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REVIEW PAPER

ASSESSMENT OF QUALITATIVE BODY COMPOSITION, INCLUDING PHASE ANGLE, IN THE CONTEXT OF PRIMARY PREVENTION AND SECONDARY PREVENTION OF CARDIOVASCULAR DISEASES (CARDIAC REHABILITATION)

Aleksandra Ślązak, Małgorzata Paprocka-Borowicz

Wroclaw Medical University, Wrocław, Poland
Department of Physiotherapy

Abstract

Cardiovascular diseases (CVDs) are one of the main causes of morbidity and disability worldwide. Due to modern methods of diagnosis and treatment, it is possible to protect patients with acute coronary syndromes from myocardial infarction as well from its early complications. However, the challenge remains to improve the long-term prognosis of CVDs. Analysis of body composition using the bioelectrical impedance (BIA) appears to be a good method for assessing changes in patients' organisms following various cardiac incidents, as well as those participating in rehabilitation programmes. This study aims to provide a complementary analysis of the scientific literature and a critical review of the data from the use of BIA to assess phase angle in people with a history of cardiac diseases. This critical literature review was prepared based on the *Scale for the Assessment of Narrative Review Articles* recommendations. Inclusion criteria included: 1) original publications of a research nature, 2) papers indexed in PubMed, Scopus, Embase databases, 3) full-text articles in English, 4) recent papers published between 2013–2023, 5) papers on the use of BIA with phase angle assessment as a prognostic factor in multiple aspects of health and disease, 6) papers showing changes in body composition in the process of cardiac rehabilitation. Based on a review of PubMed, Scopus and Embase databases, 36, 31 and 114 publications were found, respectively, chosen on the basis of precisely selected keywords and included for further full-text analysis. Exploring the role of the BIA holds lots of hope as a non-invasive method that can be used as a predictive marker for changes in the state of health in various fields of medicine. In young, healthy adults, BIA parameters may be important in identifying risk factors for the development of particular diseases, in predicting the rapid development of disease symptoms and in promoting motivation to lifestyle changes.
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Key words: cardiac rehabilitation, phase angle, electric impedance, MC-AMI, myocardial infarction, KOS-zawał

Corresponding author: Aleksandra Ślązak, Wroclaw Medical University, Department of Physiotherapy, Chałubińskiego 3, 55-355 Wrocław, Poland, e-mail: aleksandra.slazak@student.umw.edu.pl
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INTRODUCTION

The issues of cardiovascular diseases

Cardiovascular diseases (CVDs) remain the leading cause of deaths and the leading cause of morbidity in Europe. Cardiovascular diseases are the cause of 45% of deaths in Europe [1,2]. The prognosis in patients after cardiovascular events (including myocardial infarction) is negatively affected by demographic changes, ageing of the population, exposure to cardiovascular risk factors (smoking, obesity, hypercholesterolaemia, hypertension, diabetes, stress) [3,4]. Cardiovascular diseases are itself the leading cause of mortality <65 years. In Europe, 15% of deaths caused by CVDs are due to high blood glucose levels. Most adults in European countries do not engage in physical activity at an adequate level, with physical inactivity being more common among women than men. Obesity levels in Europe are high among both adults and children, although rates vary considerably from country to country [1,2].

Epidemiology

The number of deaths caused by CVDs in European Society of Cardiology (ESC) member countries far exceeds the number of cancer deaths for both sexes (women N = 887 688, men N = 1.1 million), although in some high-income countries cancer currently causes more deaths than CVDs. In 2020, 19.05 million deaths due to CVDs were estimated worldwide, an increase of 18.71% compared to 2010 [1,2,5].

On the other hand, it has been estimated that in the United States, one person dies every 33 s from CVDs. This results in significant costs of healthcare services, medicines and loss of productivity due to disability or death [6].

Ischemic heart disease, including myocardial infarction, is the most common cause of heart failure due to ischemic myocardial damage [7]. Post myocardial infarction patients may have a number of problems due to, e.g., reduced left ventricular ejection fraction (dyspnoea, peripheral oedema, repeated hospitalisations), valvular defect, cardiac remodelling (recurrence of supraventricular and ventricular arrhythmias). All of these causes result in more frequent hospitalisations of patients, which carries the risk of infectious complications and generates costs. However, despite the widespread use of revascularisation in acute myocardial infarction, mortality after hospital discharge exceeds 10% within the first year and 20% within the next 3 years [7–9].

Complications after myocardial infarction, e.g., heart failure and sudden cardiac death, remain a challenge and a major problem in clinical cardiology [7]. A proper evaluation of health policy, which requires regular monitoring of the clinical epidemiology and treatment of myocardial infarction nationwide, seems important. This indicates the need to intensify primary prevention efforts. Opportunities for health improvement resulting from secondary prevention, especially in cardiac rehabilitation, are also underused [8,10,11].

The role of primary prevention and secondary prevention in ischemic heart disease

There is a worldwide trend towards ageing of the population, with a consequent increase in the incidence of CVDs [12]. Therefore, national programmes for the primary prevention of CVDs in young adults concerning awareness-raising about the harmful effects of nicotinism, promotion of a healthy diet and physical activity are emerging in many countries. Interest in different types of physical activity is also evident. Research is also being conducted on the effects of different types of exercise (high-intensity interval training – HIIT and moderate-intensity continuous training – MICT [13], resistance training [14–16] and electrical muscle stimulation – EMS [17]) on anthropometric, biochemical, as well as body composition parameters in both young healthy adults, the elderly, and occupational groups (e.g., professional soldiers) [13–16]. This provides choice and has a positive impact on broadening awareness of primary prevention [13,18]. Effects on the state of health after cessation of physical activity have also been observed among older people who previously led active lifestyles and participated in regular training [19].

Due to the persistently high post myocardial infarction mortality rate observed over several years, as well as the complications of myocardial infarction, it became necessary to introduce cardiac rehabilitation programmes (recommendation class IA). Many studies have shown the positive impact of cardiac rehabilitation involving physical rehabilitation, but also educational programmes and outpatient care [20].

Due to the alarming statistics, also in Poland (by 2050, the percentage of Poles aged ≥65 will increase from 14.7% to 32.7%), it is to be expected that the number of myocardial infarctions will also increase in the following years [3,9]. In 2017, a national co-ordinated specialist care programme for patients after myocardial infarction called in Polish KOS-zawał – Managed Care after Acute Myocardial Infarction (MC-AMI) – was introduced. This programme provides patients with quick access to rehabilitation, as well as 12 months of outpatient cardiac care with follow-up biochemical testing, treadmill exercise testing, Holter electrocardiogram (ECG) testing and echocardiographic assessment (in order to spot patients eligible for implantable cardioverter defibrillator – ICD) or cardiac resynchronization therapy with cardioverter defibrillator (CRT-D) implantation for primary prevention of sudden cardiac death. Furthermore, dietary and psychological education is provided. The programme has continued to the present day with studies showing its significant clinical benefits [7,21–28].

The hope that comes from the use of bioelectrical impedance

Over the past few years, there has been a significant increase in interest in the use of bioelectrical impedance (BIA) as an easy, accessible, safe method of body composition analysis, in various fields of medicine. Bioelectrical impedance analysis is a technique used primarily to assess muscle mass, hydration and phase angle (PhA). With PhA, the hydration state can be expressed and the quality of cell membranes can be assessed. A pulse of low-intensity current passes through the body and assesses the resistance of particular tissues (resistance – R) providing data on water volume and hydration and the reactance parameter (Xc) assessing the integrity of cell membranes. Current research on PhA is progressing in the direction of showing how physical activity, rehabilitation, and various pharmacological or surgical treatments modify PhA, which in turn leads to a prognostic change in morbidity and mortality. External validation of PhA with other techniques used in clinical practice, such as, e.g., ultrasonography or methods for measuring the muscles mass and handgrip for assessing muscles strength, is important [29].

In a systematic review, Garlini et al. [30] assessed the relationship between phase angle and mortality through a literature review. The phase angle appears to be a good indicator of mortality in a number of clinical settings and can be used in screening for those susceptible to this outcome. In kidney disease, liver disease, patients with human immunodeficiency virus (HIV), chronic obstructive pulmonary disease 100% of publications showed an association between PhA and mortality. Even in clinical settings where there is some discrepancy [heart disease, critically ill intensive care unit (ICU) patients], there are strong indications of an association between reduced PhA values and mortality [30].

Aims

This study aims to provide a complementary analysis of the scientific literature and a critical review of the data from the use of BIA to assess, among other things, PhA in physically active, healthy people, as well as in people rehabilitated due to CVDs. The aim will also be to analyse the global trend in the publication of papers on this topic over the last 10 years (2013–2023).

METHODS

Methodological quality

This critical review of literature was prepared based on the international *Scale for the Assessment of Narrative Review Articles* (SANRA) recommendations for the methodological quality of these types of works [31]. The patient/population, intervention, comparison, outcomes (PICO) strategy [32] was used to formulate a guiding question and literature review for the following components: patient (CVDs prevention), intervention (epidemiology, prevention, prognosis, rehabilitation), control (not applicable), outcomes (PhA, BIA parameters). The *Narrative Review Checklist* was also used in the preparation of the publication in terms of the appropriate standard of content, form and structure of the article [33].

A combination of the following keywords was used during the search: phase angle, myocardial infarction, cardiac rehabilitation, MC-AMI, KOS-zawał, electric impedance.

Qualification procedure

The inclusion criteria were:

- original scientific-clinical publications,
- studies indexed in PubMed, Scopus, Embase databases,
- full-text articles in English,
- recent papers published in the last decade, i.e., 2013–2023,
- papers on the use of electrical BIA with PhA assessment as a prognostic parameter in multiple aspects of health and disease,
- papers showing changes in PhA and body composition in the process of cardiac rehabilitation.

The exclusion criteria were:

- review publications of systematic reviews nature or meta-analysis nature,
- studies indexed in medical databases other than those indicated above,
- articles available only as abstracts, post-conference materials, posters,
- articles published before 2013,
- publications significantly deviating from the leading theme or in a language other than English.

RESULTS

Database searching

In the PubMed database, after using the initial combination of the words "phase angle AND myocardial infarction," 25 records were retrieved after narrowing the search to the last 10 years and to articles in English by entering the following word combinations, the results were consecutively obtained: "phase angle AND myocardial infarction" – 14, "phase angle AND cardiac rehabilitation" – 3, "cardiac rehabilitation AND electric impedance" – 4, "MC-AMI" – 7, "KOS-zawał" – 8.

In the Scopus database, after using the initial combination of the words "phase angle AND myocardial infarction," 28 records were retrieved after narrowing the search to the last 10 years and to articles in English by entering the following word combinations, the results were consecutively obtained: "phase angle AND myocardial infarction" – 13, "phase angle AND cardiac rehabilitation" – 1, "cardiac rehabilitation AND electric impedance" – 3, "MC-AMI" – 7, "KOS-zawał" – 8.

In the Embase database, after using the initial combination of the words "phase angle AND myocardial infarction," 44 records were retrieved after narrowing the search to the last 10 years and to articles in English by entering the following word combinations, the results were consecutively obtained: "phase angle AND myocardial infarction" – 28, "phase angle AND cardiac rehabilitation" – 10, "cardiac rehabilitation AND electric impedance" – 54, "MC-AMI" – 10, "KOS-zawał" – 13.

The PRISMA 2020 flow diagram was helpful to show the scheme for selecting publications for the review [34]. Records identified from databases (N = 185), from registers (N = 5). Records removed before screening: duplicate records removed (N = 49), records moved to others reasons (N = 28). Records screened (N = 113). Records excluded (N = 50). Records sought for retrieval (N = 63). Records not retrieved (N = 6). Records assessed for egilibility (N = 57). Records excluded (N = 16). Finally 38 studies and 3 reports of included studies were used in this review.

Publication review

In a publication by Lira et al. [13], the authors conducted a study on a group of young, healthy, eutrophic men who were divided into groups and took part in 5-week training sessions. One group did HIIT, while the other did MICT. The study aimed to evaluate plasma lipidograms taken at different, well-defined stages of training and to assess PhA and heart rate. Both HIIT and MICT training resulted in an increase in lipid parameters: high-density lipoprotein (HDL), low-density lipoprotein, total cholesterol and triglicerydes in the acute post-exercise phase; however, only HIIT showed a trend towards a chronic increase in HDL levels. The study did not result in a significant change in phase angle values after the training session. Previous research by Campa et al. [16] on a group of elderly men and women, showed a positive effect of resistance training on PhA changes. It was therefore hypothesised that the good physical condition of the participants in this study [13] (eutrophic, physically active, baseline healthy men) may have explained the lack of change in PhA values [13,16].

It can be assumed that the improvement in body quality composition and PhA is influenced by the length of systematic training. This was demonstrated, among other things, in a study on young men who underwent 6 months of physical training according to the Brazilian military guidelines manual. At the end of the 6-month training cycle, a significant increase in PhA and reactance measured by bioimpedance, an improvement in body composition parameters (bone mineral content, lean soft tissue) measured by dual energy X-ray absorptiometry (DXA) and a decrease in serum glucose levels were confirmed [14].

Freitas et al. [19] examined a group of elderly people who had maintained a regular training cycle for 6 months. For the study, the subjects would undergo 2 weeks of de-training involving a discontinuation of training and a reduction in their usual daily physical activity. The study showed a significant decrease in PhA; however, this was not accompanied by a reduction in muscle strength. This indicates increased cell death or greater fragility of cell membranes. A lower Xc with a normal R (no change in R was observed; this most likely related to the short period of de-training, which did not alter body composition and total body water (TBW) indicated a change in body water ratio (less intracellular water – ICW, more extracellular water – ECW). These findings highlight how important it is to maintain a structured exercise regimen in older people and demonstrate the role of PhA as a sensitive indicator to detect acute changes in muscle cell integrity when changes in training occur [19]. The phase angle can be used as a marker for predicting morbidity and mortality in a variety of clinical situations, as well as in initially healthy individuals.

Also of interest is a study in the Danish population, which assessed the change in PhA values >6 years in people without primary chronic diseases and then examined what impact this change had on morbidity and mortality over a further 18-year follow-up. A statistically significant association was found between the decline in PhA over the 6-year period and the risk of total mortality and cardiovascular incidents <50% ($p < 0.001$). In contrast, the highest risk was observed <5% (PhA = 2.6) [35].

Similarly, a study by Saad et al. [12] examined a group of 402 elderly patients, aged >60 years (M±SD 70.4±6.9 years, 74% female), treated in primary healthcare. This included taking anthropometric measurements, measuring blood pressure, assessing the homeostatic model assessment (homa index) and the global cardiovascular risk score that considers such variables as age, cholesterol fractions, smoking, systolic blood pressure, diabetes and gender, and measuring PhA by bioimpedance. The study showed an independent relationship between PhA values and estimated global cardiovascular risk in the elderly population.

An increasing role has been attributed to vascular endothelial function in the development of early atherosclerosis. Kwaśniewska et al. [18] found that even subtle changes in the metabolic profile can affect microvascular endothelial function. Therefore, Pigłowska et al. [36] conducted a 25-year cohort study on healthy, physically active men, comprehensively assessing the relationship between body quality composition and cardiometabolic parameters and assessing endothelial function with the non-invasive Endo-Pat2000 device (assessing the reactive hyperaemia index – RHI). Among metabolic parameters, HDL cholesterol and uric acid were significantly associated with most body composition parameters. In light of the endothelial assessment, there was a negative correlation between RHI and body weight and a positive correlation between RHI and body cell mass, calcium and potassium. Engaging in regular physical activity and maintaining a proper metabolic state throughout early and middle adulthood can have a beneficial effect on body composition parameters and prevent fat-free mass decline and endothelial dysfunction in old age.

Another study that focused on assessing the degree of nutrition and body quality composition in cardiac patients was that by Popiolek-Kalisz et al. [37]. As part of the study, the researchers examined patients with chronic coronary syndrome and performed coronary angiography, as well as BIA and echocardiography on them. It was also assessed the patients' Canadian Cardiovascular Society (CCS), Nutritional Risk Score 2002 (NRS 2002) and BMI scores. It was found a moderate inverse correlation between the NRS 2002 score and PhA measured at 50 kHz. The analysis of clinical parameters showed a significant correlation between NRS 2002 and CCS score. The left ventricular ejection fraction was correlated with hydration parameters assessed by BIA: positively with intracellular fluid ($p < 0.02$), negatively with extracellular fluid ($p < 0.02$). Malnutrition was associated with increased angina pectoris symptoms, mainly in women.

A study by Sala et al. [15] on Brazilian cadets attending the Brazilian Army Cadet Preparatory School, training for 7 months according to standard military training or military sports training protocol, assessed the cadets' body composition by BIA and DXA. In this group of military personnel, BIA and DXA methods showed consistent changes, including an increase in lean mass and a consistent percentage of fat mass in both training groups. The results regarding fat mass are less consistent in other studies on the military population. Finnish servicemen training for 6–12 months showed an increase in total fat mass (at normal body weight), but a decrease in visceral adipose mass. Intense physical activity promotes a greater reduction in visceral rather than subcutaneous adipose tissue in people who train intensively, even with weight gain.

In their study on a large group of patients with stable heart failure (406 outpatients), Bernal-Ceballos et al. [38] compared the results of bioimpedance parameters performed with single- and multi-frequency devices, finding good agreement in the classification of hydration status and body cell mass (the results of this study show a strong correlation in all BIA parameters: R, Xc, PhA between the 2 devices); however, due to the variability reported in previous studies, caution is advisable when assessing Xc and PhA.

Yokomachi et al. [39] examined a group of 590 patients after cardiac rehabilitation, in which BIA parameters (skeletal muscle mass and water composition), as well as the Controlling Nutritional Status (CONUT) score [including the assessment of biochemical parameters: albumin (Alb), haemoglobin (Hgb), peripheral lymphocytes and total cholesterol], and ultrasound measurement of the thigh quadriceps muscle thickness, handgrip strength and gait speed were taken into account. The study found that phase angle correlates with Alb and Hgb levels in women. Further, with an ECW/TBW ratio of <0.4, both PhA and skeletal muscle mass index (SMI) are independent determinants of handgrip strength and logarithmic thigh thickness; however, for ECW/TBW ≥0.4, PhA was a stronger independent determinant of handgrip strength and logarithmic thigh muscle thickness in people with chronic heart failure (SMI is elevated if oedema occurs). This demonstrates that PhA is a good marker of sarcopenia and malnutrition in patients with cardiovascular disease, including chronic heart failure. In this study, the cut-off point for sarcopenia was 4.65° in men and 3.95° in women.

In another study, Hirose et al. [40] examined 412 patients with various cardiac conditions, including those after cardiac surgery (valve replacement, coronary artery bypass grafting, aortic aneurysm surgery) using testing methods such as those above (CONUT, BIA, ultrasound, hand-held dynamometer) as well as the Short Physical Performance Battery (SPPB) test examining the physical activity of the elderly. They found a positive correlation of PhA and SMI with CONUT, Alb and Hgb results in men (but PhA was more strongly associated with these); in women, PhA but not SMI was associated with Alb and Hgb; PhA and SMI correlated positively with BMI, handgrip strength, knee extension strength and SPPB score in both sexes. Sarcopenia was found in 31.6% of men and 32.4% of women, and cachexia in 11.5% and 14.1%, respectively. In this study, the PhA cut-off point for sarcopenia in patients with various cardiac conditions was 4.55 for men and 4.25 for women (these values differed from those calculated by Yokomachi et al. [39]). The PhA cut-off point for cachexia in men was 4.15; however, no value could be determined in women. Multivariate regression analysis showed that grip strength and brain natriuretic peptide (BNP) were independent determinants of SMI, whereas grip strength, BNP and Hgb were independent determinants of PhA. Thus, PhA appears to be a useful marker of sarcopenia, malnutrition and cachexia in people hospitalised for cardiovascular disease [40].

In contrast, a study by Scicchitano et al. [41] showed that the main determinant of phase angle values in heart failure patients (both acute and chronic) is hyperaemia and, in particular, the calculated relative plasma volume status (PVS). Hyperaemia was assessed by examining such parameters as the presence of peripheral oedema, BNP levels, blood urea nitrogen (BUN) to creatinine ratio and PVS. In turn, nutritional status (assessed by the geriatric malnutrition risk index) was found to have a marginal effect on PhA change.

A study by Kawakami et al. [42] examined a group of patients with chronic heart failure. It was found that PhA was related to handgrip strength but not to SMI, SPPB and one-leg stand time. It was found that the PhA was not related to muscle mass or physical function in these patients. Increased PhA may be influenced by improvements in muscle quality rather than simply greater muscle mass and fitness. Handgrip strength is an important parameter that may improve the prognosis of patients with chronic heart failure.

Salmons et al. [43] examined obese patients with heart failure with preserved ejection fraction in terms of cardiorespiratory fitness (single photon emission computed tomography spiroergometry), BIA, and biochemical parameters. It was found that patients with higher PhA (above a mean PhA of 5.8°) showed better peak oxygen consumption (VO_2) than those with lower PhA. Importantly, the results of these analyses show a relationship between PhA and peak VO_2, independent of fat free mass index. Like the study by Kawakami et al. [42], this suggests that the interactions of PhA, body fat and muscle quantity and quality are more important in predicting cardiorespiratory fitness than the analysis of muscle quantity alone [43].

A study by Portugal et al. [44] showed that people with a higher PhA value had a lower risk of a first cardiovascular event (myocardial infarction, stroke, angina pectoris). In turn, a study by Massari et al. [45] aimed to investigate the impact of the 4 parameters responsible for hyperaemia (BNP, PVS, hydration index – HI, blood urea nitrogen/creatinine ratio – BUN/Cr) on mortality in a population with acute and chronic heart failure. As mentioned above, these parameters were BNP, PVS calculated using the Duarte formula (100-Hematocrit%)/Hgb (g/dl) (responsible for "intravascular" hyperaemia), HI measured by bioelectrical impedance vector analysis (BIVA) ("peripheral" hyperaemia) and BUN/Cr ("venous" hyperaemia). After a median follow-up of 463 days, the following cut-off points were identified: for BNP >441 pg/ml, for PVS >5.3 l/g, for HI >73.8%, for BUN/Cr >25. If these values are exceeded, with all 4 criteria met, the probability of mortality rises to 40%.

On the other hand, Ogawa et al. [46] examined the relationship between arterial stiffness (assessed by the cardio-ankle vascular index – CAVI) with physical fitness in patients with heart failure. A significant correlation was found between increased arterial stiffness and the occurrence of sarcopenia. Age, handgrip strength, 6-minute walk test (6MWT), 5-metre walk speed (5MWS) and 5 times sit-to-stand test (5RSST) scores were all associated with CAVI. It has been suggested that in order to improve cardiac function it may be advisable to improve physical fitness and thus reduce arterial stiffness.

Razzera et al. [47] conducted a study evaluating the effect of BIA parameters on critically ill ICU patients. In critically ill patients, the stress of being placed in the ICU is related to high inflammation and protein catabolism, as well as reduced efficiency of protein utilisation leading to muscle dysfunction and impaired contractility. Thus, early identification of patients at high nutritional risk is of paramount importance, and using a malnutrition risk screening tool as the first step of a nutritional care plan would be highly beneficial. In ICU patients, nutritional risk assessment is limited because applying scales such as The Nutrition Risk in Critically Ill Score and NRS 2002 requires data that are not always available at the time of admission. As such, new prognostic methods are being sought. According to that study, a PhA of <5.5% showed a 79% accuracy in identifying patients at high nutritional risk and was associated with a twofold higher risk of ICU stay >5 days. Overhydration was a significant predictor of mortality.

Phase angle assessment has also found its way into cardiac surgery. Assessing PhA by BIA and handgrip strength in patients before cardiac surgery, Panagidi et al. [48] found a positive correlation of PhA with handgrip strength (HS) ($p < 0.005$) and a negative correlation with the European System for Cardiac Operative Risk Evaluation II score ($p < 0.005$), which assesses the risk of death after cardiac surgery. The combination of low preoperative PhA and HS values was significantly associated with a higher risk of death from any cause at 12-month follow-up and with prolonged ICU stay (patients with PhA <5.15 and HS <25.5 were 5 times more likely to die during this follow-up). The link between PhA and HS appears to be a promising prognostic marker in patients undergoing cardiac surgery.

It is worrying that cardiac rehabilitation after myocardial infarction is used by far fewer women than men (socio-economic reasons); hence, the long-term prognosis of women after myocardial infarction is worse than that of men. In a study by Wilkosz et al. [22], there were no significant differences in major adverse cardiac and cerebrovascular event (MACCE) rates between the 2 sexes at a 12-month follow-up of patients in MC-AMI. This shows that women need to be encouraged to participate in MC-AMI and that rehabilitation programmes must be tailored to women's needs (e.g., through online rehabilitation and hybrid rehabilitation).

In Poland, MC-AMI allows patients to participate in physical exercise as part of telerehabilitation. This mode of early post-myocardial infarction rehabilitation was evaluated by Orzechowski et al. [24] and the results after a 12-month follow-up showed that hybrid cardiac telerehabilitation (HTR) is a feasible, safe and patient-acceptable form of rehabilitation. Participation in HTR rehabilitation was associated with a significantly lower risk of all-cause death than in those not undergoing rehabilitation. Of great importance in this were the initial education courses on how to use the equipment (monitoring ECG electrodes, uploading ECG results, completing a daily well-being questionnaire before training), education regarding worrying symptoms and well-being, psychologist visits and a week of controlled exercise in the outpatient clinic under the supervision of a rehabilitation therapist.

The Polish MC-AMI programme (KOS-zawał) was also examined by Wita et al. [7]. In a single-centre study, the association between participation in MC-AMI and MACCE at 12-month follow-up was investigated. The results were very positive as there was 40% less MACCE in the group participating in MC-AMI; in addition, patients were more likely to receive cardiac rehabilitation (98% vs. 14%), had more elective revascularisation (coronary artery bypass graft – CABG 9.8% vs. 4.9%, $p < 0.001$; percutaneous coronary intervention – PCI 3.0% vs. 2.1%, $p < 0.05$); and were more likely to have an ICD implanted (2.8% vs. 0.6%, $p < 0.05$) compared to the control group.

Another study by Wita et al. [25], conducted on a large group of patients (>10 000 from 16 acute coronary syndrome treatment centres) from across Poland's Śląskie Voivodeship (Silesian Cardiovascular Database registry) found a 38% reduction in all-cause mortality compared to the control group (after propensity matching) at 12-month follow-up. This effect persisted even after the programme ended. After analysing the different MC-AMI stages, it was found that not only CR but also follow-up outpatient care with education had an impact on reducing overall mortality.

In contrast, Gąsior et al. [27] studied patients with previously diagnosed heart failure who had undergone a myocardial infarction and agreed to participate in the MC-AMI programme. The study group was assembled between November 2017 and December 2020, ultimately including 2268 patients. The study showed that participation in MC-AMI was associated with lower rates of stroke (perhaps more frequent cardiac follow-up results in earlier detection of AF and better treatment control), hospitalisation for HF and all-cause mortality (16.8% vs. 10%, $p < 0.01$ after propensity score matching) at 12-month follow-up. As for the decrease in mortality, this value was confirmed by Kubielas et al. [21] who also estimated that the costs incurred by the programme's participants were higher than those of non-participants. However, the benefits of this programme far outweigh the costs [28].

As early as the first months of the programme, Kułach et al. [23] already found a 45% decrease in MACCE – death, myocardial reinfarction, hospitalisation for HF – at 3-month follow-up in patients who agreed to participate in MC-AMI. Further, old age, male sex, peri-infarction atrial fibrillation, peripheral artery disease, and a history of unstable angina pectoris were significantly associated with MACCE.

The issue of PhA assessment in patients after myocardial infarction was examined by Azevedo-Queiros et al. [5], who assessed BIA parameters on day 4 after AMI and observed short- and long-term adverse effects for up to 12 months. Patients with low PhA had a longer infarct-related length of stay compared to patients with normal PhA (Me = 14 vs. 8 days, $p < 0.007$) and a shorter time to death (Me = 320 vs. 354 days, $p < 0.024$). The researchers did not find a correlation between low PhA and long-term adverse effects, nor did they link the number of ischaemic heart disease risk factors to low PhA, probably due to the small sample size. Further, it was suggested that PhA measurement should be performed earlier after an AMI incident (rather than on day 4, as in their study) and repeated during hospitalisation.

As early as 2017, a study by Suzuki et al. [49] on patients participating in a 3-month rehabilitation programme after PCI-treated myocardial infarction and after CABG (mainly due to stable angina pectoris, unstable angina pectoris or silent myocardial ischaemia), looked for predictors of improved exercise capacity in rehabilitated patients. At the start of the study, age- and sex-adjusted predicted peak oxygen consumption during cardiopulmonary exercise test the percentage of predicted peak oxygen uptake (%pred-PVO_2), maximum thigh quadriceps isometric strength (QIS) and Hgb were significantly higher, and CRP significantly lower in the post-CABG patients than in the AMI group. After rehabilitation, PVO_2, QIS, Hgb and CRP improved significantly in both groups, but the magnitude of this improvement was more significant in patients after CABG. In the CABG group, the predictors of improved exercise capacity were baseline BNP, the percentage change in QIS, and Hgb, while the only predictor in the AMI group was %pred-PVO_2. Interestingly, baseline maximal QIS was lower than in the AMI group while baseline lower limb muscle mass was similar in both groups, consistent with the reported effects of anaemia and high CRP on reduced muscle strength. This suggests that correcting anaemia and enhancing QIS may improve exercise capacity after cardiac rehabilitation in these patients. Limitations of this study included the fact that there are no data on the frequency and intensity of exercises performed at home (there were about 19 controlled exercise sessions in each group, the remaining exercises up to 3 months were patient-controlled exercises).

In a study by Tuesta et al. [50], the authors evaluated the effects of cardiac rehabilitation, during which the number of exercise sessions (22–36 sessions) was adjusted according to the cardiovascular risk of individual cardiac patient profiles (4 profiles were distinguished). It was found improvements in cardiorespiratory fitness, life quality, as well as in the emotional sphere, with mean scores showing high individual variability. Furthermore, it was pointed out that expert positions on the optimal duration of a rehabilitation programme for patients are still unclear [50,51]. It is recommended that the minimum number of training sessions should be between 24, and preferably 36 sessions [50,52].

Matsuo et al. [17] in their study looked at a group of patients hospitalised for acute heart failure. It was wanted to see if the EMS method could reduce muscle loss in these patients. It was conducted a 2-week cycle of cardiac rehabilitation during which, in addition to standard rehabilitation, EMS was applied to the right lower limb for 20 min every day, 5 days a week. By doing an ultrasound examination of the thickness of the quadriceps femoris muscle and assessing muscle mass by BIA, a statistically significant reduction in muscle mass loss in the limb subjected to EMS was proven. No significant EMS-related adverse events were recorded. The method of rehabilitation with the parallel use of EMS appears promising in severe patients, practically as soon as hospitalisation for HF decompensation begins, as it is safe and well tolerated by patients.

Hosseini et al. [53], by conducting complex statistical analyses, found that the variability of PhA values in patients with cardiovascular diseases depends primarily on total body water, intracellular water, basal metabolism, sex and age.

CONCLUSIONS

Exploring the role of BIA, as well as the assessment of PhA by examining R-resistance and Xc-reactance, holds a lot of hope as a easily accessible, non-invasive method that can be used as a predictive marker of deterioration or improvement in patient's condition in various medical fields.

In young, healthy adults, on the other hand, BIA parameters may be relevant in predicting the rapid development of disease symptoms and, at the same time, appear to mobilise to improve exercise capacity and to implement lifestyle changes, both in active healthy individuals and in patients undergoing rehabilitation.

The above studies show that PhA appears to be an independent predictive marker of worse prognosis, and that changes in other parameters assessed by BIA may precede the emergence of clinical symptoms (e.g., assessment of extracellular water content) or dispel doubts about fat or muscle tissue content not verifiable by BMI measurement alone.

In published studies, it is possible to see attempts to assess changes in body composition parameters in patients after different periods of training or rehabilitation. The duration and type of training is relevant for changing these parameters, which seems promising for determining the optimal rehabilitation programme and for setting PhA cut-off values for specific clinical settings.

Limitations

This review of publications has some limitations that must be taken into account. The analysed publications were sourced from 3 databases. In the future, it would be worth expanding the number of assessed publications to include those retrieved from other databases, and to also consider non-English publications. The database review period lasted 1 month. Given the growing interest in the topic of PhA and the dynamically emerging new publications referring to BIA in the field of cardiology, in the future, new studies published in 2023/2024 are also worth taking into account.

Author contributions

Research concept: Aleksandra Ślązak, Małgorzata Paprocka-Borowicz
Research methodology: Aleksandra Ślązak, Małgorzata Paprocka-Borowicz
Collecting material: Aleksandra Ślązak, Małgorzata Paprocka-Borowicz
Interpretation of results: Aleksandra Ślązak, Małgorzata Paprocka-Borowicz
References: Aleksandra Ślązak, Małgorzata Paprocka-Borowicz

REFERENCES

1. World Health Organization [Internet]. Geneva: The Organization [cited 2023 Nov 27]. Cardiovascular diseases (CVDS). Available from: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds).
2. Timmis A, Townsend N, Gale CP, Torbica A, Lettino M, Petersen SE, et al. European Society of Cardiology: Cardiovascular Disease Statistics 2019. Eur Heart J. 2020;41(1):12–85. https://doi.org/10.1093/eurheartj/ehz859.
3. Jankowski P, Gasior M, Gierlotka M, Cegłowska U, Słomka M, Eysymontt Z, et al. Coordinated care after myocardial infarction. The statement of the Polish Cardiac Society and the Agency for Health Technology Assessment and Tariff System. Kardiol Pol. 2016;74(8):800–11. https://doi.org/10.5603/KP.2016.0118.
4. Feusette P, Gierlotka M, Krajewska Redelbach I, Kamińska Kegel A, Warzecha S, Kalinowska L, et al. Comprehensive coordinated care after myocardial infarction (KOS Zawał): a patient's perspective. Kardiol Pol. 2019;77(5):568–70. https://doi.org/10.5603/KP.a2019.0038.
5. Azevedo Queiroz S, Gonzalez MC, Monteiro Bispo da Silva A, de Araujo Costa JC, de Oliveira DR, de Sousa IM, et al. Is the standardized phase angle a predictor of short- and long-term adverse cardiovascular events in patients with acute myocardial infarction? A cohort study. Nutrition. 2022;103–104:111774. https://doi.org/10.1016/j.nut.2022.111774.
6. Centers for Disease Control and Prevention (CDC) [Internet]. [cited 2021 Nov 15]. Heart disease facts. Available from: https://www.cdc.gov/heart-disease/data-research/facts-stats/index.html.
7. Wita K, Wilkosz K, Wita M, Kułach A, Wybraniec MT, Polak M, et al. Managed Care after Acute Myocardial Infarction (MC-AMI) – a Poland's nationwide program of comprehensive post-MI care – improves prognosis in 12-month follow-up. Preliminary experience from a single high-volume center. Int J Cardiol. 2019;296:8–14. https://doi.org/10.5114/aoms.2019.85649.
8. Gierlotka M, Zdrojewski T, Wojtyniak B, Poloński L, Stokwiszewski J, Gasior M, et al. Incidence, treatment, in-hospital mortality and one-year outcomes of acute myocardial infarction in Poland in 2009-2012 – nationwide AMI-PL database. Kardiol Pol. 2015;73(3):142–58. https://doi.org/10.5603/KP.a2014.0213.
9. Jankowski P, Czarnecka D, Badacz L, Bogacki P, Dubiel JS, Grodecki J, et al. Practice setting and secondary prevention of coronary artery disease. Arch Med Sci. 2018;14(5):979–87. https://doi.org/10.5114/aoms.2017.65236.
10. Townsend N, Wilson L, Bhatnagar P, Wickramasinghe K, Rayner M, Nichols M. Cardiovascular disease in Europe: epidemiological update 2016. Europ Heart J. 2016;37(42):3232–3245. https://doi.org/10.1093/eurheartj/ehw334.
11. Gale CP, Allan V, Cattle BA, Hall AS, West RM, Timmis A, et al. Trends in hospital treatments, including revascularisation, following acute myocardial infarction, 2003-2010: a multilevel and relative survival analysis for the National Institute for Cardiovascular Outcomes Research (NICOR). Heart. 2014;100(7):582–9. https://doi.org/10.1136/heartjnl-2013-304517.
12. Saad MAN, Jorge AJL, de Andrade Martins W, Cardoso GP, dos Santos MMS, Rosa MLG, et al. Phase angle measured by electrical bioimpedance and global cardiovascular risk in older adults. Geriatr Gerontol Int. 2018;18(5):732–7. https://doi.org/10.1111/ggi.13241.
13. Lira FS, Antunes BM, Figueiredo C, Campos EZ, Panissa VLG, St-Pierre DH, et al. Impact of 5-week high-intensity interval training on indices of cardio metabolic health in men. Diabetes Metab Syndr Clin Res Rev. 2019;13(2):1359–1364. https://doi.org/10.1016/j.dsx.2019.02.006.
14. Langer RD, Silva AM, Borges JH, Cirolini VX, Páscoa MA, Guerra-Júnior G, et al. Physical training over 6 months is associated with improved changes in phase angle, body composition, and blood glucose in healthy young males. Am J Hum Biol. 2019;31(5):e23275. https://doi.org/10.1002/ajhb.23275.

15. Sala CA, Gobbo LA, David Langer R, Marini E, Buffa R, Borges JH, et al. Effect of Physical Training on Body Composition in Brazilian Military. Int J Environ Res Public Health. 2022;19(3):1732. https://doi.org/10.3390/ijerph19031732.
16. Campa F, Colognesi LA, Moro T, Paoli A, Casolo A, et al. Effect of resistance training on bioelectrical phase angle in older adults: a systematic review with meta-analysis of randomized controlled trials. Rev Endocr Metab Disord. 2023;24:439–49. https://doi.org/10.1007/s11154-022-09747-4.
17. Matsuo K, Yoneki K, Tatsuki H, Mibu K, Furuzono K, Kobayashi K, et al. Effect of Electrical Muscle Stimulation on the Reduction of Muscle Volume Loss in Acute Heart Failure Patients. Int Heart J. 2022;63(6):1141–9. https://doi.org/10.1536/ihj.22-207.
18. Kwaśniewska M, Kozińska J, Dziankowska-Zaborszczyk E, Kostka T, Jegier A, Rębowska E, et al. The impact of long-term changes in metabolic status on cardiovascular biomarkers and microvascular endothelial function in middle-aged men: a 25-year prospective study. Diabetol Metab Syndr. 2015;7(1). https://doi.org/10.1186/s13098-015-0074-8.
19. Freitas SP, Júdice PB, Hetherington-Rauth M, Magalhães JP, Correia IR, Lopes JM, et al. The impact of 2 weeks of detraining on phase angle, BIVA patterns, and muscle strength in trained older adults. Exp Gerontol. 2021;144:111175. https://doi.org/10.1016/j.exger.2020.111175.
20. Anderson L, Thompson DR, Oldridge N, Zwisler AD, Rees K, Martin N, et al. Exercise-based cardiac rehabilitation for coronary heart disease. Cochrane Db Syst Rev. 2016(1). https://doi.org/10.1002/14651858.cd001800.pub3.
21. Kubielas G, Diakowska D, Uchmanowicz I. Survival analysis of patients with acute coronary syndrome receiving comprehensive coordinated care after myocardial infarction (KOS-Zawał). Kardiol Pol. 2022;80(3):315–21. https://doi.org/10.33963/KP.A2022.0035.
22. Wilkosz K, Wybraniec MT, Wita M, Fluder J, Matla M, Chmurawa J, et al. Does gender affect the outcomes of patients in program of managed care for acute myocardial infarction. J Rehabil Med. 2021;53:238. https://doi.org/10.2340/16501977-2848.
23. Kułach A, Wita K, Wita M, Wybraniec MT, Wilkosz K, Polak M, et al. Managed Care after Acute Myocardial Infarction (KOS-zawał) reduces major adverse cardiovascular events by 45% in 3-month follow-up-single-center results of Poland's National Health Fund program of comprehensive post-myocardial infarction care Clinical research Cardiology. Arch Med Sci. 2020;16(3):551–8. https://doi.org/10.5114/aoms.2019.85649.
24. Orzechowski P, Kowalik I, Piotrowicz E. Feasibility of hybrid telerehabilitation as a component of Managed Care after Acute Myocardial Infarction (MC-AMI) in a 12-month follow-up: experience from a single center. Pol Arch Intern Med. 2023;133(9). https://doi.org/10.20452/pamw.16456.
25. Wita K, Kułach A, Sikora J, Fluder J, Nowalany-Kozielska E, Milewski K, et al. Clinical Medicine Managed Care after Acute Myocardial Infarction (MC-AMI) Reduces Total Mortality in 12-Month Follow-Up-Results from a Poland's National Health Fund Program of Comprehensive Post-MI Care – A Population-Wide Analysis. J Clin Med. 2020;9:3178. https://doi.org/10.3390/jcm9103178.
26. Kułach A, Wilkosz K, Wybraniec M, Wieczorek P, Gąsior Z, Mizia-Stec K, et al. Managed Care after Acute Myocardial Infarction (MC-AMI) – Poland's nationwide program of comprehensive post-MI care improves prognosis in 2-year follow-up. A single high-volume center intention-to-treat analysis. Kardiol Pol. 2023;81(2):123–31. https://doi.org/10.33963/kp.a2022.0260.
27. Gąsior M, Wita K, Buszman P, Mizia-Stec K, Kalarus Z, Nowalany-Kozielska E, et al. Managed Care after Acute Myocardial Infarction (MC-AMI) improves prognosis in AMI survivors with pre-existing heart failure: A propensity score matching analysis of Polish nationwide program of comprehensive post-MI care. Kardiol Pol. 2022;80(3):302–6. https://doi.org/10.33963/KP.A2022.0029.
28. Kubielas G, Diakowska D, Czapla M, Uchmanowicz B, Berezowski J, Uchmanowicz I. Comprehensive Cardiac Care: How Much Does It Cost? Int J Environ Res Public Health. 2023;20(6):4980. https://doi.org/10.3390/ijerph20064980.
29. Bellido D, García-García C, Talluri A, Lukaski HC, Garcia-Almeda JM, et al. Future lines of research on phase angle: Strengths and limitations. Rev Endocr Metab Disord. 2023;24:563–83. https://doi.org/10.1007/s11154-023-09803-7.
30. Garlini LM, Alves FD, Ceretta LB, Perry IS, Souza GC, Clausell NO. Phase angle and mortality: a systematic review. Eur J Clinic Nutr. 2018;73(4):495–508. https://doi.org/10.1038/s41430-018-0159-1.
31. Baethge C, Goldbeck-Wood S, Mertens S. SANRA – a scale for the quality assessment of narrative review articles. 2019;5. https://doi.org/10.1186/s41073-019-0064-8.
32. Brown D. A Review of the PubMed PICO Tool: Using Evidence-Based Practice in Health Education. Health Promot Pract. 2020;21(4):496–8. https://doi.org/10.1177/1524839919893361.
33. Green BN, Johnson CD, Adams A. Writing narrative literature reviews for peer-reviewed journals: secrets of the

trade. J Sports Chiropr Rehabil. 2001;15:5–19. https://doi.org/10.1016/S0899-3467(07)60142-6.
34. PRISMA [Internet]. [cited 2023 Oct 17]. PRISMA 2020 flow diagram. Available from: https://www.prisma-statement.org/prisma-2020-flow-diagram.
35. Langer RD, Ward LC, Larsen SC, Heitmann BL. Can change in phase angle predict the risk of morbidity and mortality during an 18-year follow-up period? A cohort study among adults. Front Nutr. 2023;10. https://doi.org/10.3389/fnut.2023.1157531.
36. Pigłowska M, Kostka T, Drygas W, Jegier A, Leszczyńska J, Bill-Bielecka M, et al. Body composition, nutritional status, and endothelial function in physically active men without metabolic syndrome – a 25 year cohort study. Lipids Health Dis. 2016;15(1). https://doi.org/10.1186/S12944-016-0249-9.
37. Popiolek-Kalisz J, Blaszczak P. Nutritional Status of Coronary Artery Disease Patients – Preliminary Results. Int J Environ Res Public Health. 2023;20(4). https://doi.org/10.3390/ijerph20043464.
38. Bernal-Ceballos F, Wacher-Rodarte NH, Orea-Tejeda A, Hernández-Gilsoul T, Castillo-Martínez L. Bioimpedance vector analysis in stable chronic heart failure patients: Level of agreement between single and multiple frequency devices. Clin Nutr ESPEN. 2021;43:206–11. https://doi.org/10.1016/j.clnesp.2021.04.015.
39. Yokomachi J, Fukuda T, Mizushima Y, Nozawa N, Ishizaka H, Matsumoto K, et al. Clinical usefulness of phase angle as an indicator of muscle wasting and malnutrition in inpatients with cardiovascular diseases. Asia Pac J Clin Nutr. 2023;32(3):297–307. https://doi.org/10.6133/apjcn.202309_32(3).0001.
40. Hirose S, Nakajima T, Nozawa N, Katayanagi S, Ishizaka H, Mizushima Y, et al. Phase Angle as an Indicator of Sarcopenia, Malnutrition, and Cachexia in Inpatients with Cardiovascular Diseases. J Clin Med. 2020;9(8):2554. https://doi.org/10.3390/jcm9082554.
41. Scicchitano P, Ciccone MM, Passantino A, Valle R, De Palo M, Sasanelli P, et al. Congestion and nutrition as determinants of bioelectrical phase angle in heart failure. Heart Lung. 2020;49(6):724–8. https://doi.org/10.1016/j.hrtlng.2020.07.007.
42. Kawakami W, Umehara T, Iwamoto Y, Takahashi M, Katayama N. Phase Angle Is Associated With Handgrip Strength in Older Patients With Heart Failure. Ann Rehabil Med. 2023;47(2):129–37. https://doi.org/10.5535/ARM.22138.
43. Salmons HM, Imran Ahmed MBBS S, Billingsley MS HE, Markley R, Damonte JI, Del Buono MG, et al. Skeletal muscle quality, measured via phase angle, and cardiorespiratory fitness in patients with obesity and heart failure with preserved ejection fraction. Nutrition. 2023; 116:12163. https://doi.org/10.1016/j.nut.2023.112163.
44. Portugal MRC, Canella DS, Curioni CC, Bezerra FF, Faerstein E, Neves MF, et al. Bioelectrical impedance analysis–derived phase angle is related to risk scores of a first cardiovascular event in adults. Nutrition. 2020;78:110865. https://doi.org/10.1016/J.NUT.2020.110865.
45. Massari F, Scicchitano P, Iacoviello M, Passantino A, Guida P, Sanasi M, et al. Multiparametric approach to congestion for predicting long-term survival in heart failure. J Cardiol. 2020;75(1):47–52. https://doi.org/10.1016/j.jjcc.2019.05.017.
46. Akihiro O, Shimizu K, Nagahami T, Maruoka H, Shirai K. Physical Function and Cardio-Ankle Vascular Index in Elderly Heart Failure Patients. Int Heart J. 2020;61(4). https://doi.org/10.1536/ihj.20-058.
47. Razzera EL, Marcadenti A, Rovedder SW, Alves FD, Fink J da S, Silva FM. Parameters of Bioelectrical Impedance Are Good Predictors of Nutrition Risk, Length of Stay, and Mortality in Critically Ill Patients: A Prospective Cohort Study. J Paren Ent Nutr. 2020;44(5):849–54. https://doi.org/10.1002/jpen.1694.
48. Panagidi M, Papazoglou AS, Moysidis DV, Vlachopoulou E, Papadakis M, Kouidi E, et al. Prognostic value of combined preoperative phase angle and handgrip strength in cardiac surgery. J Cardiothorac Surg. 2022; 17(1). https://doi.org/10.1186/S13019-022-01970-Z.
49. Suzuki Y, Ito K, Yamamoto K, Fukui N, Yanagi H, Kitagaki K, et al. Predictors of improvements in exercise capacity during cardiac rehabilitation in the recovery phase after coronary artery bypass graft surgery versus acute myocardial infarction. Heart Vessels. 2018;33(4):358–66. https://doi.org/10.1007/s00380-017-1076-2.
50. Tuesta M, Alvarez C, Pedemonte O, Araneda OF, Manríquez-Villarroel P, Berthelon P, et al. Average and Interindividual Effects to a Comprehensive Cardiovascular Rehabilitation Program. Int J Environ Res Public Health. 2023;20(1):261. https://doi.org/10.3390/ijerph20010261.
51. Price KJ, Gordon BA, Bird SR, Benson AC. A review of guidelines for cardiac rehabilitation exercise programmes: Is there an international consensus? Eur J Prev Cardiol. 2016;23(16):1715–33. https://doi.org/10.1177/2047487316657669.
52. Abreu A, Frederix I, Dendale P, Janssen A, Doherty P, Piepoli MF, et al. Standardization and quality improvement of secondary prevention through cardiovascular rehabilitation programmes in Europe: The avenue towards EAPC accreditation programme: A position statement

of the Secondary Prevention and Rehabilitation Section of the European Association of Preventive Cardiology (EAPC). Europ J Prevent Card. 2021;28(5):496–509. https://doi.org/10.1177/2047487320924912.

53. Hosseini SAT, Rahimi F, Esmaeili M, Khalili M. Phase Angle determinants in patients with cardiovascular disease using machine learning methods. Health Technol. 2022; 12(1):83–8. https://doi.org/10.1007/s12553-021-00622-x.

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