author-s contribution

Conceptualization, T.D. and L.Š.; methodology, T.D., L.Š. and D.P.; software, T.D.; validation, D.P.; formal analysis, T.D. and L.Š.; investigation, T.D.; resources, T.D.; data curation, T.D. and D.P.; writing—original draft preparation, T.D., L.Š. and D.P.; writing—review and editing, T.D., L.Š. and D.P.; visualization, T.D. and L.Š.; supervision, D.P.; project administration, T.D. All authors have read and agreed to the published version of the manuscript.

References

1. Anderson Sofras P. *Dance Composition Basics (2nd Edition)*. Human Kinetics: Champaing, IL, 2019.
2. Brown AF, Brooks SJ, Smith SR, Stephens JM, Lotstein AK, Skiles CM, Alfiero CJ, Meenan MJ. Female collegiate dancers body composition, macronutrient and micronutrient intake over two academic years: A longitudinal analysis. *J Funct Morphol Kinesiol*. 2020;5(1):17. doi: 10.3390/jfmk5010017.
3. Yannakoulia M, Keramopoulos A, Tsakalakos N, Matalas AL. Body composition in dancers: the bioelectrical impedance method. *Med Sci Sports Exerc*. 2000;32(1):228–234. doi: 10.1097/00005768-200001000-00034.
4. Gammone MA, D'Orazio N. Assessment of body composition and nutritional risks in young ballet dancers - The bioelectrical impedance analysis. *J Electr Bioimpedance*. 2020;11(1):26-30.
5. Koutedakis Y, Jamurtas A. The dancer as a performing athlete. *Sports Med*. 2004;34:651–661. doi: 10.2165/00007256-200434100-00003.
6. Wyon MA, Hutchings KM, Wells A, Nevill AM. Body mass index, nutritional knowledge, and eating behaviors in elite student and professional ballet dancers. *Clin J Sports Med.* 2014;24:390–396. doi: 10.1097/JSM.0000000000000054.
7. Wilmerding MV, McKinnon MM, Mermier C. Body composition in dancers a review. *J Dance Med Sci.* 2005;9(1):18-23. doi: 10.1177/1089313X05009001
8. Abraham S. Eating and weight controlling behaviours of young ballet dancers. *Psychopathology*. 1996;29(4):218-222. doi:10.1159/000284996
9. Calabrese LH, Kirkendall DT, Floyd M, Rapoport S, Williams GW, Weiker GG, Bergfeld JA. Menstrual abnormalities, nutritional patterns, and body composition in female classical ballet dancers. *Phys Sportsmed*. 1983;11(2):86-97. doi: 10.1080/00913847.1983.11708458.
10. Hergenroeder AC, Brown B, Klish WJ. Anthropometric measurements and estimating body composition in ballet dancers. *Med Sci Sports Exerc*. 1993;25(1):145-50. doi: 10.1249/00005768-199301000-00020.
11. Hergenroeder AC, Wong WW, Fiorotto ML, Smith EO, Klish WJ. Total body water and fat-free mass in ballet dancers: comparing isotope dilution and TOBEC. *Med Sci Sports Exerc*. 1991;23(5):534-41.
12. Amorim T, Koutedakis Y, Nevill A, Wyon M, Maia J, Machado JC, Marques F, Metsios GS, Flouris AD, Adubeiro N, Nogueira L, Dimitriou L. Bone mineral density in vocational and professional ballet dancers. *Osteoporos Int*. 2017;28(10):2903-2912. doi: 10.1007/s00198-017-4130-0.
13. Micheli LJ, Gillespie WJ, Walaszek A. Physiologic profiles of female professional ballerinas. *Clin Sports Med*. 1984;3(1):199-209.
14. van Marken Lichtenbelt WD, Fogelholm M, Ottenheijm R, Westerterp KR. Physical activity, body composition and bone density in ballet dancers. *Br J Nutr*. 1995;74(4):439-51. doi: 10.1079/bjn19950150. PMID: 7577885.
15. Eliakim A, Ish-Shalom S, Giladi A, Falk B, Constantini N. Assessment of body composition in ballett dancers: correlation among anthropometric measurements, bio-electrical impedance analysis, and dual-energy X-ray absorptiometry. *Int J Sports Med*. 2000;21(8):598-601. doi: 10.1055/s-2000-8489.
16. Saenz C, Sanders DJ, Brooks SJ, Bracken L, Jordan A, Stoner J, Vatne E, Wahler M, Brown AF. The Relationship between dance training volume, body composition, and habitual diet in female collegiate dancers: The Intercollegiate Artistic Athlete Research Assessment (TIAARA) Study. *Nutrients*. 2024;16(21):3733. doi: 10.3390/nu16213733.
17. Leal LLA, Barbosa GSL, Ferreira RLU, Avelino EB, Bezerra AN, Vale SHL, Maciel BLL. Cross-validation of prediction equations for estimating body composition in ballet dancers. *PLoS One*. 2019;14(7):e0219045. doi: 10.1371/journal.pone.0219045.
18. Jackson AS, Pollock ML. Generalized equations for predicting body density of men. *Br J Nutr*. 1978;40:497–504. doi: 10.1079/bjn19780152.
19. Jackson AS, Pollock ML, Ward A. Generalized equations for predicting body density of women. *Med Sci Sports Exerc*. 1980;12:175–181.
20. Elsey AM, Lowe AK, Cornell AN, Whitehead PN, Conners RT. Comparison of the three-site and seven-site measurements in female collegiate athletes using BodyMetrix™. *Int J Exerc Sci*. 2021;14(4):230-238. doi: 10.70252/MBCK9241.
21. Freedman DS, Ogden CL, Blanck HM, Borrud LG, Dietz WH. The abilities of body mass index and skinfold thicknesses to identify children with low or elevated levels of dual-energy X-ray absorptiometry-determined body fatness. *J Pediatr*. 2013;163(1):160-6.e1. doi: 10.1016/j.jpeds.2012.12.093.
22. Taylor AE, Ebrahim S, Ben-Shlomo Y, Martin RM, Whincup PH, Yarnell JW, Wannamethee SG, Lawlor DA. Comparison of the associations of body mass index and measures of central adiposity and fat mass with

coronary heart disease, diabetes, and all-cause mortality: a study using data from 4 UK cohorts. *Am J Clin Nutr*. 2010;91(3):547-56. doi: 10.3945/ajcn.2009.28757.
23. Marrodán M, Alvarez JM, de Espinosa MG, Carmenate M, López-Ejeda N, Cabañas M, Pacheco J, Mesa M, Romero-Collazos J, Prado C, Villarino A. Predicting percentage body fat through waist-to-height ratio (WtHR) in Spanish schoolchildren. *Public Health Nutr*. 2014;17(4):870-876. doi: 10.1017/S1368980013000888.
24. White SB, Philpot A, Green A, Bemben MG. Physiological comparison between female university ballet and modern dance students. *J Dance Med Sci.* 2004;8(1):5-10.
25. Killion L, Culpepper D. Comparison of body image perceptions for female competitive dancers, fitness cohort, and non-dancers in a college population. *Sport J.* 2014;17(1). available:https://link.gale.com/apps/doc/A676651038/AONE?u=anon~8094b9b4&sid=sitemap&xid=c074e93a [accessed 13 May 2025].
26. Kang H. Sample size determination and power analysis using the G*Power software. *J Educ Eval Health Prof*. 2021;18:17. doi: 10.3352/jeehp.2021.18.17.
27. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA*. 2013;310(20):2191-4. doi: 10.1001/jama.2013.281053.
28. Lohman TG, Roche AF, Martorell R. *Anthropometric standardization reference manual*. Human Kinetics; Champaign, IL, USA, 1991.
29. Tybor DJ, Lichtenstein AH, Dallal GE, Must A. Waist-to-height ratio is correlated with height in US children and adolescents aged 2-18 years. *Int J Pediatr Obes*. 2008;3(3):148-51. doi: 10.1080/17477160802068957.
30. Schober P, Boer C, Schwarte LA. Correlation coefficients: Appropriate use and interpretation. *Anesth Analg*. 2018;126(5):1763-1768. doi: 10.1213/ANE.0000000000002864.
31. Kerruish KP, O'Connor J, Humphries IR, Kohn MR, Clarke SD, Briody JN, Thomson EJ, Wright KA, Gaskin KJ, Baur LA. Body composition in adolescents with anorexia nervosa. *Am J Clin Nutr*. 2002;75(1):31-7. doi: 10.1093/ajcn/75.1.31.
32. Chmelar RD, Fitt S. *Dancing at Your Peak: Diet*. Princeton: Dance Horizons/Princeton Book Company, 1990.
33. Krebs NF, Himes JH, Jacobson D, Nicklas TA, Guilday P, Styne D. Assessment of child and adolescent overweight and obesity. *Pediatrics*. 2007;120(4):193–228. doi: 10.1542/peds.2007-2329D.
34. Bray GA, DeLany JP, Volaufova J, Harsha DW, Champagne C. Prediction of body fat in 12-y-old African American and white children: evaluation of methods. *Am J Clin Nutr*. 2002;76:980–90. doi: 10.1093/ajcn/76.5.980.
35. Pollock ML, Hickman T, Kendrick Z, Jackson A, Linnerud AC, Dawson G. Prediction of body density in young and middle-aged women. *J Appl Physiol*. 1975;40:300–304. 10.1152/jappl.1975.38.4.745.
36. Petroski EEL, Pires-Neto CS, Neto CP. Validação de Equações Antropométricas para estimativa da densidade Corporal em Mulheres. *Rev Bras Atividade Física e Saúde*. 1995;2:65–73.
37. Santos DA, Dawson JA, Matias CN, Rocha PM, Minderico CS, Allison DB, Sardinha LB, Silva AM. Reference values for body composition and anthropometric measurements in athletes. *PLoS One*. 2014;9(5):e97846. doi: 10.1371/journal.pone.0097846.

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