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Associations of Anthropometric Parameters with Thyroid Hormone Profiles and the Serum Proteins in Healthy Young Women in the Preconception Period

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Abstract

Background: Establishing the associations between anthropometric parameters and thyroid hormones and serum proteins in apparently healthy young women may identify early predictors of possible latent pathology with potential impact on future pregnancy outcome and offspring heath.

Methods: Body mass index [BMI], waist circumference, hip circumference, thyroid-stimulating hormone [TSH], free tri-iodothyronine [fT3], free thyroxine [fT4]) and serum proteins (total protein [TP], electrophoretic profile, high-sensitivity C-reactive protein [hs-CRP], thyroxine-binding globulin [TBG], transthyretin [TTR]) were measured in 101 young (22.1±1.1 years) healthy women.

Results: BMI was not associated with serum thyroid hormone concentrations, TP, hs-CRP, TBG, TTR and protein electrophoretic fractions ($p>0.05$). Interconnections ($p<0.05$) between serum thyroid hormones and protein concentrations were highest at normal weights and differed between underweight and overweight subjects. In underweight subjects negative association was between waist circumference and fT3/fT4 ratio ($r=-0.49$, $p<0.05$). In overweight subjects, hip circumference was positively associated with fT3/fT4 ratio ($r=0.75$, $p<0.05$).

Conclusions: Interdependencies of serum thyroid hormone concentrations with protein profiles between young normal-, under- and overweight women may indicate involvement of these parameters in regulation of body-weight-dependent metabolic processes. Waist circumference in underweight females and hip circumference in overweight individuals may signal altered local metabolic homeostasis involving thyroid hormones.

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Keywords: Preconception period; Young women; Anthropometric parameters; Thyroid hormones; Serum proteins.

Introduction

The search for diagnostic markers for use in a preliminary health assessment of young women at undefined time before conception is guided by the need for the early detection of latent disease and nutritional disorders in the preconception period to avoid their potential adverse effects on the outcomes of pregnancy in the future and impact on offspring health [1-3].

Establishing the possible associations between anthropometric measurements morphologically assessing the body composition with the thyroid hormone panel and serum protein profile can facilitate the understanding of the mechanisms of interdependence of these measurements and select a practical diagnostic panel for further strategic diagnostic decisions in young women [4-7]. Clinical symptoms may be, on the one hand, the effect of alterations in the body weight classified by the World Health Organization by body mass index (BMI) as underweight, normal weight, overweight and obesity or be due to altered body fat distribution assessed by other measurements (waist circumference, hip circumference). On the other hand, specific pathogenic mechanisms may be responsible for these abnormal anthropometric measurements [8].

Although underweight is commonly thought to be associated with hyperthyroidism while overweight and obesity are believed to occur in hypothyroidism, there is no consistent evidence to support this opinion [9,10]. Thyroid hormones can potentially stimulate or regulate numerous metabolic processes and play a role in energy expenditure. Low concentrations of the thyroid hormones tetraiodothyronine (thyroxine, T4) and triiodothyronine (T3) trigger increased release of thyrotropin-releasing hormone (thyroliberin, TRH) by the hypothalamus and of thyroid-stimulating hormone (TSH) by the pituitary gland [9,10]. TSH is the most commonly used, sensitive and specific marker of primary thyroid disease. Free T4 (fT4) is a prohormone which is converted to the biologically active fT3 with the use of the deiodinases, organ-specific, selenium-containing enzymes [11,12].

Published reports, so far limited in number, confirm the effect of thyroid hormones on the concentrations and composition of serum proteins. The strategy of searching for specific links between the thousands of proteins that make up total protein (TP) with serum thyroid hormones is based on analytical methods of varying sensitivity [13,14]. Serum protein electrophoresis is an easy and cheap routinely used screening method classifying 22 most abundant protein which represent 99% of the total protein mass in human serum [15,16]. Albumins and globulins are the main constituents of serum proteins. Albumin levels reflect the nutritional status of the human body. The globulin family has several members including alpha, beta and gamma globulins, the latter accounting for the largest proportion. Albumin-to-globulin ratio (A/G) has been considered an effective combination of two strong prognostic factors [17,18]. On the other hand, identification of individual serum proteins, specifically related to variations in thyroid hormone concentrations requires the selection of specific immunological techniques.

The aim of the study was investigate possible associations of the popular and easy-to-self-assess anthropometric parameters (BMI, waist circumference, hip circumference) with the thyroid hormone panel (TSH, fT4, fT3, fT3/fT4 ratio), total serum protein concentration [TP], electrophoretic pattern of proteins, albumin/globulin (A/G) ratio, individual proteins, including thyroid hormone-binding proteins (thyroxine-binding globulin [TBG], transthyretin [TTR]), and a marker of inflammation, high-sensitivity C-reactive protein [hs-CRP] in the sera of underweight, normal-weight and overweight young women belonging to the preconception population.

Material and methods

Subjects

The subjects were 101 healthy unrelated female students aged (mean age±SD 22.1±1.1 years, range 19.0-25.0 years) participating as volunteers in the Cholesterol Alert program at the Medical University of Warsaw from March 2013 to July 2014. Medical history was obtained by the examining physicians to exclude cardiovascular disorders, inflammation, diabetes mellitus, malignancy, autoimmune disease, thyroid disease, thyroid supplementation or antithyroid treatment, hypolipidemic treatment, and pregnancy.

The study protocol was reviewed and approved by The Bioethics Committee of the Medical University of Warsaw, Number KB/258/2012, December 11th 2012. All participants signed an informed consent form after receiving an explanation of the study objectives and methodology.

Anthropometric measurements

Body weight was measured in subjects wearing light clothing and without shoes, and recorded to the nearest 0.1 kg. Height was measured using a stadiometer in subjects without shoes and recorded to the nearest 1 cm.

Body Mass Index (BMI) [kg/m^2] was calculated by dividing weight (kg) by the square of height (m^2). Subjects were classified by their BMI in accordance with the World Health Organization guidelines [6] as follows: underweight BMI less than 18.5 (n=17; 16.8%), normal-weight BMI 18.5 to 24.9 (n=75; 74.3%), overweight BMI 25.0 to 29.9 (n=9; 8.9%).

Waist circumference was measured in the horizontal plane at the midpoint between the lowest ribs and the iliac crest, to the nearest 1 cm. Hip circumference was measured around the widest portion of the buttocks, to the nearest 1 cm. Waist-to-hip ratio (WHR) is the ratio of the circumference of the waist [cm] to that of the hips [cm].

Anthropometric measurements were carried out in accordance with The International Society for the Advancement of Kinanthropometry (ISAK) [19].

Material

Blood samples were collected after overnight fast of at least eight hours. In total, 101 blood samples were drawn by venipuncture into test tubes which did not contain an anticoagulant and allowed to clot at room temperature. After centrifugation at 3000 g for 10 min at 4^{O}C, the serum was obtained immediately and stored at -80^{O}C until assayed. On the day of measurements serum samples were thawed at room temperature using gentle vortexing.

Laboratory methods

Serum TSH, fT3 and fT4 were measured using electrochemiluminescence immunoassays (Roche Diagnostics, Mannheim, Germany). The normal reference ranges: TSH 0.4-4.0 mU/L; fT4 9.0-25.0 pmol/L; fT3 3,5-7.8 pmol/L.

Total serum proteins were measured by the biuret method (COBAS 8000c 502). Serum proteins were separated into 6 fractions (albumin, alpha-1, alpha-2, beta-1, beta-2 and gamma globulins) by gel electrophoresis (Interlab G26 Sebia, Rome, Italy). Concentrations of individual proteins were determined by ELISA; Human Thyroxine Binding Globulin (TBG) using ELISA kit DRG MedTek; Human Transthyretin (TTR) using ELISA kit DRG MedTek; hs-CRP was determined by an immunoturbidimetric assay (COBAS 8000c 502).

Statistical analysis

Anthropometric parameters (BMI, waist circumference, hip circumference, WHR) and serum thyroid hormones (TSH, fT3, fT4, fT3/fT4 ratio), total serum protein (TP), the concentrations of protein in each electrophoretic fraction and of individual proteins (TBG, TTR, hs-CRP), and A/G ratio were adjusted for the 3 groups classified by BMI (underweight, normal-weight and overweight) and compared using the Kruskal-Wallis one-way analysis of variance by ranks (ANOVA). The power of the Kruskal-Wallis test for certain comparisons between BMI groups (only there, where the covariance matrix could be positively defined), was calculated using the Monte Carlo simulation with B=10000 repetitions. Before starting the statistical analysis, the normality of the distributions was checked using the Shapiro-Wilk test. Data are presented within each group as mean ± standard deviation (SD), median, range, coefficient of variation (CV%). The correlations between the parameters within each group were assessed by the Spearman's rank order correlation test. The statistical analyses were performed using STATISTICA version 13.3.www.statsoft.com. A *p* value less than 0.05 was considered statistically significant.

Results

Table 1 compares the anthropometric parameters, thyroid panel, TP concentrations, the electrophoretic pattern of serum proteins and A/G ratio values between underweight, normal-weight and overweight healthy young women.

No statistically significant differences in the concentrations of thyroid hormones, TP and the electrophoretic pattern of serum proteins were found between these three groups (p>0.05). A slight elevation in the A/G ratio was demonstrated in underweight women, which differed significantly from the values in overweight women (p=0.044). The anthropometric measurements consistently increased with each BMI range (p<0.05) with the exception of WHR which differed significantly between underweight *vs* overweight subjects. Table 2 compares the concentrations of hs-CRP and thyroid hormone-binding proteins (thyroxine-binding globulin [TBG], and transthyretin [TTR]) as individual serum proteins between underweight, normal-weight and overweight young women. No significant differences (p>0.05) in the concentrations of hs-CRP, TBG, and TTR were found between underweight, normal-weight and overweight subjects. Table 3 quantifies and characterizes the associations (significant correlation coefficients, p<0.05) between the thyroid panel, A/G ratio, TP, electrophoretic pattern of serum proteins, concentrations of individual proteins (hs-CRP, TBG and TTR) in underweight, normal-weight and overweight subjects.

The greatest number of statistically significant associations (p<0.05) of the thyroid panel with the concentrations of TP and proteins in the electrophoretic fractions and A/G ratio was found in normal-weight subjects. Only in underweight subjects a negative association was observed between TSH and serum proteins (alpha-2 globulins and hs-CRP) and a positive correlation between fT4 and gamma globulin. The A/G ratio was negatively associated with the concentrations of fT4 in underweight and normal-weight subjects and positively correlated with TBG concentrations in underweight subjects. Such associations were not seen in overweight subjects (p>0.05).

Inthe three groups (underweight, normal-weight, overweight) no significant correlations (p>0.05) were found between the concentrations of thyroid hormone-binding proteins and thyroid hormones. Table 4 shows the associations between the anthropometric parameters, thyroid panel and composition of serum proteins in underweight, normal-weight and overweight subjects. In normal-weight women no significant associations were found between the anthropometric parameters and either thyroid hormones or serum protein composition (p>0.05).

In underweight and overweight subjects characteristic associations were established. Small waist circumference which is considered an indicator of underweight negatively correlated with the fT3/fT4 ratio and positively correlated with the concentrations of TP, albumin and thyroid hormone-binding proteins (TBG, TTR). Larger hip circumference is seen in overweight young women and it was positively associated with the fT3/fT4 ratio and the concentrations of beta-2 globulins. WHR was significantly associated with albumin concentrations and A/G ratio exclusively in underweight women.

Table 1: Anthropometric measurements, thyroid hormones, total serum protein and serum electrophoretic protein fractions across BMI ranges in healthy young women.

Parameter	Mean±SD, median (range); CV(%)			ANOVA p
	Underweight BMI<18.5 (n=17)	Normal weight BMI=18.5-24.99 (n=75)	Overweight BMI≥25 (n=9)	
Anthropometric measurements				
BMI [kg/m²]	17.7±0.6, **17.8** (16.9–18.5); *3.2*	20.9±1.3, **20.8** (18.60-24.70); *6.2*	27.2±3.1, **26.2** (25.0-34.7); *11.4*	0.000
Waist circumference [cm]	66.4±2.4, **67.0** (62.0–70.0); *3.6*	73.5±4.6, **74.0** (64.0–85.0); *6.3*	84.9±8.8, **84.0** (77.0–105.0); *10.3*	0.000
Hip circumference [cm]	90.5±3.8, **90.0** (85.0–97.0); *4.2*	96.7±8.9, **98.0** (84.0-109.0); *9.2*	107.1±6.1, **106.0** (100.5-121.0); *5.7*	0.000
WHR*	0.73±0.03, **0.73** (0.68–0.80); *4.7*	0.77±0.15, **0.76** (0.67-2.03); *19.9*	0.79±0.05, **0.78** (0.73–0.87); *5.8*	0.011

Thyroid hormones				
TSH [IU/ml]	2.23±1.18, **1.95** (0.44–4.89); *53.1*	3.04 ± 2.70, **2.48** (0.30–22.70); *88.8*	2.45 ± 1.36, **2.08** (1.30–5.58); *55.7*	0.214
fT4 [pmol/L]	17.33±2.63, **17.30** (13.30-22.50); *15.2*	17.34 ± 2.96, **17.20** (11.70–31.80); *17.1*	16.44 ± 1.52, **16.40** (13.30–18.70); *9.3*	0.652
fT3 [pmol/L]	4.76±0.65, **4.90** (2.82-6.15); *13.7*	5.03 ± 0.66, **5.00** (3.41–7.88); *13.2*	5.24 ± 0.52, **5.16** (4.53–5.93); *9.9*	0.121
fT3/fT4	0.28±0.05, **0.27** (0.20–0.36); *18.5*	0.30 ± 0.05, **0.30** (0.16–0.43); *16.3*	0.32 ± 0.05, **0.32** (0.25–0.39); *13.9*	0.090
Total protein (TP) and serum protein electrophoresis				
TP [g/L]	74.8±5.4, **77.0** (64.0–82.0); *7.3*	74.1±7.1, **76.0** (56.0–88.0); *9.6*	74.9±6.8, **75.0** (65.0–86.0); *9.1*	0.897
albumin [g/L]	40.87±3.92, **41.00** (34.38–48.80); *9.6*	39.15±4.00, **40.00** (28.90–46.05); *10.2*	38.83±3.36, **38.81** (34.10–43.77); *8.7*	0.320
alpha1 [g/L]	2.10±0.34, **2.08** (1.50–2.85); *16.0*	2.19±0.41, **2.10** (1.30–3.22); *18.9*	2.34±0.40, **2.40** (1.60–2.90);*17.2*	0.373
alpha2 [g/L]	9.28±0.92, **9.50** (7.30–10.86); *9.9*	9.31±1.29, **9.35** (6.00–12.24); *13.8*	9.82±0.94, **9.90** (8.38–11.10); *9.6*	0.375
beta 1 [g/L]	7.65±0.85, **7.70** (6.16–9.24); *11.2*	7.94±1.21,**7.85** (5.20–11.12); *15.2*	8.62±1.06, **8.45** (6.57–10.40); *12.3*	0.072
beta2 [g/L]	2.52±0.67, **2.56** (1.47–3.70); *26.5*	2.51±0.86, **2.24** (1.40–5.67); *34.4*	2.66±0.87, **2.57** (1.40–4.13); *32.6*	0.732
gamma [g/L]	12.41±2.97, **12.83** (7.60–19.60); *24.0*	12.80±2.64, **12.88** (7.66–21.68); *20.6*	12.83 ±2.98, **12.79** (8.60–18.86); *23.2*	0.785
A/G**	1.22 ± 0.20, **1.18** (0.91 – 1.79); *16.2*	1.13 ± 0.15, **1.13** (0.81 – 1.86); *13.3*	1.08 ± 0.08, **1.04** (0.99 – 1.25); *7.7*	**0.044**

*Waist-hip ratio (WHR) The ratio of the circumference of the waist to that of the hips, calculated as waist measurement divided by hip measurement. A significantly higher WHR (p=0.0087) in overweight vs underweight women.
**A/G Albumin/Globulin ratio. A significantly higher A/G ratio (p<0.05) in underweight vs overweight women.

Table 2: Associations of BMI with ***hsCRP***, TBG and TTR in the serum of apparently healthy young women.

Parameter	Mean ± SD, median (range), *CV(%)*			ANOVA *p*
	Underweight BMI < 18.5 (n=17)	Normal weight BMI = 18.5-24.99(n=75)	Overweight BMI ≥ 25 (n=9)	
hsCRP[mg/L]	0.64±1.80, **0.20** (0.00-7.60); *283.4*	0.70±1.22, **0.20** (0.00-7.70); *173.6*	1.67±2.38, **1.20** (0.00-7.60); *142.6*	0.174
TBG [µg/mL]	31.2±14.9, **29.1** (11.5–56.8); *47.7*	32.4±20.2, **27.5** (2.0-72.0); *62.4*	24.8±16.1, **24.1** (8.1-58.0); *64.8*	0.512
TTR [µg/mL]	466.9 ± 306.8, **439.2** (146.6–1227.7); *65.7*	453.5±343.6, **316.0** (23.0-1280.0); *75.8*	420.4±251.7, **475.8** (154.1-771.3); *59.9*	0.863

Table 3: Significant associations (Spearman's correlation coefficient p<0.05) between thyroid hormones, electrophoretic protein fractions, A/G ratio and individual protein levels (hsCRP, thyroid hormone-binding proteins) in the sera of young underweight, normal-weight and overweight young women.

Parameter	Associations (p<0.05) between parameters measured in sera of young healthy women		
	Underweight BMI<18.5 kg/m (n=17)	Normal weight BMI 18.5-24.99 (n=75)	Overweight BMI≥25.0 (n=9)
Thyroid hormones			
TSH	alfa-2- globulin r= -0.60 hsCRP r= -0.60	p>0.05	p>0.05
fT4	gamma-globulin r=0.52 *A/G* r= -0.52	*A/G* r=-0.23 alfa-1-globulin r=0.28 alfa-2-globulin r=0.23 beta-1-globulin r=0.32	p>0.05

fT3	p>0.05	TP r=0.25 alfa-2-globulin r=0.35 beta-1-globulin r=0.27	p>0.05
fT3/fT4	p>0.05	p>0.05	p>0.05
Individual serum protein			
TBG [µg/mL]	*A/G* r=0.64 Albumin r=0.54 TTR r=0.83	TTR r=0.69	TTR r=0.98
TTR [µg/mL]	TBG r=0.83	Albumin r= 0.25 TBG r=0.68	TBG r=0.98 gamma globulin r=0.70
hsCRP	alfa-2-globulin r=0.55 TSH r=-0.60	alfa-1-globulin r=0.27	alfa-1-globulin r=0.81 beta-1- globulin r=0.73
Albumin/Globulin ratio			
A/G	fT4 r=-0.52 TBG r=0.64 beta-1-globulin r=-0.61 gamma globulin r=-0.69	fT4 r= - 0.23 Albumin r= 0.36 alfa-1-globulin r= - 0.52 alfa-2-globulin r= - 0.38 beta-1-globulin r= - 0.41 beta-2-globulin r= - 0.28 gamma globulin r= - 0.39	beta-1-globulin r=-0.92

Table 4: Significant associations (Spearman's correlation coefficient p<0.05) between anthropometric parameters, thyroid hormones and serum proteins in the sera of underweight, normal-weight and overweight young women.

Anthropometric parameter	**Associations (Spearman`s correlation coefficient p<0.05) between anthropometric parameters, thyroid hormones and serum proteins in the sera of underweight, normal-weight and overweight young women.**		
	Underweight BMI<18.5 (n=17)	**Normal weight BMI=18.5-24.99 (n=75)**	**Overweight BMI≥25 (n=9)**
BMI [kg/m²]	p>0.05	p>0.05	alfa-2-glob. r=-0.70
Waist circumference [cm]	fT3/fT4 r=-0.49 TP r=0.66 Albumin r= 0.58 TBG r=0.50 TTR r=0.54	p>0.05	p>0.05
Hip circumference [cm]	*A/G* r=- 0.49	p>0.05	fT3/fT4 r=0.75 beta- 2- globulin r=0.73
WHR	Albumin r=0.65 *A/G* r=0.49	p>0.05	p>0.05

Discussion

The results demonstrate the differences in the interdependence of the serum thyroid hormone and protein concentrations between young seemingly healthy women who were normal-weight, underweight or overweight. According to the recommendations and conclusions of The American College of Obstetricians and Gynecologists' Committee on Gynecologic Practice and the American Society for Reproductive Medicine prepregnancy counseling gives the opportunity to reduce the risk of adverse health effects for the woman, fetus and neonate [4]. Thyroid disorders are more common in women, and vague/non-specific symptoms and delayed diagnosis can lead to long-term adverse health outcomes. Many authors emphasize a high impact exercised by thyroid hormones on the biological functions of the body as even slight variations in the levels of thyroid hormones may result in complex health problems and so careful analysis is needed to fully understand their role in the regulation of systemic processes [12,13]. Their participation in multiple metabolic processes may explain their role in the manifestation or exacerbation of clinical symptoms of specific organ dysfunction as well as the maintenance of homeostasis [3,9,12]. Our exploration of possible associations between thyroid hormones and serum proteins has been prompted by published results [13,14] of proteomic analyses of differences in the composition of plasma proteins between patients with hypothyroidism and euthyroid patients. Association of the thyroid hormones with the specific, functionally related serum proteins seem to offer a convincing argument for thyroid involvement in metabolic processes. A research question has emerged concerning potential usefulness of a set of anthropometric parameters (BMI, waist circumference, hip circumference), which could provide new diagnostic knowledge on the metabolic equilibrium between the serum levels of thyroid hormones and proteins.

Although we did not demonstrate any significant differences in the serum concentrations of TP, electrophoretic protein fractions, hs-CRP and thyroid hormone -binding proteins, the characteristic correlations between these parameters show different profiles of their mutual dependencies in underweight, normal-weight and overweight young healthy women. The highest rate of statistically significant associations between the serum concentrations of thyroid hormones and proteins demonstrated in normal-weight young women may suggest the active participation of these parameters in maintaining the homeostasis of the body and their disturbed balance in underweight and overweight women. In overweight young women, no associations were established between the thyroid hormones and serum proteins. On the contrary, in underweight women such specific, population-unique features as a slight elevation in the albumin-globulin ratio (A/G) indicating a tendency to reduced globulin concentrations, a positive correlation of fT4 *vs* gamma-globulins, and a negative association of TSH *vs* alpha-2-globulins and hs-CRP may be indicative of potentially prognostic altered proportions of serum proteins to serum concentrations of thyroid hormones. Although the mechanism responsible for the link between low globulin levels and fT4 levels is unclear, further research may confirm the possible uses of this association as a diagnostic panel to demonstrate a weakened immune system and a characteristic clinical finding in underweight women. Based on the literature data [3] indicating the physiological significance of the availability of maternal fT4 for the proper development of the fetal brain already in the first trimester of pregnancy, it is logical to suppose that the analysis of normal homeostasis of thyroid hormones in young women in the preconception period may provide important information about possible risks to the postnatal development of the offspring. There is no firm evidence that would explain the mechanisms responsible for the negative association of the TSH levels with alpha-2 globulins and hs-CRP in underweight women. Some authors suggest that low thyroid hormone levels in protein-energy malnutrition are probably due to the reduction in circulating plasma proteins. According to their observations, the altered thyroid profile characterizing anorexia, i.e. low thyroid hormone levels and no changes in TSH, may be a marker of a negative feedback in the pituitary gland and hypothalamus [20-22]. Protein-energy malnutrition consistently affects the regulation of thyroid hormone-binding proteins circulating in blood, although the results presented here did not show any differences in their concentrations between underweight, normal-weight and overweight women. It remains unclear whether in young women abnormally low body weight (underweight) is associated with undernutrition or more specifically with protein deficiency or inadequate dietary intake of vitamins and other micronutrients, such as iodine, iron, selenium and zinc which inhibits normal synthesis and function of the thyroid hormones [23,24].

Published studies describe numerous mechanisms underlying the adverse effects of obesity on the development of chronic metabolic disorders [2,4,5], but the risks associated with underweight have not been explicitly defined. The common opinion that weight loss is characteristic of hyperthyroidism and weight gain of hypothyroidism is actually not evidence-based [9,10]. Absence of differences in the serum concentrations of thyroid hormones between underweight, normal-weight and overweight young women observed in this study may confirm the results of these authors who found that thyroid dysfunction was not associated with BMI [10], which questions the use of BMI as a predictor of thyroid problems in young women. However, many epidemiological studies have found that alternative measures such as waist circumference, hip circumference and waist-hip ratio are superior to BMI as markers of abdominal obesity [2,10]. The availability of thyroid hormones to the cells of body organs depends on the conversion of the biologically inactive precursor T4 into T3 by the organ-specific deiodinases. Determination of the concentrations of various deiodinases creates the opportunity to capture changes not only in the activity and metabolism of thyroid hormones for the whole organism, but also allows their specific connection at the level of a single cell of different organs. In laboratory practice, the activity of this process is quantified as the fT3/fT4 ratio [12,25,26,27]. The opposite associations of the fT3/fT4 ratio reported in this paper, with waist circumference in underweight women and with hip circumference in overweight women, suggest that this observation may be used to obtain preliminary diagnostic information related to body weight abnormalities and metabolic homeostasis in the preconception period. According to the authors, obese individuals have a positive association of the fT3/fT4 with waist circumference [28].

Conclusion

In conclusion, the differences in the association between anthropometric indices and the thyroid hormone panel and serum proteins demonstrated in healthy young women in the preconception period, suggest a chance to select a set of test parameters of prognostic potential, specifically targeted to this sex and age group. Although BMI is the obvious and most commonly employed measure of abdominal obesity, it is not a reliable marker of altered thyroid function in young otherwise healthy women. The optimal selection of body composition indices, not limited to BMI, but including other anthropometric parameters, is best guided by the actual diagnostic issues and specific requirements of individual health assessment. Waist circumference in underweight women and hip circumference in overweight women are these measurements which may provide additional diagnostic information to estimate altered metabolic equilibrium linked to thyroid hormone function in this age group.

Declarations

Ethics approval and consent to participate: The study protocol was reviewed and approved by The Bioethics Committee of the Medical University of Warsaw, Number KB/258/2012, December 11th 2012. All participants signed an informed consent form after receiving an explanation of the study objectives and methodology.

Consent for publication: All authors have seen and approved the manuscript being submitted.

Availability of data and materials: All data generated or analysed during this study are included in this published article.

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Authors' contributions: BLM: Devised and supervised the project, wrote the manuscript and prepared it for publication, ES: Performed statistical analyses, performed the laboratory measurements, HZ: Performed and supervised the laboratory measurements, MW: Prepared the manuscript for publication, BS: collected serum samples; PW and KM: sponsored the project.

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