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SELECTED TREATMENT APPROACHES FOR METABOLIC SYNDROME: A LITERATURE REVIEW

WYBRANE METODY LECZENIA W ZESPOLE METABOLICZNYM - PRZEGLĄD PIŚMIENNICTWA

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Summary

Cardiovascular disease (CVD) is an important risk factor for premature death amongst the Polish population. In 2014, CVD accounted for 45.1% of all deaths. According to a World Health Organization expert analysis published in 2004, around 80% of cases of CVD, stroke and type 2 diabetes mellitus are preventable if the most important risk factors can be addressed. Metabolic syndrome (MetS) defines a constellation of risk factors, including obesity, insulin resistance, dyslipidemia, and hypertension, associated with the development of CVD. National cross-sectional research on the health of Poles indicates that over 90% of men and 89% of women have at least one risk factor. It is estimated that in the coming years the number of obese people will increase and the incidence of diabetes and arterial hypertension will increase. This paper presents the most important and effective methods for the treatment of MetS, which include a well-balanced diet, physical activity, vibrotherapy, and pharmacotherapy. Effective action taken early on can reduce not only mortality risk, but also decrease prevalence and disability and improve the quality of life of Polish citizens.

Keywords: vibration therapy, metabolic syndrome, obesity, physical activity, diet

Streszczenie

Choroby sercowo-naczyniowe (ChSN) są identyfikowane jako ważny czynnik ryzyka przedwczesnych zgonów wśród ludności Polski. W 2014 r. odsetek zgonów z powodu ChSN wyniósł 45,1%. Z analiz ekspertów Światowej Organizacji Zdrowia (WHO) opublikowanych w 2004 r. wynika, że ok. 80% przypadków ChSN, udarów mózgu oraz cukrzycy typu 2 można uniknąć, o ile uda się wyeliminować najważniejsze czynniki ryzyka. Zespół metaboliczny (ZM) określa grupę czynników ryzyka związanych z rozwojem ChSN, w skład której wchodzą: otyłość, insulinooporność, dyslipidemie i nadciśnienie tętnicze. Ogólnopolskie przekrojowe badania zdrowia Polaków wskazują, że ponad 90% mężczyzn i 89% kobiet ma co najmniej jeden czynnik ryzyka. Szacuje się, że w najbliższych latach nastąpi wzrost liczby osób otyłych, zwiększy się częstotliwość występowania cukrzycy oraz nadciśnienia tętniczego. W niniejszej pracy przedstawiono najważniejsze i najskuteczniejsze metody leczenia ZM, do których zaliczono: odpowiednio zbilansowaną dietę, aktywność fizyczną, wibroterapię oraz farmakoterapię. Efektywne działania podejmowane odpowiednio wcześnie pozwolą zmniejszyć nie tylko umieralność, ale także ograniczyć chorobowość i niepełnosprawność oraz poprawić jakość życia polskiego społeczeństwa.

Słowa kluczowe: wibroterapia, zespół metaboliczny, otyłość, aktywność fizyczna, dieta

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Introduction

Cardiovascular disease (CVD) is the primary cause of death among the Polish population. In 1960, CVD was responsible for 23.4% of all deaths; in 1991, it accounted for 52.7%. In 2014, despite a downward trend, 169,735 people died in Poland as a result of CVD (441/100,000 population), representing 45.1% of all deaths (40.3% among men, 50.3% among women) [1].

In recent years, metabolic syndrome (MetS) has been recognized as one of the primary risk factors for the development of CVD and type 2 diabetes mellitus (DM II), the diagnostic criteria for which are outlined in Table 1 [2].

Table 1. Diagnostic criteria for MetS according to the joint statement of the IDF with the American Heart Association (AHA) and the National Heart, Lung, and Blood Institute (NHLBI) in 2009 [2]

Three of the following five irregularities must be present	
Central obesity defined based on waist circumference	Depending on the population group: - Caucasian: men ≥94 cm, women ≥80 cm, - American (USA, Canada): men ≥102 cm, women ≥88 cm - Middle East and Mediterranean: men ≥94 cm, women ≥80 cm - Asian: men ≥90 cm, women ≥80 cm
Triglycerides	≥150 mg/dL or receiving treatment for elevated triglycerides
High-density lipoprotein cholesterol	men <40 mg/dL, women <50 mg/dL, or ongoing treatment
Blood pressure	≥130/85 mmHg or receiving antihypertensive drug treatment
Fasting glucose	≥100 mg/dL or treatment for elevated glucose

The results of epidemiological studies indicate a significant prevalence of MetS in the USA as well as European countries, including Poland. The Asia-Pacific region has also seen rapid increases in the prevalence of obesity, DM II, and CVD in recent years [3]. MetS is also not uncommon in sub-Saharan Africa. The highest prevalence of MetS is in South Africa, followed by countries located in the eastern, western and central regions of Africa [4]. It is estimated that, among adults in developed countries, 20-25% of middle-aged people meet the diagnostic criteria for MetS [5]. In Poland, data from the NATPOL PLUS (Hypertension in Poland Plus Lipid Disorders and Diabetes), WOBASZ (Multicenter National Population Health Survey) and POL-MONICA (Multinational Monitoring of Trends and Determinants in Cardiovascular Diseases) studies were used to estimate the prevalence of MetS [6]. The NATPOL PLUS study (2002) examined 2,329 adults using the NCEP/ATP III criteria (National Cholesterol Education Program, Adult Treatment Panel III) and found that 518 participants met the diagnostic criteria for MetS, representing a prevalence of 22%. Research carried out as part of the WOBASZ programme revealed that, in the Polish population aged 20-74 years, MetS affected 19-20% of women and 19-23% of men. This represents a total population of around 5.8 million in Poland. Studies have also shown that the incidence of MetS increases in parallel with advancing age (7.5% in those aged between 18-39 years, 23.9% in those aged 40-59 years, and 39.5% in those aged ≥60 years) and is more severe in women [7,8].

Aim of the work

Considering the data described above, it can be concluded that MetS is one of the biggest public health challenges in the world. Therefore, measures for the prevention and treatment of MetS should be taken as early as possible. The aim of this paper was to present the current state of knowledge on available treatment options for MetS.

Selected treatment methods for MetS

MetS is a complex disorder; therefore, patient therapy requires modification of all components of the syndrome to achieve normoglycemia, normolipidemia, normoinsulinemia, and normalization of coagulation and fibrinolysis abnormalities [9].

According to the NCEP/ATP III recommendations, the primary treatment for patients with MetS is weight reduction through appropriate diet and regular physical activity. A 10% reduction in body weight over 12 months should result in:

– improved glycemic control,

- a 30% reduction in triglyceride (TG) levels,
- an increase in high-density lipoprotein (HDL) cholesterol by 8%,
- a reduction in blood pressure, and
- anti-inflammatory, anticoagulant and antioxidant effects [10].

In order to reduce body weight, non-pharmacological therapy involving patient education and lifestyle changes is usually applied for 3-6 months, and only when this fails to bring the expected results is combination therapy introduced, i.e., a combination of non-pharmacological methods with pharmacotherapy [11].

Pharmacotherapy

Cases in which pharmacological treatment should be considered and commenced are:
- people at high risk of developing CVD and DM II who have been diagnosed with a metabolic disorder that is significantly abnormal,
- patients with known atherosclerotic CVD and DM II,
- people for whom lifestyle changes have not been successful in treating MetS [12].

For overweight or obese patients, according to National Institutes of Health (NIH) guidelines, patients who should be eligible for pharmacological treatment include:
- those with obesity when BMI ≥30 kg/m^2,
- those who are overweight with a BMI ≥27 kg/m^2 and at least one MetS risk factors or comorbidities, including hypertension, dyslipidemia, CVD, or obstructive sleep apnea, where non-pharmacological methods have failed [13].

The National Institute of Health (NIH) guidelines indicate that weight loss during the first month should be 2 kg, while weight loss >5% is expected after 3-6 months of pharmacotherapy [13]. After this time, it is important to stabilize the patient's weight. If these objectives are not met, consideration should be given to changing the dose of the drug or stopping drug treatment altogether.

In Poland, the only available treatment for a long period of time was Orlistat, which was approved for the treatment of obesity in 1998. This drug reduces the absorption of fat by about 30%. Patients who used Orlistat achieved a 3% greater weight reduction at 1 year than patients receiving a placebo [12]. In addition to its effect on body weight, Orlistat may also reduce low-density lipoprotein (LDL) cholesterol levels and positively modify carbohydrate metabolism in patients with DM II [14]. In 2015, the European Medicines Agency (EMA) approved the registration of two new drugs: liraglutide, which is administered by subcutaneous injection, and a complex therapeutic formulation containing buproprion and naltrexone, which have also been available for the treatment of obesity in Poland since 2016. The active substances buproprion and naltrexone stimulate the sensation of satiety and suppress appetite by acting on the central nervous system [14,15].

Another group of drugs that have applications in MetS are those that lower glucose and increase insulin sensitivity. Their use is aimed at delaying the onset of DM II or inhibiting its development in order to reduce cardiovascular complications. One of the main drugs for increasing insulin sensitivity and reducing glucose levels is metformin. In addition to its hypoglycemic effect, it also reduces body weight and normalizes blood pressure, which is why its use offers the most benefit for patients with DM II and who are overweight or obese.

Another group of drugs that reduce insulin resistance are thiazolidinediones (TZDs), which are known to reduce fasting glucose, postprandial hyperglycemia, and plasma free fatty acid concentrations [12]. Treatment with TZDs may cause weight gain and are thus contraindicated in patients who are overweight or obese. Improvements in insulin sensitivity have also been shown with fibrates, which are essentially intended for the treatment of dyslipidemia. Studies have confirmed that fibrates effectively lower TG by up to 50%, reduce LDL cholesterol by ≤20%, increase HDL cholesterol by ≤20%, and reduce the rate of transition from elevated fasting glycaemia to full-blown DM II. Treatment with fibrates is also associated with a significant (32%) reduction in the risk of coronary incidents in patients with dyslipidemia and DM II [16].

Statins are also used as drugs in hypolipemic therapy, and are effective in:
- lowering the concentration of LDL cholesterol and the small dense LDL fraction. Intensive treatment with statins reduces LDL concentrations by ≥50% compared to baseline, while moderate treatment reduces LDL by 30-50%;
- reducing TG levels (on average by 10–20% compared to baseline);
- increasing HDL cholesterol concentrations by 1-10%;

- improving endothelial function by increasing vascular nitric oxide biosynthesis and reducing the action of vasoconstrictor factors such as endothelin 1 and angiotensin II;
- inhibiting the expression of cytokines and adhesion molecules and the reduction of C-reactive protein (CRP) levels, and
- inhibiting the formation of blood clots [12,17].

Statins are most effective in reducing LDL cholesterol levels, while fibrates remain the drugs of choice for lowering TG levels and increasing HDL cholesterol levels.

Anti-hypertensive agents are initiated for all patients with DM II and a blood pressure above 140/90 mmHg. According to the guidelines of the European Society of Cardiology (ESC) and the European Society of Hypertension (ESH), five main groups of drugs are used to treat hypertension:

1. inhibitors of the renin-angiotensin system (ACE inhibitors and ARBs) – the most common drugs used to regulate blood pressure. It is recommended that they not be combined due to the risk of renal complications;
2. calcium channel blockers (CCBs);
3. thiazide and thiazide-like diuretics (e.g., chlorthalidone and indapamide) – essential drugs in the management of hypertension, but has some negative metabolic effects, and
4. β-blockers – they can be used, but may increase the risk of developing diabetes in patients with MetS [18].

For patients with MetS who have pre-diabetes or established DM II, drugs for the treatment of hypertension with at least a neutral metabolic profile are recommended. These include ACE inhibitors, ARBs as primary drugs as well as calcium channel blockers (CCBs), which together with thiazide-like diuretics are second-line drugs [19].

Several lines of evidence suggest that the optimal medication in patients with hypertension and DM II is a combination of perindopril and indapamide. The Prevention of Cardiovascular Events in Ischemic Stroke Patients with High Risk of Cerebral Hemorrhage (PICASSO) trial confirmed the efficacy of combining perindopril with indapamide not only in terms of controlling blood pressure, but also in improving metabolic parameters such as lipid and glucose profiles. The OPTIMAX: Real-life Rates of Blood Pressure Normalization With First-line Therapy trial demonstrated the effectiveness of this combination in patients with MetS. Indapamide is a thiazide-like diuretic; however, it has a different chemical structure to thiazide diuretics, and thus has a favorable metabolic side-effect profile in patients with DM II and other MetS risk factors [20,21].

Diet

The diet used both in the prevention and treatment of MetS should have hypolipemic and hypotensive effects, a positive effect on carbohydrate metabolism, and should contribute towards a reduction in central adiposity. At present, there is no single nutritional model for patients with MetS, and recommendations for dietary modification relate to individual dietary requirements.

One of the primary nutritional goals in MetS is weight reduction in overweight or obese patients, which can be achieved in part by reducing energy intake. The reduction in energy intake should be adapted to the patient's initial weight and should range from 500 kcal/day (at 70-90 kg) to as much as 1500 kcal/day (patients weighing >150 kg). According to experts, women should, on average, consume 1200-1500 kcal/day, and men 1500-1800 kcal/day, during a weight reduction diet. It is recommended that weight loss due to reduced energy intake should amount to 0.5-1.0 kg/week. American experts recommend a weight reduction of approximately 7-10% from baseline during the first 6-12 months of treatment [12,22].

Basic principles of a weight reduction diet include:

- approximately 60% of daily energy intake should come from carbohydrates;
- approximately 15-30% of daily energy intake should be provided by fats, including:
  - saturated fatty acids up to 7%,
  - monounsaturated fatty acids up to 25%,
  - polyunsaturated fatty acids up to 10%;
- the recommended ratio of omega-3 to omega-6 fatty acids is 1:5;
- trans-saturated fatty acids (TFAs) should be avoided;
- approximately 15% of daily energy intake should come from protein (0.8 g/kg body weight + 1.75 g/100 kcal energy deficit);
- a maximum salt intake of 5 g/day;
- maximum intake of cholesterol up to 250 mg/day;
- dietary fiber intake should be 20-30 g/day;

- the National Centre for Nutrition Education recommends a fluid intake of 2.0-2.5 L/day. In cases of intense physical activity or high temperatures, the World Health Organization (WHO) recommends increasing the fluid intake to 3-4 L/day;
- meals should be taken five times a day at regular intervals;
- the last meal must not be the largest and is best eaten 3-4 hours before bedtime;
- the recommended cooking techniques are boiling, roasting, braising without fat, frying without fat, and grilling [22].

Weight reduction is a common element in improving all metabolic indicators, but it should not be forgotten that there are individual dietary recommendations applicable to specific components of MetS.

The dietary factors that strongly influence LDL levels are saturated fatty acids (SFAs) and TFAs. Quantitatively, SFAs and TFAs have a similar effect – an increase of 1% in their contribution to energy intake increases LDL concentrations by 0.8-1.6 mg/dL [23]. TFAs also reduce HDL cholesterol levels. The amount of TFAs consumed should not exceed 1% of energy per day. In a 1500 kcal/day diet, this can amount to as little as 1.5 g/day [24].

In addition to their negative effects on lipid profiles, TFAs also have a major impact on other processes involved in the development of MetS, including:

- increased abdominal obesity,
- increased insulin resistance,
- increased risk of developing DM II, and
- increased risk of developing CVD [24].

Another group of lipids that affects the lipid profile are mono- and polyunsaturated fatty acids. Essential fatty acids (EFAs) in the form of omega-6 linoleic acid and omega-3 α-linolenic acid deserve special attention in patients with MetS. Omega-3 polyunsaturated fatty acids reduce TG levels, increase HDL cholesterol levels, and lower blood pressure, and have anti-atherosclerotic and arrhythmogenic effects [9]. Conjugated linoleic acid (CLA), which occurs naturally in animal products, also has an anti-atherosclerotic effect. The literature indicates that CLA (trans-10 and cis-12 isomer) can cause equal weight and body fat loss. Laso et al. noted that overweight individuals with early signs of MetS who took 3 g of mixed CLA daily experienced a reduction in obesity without any noticeable detrimental effects on glucose or liver metabolism [25]. Meanwhile, Belury et al. studied patients with DM II who were given 8 g/day of mixed CLA (isomers 10 and 12) and showed that CLA was effective in reducing body weight in patients with insulin resistance [26].

Carbohydrates are another source of energy and often the largest contributor to the total daily dietary intake. Recommendations for carbohydrate intake vary depending on the source: the literature often recommends that carbohydrates should constitute 55-60% of daily energy intake in patients with MetS, while the ESC and EAS (European Atherosclerosis Society) indicate that the optimal amount is 45-55% total energy from carbohydrates. In patients with MetS, particular attention should be paid to dietary fiber and simple sugars (monosaccharides). In the case of dyslipidemia, it is recommended that the amount of dietary fiber should be 25-40 g/day, of which water-soluble fiber (pectins, β-glucans, gums, mucilages) should be 7-13 g. Adequate dietary fiber reduces TG and increases HDL cholesterol [25].

In turn, carbohydrate intake from simple sugars should not exceed 10% of the total energy substrate intake, not including natural sugars present in dairy products and fruit [23]. Although fruit can contain a significant amount of sugar, it also contains dietary fiber, which slows down the breakdown of sugars in the gut and the rate at which they are absorbed into the bloodstream.

The amount and type of carbohydrates consumed and the type of starch in them affect not only the lipid profile, but also post-prandial glucose levels. In 1981, Jenkins et al. [27] developed the idea of the glycemic index (GI) and based on this concept categorized products into three groups:

- those with a low glycemic index – GI ≤55%,
- those with a medium glycemic index of 55-70% GI,
- those with a high glycemic index – GI >70%.

A diet rich in carbohydrates with a high glycemic index affects:

- the risk of developing insulin resistance,
- the risk of DM II - with a high-GI diet this risk is 40% higher than with a low-GI diet,
- an increase in TG,
- a reduction in HDL cholesterol levels,
- an increased risk of CVD,
- an excessive accumulation of body fat,
- an increase in CRP levels, especially in overweight or obese women [27].

Protein is another basic source of energy and should be consumed at a rate of 1 g/kg of body weight. It is advisable that the ratio of animal protein to vegetable protein is 50% to 50% [28]. Patients with MetS are advised to obtain animal protein by eating lean meat, preferably skinless poultry, fish and low-fat dairy products. An adequate intake of protein combined with physical activity increases muscle mass, thus reducing insulin resistance.

For people with dyslipidemia, hypertension, carbohydrate disorders or DM II and who are overweight or obese, four types of diets are usually recommended:

1. a low-calorie diet, i.e., a diet for a healthy person with reduced calories and good nutritional choices,
2. a low-carbohydrate diet,
3. the Mediterranean diet,
4. the DASH diet [14].

The Mediterranean diet is often identified in the literature as the optimal choice for patients with MetS. This diet, in most variants, consists of low-GI carbohydrate foods that are rich in dietary fiber and an increased intake of unsaturated fatty acids in the form of olive oil, fish and nuts (the proportion of fats in the diet can be as high as 30-40% of total daily energy requirements) [29]. In the Mediterranean diet, careful attention should be paid to the ratio of omega-3 to omega-6 fatty acids, as an excess of omega-6 fatty acids can increase the risk of atherosclerosis and cardiac arrhythmias, resulting in an increased rate of death from CVD.

Numerous researchers indicate that it is one of the more effective dietary therapies for treating MetS. Studies by Esposito et al. [30] and Saltopoulou et al. [31] have shown that a diet rich in mono- and poly-unsaturated fatty acids with a low omega-6 to omega-3 ratio, rich in fiber, containing an adequate intake of fruit, vegetables as well as nuts and olive oil can reduce blood pressure, improve lipid profile, increase insulin sensitivity and endothelial function, and reduce the risk of thrombogenesis. Similar conclusions were reached by Rallidis et al. [32] who, after a 2-month study of the effects of the Mediterranean diet on endothelial function in patients with central obesity, found that the diet improved endothelial function and reduced diastolic blood pressure [32]. Furthermore, Romaguera et al. [33] observed a significant reduction in waist circumference in people aged 25-70 years who followed the Mediterranean diet recommendations [33]. The effectiveness of the Mediterranean diet in reducing body weight was also confirmed in the DiRECT (Diabetes Remission Clinical Trial) trial, which compared the effects of Mediterranean, low-fat and low-carbohydrate diets. The study lasted 6 months and involved 322 individuals with obesity and either DM II or CVD. A low-carbohydrate diet was also equally successful in reducing body weight, but those following the Mediterranean diet additionally showed a reduction in fasting blood glucose and insulin resistance [14]. In conclusion, the Mediterranean diet used in patients with MetS has anti-atherosclerotic, anti-inflammatory, antioxidant, and anti-thrombotic qualities, and reduces lipemia, glycaemia and post-prandial insulinemia [22].

The dietary recommendations for the prevention and treatment of MetS have been reviewed and modified over time. Some researchers confirm the more beneficial effect of diets with reduced carbohydrates, especially simple sugars, and with an increased proportion of unsaturated fats compared to high-carbohydrate and low-fat diets [11]. Pałkowska et al. [34] examined the effect of a low-energy diet with a modified ratio of n-3 to n-6 fatty acids in the treatment of MetS. Twenty-three patients aged 29-65 years with obesity were allocated to a dietary intervention of 1200-1500 kcal/day for 12 weeks with the corresponding nutrient ratios: protein, 18%; fats, 28%; carbohydrates, 53% of energy provided; fiber, >29 g/day; cholesterol, <200 mg/day and a n-3/n-6 ratio of 1:5 or 1:10. The researchers found that a low-energy diet with a modified n-3/n-6 ratio (1:4-1:6) led to a significant reduction in body weight, lowered BMI, reduced waist circumference and body fat content, and lowered blood pressure and lipid disorders in patients with obesity and coexisting diagnostic features consistent with MetS [34].

The WHO also highlights the health effects associated with a healthy Nordic diet. Several indicators have been developed to assess the quality of the Nordic diet, including the Recommended Food Score (RFS), Healthy Nordic Food Index (HNFI), New Nordic Diet, and Baltic Sea Diet Score. The RFS index separates 'good' and 'bad' foods, while the HNFI includes only healthy foods based on the traditional Nordic diet and includes six product groups:

- rye bread,
- fish,
- apples and pears,
- root vegetables,
- cabbage,
- oat flakes [35].

A diet based on local produce and food traditions is believed to be easier to adhere to, and therefore research is recommended to demonstrate the health benefits of a regional Nordic diet. Gunge et al. [36] examined the relationship between HNFI and the risk of myocardial infarction in middle-aged Danes and found that adherence to HNFI can reduce CVD risk [36]. In contrast, Hansen et al. [37] conducted a cohort study involving 28,997 women and 26,341 men in Denmark and after 13 years of follow-up. They found an inverse relationship between HNFI and a 14% reduction in stroke risk [37]. On the other hand, Lacoppidan et al. [38], found that adherence to the HNFI is inversely related to the risk of developing DM II. They noted that regional diets other than the Mediterranean may also be recommended for the prevention of DM II [38].

Researchers have also highlighted products that should be reduced or eliminated in people with MetS regardless of diet:

- salt intake should be limited to 3-5 g/day,
- spice mixtures with monosodium glutamate and products preserved with monosodium benzoate should be avoided,
- minimize or eliminate the consumption of fast food, chips, instant soups and sauces, smoked products, yellow cheese, cold cuts, salted nuts and sticks [9].

Physical exercise

Dietary intervention forms a key element in the treatment of MetS; however, it must be combined with physical activity for optimal results. Kowalska and Cieslinska-Świder [39] performed a study which enrolled 23 women aged 61-69 years with central obesity and DM II. After 6 months of following easily digestible diet and general gymnastics, they reported an average body weight reduction of 9.7 kg, a decrease in blood pressure, a decrease in BMI of 3.49, and an average decrease in blood glucose from average of 106.52 mg/dL to 97.30 mg/dL [39]. The Kuopio Ischemic Heart Disease Risk Factor Study (KIHD), which was conducted on 1,069 middle-aged men, found that subjects doing less than 1 hour of physical activity per week had a 60% higher incidence of MetS than those doing a minimum of 3 hours of moderate exercise/ week [40]. Several studies have confirmed that adequate physical exercise contributes to the improvement of several indicators in MetS, insofar as:

- reducing body fat,
- increasing muscle mass,
- increasing tissue sensitivity to insulin (in both muscle and liver),
- improving glycemic control,
- improving lipid profile (increases HDL cholesterol; lowers total cholesterol, LDL cholesterol and TG),
- lowering blood pressure,
- reducing the production of pro-inflammatory cytokines (e.g., CRP and interleukin 6) [14,29].

It is important to consult with a doctor about the type of physical activity and to adapt it to the age of patient and any potential comorbidities that they may have. The type of exercise and its intensity should be based on the patient's physical fitness (cardiac capacity, blood pressure and response to exercise, respiratory capacity), functional capacity, preferences and motivation. Studies have shown that, for patients with MetS and obesity, the best results in sustained weight reduction are obtained by performing regular aerobic physical training of moderate to high intensity, i.e., the maximum heart rate (HR_{max}) should be around 55-85%. Based on the results of the Healthy Lifestyle programme, De Feo et al. [40] recommended that patients with MetS start their exercise programme with moderate intensity at 50% of their maximal aerobic capacity (VO_{2max}), and then gradually increase by about 5% of VO_{2max} every six training sessions, until 65% of maximal capacity is reached. After 3 months, once the patient's fitness and performance has improved, interval training at sub-maximal intensity can be introduced, preferably under the supervision of a physiotherapist [40]. This type of exercise results in the use of muscle glycogen in the initial phase, followed by a loss of fat tissue after about 30 minutes. High-intensity exercise works more effectively for fat loss than moderate exercise, as increased lipid oxidation continues even after the workout. Patients who are obese are more likely to undertake moderate intensity training, often perceiving intensive exercise as impossible to perform. Resistance exercises are also effective in reducing body weight, but the need for a physiotherapist to monitor the correctness of the exercises performed may present some limitations. For patients who are overweight or obese, performing exercises incorrectly reduces the effectiveness of the exercises and put themselves at risk of injury.

Physical activity improves insulin resistance and glucose utilization, and counteracts the cardiovascular complications of DM II. According to LaMonte et al. [41], moderate physical activity performed for at least 30 minutes/day reduces the risk of developing DM II and CVD by at least 30% [41]. For patients with DM II, physical

activity should be planned in such a way as to minimize the risk of hypoglycemia. The main elements to be considered are exercise intensity, duration, the frequency of training, and the environment in which it will be performed. Exercise in patients with DM II should include moderate-intensity aerobic exercise without heavy loads. HR_{max} in patients with DM II should be adjusted for age:

- people aged 40-50 years – heart rate up to 130/min,
- persons under 60 years of age – heart rate 100-125/min,
- people under 70 years of age – heart rate 90-115/min [42].

However, in patients with DM I, activity planning should be even more individualized, and should be matched to meals and insulin doses and should not exceed 30% of the patient's physical capacity, regardless of the duration of training. Resistance exercise in patients with DM II causes a milder drop in glycaemia than aerobic training. When both types of exercise are performed in one training session, resistance exercise should be performed before aerobic exercise, which significantly improves glycemic compensation both during and after training [40]. The recommendations for patients with DM II are:

- a minimum of 150 minutes per week of moderate intensity aerobic exercise, or
- 75 minutes per week of high intensity training,
- in addition, 2-3 times a day physical activity lasting 10-30 minutes, performed after meals,
- in addition, resistance exercises 3-5 times/week [40].

Suggested activities include walking, cycling, swimming, water exercise, aqua-aerobics, Nordic walking, dancing, spinning, canoeing and team games, badminton, and tennis. However, exercises that should be avoided include jumping, fast running, weightlifting, intense gym exercises with heavy loads, climbing, and diving [42].

In the initial stage of introducing physical activity in individuals who are obese or have hypertension with arterial wall stiffness, low-intensity exercise, preferably with load reduction, is advisable, as over-intensive training may cause excessive increases in blood pressure.

Vibrotherapy

Over the last few years, the literature on lifestyle changes in patients with MetS has increasingly addressed issues related to the therapeutic and preventive effects of vibration.

Vibrations, also known as oscillations, are physical stimuli transmitted directly from the vibrating medium to the human biological system and lead to physiological changes on many levels. Among other things, vibration affects skin tissue, muscle tissue, joints and ligamentous apparatus, the circulatory and lymphatic systems, and the nervous system [43].

Rubio-Arias et al. [44] conducted a meta-analysis of 23 studies which evaluated the effects of whole-body vibration training (WBVT) on body composition, blood pressure, metabolic profile and lower limb strength in patients who were overweight or obese. WBVT resulted in reduced fat mass, lower systolic and diastolic blood pressure and heart rate, as well as an increase in lower limb strength. However, there were no changes in BMI, muscle mass, cholesterol, TG or glucose [44]. In contrast, Koutnik et al. [45] and Issurin [46] found that vibration therapy improves vascular endothelial function, reduces arterial stiffness and increases nitric oxide levels, which inhibits platelet and leukocyte aggregation. Just 5 minutes of vibration at 50 Hz is enough to significantly increase nitric oxide levels and thus reduce the risk of cardiovascular complications. The use of vibration therapy may lower total cholesterol and may have an anti-atherosclerotic effect [46].

The use of vibrotherapy treatments can increase the work of the entire body without an increase in physical exertion. Appropriate vibration parameters can affect visceral adipose tissue, resulting in, among other things, a reduction in body weight and composition and a reduction in waist circumference, and can also activate muscle activity without patient participation [47]. Muscle stimulation and improved circulation can increase insulin sensitivity in tissues and reduce fasting glucose levels, which may ultimately prevent the development of DM II.

Nam et al. [48] also included whole-body vibration (WBV) in their study, which examined the effects of diet and physical activity on obesity in middle-aged women. Thirty-three women were enrolled, and divided into three groups: a diet group as the control group, a vibration group and an aerobics group. In the aerobics group, in addition to diet, participants performed aerobic exercise in the form of cycling and treadmill walking for 33 min/day, 5 days/week. The intensity of the training was adjusted to the patients' heart rate, which was set at 75% HRmax. In the vibration group, on the other hand, patients received a diet and additionally performed vibration training for 33 minutes, 5 days/week. The vibration frequency was dependent on the position during training: 16-23 Hz in standing position, 28-34 Hz in squatting position and 22-26 Hz in sitting position. After 9 months of intervention, there was a significant decrease in relative body fat levels in all three study groups, with

the aerobic and vibration groups showing a greater reduction in fat mass than the diet only group. Long-term vibration training used in conjunction with a diet programme was thus as effective as aerobic exercise combined with a diet programme in improving body composition in obese middle-aged women [48].

Similar conclusions were reached by Bellia et al. [49], who investigated the effect of WBV added to a low-calorie diet on insulin resistance and other parameters related to glucose regulation in individuals who were obese and had a sedentary lifestyle. The study involved 34 subjects who were allocated to one of two groups: the first group followed the diet alone, while the second group underwent WBV in addition to the diet. After 8 weeks of treatment, a weight loss of approximately 5% was observed in both groups. In addition, greater changes were seen in the vibration group with regard to improved insulin resistance, glucose regulation, and adiponectin levels, and there was a greater reduction in body fat than in the diet-only group [49].

Zaki [50] found that vibration training was as effective as resistance exercise on BMI, WHR and bone mineral density (BMD) in a sample of 80 post-menopausal women aged 50-68 years who were obese. The effect of vibration on body composition in post-menopausal women over 50 years of age who were obese was also examined by Song et al. [51]. After 8 weeks of treatment, they observed a decrease in body weight (-1.18±1.61 kg), a decrease in BMI (-0.49±0.66 kg/m^2), a decrease in waist circumference (-2.34±2.24 cm) and a decrease in muscle mass (-0.54±0.59 kg),which was directly correlated with the decrease in body weight.

Several Polish studies have also examined the effects of WBV on body composition. Pilch et al. [47] conducted a study which included ten women who received 4 weeks of oscillatory-cycloidal vibration therapy. After the treatments, the authors found an average decrease in thigh circumference of 1.55 cm for the right thigh and 1.50 cm for the left thigh, and an average decrease in hip circumference of 1.25 cm and waist circumference of 2.30 cm. A reduction in total body fat by an average of 0.42 kg was also noted [47]. Jarska et al. [52] examined the effect of static exercise on the vibration platform on changes in BMI, body mass composition, heart rate and selected morphological characteristics in young women with moderate physical activity. After 2 weeks of intervention, the researchers found statistically significant: reduction in body weight, reduction in skinfold thickness and body circumference, and reduction in BMI. Vibration devices used in rehabilitation and sports medicine mainly serve people who, for various reasons, cannot or do not want to take part in various sports or who should reduce the intensity of their current physical effort. Vibration training can thus be used as an addition to traditional exercise if the patient is able to exercise or can be a stand-alone method of maintaining physical form, especially in people whose impairment precludes normal training [52].

The effect of vibration on the performance of post-menopausal women aged 54.3 years was examined by Pérez-Gómez et al. [53]. In a training programme, vibrations with a frequency of 12-24 Hz and a constant amplitude of 3 mm were used. After 3 months of intervention, a 4.4% reduction in fat mass was achieved, and a 23.1% reduction in the time to perform the "get up and go" test was observed, as well as a 12.5% improvement in the results obtained in the "6-minute walk" test. Vibration thus not only affects anthropometric performance and body composition but may also improve fitness in older people with MetS. The beneficial effects of vibration on the cardiovascular system have also been described. Wong et al. [54] evaluated the effects of vibration training at 25-40 Hz and variable vibration amplitude on heart rate and blood pressure variability in post-menopausal women who were obese, but not morbidly so. After 8 weeks, a significant decrease in blood pressure and improvement in sympatho-vagal tone was noted in the vibration group. WBV is an unconventional exercise therapy that appears to provide the same benefits as resistance training in post-menopausal women while being safer and gentler on the joints [54].

On the other hand, Figueroa et al. [55] performed a study which enrolled ten young females who were overweight or obese. The participants were divided into two groups: the case group used WBV with a frequency of 25-30 Hz and a vibration amplitude of 1-2 mm for 6 weeks, while the control group remained without exercise. After 6 weeks, there was a significant reduction in systemic arterial stiffness and aortic systolic blood pressure, and improvements in wave reflection and sympatho-vagal tone. The authors also found a 6.3% increase in leg strength in the WBV group. WBV training could thus benefit arterial function and muscle strength in people who cannot perform conventional exercise [55]. The use of vibration training in cardiac rehabilitation was examined by Damijan [56]. The author found a significant decrease in systolic blood pressure in 96% of subjects, heart rate in 92% of subjects, body fat in 76% of subjects, body weight in all subjects, and total cholesterol in 76% of subjects. There were also significant increases in temperature in 88% of subjects, and HDL cholesterol in 76% subjects, as well as increases in general balance in 71% of subjects, and hand speed in 96% of subjects. Vibration training thus had positive effects on hypertension, obesity, atherosclerosis risk and physical fitness [56].

Vibration therapy can therefore safely be used to prepare patients with MetS and severe obesity for lifestyle changes. It may also constitute a permanent element of supportive therapy, or substitute physical activity if the patient is unwilling to introduce other forms of physical activity.

Conclusions

The risk of developing CVD, hypertension and DM II is closely linked to dietary habits and physical activity. There is currently ample scientific evidence to suggest that making small lifestyle modifications through diet, exercise and vibration therapy can significantly reduce the incidence of MetS risk factors and their clinical sequelae. In conclusion, lifestyle changes are a key element in the treatment of MetS, and that their effectiveness depends on the systematic and long-term nature of the changes introduced.

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