



Sex differences in relationship between body composition and digit length ratio (2D:4D) in students of military courses

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ABSTRACT: It is believed that the second to fourth finger length ratio is an indirect indicator of fetal testosterone levels. It is pointed out that there is a relationship between the 2nd to 4th finger length ratio and the body structure in women and men. Studies on the relationship between body composition and 2D:4D finger length among military students have not been carried out so far. The work aims to determine the dependence of body composition and the quotient of the 2nd and 4th fingers length of military students. The research material has been gathered as a result of examinations of women and men studying military subjects. The study involved 55 women and 65 men. The tests included anthropometric measurements (body height, body weight, length of the second and the fourth fingers) and body composition measurements. As a result of the tests, no dimorphic differentiations in the digit length ratio (2D:4D) was indicated. The BMI, muscle mass, lean body mass and water in the body demonstrated higher values in men than in women. However, the fat content in men was low. It was found that the relationship exists between muscle mass, lean mass and total water content in the body and the 2D:4D finger length ratio in the left hand in women. A higher level of fetal testosterone, characterized by lower values of the 2nd to 4th finger length ratio, may be associated with a higher content of muscle mass, lean body mass and water in the body of adult women leading a similar lifestyle.

KEY WORDS: Body composition, military students, digit ratio, 2D:4D, prenatal testosterone

Introduction

A growing percentage of overweight and obese people has been observed in many countries with an optimal level of economic development. It applies to both children and adolescents as well as adults and older people (NCD-RisC 2017). The WHO proposes that the relative body mass index (BMI) is commonly used to evaluate nutritional status. Low

index values ($<18.5 \text{ kg/m}^2$) indicate excessive leanness, malnutrition, and little muscle mass, while values above 25 and 30 kg/m^2 suggest overweight and obesity and the related risk of civilization diseases (Prospective Studies Collaboration 2009; Bohm and Heitmann 2013). However, the BMI index contains some imperfections. Low values may be associated with severe weight loss and fashion for slimness. In turn, overweight in

young people and adults systematically practicing sports may reflect a more pronounced development of muscle tissue, especially in men (Doliński and Ignasiak 2001). In some professions (e.g., soldier, policeman, fireman) a high level of physical and intellectual (mental) fitness is necessary and decides about professional success (Voracek et al. 2010; Kociuba et al. 2016; Kozieł et al. 2018). In this case, it would be reasonable to use more sensitive methods to assess body composition.

In this case, it would be reasonable to use more sensitive methods to assess body composition. At the end of the last century, bioimpedance methods appeared to determine body composition using the phenomenon of resistance and reactance, which allow for in-depth and more detailed analysis of fat content, lean mass (LBM) and water content in the body of the examined person. Authors dealing with in-depth body composition analysis believe that this method also allows the risk of morbidity and mortality to be captured (Marques-Vidal et al. 2009; Wallstrom et al. 2009; Bohm and Heitmann 2013). Some of the methods used to study the composition of the body separately estimate the muscle mass in addition to the assessment of the lean body mass (LBM). The lean body mass (LBM) consists primarily of muscle mass (about 45-55% of the total body weight), whose development significantly depends on the testosterone level (Sinclair et al. 2016). This hormone is the primary androgen of the male organism and works via androgen receptors, determining normal sexual differentiation during the fetal period (Goymann and Wingfield 2014). In the second decade of life, gender differences in body composition are finally established.

One of the dimorphic features is the quotient of the second (2D) and fourth

(4D) finger length. The value of the quotient of finger lengths is determined at the end of the third month of embryonic development, mainly under the influence of prenatal testosterone (PT) and remains unchanged throughout all phases of human ontogenesis (Phelps 1952; Garn et al. 1975; Manning et al. 1998; Manning et al. 2007). On average, in men, finger 4 is longer than the other, i.e., the 2nd and 4th fingers length quotient is lower compared to women whose second finger is longer and the quotient approaches 1.00 (Galis et al. 2010; Manning et al. 2010; Kociuba et al. 2017).

Many researchers became intrigued by the problem of the consequences of certain prenatally determined traits on the further course of psychophysical development of man, including mainly physical fitness, the body structure, mobility and space-time orientation and greater sensitivity and vulnerability to specific dysfunctions and diseases, as well as on personality traits and character, including also the choice of profession (Manning and Taylor 2001; Lutchmaya et al. 2004; Putz et al. 2004; Rahman et al. 2011; Kociuba et al. 2016). It was mentioned above that one of the traits established at the beginning of embryonic development is the quotient of the 2nd and 4th fingers length. It was confirmed that people with its lower value (men) more often choose professions associated with a high degree of competitiveness, burdened with a higher degree of risk of professional or sporting success (Apicella et al. 2008; Coates et al. 2009; Garbarino et al. 2011; Kozieł et al. 2018).

Researchers are focusing on the correlation between relative weight and body fat distribution and the 2D:4D digit length ratio expecting that lower BMI values in men will be combined with lower

values of finger length quotients, unlike women (Fink et al. 2003; Majumder and Bagepally 2015). The findings of the research conducted by Fink et al. (2006a) show that the higher quotient of the 2nd and 4th fingers length and neck circumference in men indicates a higher risk of obesity and the associated risk of cardiovascular disease. Parallel studies by McIntyre et al. (2003, 2006) on hormonal exposure (TP) in prenatal age and 2D:4D finger length quotient indicate the possibility of significant associations with increased abdominal fat, and thus an increased risk of cardiovascular disease especially in men. Few researchers point out the weak or no relationship between the 2nd and 4th finger length quotient with selected physical parameters, mainly height, body weight and trunk circumference (Muller et al. 2013; Kalichman et al. 2017). It should also be noted that the tested groups may be different both ethnically and genetically.

It is worth conducting an in-depth analysis of interdependencies between the detailed body composition and the 2D:4D digit length ratio in adults representing different professional environments, while being a homogeneous group both ethnically and genetically (Bielicki et al. 2003). Therefore, the goal of the work is to analyze the relationship between the body composition and the the 2nd and 4th fingers length quotient of military students.

Material and Methods

The study involved women (N=55) and men (N=65), who were students of military faculties (cadets), pursuing the education at the Military University of Land Forces in Wroclaw. The average age of the surveyed men was 24.9 years (SD=1.83),

while women 21.6 years (SD=1.73). Participation in the research was voluntary, and all participants gave their agreement in writing. The principles of ethics specified in the Helsinki Declaration were adhered to (Goodyear et al. 2007). Written permission from the concerned university authority was also procured. The project was approved by the Senate Ethics Committee for Scientific Research of the Academy of Physical Education in 2017.

A candidate for professional military service should have certain psychophysical predispositions. Therefore, the recruitment process for military studies includes, among others, a physical fitness test. Officer cadets are accommodated and fed at the university. The daily functioning of students is regulated by the daily schedule, starting with the wake-up at 6:00 am to the end of the day at 10:00 pm. The day begins with a mandatory morning physical classes involving a 3 km long marathon. Sports activities take place in the afternoon. As part of the examination sessions, beyond the control of the level of knowledge, there is also a physical fitness check after each semester covering, among others, a 3000 m run, pull-up on a bar, swimming, and gymnastics.

The research was carried out in the morning. For the purposes of this study, there was no morning physical exercise. First, they were asked to complete the questionnaire, then the height and body weight were measured. The relative body mass index (BMI) was calculated based on those measurements. The length of the second and fourth fingers as well as the body composition (muscle mass, fat mass, slim body mass, total water content, the percentage of adipose tissue) were measured. The survey provided information on the age and injuries of the

right and left fingers. Persons who declared injuries were excluded from the research. The stadiometer (GPM, Switzerland) was used to measure the body height. The InBody 230 device measured body composition (InBody Co. Ltd). The length of the fingers was measured with a digital caliper (TESA SHOP-CAL). The respondent put the forearm on the table with the palm facing upwards, with straight, joined fingers. The measurement was carried out from the root to the top of the finger (Manning et al. 1998). In every tenth person, the second and fourth finger length measurements were repeated to calculate the technical measurement error.

The characteristics of the measurement features in the studied groups were based on the arithmetic mean, median and standard deviation. The significance of differences in mean values of between the two groups was determined using Student's t-test for independent groups. To estimate the strength and direction of dependence between the 2nd to 4th finger length ratio and selected parameters of body composition, the partial coefficients of r-Pearson linear correlation were calcu-

lated, taking the age into account.

Results

Since there was a significant difference in mean age between males and females ($t = -0.96; p < 0.001$), the relationship between the body composition parameters and the digit ratio was determined by partial Pearson moment correlation controlling for the age, separately for each sex.

Descriptive statistics of all analyzed parameters and digit ratios of two fingers were presented in Table 1. The men and women substantially differed in BMI and the following body composition parameters: muscle mass in kilograms, total body water in kilograms and fat free mass in kilograms. The men had significantly higher values in all these parameters. However, there was no sex differences in digit length ratio (2D:4D).

Results of the partial correlation controlling for age are presented in Table 2. Significant relations were only noticed in women between left-hand 2nd to 4th finger length ratio and muscle mass, total body water, and fat-free mass, all in ki-

Table 1. Descriptive statistics of the variables used in this study by sex (men N=65, women N=55).

Variable	Men N=65			Women N=55			t
	Mean	Median	SD	Mean	Median	SD	
Age	24.89	24.30	1.83	21.63	21.30	1.73	-9.96*
2D4D R	0.975	0.974	0.031	0.982	0.984	0.031	1.32
2D4D L	0.982	0.977	0.028	0.991	0.997	0.032	1.80
BMI	25.11	24.85	1.98	22.44	22.22	1.85	-7.57*
Muscle [kg]	40.45	40.00	4.93	26.68	26.50	2.60	-18.64*
Fat [kg]	11.14	10.70	3.87	14.06	13.20	3.60	4.25*
TBW [kg]	51.56	50.90	5.96	35.18	34.90	3.20	-18.26*
FFM [kg]	70.37	69.50	8.18	48.04	47.70	4.38	-18.15*
PBF [%]	13.59	13.00	4.23	22.43	22.20	4.04	11.63*

* $p < 0.01$

Table 2. Partial correlation between digit ratio and body composition parameters, controlling for the age in men and women.

	Men N=65				Women N=55			
	2D4D right hand		2D4D left hand		2D4D right hand		2D4D left hand	
	r	p	r	p	r	p	r	p
BMI	-0.02	n.s.	0.05	n.s.	0.02	n.s.	-0.27	n.s.
Muscle [kg]	-0.06	n.s.	0.00	n.s.	-0.20	n.s.	-0.28	<0.05
Fat [kg]	0.07	n.s.	0.01	n.s.	0.07	n.s.	-0.16	n.s.
TBW [kg]	-0.06	n.s.	0.01	n.s.	-0.19	n.s.	-0.27	<0.05
FFM [kg]	-0.06	n.s.	0.01	n.s.	-0.19	n.s.	-0.27	<0.05
PBF [%]	0.12	n.s.	0.04	n.s.	0.15	n.s.	-0.05	n.s.

lograms. The negative correlation result indicates that the higher the values of the digit length ratio (2D:4D), the lower the values of the analyzed parameters.

Discussion

The studies carried out have shown significant relationships between muscle mass, lean mass and total water content in the body and the left-hand 2D:4D ratio in the women, not the men. The lower digit ratios the highest values of mentioned body composition parameters. These are the first studies on the relationship between the 2D:4D quotient and body composition parameters carried out among women and men, who constitute an unusually homogeneous group regarding lifestyle. The presented results indicate that a significant dependency between selected parameters of the body composition and the quotient of the 2nd and 4th fingers length may occur only in women and not in men.

The 2D:4D fingers length ratio is used as an indirect measure of testosterone concentration in the fetal period when assessing the effect of prenatal testosterone on the somatic structure, behavior or level of motor development (Folland

et al. 2012; Koziel et al. 2017; Eler 2018; Pruszkowska-Przybylska et al. 2018).

Military students chose the soldier profession expecting excellent intellectual and psychomotor preparation. Many activities performed in this profession are associated with a high degree of risk, require a lot of discipline and quick decisions in extraordinary situations. For a considerable part of the year, young people are covered by the same lifestyle and nutrition (Kociuba et al. 2016). Similar emotional, intellectual and psychophysical situation refers to athletes with a high level of competitive sport in whom low values of the digit length ratio (2D:4D) were observed, especially in individual disciplines (Fink et al. 2006b; Hampson et al. 2008; Coates et al. 2009; Koziel et al. 2016).

In the research, significant dimorphic differences in the analyzed parameters were observed. A similar character of dependencies was demonstrated by Steed et al. (2016) by examining a group of military students. In turn, Beals et al. (2015) conducted research among soldiers of both sexes from military units, showing substantial dimorphic differences in the fat content, which was higher in women.

Results of the conducted research

indicate that no significant differences in the digit length ratio (2D:4D) were found in the men compared to the women from military academies. In recent research, there has also been no demonstrable variation in the dimorphic value of the 2D:4D finger length in the group of military students (Kociuba et al. 2016). In other studies, it has been documented that women working in professions dominated by men are characterized by lower values of the 2nd and 4th finger length quotient than those involved in typically female occupations (Manning et al. 2010). It seems that there was a selection of women entering the military course in relation to digit ratio. Women with lower 2D:4D digit ratio were more disposed to become cadets. In results their 2D:4D digit ratio did not differ from males.

Attention should be paid to the composition of the body and the 2D:4D fingers length in both sexes. Numerous works indicate that the structure of the body, mainly the distribution of adipose tissue, especially the abdominal one, may be associated with the inclination to the incidence of numerous civilization diseases (Ward et al. 2015). It is evident that the composition of the body is a high-lability parameter, depends on sex, but also changes with age, diet, and lifestyle as well as physical activity (Hughes et al. 2002; Oliver et al. 2017; Wood et al. 2017). Therefore, the work tries to evaluate the relationship of body composition as a very variable factor with the quotient of the 2nd and 4th fingers length as a trait stabilized in the early stages of fetal development. High values of muscle mass and body water in men with clearly low-fat content do not show any relation to the 2D:4D finger length ratio. Among women, interdependencies between muscle mass, lean mass and total water con-

tent in the body and the left-hand 2D:4D finger length ratio were noticed. The dependence between the 2D:4D index and the anthropometric parameters discussed in this paper are consistent with the results of the research conducted so far. Eler (2018) showed correlations between the 2D:4D index and the relative fat level in women, not men. In one of the latest research it was found negative correlation between 2D:4D finger length and muscle mass in girls aged 6-13 years (Pruszkowska-Przybylska et al. 2018). One of the scientific studies presents the results of research conducted among children (Ranson et al. 2015). The authors found significant relationships between the quotient of 2nd and 4th fingers length and body height and weight, BMI and waist circumference only in girls, not in boys. Researchers indicate that low levels of prenatal testosterone and high levels of prenatal estrogen in girls are associated with large body size. In other studies, a relation between the 2D:4D finger length and anthropometric parameters were found in both women and men (Fink et al. 2003). There were significant negative correlations between the quotient of the 2nd and 4th fingers length of the left and right hands, and a waist and hip circumference and waist and chest circumference in women. In men, BMI proved to be positively associated with the 2D:4D finger lengths, but only for the left hand. Generally, relationships were stronger for women than for men. On the other hand, the research carried out by Muller et al. (2013) did not show the relation between the 2D:4D fingers length ratio and height and body mass, waist and hip circumference and body composition parameters in adults. However, no ratios of the 2D:4D finger length have been found so far with muscle mass,

lean mass and total water content in the body. Perhaps female students implementing a very restrictive mode of military studies with a typical lower 2nd and 4th finger length quotient (because of the standards set and consistently required by the study mode) achieved a significant level of muscle mass and total water with simultaneous reduction of fat in the body, which correlates with the quotient of fingers length. Lower values of the digit length ratio imply higher values of the abovementioned body composition parameters.

An interesting aspect of the discussed research results seems to be the fact that the significant relationship between the quotient of the 2nd and 4th fingers length and selected body composition parameters was found for the left hand and not the right hand ($P < 0.05$). The nature of these results corresponds to the scientific reports of other authors. In studies carried out by Fink et al. (2003) significant relationships between the 2D:4D finger index for the left hand and BMI were found. Newer research results indicate a relation between the digit length ratio (2D:4D) of the left hand with the risk of breast cancer in women (Muller et al. 2012). On the other hand, Eler (2018) showed correlations of body height and body fat content with the 2nd and 4th finger length quotient in the left hand in women.

Most scientific studies carried out to date indicate the relationship between the 2D:4D finger length ratio, the level of testosterone and estrogen during the fetal period (Manning et al. 1998) and the lack of significant changes in the 2D:4D index with age (Králík et al. 2014). Manning et al. (2010) suppose that the choice of a specific area of professional activity by women may be related to the level of

fetal testosterone levels.

One of the possible ways of explaining the results presented in this paper could be sought in the fact that the profession related to the safety of the state and society has always been associated with high psychophysical efficiency and required from a soldier very intense and everyday exercises that favor the expansion of the active movement system (muscles) and thus minimize fat content. For women it is an entirely new and different profession, which does not eliminate some biological processes, pointing to their greater biological determination related to gender.

However, the interpretation of the presented results is subject to limitations. The first of these is the small number of respondents (65 men and 55 women). Another real restriction is the research group that is exceptionally homogeneous regarding style and lifestyle. Differences in the composition of the body due to physical activity or performed profession were demonstrated by Gutiérrez et al. (2015) and Vuvor and Harrison (2017). Gutiérrez et al. (2015) found a lower content of adipose tissue in training boys than in those not practicing sports. In turn, Vuvor and Harrison (2017) described lower adipose tissue content in police officers (11.5%) than in drivers (36.3%). The presented limitations do not authorize the generalization of the results, however, they provide tips for further research and conducting in-depth analyses aimed at elucidating selected biological phenomena and their mutual interdependencies on a more extensive data gathered, taking into account age, sex and professional or sports preferences, as well as social, cultural or ethnic conditions.

Conclusions

Summing up, the conducted research it should be noted that both the age and individual components of the body mass differentiate the examined persons. The men were significantly older than women, and this can be an essential argument for the more beneficial results of body composition. The studies are difficult for women in the psychophysical and biological sense. In this group of sexes, the dependence of individual body composition parameters with the quotient of the 2nd and 4th fingers length for the left and not the right hand is more strongly determined. A negative correlation indicates that the low values of the 2D:4D quotient correspond with a greater mass of muscles, lean mass and total water content in women involved in a typically male occupation. The obtained results suggest the necessity to conduct further research in this professional group to document the interrelations between the body composition, the 2D:4D index finger, the optimal program and contents of military studies, and possible professional successes. Oxford Academic Google Scholar

Authors' contributions

MK collected data, prepared data for analysis, prepared the draft, ZI supervised the study, prepared the draft, AS, KK prepared data for analysis, searched in literature, IC, AD, MZ collected data and prepared them for analysis, SK designed and supervised the study, and prepared the final draft.

Conflict of interest

The authors declare no conflict of interests.

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