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ORIGINAL ARTICLE

Effect of sanatorium treatment on increasing phase angle values

Wpływ leczenia sanatoryjnego na wzrost wartości kąta fazowego

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Abstract

Introduction and Objective. The phase angle is considered an indicator of the integrity and function of cell membranes and the overall nutritional status of the body. Phase angle measurement can be an indicator to improve performance and recovery in athletes. It also informs about hydration of the body, occurrence of swelling, and monitoring the level of fluids in the body. The aim of the article is to determine the impact of a 21-day sanatorium stay on the tissue condition of the participants by analyzing the phase angle values.

Materials and Method. The study included 261 patients aged 39–89 years undergoing a sanatorium stay at the 'Solinka' Sanatorium in Polańczyk in the Subcarpathian Province, south-east Poland. Phase angle measurements were taken at the beginning and end of the stay using the Tanita MC-780 MA-N multi-frequency bio-electrical impedance analyzer.

Results. The results of the study show that the 21-day sanatorium stay had a significant impact on improving the tissue condition of the participants, as reflected in changes in phase angle values. Before the stay, the average phase angle was 5.53°, while after the stay, it increased to 5.69°, F K-W=184.006. This change is statistically significant, suggesting that the sanatorium treatment brought measurable health benefits. The greatest increase in this parameter was observed in individuals who participated in pool exercises and balneotherapy, highlighting the role of these treatments in improving physical condition.

Conclusions The 21-day sanatorium stay had a positive effect on cellular health, as reflected in the increase in phase angle values. Physiotherapy treatments, such as pool exercises, balneotherapy and mud wraps, are particularly effective in improving tissue condition.

Key words

water, fat, phase angle, electrical bioimpedance, muscle mass

Streszczenie

Wprowadzenie i cel pracy. Kąt fazowy jest uważany za wskaźnik integralności i funkcji błon komórkowych oraz ogólnego stanu odżywienia organizmu. Pomiar kąta fazowego może być wskaźnikiem poprawy wydolności i regeneracji u sportowców. Informuje również o nawodnieniu organizmu i występowaniu obrzęków, monitorując poziom płynów w organizmie. Celem artykułu było określenie wpływu 21-dniowego pobytu uczestników badania w sanatorium na stan ich tkanek poprzez analizę wartości kąta fazowego.

Materiał i metody. Badaniem objęto 261 pacjentów w wieku 39–89 lat, przebywających w Sanatorium „Solinka" w Polańczyku. Pomiary kąta fazowego wykonano na początku i na końcu pobytu za pomocą wieloczęstotliwościowego analizatora impedancji bioelektrycznej Tanita MC-780 MA-N.

Wyniki. Wyniki badania wskazują, że 21-dniowy pobyt sanatoryjny miał istotny wpływ na poprawę stanu tkanek u jego uczestników, co znalazło odzwierciedlenie w zmianach wartości kąta fazowego. Przed pobytem średni kąt fazowy wynosił 5,53°, natomiast po pobycie wzrósł do 5,69°; FK-W = 184,006. Zmiana ta jest istotna statystycznie, co sugeruje, że leczenie sanatoryjne przyniosło wymierne korzyści zdrowotne. Największy wzrost tego parametru zaobserwowano u osób korzystających z ćwiczeń w basenie i balneoterapii, co podkreśla rolę tych zabiegów w poprawie kondycji fizycznej.

Wnioski. 21-dniowy pobyt w sanatorium ma pozytywny wpływ na zdrowie komórek, co znajduje odzwierciedlenie we wzroście wartości kąta fazowego. Zabiegi fizjoterapeutyczne, takie jak ćwiczenia w basenie, balneoterapia i okłady borowinowe, są szczególnie skuteczne w poprawie kondycji tkanek.

Słowa kluczowe

tkanka tłuszczowa, woda, kąt fazowy, bioimpedancja elektryczna, masa mięśniowa

INTRODUCTION

Electrical bioimpedance is a non-invasive and cheap method of determining body composition which allows monitoring of the course of treatment of metabolic diseases, cancer cachexia, heart diseases, and is widely used in sports medicine, fitness clubs, and many laboratories worldwide [1]. The principle of bioimpedance is to measure the resistance of individual components of the human body using a set of electrodes and applying a current of appropriate frequency and intensity using computer analysis. The amount of electrical resistance

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(R) of a uniform object is directly proportional to its length (L) and resistivity (ρ), and inversely proportional to its cross-sectional area (A). Impedance (Z) is a function of resistance and reactance (Xc) which, in turn, is inversely proportional to the current frequency and electrical capacity of the system [2].

The phase angle (PA) is determined based on the reactance and resistance values obtained using bioimpedance analysis [2, 3]. The PA value closely correlates BCM (Body Cell Mass) [4]. Based on the aforementioned formula defining the phase angle, where Xc is the reactance responsible for the electrical capacity of cell membranes, and R is the resistance responsible for the conduction resistance through extracellular water, it can be concluded that with a higher reactance, corresponding to the degree of cell nutrition, the value of the phase angle increases. As the resistance increases, corresponding to the amount of unfavourable extracellular water, the value of the phase angle decreases. [1] This angle depends on the state of cell organelles responsible for energy and biochemical activity. Research on a large group of volunteers of many nationalities showed differences depending on gender, age and ethnic group. It is believed that the value of the phase angle in healthy adults ranges between 5–7°, while a value below 5° indicates malnutrition. Studies have proven that the size of PA is a prognostic marker of many serious diseases [1, 4, 5].

Phase angle measurement can be an indicator to improve performance and recovery in athletes. It also informs about hydration of the body and the occurrence of swelling, monitoring the level of fluids in the body. BIA can be used both as a screening method and for monitoring the health of cancer patients.

The phase angle is of great importance, considered an indicator of cell health, and closely correlates with the body's cell mass.

If precautions are taken and the conditions for proper test performance are maintained, the repeatability of the results using this method is very high. The test-retest reliability coefficient using the four-electrode system is 99%. The test results showed no deviations within five measurements if the electrodes remained in the same place. These values did not differ by more than 2%. BIA tests are considered safe for the body; the current frequencies used do not stimulate the nerves. The threshold for sensing current in humans is 1–1.5 mA, thus the current of 0.8–1 mA used during the measurement is basically unnoticeable. So far, no adverse events have been reported during or after the study, with the use of batteries and low-voltage energy sources minimizing the risk of irritation. So far, the problem of the influence of the analyzer on devices emitting electromagnetic fields and vice versa has not been solved. However, until there is clear evidence of safety, people with an implanted defibrillator are advised not to perform the test as even a small current may interfere with the proper functioning of the device.

The phase angle method has been widely used, not only on healthy people but also on patients, especially those with metabolic syndrome [6]. It also has potential use in the early detection of inflammation and oxidative stress, and as an indicator of physical activity in patients with stable chronic obstructive pulmonary disease. Physical activity was positively associated with the phase angle in patients with chronic obstructive pulmonary disease, and also has potential use in the early detection of inflammation and oxidative stress. Phase angle seems to be a good mortality indicator in many clinical situations and can be used in screening individuals prone to this outcome [7].

Spa treatment uses natural raw materials (water, peloids, medicinal gases) and the health properties of the climate [8]. According to the balneologist's recommendation, personalized kinesitherapy, physiotherapy, hydrotherapy and dietary treatments are used. The effectiveness of treatment is determined not only by the type but also by the appropriately selected duration of therapy. Balneological treatments have a training and improvement effect on many physiological functions, thus accelerating regenerative processes in the organs. Spa therapy leads primarily to reducing pain, improving fitness and increasing resistance to stress [9]. Compared to pharmacological treatment, the effect of these treatments is slow, but the gradually occurring changes in the of peloid is based on thermal and mechanical impact. Water-soluble minerals also play a role. The characteristics of peloid that determine its therapeutic properties, such as: water absorption, heat capacity, sedimentation and sorption-exchanger properties, depend primarily on the humic compounds contained in the peloid, which are colloids. The therapeutic effect of peloids is based on the complex action of natural pharmacodynamic and thermal and mechanical effects. Humic acids, micronutrients and other compounds that are found in the mud have anti-inflammatory and astringent properties [10–12].

OBJECTIVE

The phase angle, determined using the bioelectrical impedance analysis (BIA) method, has been widely used as a reliable marker to assess the functional state of cells in various diseases. This study aims to evaluate the impact of a 21-day sanatorium treatment on changing phase angle values, thereby assessing the effect of the treatment on the overall condition and integrity of body tissues

MATERIALS AND METHOD

The research included patients undergoing spa treatment at the 'Solinka' Sanatorium in Polańczyk-Zdrój in the Subcarpathian Province of south-east Poland, and received the approval of the Bioethics Committee at Jan Grodek State University in Sanok on 9 December 2022. People qualified for the study stayed in the sanatorium for 21 days, the standard period of stay in a sanatorium in Poland. The study type is pre-post design with participants volunteering to participate in the study. After analyzing the disease diagnoses from referrals to the sanatorium, participants with musculoskeletal disorders and comorbidities, such as hypertension, type 2 diabetes, ischemic heart disease, overweight and obesity, were selected. Those with contraindications to BIA measurement, such as the presence of metal implants in the body, a cardiac defibrillator, epilepsy, pregnancy, and conditions after paresis and paralysis, were excluded from the study, as were minors, people not staying in a sanatorium, and people with cancer. The inclusion criteria were as follows: adults staying in a sanatorium, having metabolic diseases listed above. The study group finally consisted of 261 patients, of both genders, aged 39–89 who were informed about the purpose of the research which was free of charge. They were additionally

informed that about the possibility of withdrawing from participation in the study at any time, without incurring consequences. A survey was conducted at the beginning of the stay which provided data on medications taken, past illnesses, and lifestyle: physical activity and stimulants used.

The research was conducted periodically from December 2022-o June 2023 in the Physiotherapy Diagnostics Laboratory of the Natural Medicine Department of the 'Solinka' Sanatorium in Polańczyk. The examination with a multi-frequency bioelectrical impedance analyzer Tanita MC-780 MA-N was performed at the beginning (on the second day of the stay) and at the end of the stay (on the last day). During body composition tests, phase angle (PA) values were obtained, which was the ratio of reactance and resistance. Values at a frequency of 50 kHz were adopted for evaluation. Measurement with the four-electrode technique at a constant frequency of 50 kHz provides knowledge about extracellular water and its relation to the total water content in the body.

Measurements were always performed in the morning at 06.00–09.00, on an empty stomach and after urination. The test was not performed in situations that affect the fluid balance in the body, e.g. physical exercise, alcohol consumption, or diuretic drug use. The plan of physiotherapy treatments was determined based on initial medical examination and adjusted to the age of the subjects, as well as to comorbidities. The selection of treatment methods for individual patients was made by a doctor specializing in rehabilitation on the basis of a referral to a sanatorium and comorbidities.

During the sanatorium stay, an extensive range of balneological and physiotherapy procedures were used by the participants, the main goal of which was to treat the musculoskeletal system by reducing pain, improving range of motion, and increasing strength and muscle mass. This is due to better nutrition of the tissues associated with increased blood supply. Procedures used – balneological procedures used during the treatment of this group of patients included upper and lower limb whirlpool baths, total brine baths, group pool exercises, mud suspension baths, wet and dry carbonic acid baths, local mud compresses and crenotherapy procedures. Physiotherapy procedures – diadynamic currents, laser therapy, inhalation, massage, local CO_2 cryotherapy, ultrasound, low-frequency magnetic field, TENS currents, Nemec currents, Trabert currents (Ultra Reiz) and Sollux lamp (IR). Kinesiotherapeutic procedures were also used – individual and group general rehabilitation exercises, active exercises, breathing exercises, active exercises in relief and morning gymnastics. The minimum number of ordered treatments was 54 throughout the duration of spa treatment, with a maximum of 74 treatments.

Statistical analysis was performed using IBM SPSS 23. Compliance with the theoretical distribution was checked using Kolmogorov-Smirnoff (N>100). Basic statistics were calculated depending on the nature of the variables. For quantitative variables, measures of location (means) and dispersion (standard deviations) were calculated. For qualitative variables, numerical and percentage distribution was calculated. The regression included the following variables: BMI, phase angle, muscle mass, fat mass. The hypotheses were tested using the Chi2 test, Kruskall-Wallis ANOVA and multiple regression for the dependent variable delta from phase angle measurements. Non-parametric tests were used, including the Kruskal-Wallis test, because the variables did not have a normal distribution. The p level was set at 0.05.

RESULTS

The research involved 261 participants – 117 men (44.8%) and 144 women (55.2%) with an average age of 64.76 years; the youngest was 36 and the oldest 89, standard deviation (SD) – 7 years). Most respondents lived in a city (N=182, 69.7%), the countryside was indicated by approximately 30% of the respondents (N=79, 30.3%) (Tab. 1). The majority reported being treated for chronic internal diseases (N=190, 72.8%) and took stimulants (>80%), with caffeine being the most common (N=98, 37.5%) (Tab. 2).

Table 1. Characteristics of the study group

Variable	Study Group (N=261)		
Gender	N	%	
Men	117	44.8	
Woman	144	55.2	
Age (years)	Min/max	Mean	Standard Deviation
	36/89	64.76	7.17
Domicile	N	%	
Countryside	79	30.3	
City	182	69.7	

Table 2. Study group data

VARIABLE	STUDY GROUP (N=261)
Chronic diseases	
Yes	N=190
No	N=71
Stimulants	
Caffeine	N=98
Nicotine	N=72
Alcohol	N=43
Legal highs	-
Marihuana	-
Other psychoactive substances	-

Table 3 presents analysis of the overall phase angle in the study group (N=261) before and after the sanatorium stay. Prior to treatment, phase angle values ranged from 3.2° – 7.88°, with a mean of 5.53°. After the three weeks of sanatorium stay, values ranged from 3.37° – 12.1°, with the mean increasing to 5.69°.

There occurred a significant decrease in the number of participants with class II obesity by 17 individuals (–55%) and class I obesity by 12 individuals (–27%). Conversely, the number of overweight participants increased by 19 individuals (+15%), while the number of participants with normal weight rose by 10 individuals (+16%) (Tab. 4). These changes reflect the weight reduction among obese participants, who shifted into the overweight and normal weight categories.

Table 5 illustrates the results of a multiple regression analysis assessing the effect of various balneological treatments on changes in the overall phase angle following sanatorium therapy. The model was statistically significant ($F=567.75$, $p<0.001$), indicating a strong predictive value of the examined interventions. Among the independent

Table 3. Analysis of the overall phase angle before and after sanatorium stay

Variable	Study group before N=261			Study group after N=261			Change
Value	Min/max	Mean	Standard deviation	Min/max	Mean	Standard deviation	
Overall phase angle [°]	3.2/7.88	5.53	0.69	3.37/12.1	5.69	0.99	0.16

Table 4. BMI analysis before and after the sanatorium stay

Variable	Study group Measurement point I N=261		Study group Measurement point II N= 261		Difference	
BMI (kg/m2)	N	%	N	%	N	%
18.5–24.99 **(Standard)**	63	24.2	73	27.9	10	16
25–29.99 **(Ov**erweight)	123	47.2	142	59	19	15
30–34.99 **(Obesity I)**	44	16.8	32	12.2	-12	-27
35–39.99 **(Obe**sity II)	31	11.8	14	5.4	-17	-55

Table 5. Impact of balneological treatments determining the change in the phase angle after sanatorium treatment based on the multiple regression test

Independent variable	Change in the overall phase angle F=(3.A57)=567.75 **P<0.001**	
Value	**SE[a]**	**Beta[b]**
Exercises in the pool	0.07	0.359
Balneotherapy	0.024	0.057
Mud compresses	0.049	0.197

SE[a] – standard error; Beta[b] – standardized coefficient b; P[c] – test probability degree.

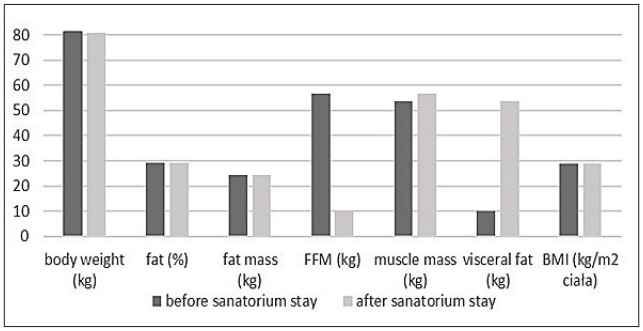

Figure 1. Detailed body composition

variables, exercises in the pool demonstrated the strongest association with improvements in the phase angle, with a standardized coefficient (Beta) of 0.359 and a standard error (SE) of 0.07. Mud compresses also contributed significantly, although to a lesser extent (Beta = 0.197; SE = 0.049). In contrast, balneotherapy showed only a minimal effect on phase angle improvement (Beta = 0.057; SE = 0.024).

DISCUSSION

Obesity is a civilization disease that affects most societies worldwide [13]. In the study group, based on the calculated BMI, 123 people (47.2%) were overweight, 44 had grade I (16.8%) and 31 grade II (11.8%) obesity (Tab. 4).

The study population reported moderate use of stimulants (Tab. 2), with caffeine being the most commonly used (37.5%). In individuals with good caffeine tolerance, moderate coffee intake has been linked to cardioprotective effects; for example, some studies suggest that consuming up to four cups of coffee daily may lower the risk of myocardial infarction. Nicotine use was reported by 27.6% of participants, making it the second most common stimulant. Nicotine addiction is strongly associated with a wide range of diseases that reduce life expectancy and is also linked to increased accumulation of abdominal fat [13]. The third most common stimulant reported was alcohol (16.5%). According to Stodolny [14], the use of the above-mentioned stimulants leads to a change in tissue metabolism, which has a direct impact on insufficient nutrition of articular cartilage and the development of progressive degenerative disease other than would result from the aging process.

The obtained results made it possible to determine the phase angle at a frequency of 50 kHz. This parameter was measured using TANITA bioimpedance analyzers, devices that fulfill the necessary methodological requirements and are widely applied in monitoring the effects of treatment and training [15]. The phase angle may be a potential screening tool used in clinical practice to assess cardiovascular risk and health status in metabolic diseases (diabetes, obesity) in adults. Dittmar et al. [16] proved that people with diabetes have lower phase angle values than healthy people. The phase angle increases with increasing cell mass. The long-term disease process in diabetes causes catabolic processes, reduced cell mass, and hence a lower PA value. It has also been shown that PA inversely correlates with serum HbA1C concentration, therefore it can be used to monitor this disease [17].

Phase angle values are also related to vitamin D levels involved in the regulation of cytokine production; therefore, PA may be a useful tool for assessing these biomarkers in people with excess adipose tissue. Norman et al. [18] suggest that PA can be used as a non-invasive and inexpensive tool to assess the condition of elderly people with disturbed nutritional status (overweight and obesity), diabetes, or the risk of sarcopenia and frailty syndrome [19]. Additionally, age, gender and BMI influence the values of this angle due to changes in the TBW (Total Body Water) in the body. In a study by Fu et al. [6] on a population of 1,729 overweight and obese Chinese people, multiple regression analysis proved that age, gender and BMI were significant ($p<0.05$) independent factors influencing PA. The average angle value for all participants in that population was 5.5°. In older

people, phase angle values decrease significantly compared to younger adults [20].

In the current study, the overall phase angle increased: before the sanatorium treatment at the first measurement point, the average for the entire group was 5.53°, while after the treatment it amounted to 5.69° (Tab. 3). This objectively confirms the positive impact of the spa treatment on the condition of all tissues of the examined participants, despite the fact that most of them were elderly and had metabolic disorders and multi-morbidities.

The results obtained indicate that enhancements in the aforementioned cellular and tissue parameters are linked to well-planned balneotherapy and physiotherapy which, in turn, increase the probability of sustained health improvement. Practical physical activities also allow the patient to learn specific forms of activity which can be continued at home after the treatment. Selecting and learning how to properly perform exercises is the domain of the physiotherapist who is part of the treatment team at the sanatorium [21–23].

Phase angle, measured by bioelectrical impedance analysis, is an important indicator of overall health: a higher phase angle generally reflects better cellular integrity and body function, while a lower phase angle is often observed in older adults, malnourished individuals, and patients with chronic conditions such as HIV/AIDS, tuberculosis, kidney disease, cirrhosis, cancer, or in those with excessive alcohol consumption. Phase angle measurement can also provide valuable insights into hydration status, fluid balance, and swelling. In athletes, it serves as a marker for performance and recovery. Additionally, BIA can be applied both as a screening tool and for monitoring the health status of cancer patients.

The multiple regression test used for statistical calculations (Tab. 5) showed that the increase in the phase angle after sanatorium treatment in the participants was significantly influenced by exercises in the swimming pool ($p<0.001$), balneological treatments ($p<0.024$), and mud compresses ($p<0.001$). Górska and Pijanowska [24] emphasize the advantages of mud treatment due to its numerous properties that normalize body functions by influencing the endocrine glands, the circulatory system and stimulating the functions of the immune system. The recommended programme of balneotherapy and physical therapy [24, 25], designed for spa settings and targeted at individuals with obesity and degenerative joint disease (as in the study group), includes the following core components: brine or sulfide–hydrogen sulfide baths, mud compresses, kinesiotherapy (with stress-relieving exercises particularly recommended in a brine pool), infrared sauna, a low-calorie diet, and health education.

CONCLUSIONS

The study demonstrated that spa treatment increased the phase angle values of the patients from 5.53° before sanatorium stay to 5.69° after the treatment. The combination of balneological and physiotherapeutic therapies employed during the treatment positively influenced cellular function and enhanced tissue condition, as evidenced by the observed increase in phase angle (PA). Furthermore, statistical analysis, including multiple regression tests, revealed that pool exercises, balneological treatments, and mud compresses had the most substantial impact on elevating PA values, underscoring the effectiveness of these interventions in improving overall tissue health. During the sanatorium treatment, the number of people with second-degree obesity and people with first-degree obesity significantly decreased.

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