10.2478/mbs-2013-0035

Medical and Biological Sciences, 2013, 27/4, 47-52

ORIGINAL ARTICLE / PRACA ORYGINALNA

Roland Wesołowski[1], Celestyna Mila-Kierzenkowska[1], Alina Woźniak[1], Tomasz Boraczyński[2], Paweł Sutkowy[1]

BODY COMPOSITION ANALYSIS IN REGULAR WINTER SWIMMERS AND PEOPLE WHO DO NOT USE THIS FORM OF RECREATION

ANALIZA SKŁADU CIAŁA OSÓB REGULARNIE KORZYSTAJĄCYCH Z KĄPIELI W ZIMNEJ WODZIE ORAZ OSÓB NIEKORZYSTAJĄCYCH Z TEJ FORMY REKREACJI

[1]The Chair of Medical Biology, Ludwik Rydygier Collegium Medicum of Nicolaus Copernicus University, Bydgoszcz, Poland
Head: Dr hab. n. med. Alina Woźniak, prof. UMK
[2]Central Research Laboratory, Józef Rusiecki Olsztyn University, Olsztyn, Poland
Head: Dr n. o kulturze fizycznej Tomasz Boraczyński

S u m m a r y

INTRODUCTION. Winter swimming is a form of physical recreation that involves bathing in cold water during winter. The aim of the study was to analyse the body composition in people who regularly take baths in ice-cold water.

MATERIAL AND METHODS. The study included 20 men. Half of them (mean age 27.7 ± 7.1 years) were regularly taking baths in cold water (winter swimmers) at least for a year, while the rest (mean age 27.0 ± 4.0 years) had never performed such a treatment (controls). In each subject, a body composition profile was evaluated, including: body mass index (BMI), body mass (BM kg), body fat percentage (BF%), fat mass (FM kg), fat-free mass (FFM kg), the fat mass-to-fat-free mass ratio (FM/FFM%), total body water (TBW% and TBW kg) and muscle mass (MM% and MM kg). The measurements were taken using the body composition analyser Tanita – BC 418 MA, which employed the BIA (*Bioelectrical Impedance Analysis*) method, and via anthropometric measurements.

RESULTS. The BMI value among the winter swimmers was significantly higher than among people not practising winter swimming. Moreover, in the winter swimmers, higher BF % and FM/FFM% ratio values, as well as a lower MM% value were found, as compared with the controls.

CONCLUSIONS. The obtained results suggest that the choice of bathing in cold water as a form of recreation may depend on the content of the adipose tissue. The tissue constitutes an insulating layer which efficiently protects overweight people from an excessive heat loss.

S t r e s z c z e n i e

WSTĘP. Morsowanie stanowi formę rekreacji ruchowej, która polega na korzystaniu z kąpieli w zimnych akwenach wodnych w okresie zimowym. Celem pracy była analiza składu ciała u osób regularnie zażywających lodowatych kąpieli.

MATERIAŁ I METODY. Badaniami objęto 20 mężczyzn, z których połowa (śr. wieku 27,7 ± 7,1 lat) co najmniej od roku regularnie korzystała z zimnych kąpieli (morsy), podczas gdy pozostali (śr. wieku 27,0 ± 4,0 lat) nigdy nie stosowali tego typu zabiegów (kontrola). U każdego z badanych oznaczono skład ciała: indeks masy ciała (BMI), masę ciała (BM kg), procentową zawartość tkanki tłuszczowej w organizmie (BF%), masę tkanki tłuszczowej (FM kg), beztłuszczową masę ciała (FFM kg), stosunek masy tkanki tłuszczowej do beztłuszczowej masy ciała wyrażony w procentach (FM/FFM%), całkowitą zawartość wody w organizmie (TBW kg i TBW%) oraz masę i procentową zawartość tkanki mięśniowej (MM kg i MM%). Wyniki uzyskano przy użyciu analizatora składu ciała Tanita – BC 418 MA, w oparciu o metodę BIA (analizę impedancji bioelektrycznej) oraz wykonując pomiary antropometryczne.

WYNIKI. Wartość BMI w grupie morsów była istotnie statystycznie wyższa niż u osób niepraktykujących zimowych kąpieli. U morsów zauważono ponadto wyższą niż w grupie kontrolnej wartość BF% oraz stosunek FM/FFM% oraz wyższą wartość MM%.

WNIOSKI. Uzyskane w niniejszej pracy wyniki pozwalają przypuszczać, że o wyborze kąpieli w zimnej wodzie, jako formie rekreacji może decydować zawartość tkanki tłuszczowej. Tkanka ta stanowi warstwę izolującą, skutecznie chroniącą osoby z nadwagą przed nadmierną utratą ciepła i wychłodzeniem.

Key words: body composition, cold temperature, winter swimming
Słowa kluczowe: analiza składu ciała, niska temperatura, morsowanie

INTRODUCTION

Bathing in water reservoirs during the winter, i.e. winter swimming, is a form of physical recreation. Throughout the world, the number of winter swimmers enjoying such a form of spending free time increases [1]. In Poland, there are many clubs whose members practise winter swimming. Immersions in cold water, apart from their social role related with group bathing in ice-cold water reservoirs, is also popular as a regenerative procedure for the organism after physical activity. The effect of cold induces several reactions in the organism of both physiological and biochemical nature [2]. It has been proven that bathing in cold water has beneficial effects, such as pain relief [3], decrease in the incidence of infections and improved mood [4]. The observed changes may be explained by the adaptive mechanism. Low temperatures induce stress in the organism and may also induce the adaptive response, one of the key concepts explaining the so-called “hardening” of the bodies of winter swimmers [5-6]. The adaptive mechanism may explain e.g., the increased immunity to diseases.

Many believe that winter swimming, sometimes considered as an extreme sport, is a way of living with good health. A correct body composition may be an indicator of a healthy lifestyle, involving e.g., healthy diet or an appropriate level of physical activity. Body composition is determined using several indirect methods, anthropometric, densitometric and hydrometric ones, as well as the most recent methods employing the electrical resistivity of tissues, computed tomography and magnetic resonance. The anthropometric methods allow determination of basic body dimensions (weight, height, thickness of cutaneo-adipose flaps) and their results provide information that is very close to the real values [7]. Recently, measurements employing the BIA technique (*Bioelectrical Impedance Analysis*) are becoming popular and are applied by various institutions analysing body composition, such as clinics, physicians' offices and fitness clubs [8]. The method is based on the difference in electrical conductivity between the water and fat compartments. Body composition is assessed using the additionally entered height, sex and age of the subject [9]. If correct conditions of the measurement are maintained, BIA is a safe and useful method characterized by high efficiency and repeatability of the results [8]. Thanks to this simple, precise and non-invasive measurement method, as well as its short duration, the BIA technique is particularly useful in performing mass studies.

The aim of this study was the comparison of the body composition of people regularly practising cold water baths (winter swimmers) and those who do not perform such activities.

MATERIAL AND METHODS

Twenty men participated in the study. Ten of them (mean age = 27.7 ± 7.1 years) were members of the winter swimming club from Olsztyn, Poland, who had regularly (once a week) practised bathing in cold water for at least one year. The remaining subjects (mean age = 27.0 ± 4.0 years) had never practised winter swimming and formed a control group. All people who declared their will to participate in the study were volunteers and had given written informed consent to participate in the study. In every subject, a body composition profile was determined, including: body mass index (BMI), body mass (BM kg), body fat percentage (BF%), fat mass (FM kg), fat-free mass (FFM kg), the fat mass-to-fat-free mass ratio, expressed as percentage (FM/FFM%), total body water (TBW kg and TBW%), as well as muscle mass and percentage (MM kg and MM%).

The measurements of arm circumference and the thickness of cutaneo-adipose flaps were also taken in four areas: the cutaneo-adipose flap above the triceps brachii muscle, the cutaneo-adipose flap above the biceps brachii muscle, the cutaneo-adipose flap below the inferior angle of the scapula, the cutaneo-adipose flap above the iliac crest. The measurements were taken using a GPM calliper (SiberHegner & Co. Ltd., Switzerland). The calliper exerted a constant pressure of 10 g/mm^2 and the accuracy of measurement was 0.1 mm. All measurements were taken on the right side of the body. Based on the measurements performed, fat-free mass, total body mass and body fat percentage were calculated using the formula established by Durnin and Womersley [10-11]. TBW%, TBW kg, MM% and MM kg were assessed using the Tanita – BC 418 MA body composition analyser (Tanita Corporation, Japan) which employed the BIA technique. The unit is composed of 8 electrodes and allows a precise calculation of the content of adipose and muscle tissue in each of the body segments. The full profile of the subject's body composition may be obtained within 20 seconds. The method is based on the measurement of impedance, i.e. the resistance of the biological conductor to alternating current. The technique makes use of the differences in the passive electrical properties exhibited by tissues acting as electrical conductors. The principles of the method are based on the Ohm's law and allow measurement of the components of electrical impedance and capacitive reactance of the examined tissues. Electrical impedance depends mainly on the concentration of electrolytes (as well as the quantity of water), while capacitance depends on the differences in electrical potential across plasma membranes. The impedance changes according to the frequency of the applied current, as well as conductor length and content of conducting liquids (electrolyte solutions). Thus body fluids containing electrolytes are responsible for conducting electricity, while plasma membranes are responsible for capacitance [9].

Statistical analysis of the results was accomplished by using Student's *t*-test to analyse the means and standard deviations of the different experimental groups. The results were considered as statistically significant with $p<0.05$.

RESULTS

The BMI value among the winter swimmers was significantly 10% higher ($p<0.05$) than in the control group. The winter swimmers also had a BF% value higher by 30% ($p<0.05$) than that of the control group. Moreover, the winter swimmers exhibited an FM/FFM% ratio higher by 37% ($p<0.05$) than that of the control group. In the winter swimmers, MM% was lower by 6% ($p<0.05$) that in people who did not practise regular baths in cold water. As regards the other parameters, no statistically significant differences were determined (Table 1.).

Table 1. *Body composition analysis in people regularly taking ice cold bathing (winter swimmers) and people not undergoing such treatment*

Tabela 1. *Analiza składu ciała u osób regularnie korzystających z zimnych kąpieli (morsy) i osób niestosujących tego typu zabiegów*

	***Controls / Kontrola* n=10**		***Winter swimmers / Morsy* n=10**	
	Mean / Średnia	±SD	*Mean / Średnia*	±SD
BMI kg/m^2	23.7	2.0	26.0*	2.5
BF%	13.4	4.2	17.4*	5.0
FM/FFM%	15.7	5.7	21.5*	7.6
MM%	45.6	2.7	42.7*	2.9
BM kg	82.3	9.2	81.6	9.3
FM kg	11.1	4.1	14.5	5.6
FFM kg	71.1	7.4	67.1	5.4
TBW%	63.2	3.1	60.4	3.7
TBW kg	51.9	5.3	49.1	4.0
MM kg	37.4	4.2	34.7	3.0

indeks masy ciała, *body mass index* – BMI*;* masa tkanki tłuszczowej, *body fat* – BF%; stosunek masy tkanki tłuszczowej do beztłuszczowej , *fat mass-to-fat-free mass ratio* - FM/FFM%; masa ciała, *body mass* – BM kg*;* masa tkanki tłuszczowej, *fat mass* – FM kg; beztłuszczowa masa ciała, *fat-free mass*- FFM kg;całkowita zawartość wody w organizmie, *total body water* – TBW%, TBW kg*;* masa tkanki mięśniowej, *muscle mass* – MM kg
Statistically significant differences: * - $p<0.05$ versus controls

DISCUSSION

Human, as a warm-blooded organism, may live in different types of environment but remaining at low temperatures involves a high energetic expense to maintain a constant, high body temperature. Exposure to low temperature may result in hypothermia [12]. Sudden temperature decrease imposes much stress on the heart and lungs. When the temperature decreases suddenly, an increase in the levels of stress hormones is observed [2, 13]. To prevent hypothermia, the organism produces heat by inducing shivering and increasing shivering thermogenesis [14]. Muscle shivering leads to the deterioration of muscle coordination and fatigue, which restrict the ability for physical effort. It is therefore contraindicated to swim in cold water except for bathing in shallow water [15]. When swimming in water at the temperature below 5°C, core body temperature and heart rate should be monitored. It is important to avoid a decrease in the body temperature below 32°C and to prevent arrhythmia, while in case of danger; the person should be taken out of water immediately [16]. Despite the existing risks, cold water may apparently bring considerable benefits, since the people who regularly practise bathing in ice-cold water are more resistant to cold [14].

Every person demonstrates a different body temperature reduction rate while bathing in cold water. The subcutaneous adipose tissue constitutes an important inhibiting factor for temperature loss during the exposure to low temperatures [17]. People with thinner cutaneo-adipose flaps lose heat more quickly than those with a higher amount of the subcutaneous adipose tissue [12]. The thickness of the subcutaneous adipose tissue also affects individual thermal perception in people bathing in cold water [16]. Therefore the maximum tolerable time that may be spent in cold water is shorter in people with a lower thickness of the subcutaneous adipose tissue [18].

Biological effects of cold depend mainly on the range of temperatures applied, tissue temperature reduction rate, exposure time and individual susceptibility of the organism. Depending on those parameters, cold may induce both the destruction of pathologically changed tissues and stimulation of physiological processes. Maintaining a relatively constant core temperature is crucial for proper functioning of a warm-blooded organism. Body temperature is constant mainly in its inner parts, while the peripheral temperature largely depends on external factors. Applying cold results in a rapid decrease in skin temperature, whereas deeper tissues lose heat much more slowly. The greatest heat loss occurs in those body parts which have a relatively large surface area compared to their volume (this refers mainly to the limbs, particularly fingers and toes). Therefore the amount of heat loss in the fingers is significantly greater than that in the trunk. Applying a bag containing 3 kg of frozen food onto the anterior face of the knee joint for 30 minutes leads to a decrease of 9.4°C in the joint temperature, while the knee skin temperature decreases by 16.4°C [19]. In this case, the significant temperature decrease inside the joint may be due to the low content of the adipose tissue in this area. Similar studies were conducted using local cold application in the area of the glenohumeral joint, but the results revealed only a slight change in the joint temperature. This is due to the thick layer of muscle tissue covering the area, as opposed to the knee joint [20]. Heat conservation as well as heat production via muscle contractile activity and shivering is the body's physiological defensive mechanisms against cold. In adults, long-term exposure to cold or short but intense exposure to extremely low temperatures additionally induce humoral response. This leads to an increase in tissue metabolism and heat production. Besides, in the case of local hypothermia, tissue metabolism becomes slowed down.

In this study, the group of winter swimmers was composed of people who were passionate about bathing in ice-cold water and regularly practised this activity (once a week). It was observed that those people had a higher content of fat in their bodies, which may constitute a form of protection against heat loss and indicates that the body heat derived from the processes involved in non-shivering thermogenesis [2, 14]. Human organism, in response to temperature reduction, employs the mechanism of adaptive thermogenesis which involves energy dissipation in the form of heat [21]. In such case, the amount of the produced heat depends on the amount of heat loss [17]. The group of winter swimmers was not in the range of normal weight, as their mean Body Mass Index classified them in the overweight range. On the other hand, the volunteers demonstrated normal body mass. It was observed that the differences in body constitution may correlate with the amount and type of reaction exerted by the organism to a thermal stimulus [22]. The different types of response between overweight people and those with normal weight may be due to the insulative properties of the adipose tissue which reduces heat loss through the skin [17].

The reactions of the human organism to cold include an increase in metabolism, decrease in the temperature of skin surface (insulation) and hypothermia. The brown adipose tissue (BAT) participates in thermoregulation and is responsible for non-shivering thermogenesis [23]. The tissue exhibits a high ability to produce heat in response to cold, in order to maintain thermal balance [13, 21]. As a result of body temperature reduction, the brown adipose tissue becomes activated, which increases its oxygen consumption rate, related mainly with the increased mitochondrial oxygen metabolism [13, 24], resulting in a more intense heat production [17]. Heat production in the brown adipose tissue is a result of the oxidation of fatty acids [25]. BAT is necessary for thermogenesis in neonates, while in adults with a higher daily basal metabolic rate and a higher muscle mass permitting heat production, the tissue is considered as useless [26]. For many years, it was believed that in adults BAT does not appear at all or may be found in traces which do not play any role in maintaining a normal body temperature. Recently, thanks to the use of novel methods, serious evidence supporting the presence of BAT in adults has been found [27]. A significant negative correlation between the activity of the brown adipose tissue and BMI or the percentage of the adipose tissue (BF%) was observed in numerous studies [25]. In this study, a statistically significant increase in the adipose tissue content was observed in the winter swimmers, as compared to the control group, which may suggest a lower activity of the brown adipose tissue in the former group. Vijgen et al. [22] demonstrated that in thin people, a significant increase in energetic expense takes place in response to moderate cold, while in obese people thermogenesis stimulated by cold is less pronounced and the insulative function of the tissue plays a more important role [22]. In other studies, it was observed that thin people exhibit almost a 3-fold more intense heat generation than obese people, which results in different energetic balance [17]. A negative correlation between the BAT activity level and the occurrence of shivering was also demonstrated [18]. It is believed that in adults, BAT may play an important role not only in heat production, but also in maintaining proper body mass [27]. It is not excluded that the increase in energy consumption in the process of the brown adipose tissue activation may contribute to the loss of body mass [22, 25]. In the control group described in this article, due to the lower thermal insulation provided by the adipose tissue, protection against heat loss might be achieved via the thermogenesis processes related with the activation of the brown adipose tissue and a larger energetic expense, as compared with the winter swimmers, necessary to maintain thermostasis. The above observations lead to a conclusion that winter swimmers, thanks to their more efficient thermal insulation and probably lower energetic expense necessary to maintain a relatively high body temperature, are better adapted to bathing in cold water.

CONCLUSIONS

The obtained results described in this article suggest that the choice of bathing in cold water as a form of recreation may depend on the content of the adipose tissue. The tissue constitutes an insulating layer which efficiently protects overweight people from an excessive heat loss.

REFERENCES

1. Kolettis TM, Kolettis MT. Winter swimming: healthy or hazardous? Evidence and hypotheses. Med Hypotheses 2003;61:654-656.
2. Bleakley CM, Davison GW. What is the biochemical and physiological rationale for using cold-water immersion in sports recovery? A systematic review. Br J Sports Med 2010;44:179-187.
3. Smolander J, Leppäluoto J, Westerlund T et al. Effects of repeated whole-body cold exposures on serum concentrations of growth hormone, thyrotropin, prolactin and thyroid hormones in healthy women. Cryobiology 2009;58:275-278.
4. Siems WG, Brenke R, Sommerburg O et al. Improved antioxidative protection in winter swimmers. Q J Med 1999;92:193-198.
5. Mujahid A, Furuse M. Oxidative damage in different tissues of neonatal chicks exposed to low environmental temperature. Comp Biochemical Physiol A Mol Integr Physiol 2009;152:604-608.
6. Dugué B, Smolander J, Westerlund T et al. Acute and long term effects of winter swimming and whole-body cryotherapy on plasma antioxidative capacity in healthy women. Scand J Clin Lab Invest 2005;65:395-402.
7. Wądołowska L, Cichon R. Aktywność fizyczna a masa ciała i jej skład u młodzieży w wieku od 16 do 19 lat. [Physical activity, body weight and body mass composition of adolescents in age between 16 and 19 years old] (in Polish, abstract in English). Nowa Medycyna, Medycyna w Sporcie IV 2000;108:454-8.
8. Jakubowska-Pietkiewicz E, Prochowska A, Fendler W et al. Porównanie metod pomiaru odsetka tkanki tłuszczowej u dzieci. [Comparison of body fat measurement methods in children] (in Polish, abstract in English). Pediatr Endocr Diabetes Metab 2009;15:246-250.
9. Drożdż D, Kwinta P, Pietrzyk JA et al. Wskaźnik masy ciała (BMI) czy analiza bioimpedancji elektrycznej (BIA) – która metoda pozwala lepiej ocenić zawartość tkanki tłuszczowej u dzieci? [Body mass index (BMI) or bioimpedance analysis (BIA) – which method enables a better assessment of fat mass in children?] (in Polish, abstract in English). Przegl Lek 2007;64:68-71.
10. Durnin JVGA, Womersley J. Body fat assessed from total body density and its estimation from skinfold thickness: measurements on 481 men and women aged from 16 to 72 years. Br J Nutrition 1974;32:77-97.
11. Siri WE. The gross composition of the body. pages 239-280. In: Lawrence JH, Tobias CA (ed). Advances in Biological and Medical Physics. Academic Press. New York,1956;239-280.
12. Keatinge W R, Khartchenko M, Lando N et al. Hypothermia during sports swimming in water below 11°C. Br J Sports Med 2001;35:352-353.

13. Virtanen KA, Lidell ME, Orava J et al. Functional brown adipose tissue in healthy adults. N Engl J Med 2009;360:1518-1525.
14. Vybíral S, Lesná I, Janský L et al. Thermoregulation in winter swimmers and physiological significance of human catecholamine thermogenesis. Exp Physiol 2000;85:321-326.
15. Tipton M, Eglin C, Gennser M et al. Immersion deaths and deterioration in swimming performance in cold water. Lancet 1999;354:626-629.
16. Knechtle B, Christinger N, Kohler G et al. Swimming in ice cold water. Ir J Med Sci 2009;178:507-511.
17. Claessens-van Ooijen AM, Westerterp KR, Wouters L et al. Heat production and body temperature during cooling and rewarming in overweight and lean men. Obesity 2006;14:1914-1920.
18. Hayward MG, Keatinge WR. Roles of subcutaneous fat and thermoregulatory relexes in determining ability to stabilize body temperature in water. J Physiol 1981;320:229-251.
19. Oosterveld F, Rasker J, Jacobs J et al. The effect of local heat and cold therapy on the intracellular and skin surface temperature of knee. Arth Rheum 1992;35:146-151.
20. Levy A, Kelly B, Lintner S et al. Penetration of cryotherapy in treatment after shoulder arthroscopy. Arthroscopy 1997;13:461-464.
21. van den Berg SA, van Marken Lichtenbelt W, Willems van Dijk K et al. Skeletal muscle mitochondrial uncoupling, adaptive thermogenesis and energy expenditure. Curr Opin Clin Nutr Metab Care 2011;14:243-249.
22. Vijgen GHEJ, Bouvy ND, Teule GJJ et al. Brown adipose tissue in mordibly obese subjects. PLoS ONE 6 2011;e17247.doi:10.1371/journal.pone.0017247.
23. Vucetic M, Otasevic V, Korac A et al. Interscapular brown adipose tissue metabolic reprogramming during cold acclimation: Interplay of HIF-1α and AMPKα. Biochim Biophys Acta 2011;1810:1252-1261.
24. van Marken Lichtenbelt WD, Vanhommerig JW, Smulders NM et al. Cold-activated brown adipose tissue in healthy men. N Engl J Med 2009;360:1500-1508
25. Yao X, Shan S, Zhang Y et al. Recent progress in the study of brown adipose tissue. Cell Biosci 2011;1:35. doi:10.1186/2045-3701-1-35.
26. Cypess AM, Lehman S, Williams G et al. Identification and importance of brown adipose tissue in adult humans. N Engl J Med 2009;360:1509-1517.
27. Saito M. Brown adipose tissue as a regulator of energy expenditure and body fat in humans. Diabetes Metab J 2013;37:22-29.
28. Ouellet V, Labbé SM, Blondin DP et al. Brown adipose tissue oxidative metabolism contributes to energy expenditure during acute cold exposure in humans. J Clin Invest 2012;122:545-552.

Address for correspondence:
mgr Roland Wesołowski
The Chair of Medical Biology,
Collegium Medicum UMK,
ul. Karłowicza 24,
85-092 Bydgoszcz
e-mail: roland@cm.umk.pl
phone: (52) 585 37 37
fax: (52) 585-37-42

Received: 14.10.2013
Accepted for publication: 15.11.2013