Kubiak A., Zwoździak B., Rodriguez D., Mitkowska A., Spaczyński R., Szymoniak Z., Pawelczyk L., Banaszewska B., Chudzicka-Strugała I. The role of probiotics in the athletes' diet and in maintaining. A proper body weight. Issue Rehabil. Orthop. Neurophysiol. Sport Promot. 2017; 21: 41–52. DOI: 10.19271/IRONS-00049-2017-21

THE ROLE OF PROBIOTICS IN THE ATHLETES' DIET AND IN MAINTAINING A PROPER BODY WEIGHT

Anna Kubiak[1]
Barbara Zwoździak[2]
Daniel Rodriguez[3]
Agnieszka Mitkowska[4]
Robert Spaczyński[5]
Zbigniew Szymoniak[4]
Leszek Pawelczyk[5]
Beata Banaszewska[5]
Izabela Chudzicka-Strugała[2]

[1]Public Healthcare Center, Kozminek

[2]Department of Medical Microbiology, Poznan University of Medical Sciences

[3]Neuropsychiatrical Hospital, Koscian

[4]Ginecological-Obstetric Clinical Hospital Poznan University of Medical Sciences

[5]Division of Infertility and Reproductive Endocrinology Poznan University of Medical Sciences

SUMMARY

Introduction

Numerous scientific articles indicate the effects of the intestinal microbial system on nutrient absorption, and adaptive alterations of energy intake and expenditure. Moreover numerous literature sources support the concept of dysbiosis (abnormalities in the composition and/or function of intestinal microflora) in relation to the occurrence of human illness, resulting in weight disorders such as obesity. Probiotic bacteria invoke beneficial effects on the entire body and above all on the digestive tract. Some research results show the promising benefits of probiotic action on the athlete immune system. Therefore, at work the

ROLA PROBIOTYKÓW W DIECIE U SPORTOWCÓW ORAZ CELEM UTRZYMANIA PRAWIDŁOWEJ MASY CIAŁA

Anna Kubiak[1]
Barbara Zwoździak[2]
Daniel Rodriguez[3]
Agnieszka Mitkowska[4]
Robert Spaczyński[5]
Zbigniew Szymoniak[4]
Leszek Pawelczyk[5]
Beata Banaszewska[5]
Izabela Chudzicka-Strugała[2]

[1]Samodzielny Publiczny zakład Opieki Zdrowotnej, Koźminek

[2]Katedra i Zakład Mikrobiologii Lekarskiej Uniwersytetu Medycznego im. K. Marcinkowskiego w Poznaniu

[3]Wojewódzki Szpital Neuropsychiatryczny, Kościan

[4]Ginekologiczno-położniczy Szpital Kliniczny Uniwersytetu Medycznego im. K. Marcinkowskiego w Poznaniu

[5]Klinika niepłodności i Endokrynologii Rozrodu Uniwersytetu Medycznego im. K. Marcinkowskiego w Poznaniu

STRESZCZENIE

Wstęp

Badania naukowe wskazują na wpływ bakterii, zasiedlających układ pokarmowy i stanowiących mikrobiota jelitowe, na absorpcję składników odżywczych oraz regulację energetyczną. Ponadto wykazano związek dysbiozy z występowaniem schorzeń u człowieka, których skutkiem są zaburzenia masy ciała m.in. nadwagi lub otyłości. Pozytywny wpływ na cały organizm, a przede wszystkim na przewód pokarmowy posiadają bakterie probiotyczne. Niektóre wyniki badań prezentują obiecujące korzyści oddziaływania probiotyków na układ odpornościowy sportowców. W związku z powyższym w pracy uwagę skupiono

focus was on the appropriateness and effectiveness of the use of probiotic formulations, based on available scientific articles. Presentation of this work has been dictated the current, although requiring further analysis, matter discussed among physicians, diabetologists and physiotherapists.

Aim
The aim of this paper is to present a supported by scientific reports of current knowledge about the application of probiotic formulas in maintaining the proper body weight in the fight against obesity or disorders of the intestinal barrier of athletes.

Materials and methods
Medline, Pubmed databases were used for the search of relevant scientific papers results.

Results
The analysis of the presented articles can indicate a positive impact of therapy/diet with probiotics application in maintaining the proper body weight in the fight against obesity and immunological system of athletes.

Conclusions
Based of the scientific literature it can be concluded, that current measures to maintain proper body weight and therapies based on probiotic formulas, in the fight against overweight/obesity, include modifications in intestinal microflora. The leading effect of probiotics affecting human metabolism is primarily observed for *Lactobacillus* and/or *Bifidobacterium* strains. There is also evidence of beneficial effects of probiotic supplementation on intestinal barrier integrity in serious conditions (eg. Ischemic colitis. Irritable bowel syndrome (IBS), chronic

na słuszności i skuteczności zastosowania preparatów probiotycznych, na podstawie dostępnych artykułów naukowych. Zaprezentowanie niniejszej pracy zostało podyktowane aktualnym, chociaż wymagające dalszych analiz, zagadnieniem dyskutowanym wśród lekarzy, diabetologów oraz fizjoterapeutów.

Cel
Celem pracy jest przedstawienie popartej doniesieniami naukowymi, aktualnej wiedzy na temat zastosowania preparatów probiotycznych w przypadku utrzymania prawidłowej masy ciała w walce z nadwagą/otyłością oraz z zaburzeniami integralności bariery jelitowej sportowców.

Materiały i metody
Do niniejszego artykułu wykorzystano doniesienia zamieszczone w bazach Pubmed i MEDLINE. Podczas wyszukiwania literatury z lat 2000–2017 zastosowano słowa kluczowe „probiotyki", "prawidłowa masa ciała", "dieta sportowców", "mikroflora jelit".

Wyniki
Analiza wniosków przedstawionych w artykułach może świadczyć o pozytywnym wpływie terapii/diety z zastosowaniem probiotyków w utrzymaniu prawidłowej masy ciała, w walce z nadwagą/otyłością oraz na układ odpornościowy u sportowców.

Wnioski
Na podstawie prezentowanej literatury przedmiotu sugeruje się, iż obecne działania mające na celu utrzymanie prawidłowej masy ciała oraz terapie oparte na preparatach probiotycznych, w walce z nadwagą/otyłością, uwzględniają modyfikacje w zakresie mikroflory jelitowej. Wiodące działanie wśród probiotyków wpływających na metabolizm człowieka obserwuje się przede wszystkim dla szczepów Lactobacillus i/lub Bifidobacterium. Istnieją dowody dobroczynnego wpływu suplementacji probiotykami na integralność bariery jelitowej

idiopathic constipation (CIC)). Moreover some research results show the promising benefits of probiotic action on the immune system, however, they require further analysis.

Keywords: probiotics, proper body weight, athlete diet, intestinal microflora

Date received: 18th October 2017
Date accepted: 10th November 2017

w poważnych schorzeniach (np. niedokrwienne zapalenie jelita grubego, zespół jelita drażliwego (IBS), chroniczne idiopatyczne zaparcia (CIC)). Ponadto wyniki badań prezentują obiecujące korzyści oddziaływania probiotyków na układ odpornościowy również u sportowców, jednak wymagają one dalszych analiz.

Słowa kluczowe: probiotyki, prawidłowa masa ciała, dieta sportowców, mikroflora jelit

Data otrzymania: 18 października 2017
Data zaakceptowania: 10 listopad 2017

Introduction

In recent years, there has been an increased interest on the subject of intestinal microflora, constituting the so-called "metabolic gates" between the external environment and the host, with particular emphasis regarding its effects on inflammatory conditions, energy metabolism and body weight homeostasis (Kobyliak 2016).

Activities aimed at maintaining a healthy body weight are becoming an increasingly important issue in the context of the ever-increasing epidemic of obesity and weight disorders. Obesity is ranked fifth among global risk factors leading to death, killing an average of 2.8 million adults each year (Rouxinol-Diasa 2016).

In addition to the environmental factors described by the WHO, genetic, neuroendocrine, and infectious factors may also play an important role in the development of obesity (Rouxinol-Diasa 2016).

Hence, a lot of literature as well as many pre-clinical and clinical studies, conducted on both animal and human models, are focused on the impact of probiotic-enriched diets and probiotic-based therapy.

Numerous scientific articles indicate the effects of the intestinal microbial system on nutrient absorption, and adaptive alterations of energy intake and expenditure. The observed differences in composition of intestinal microflora in obese individuals as compared to those with normal body weight, suggest it plays a significant role in the development of weight disorders and obesity. As a consequence, the modification of intestinal microflora through the use of a probiotic-enriched diet (living, non-pathogenic microorganisms with beneficial qualities to the host health) is increasingly being used in the treatment of obesity and weight disorders. Considering the efficacy of such treatments, a number of studies based on the use of probiotics have been conducted, mainly utilizing strains of Lactobacillus spp., Bifidobacterium spp., and Enterococcus spp (Rouxinol-Diasa 2016).

Human intestinal microflora is an ecosystem composed of millions of microorganisms encompassing thousands of bacterial species, involved in numerous metabolic reactions of the host (Kobyliak 2016).

Numerous literature sources support the concept of dysbiosis (abnormalities in the composition and/or function of intestinal microflora) in relation to the occurrence of human illness, resulting in weight disorders such as obesity (Druart 2014).

The causal relationship between intestinal microflora and the host metabolism has been demonstrated, in studies such as Turnbaugh *et al.* (2006), utilizing a mouse

model. In mice without abnormalities in body weight, the obesity phenotype was induced by the transplantation of the intestinal microflora from obese individuals. Differences in the composition of human intestinal microflora appear to be the key factor affecting energy homeostasis. In both human and mouse models, the two most common types of intestinal bacteria are Gram negative Bacteroidetes and Gram positive Firmicutes (Kobyliak 2016).

Given the disturbances in the composition of intestinal microflora in the context of weight gain and obesity, the first changes are observed in Firmicutes and Bacteroidetes (Druart 2014).

Aim

The aim of this article is to present the current knowledge supported by scientific reports regarding analysis of probiotic formulas significance in diet in maintaining the proper body weight in the fight against obesity or disorders of the intestinal barrier of athletes.

Materials and methods

PubMed, MEDLINE databases were used for the purpose of this article. Keywords "probiotics", "healthy body weight", "athlete diet", "intestinal microflora" were used for the search of literature from 2000 to 2017.

Current measures to maintain a healthy weight and implementation of probiotics in hopes of combatting weight gain and obesity are focused on modifications in intestinal microflora. One of the primary benefits of these strategies includes safety, since there are currently no reports of undesirable side-effects of their use. Probiotics are generally well tolerated and appropriate for long-term therapy. In addition, changes in intestinal microflora through the use of probiotic treatment or maintaining a proper diet can, by virtue of their beneficial effects, positively influence body weight, glucose and fat metabolism, increase insulin sensitivity, and reduce chronic systemic inflammation. The leading effect of probiotics affecting human metabolism is primarily observed for Lactobacillus and/or Bifidobacterium strains. Also recognized as a probiotic, are newly emerging microorganisms such as Saccharomyces cerevisiae var. boulardii. They are currently being identified and analyzed for their innovative mechanisms of action in the maintenance of normal weight, counteracting obesity and other related disorders. Therefore, further studies are needed to confirm the beneficial effects of newly emerging and traditional probiotics and to carry out detailed meta-analyses (Kobyliak 2016, Kailasapathy 2000).

The studies analyzed in this review are focused on the beneficial effects of probiotics on metabolic disorders, measured through supplementation for several weeks on various groups of subjects. The metabolic disorders analyzed include obesity, non-alcoholic fatty liver disease or high cholesterol levels. Special group of subjects contained athletes as well as physically active individuals and the effect of the probiotic supplementation on their immune systems and digestive health.

Results and discussion

1. Probiotics and their mechanism of action

The name *probiotic* derives from the Greek term "pro-bios," meaning "for life." Probiotics (according to Fuller) refer to live microorganisms, which, after consumption, display beneficial effects on the host organism by positively affecting the balance of intestinal microflora (Ciborowska 2014). Everyday, food companies use the term to increase sales of their products containing these bacterial strains. However, consumer knowledge is negligible. It is fashionable to live healthy and to eat heathy. The potential customer does not pay attention to which types of bacteria are contained in these products. The name is simply utilized in order to promote sales of what is considered to be a healthy product (Ciborowska 2014, Libudzisz 2006). However, exploring

the subject requires analysis of specialized literature.

Probiotic bacteria invoke beneficial effects on the entire body and above all on the digestive tract. After being introduced into the large intestine, they settle and colonize. According to current literature, the typical human digestive tract contains approximately 400 species of bacteria. They are referred to as intestinal flora (Ciborowska 2014, Clarke 2012, Libudzisz 2006).

Various strains of lactic acid bacteria display probiotic properties. The most commonly used probiotics contain strains of Lactobacillus (e.g. L. casei) and Bifidobacterium (e.g. B. animalis). Their common feature is the capability of anaerobic metabolism of carbohydrates through lactic fermentation. By covering intestinal epithelia, they form a barrier to antigens derived from dietary intake of food. A key feature is their ability to increase the absorption of appropriate nutrients (Grzymisławski 2017, Clarke 2012).

Other microorganisms displaying similar properties include Lactococcus, Leuconostoc, Pediococcus, Streptococcus, Enterococcus, Carnobacterium, Oenococcus, Tetragenococcus, Vagococcus and Weissella (Clarke 2012). Functional foods and Probiotics most commonly contain bacteria of the genus Bifidobacterium, Lactobacillus, Lactococcus and Streptococcus (Collado 2007).

The most common products containing the probiotic strains, available on the general market, are fermented milk products (Ciborowska 2014, Collado 2007, Floch 2008).

The prerequisite for allowing such a product to enter general distribution is identifying the particular strain or strains of probiotic bacteria contained within. The specific criteria to be met for distribution of probiotics should be in accordance with the recommendations of the FAO/WHO. These strains must be compatible with the human gut microbiome.

Selection of strains with the most probiotic properties is multidirectional in terms of antibacterial properties directed against pathogens of the gastrointestinal tract or genitourinary tract of women. Probiotics have a direct impact on the growth of pathogenic bacteria, by limiting the adhesion of pathogens to receptors on the surface of epithelial cells, inactivating bacterial toxins or competing for nutrients. Probiotics also produce substances with antimicrobial activity, e.g. bacteriocins or organic acids (Collado 2007, Grzymisławski 2017, Karasu 2010).

Despite the wide spectrum of research, there is no mechanism of action common to all probiotics. Their influence is predominantly upon epithelial and immunological mechanisms. In the large intestine, they help facilitate the absorption of iron, phosphorus and calcium. By generating vitamins (K and Group B), they are involved in the metabolism of bile acids and assist in regulating the absorption of cholesterol from the intestine, thus helping to prevent atherosclerosis (Ciborowska 2014, Kailasapathy 2000).

As a result of colonization, probiotic bacteria protect the body from pathogenic bacteria. They produce organic acids as well as lactic acid, which alters pH and further inhibits the growth of pathogens (Ciborowska 2014, Clarke 2012, Floch 2008, Pyne 2015).

2. The effect of microbiome imbalance on the weight disorders

The most common consequences of gut microbiome disorders are weight gain and obesity. This group of individuals are three times more likely to suffer from NAFLD (non-alcoholic fatty liver disease) and the rate of progression of this disease to cirrhosis of the liver is doubled. People with liver disease display impaired function of the intestinal barrier and high values of intestinal toxins (endotoxemia) in the body. Endotoxemia can lead to life-threatening complications, especially for individuals with liver cirrhosis. Reduction of endotoxemia, as a result of intestinal microflora modification, and improvement in function of the intestinal barrier, is associated with a decreased

risk of these complications (Clarke 2012, Heczko 2005, Szajewska 2005)

The most common weight-related diseases include:

- hepatic steatosis, liver cirrhosis
- diverticulitis of the colon
- cholelithiasis, bile duct cancer
- esophagitis, GERD, esophageal cancer
- pancreatitis, pancreatic cancer
- colorectal and colon cancer

Inadequate diet, lack of exercise, and stress increase the risk of metabolic syndrome. A diet low in fiber and high in fat, impairs microflora function thereby damaging and weakening the intestinal barrier. This condition can increase the risk of infections, cancer, and cardiovascular disease (Druart 2014, Floch 2008, Grzymisławski 2017).

In the literature based on the studies conducted both in the human population and in mice, a relationship has been observed between the development of obesity and an overall reduction of bacterial diversity in intestinal microflora, specifically the diminishment of Bacteroidetes species (Kobyliak 2016).

Manipulation of the gut microbiota through the administration of the probiotics or may assist in body weight loss, lipid levels and reduce glucose, decreasing the cardiovascular disease and type 2 diabetes mellitus. (He and Shi 2017). The role of pre-, pro- and synmbiotics in metabolic conditions eg. Obesity, prediabetes, diabetes mellitus type 2 for microbiota, in review of randomized controlled trials, was senn mostly with fermented milk or youghurt compared to capsule form. The best effect was observed with use of multiple rather than a single bacterial strain. In this study it was suggested that food as pickled and fermented foods (vegetables and beans) showed may have possible benefits for morbidity and mortality in prospective cohort studies (Barengolts 2016).

Based on the scientific research, three bacterial species have been distinguished in humans (regardless of age, gender, nationality and BMI, but in relation to eating habits) as dominant enterotypes: Bacteroides, Prevotella and Ruminococcus. In the Le Chatelier *et al.* (2013) study it was demonstrated that overweight and obese individuals in the Danish population are characterized by low genetic diversity of intestinal microflora. Such aberrations also predisposed these individuals to insulin resistance, dyslipidemia and various inflammatory conditions as compared to individuals displaying high genetic diversity of the intestinal microbial population. In addition, the Cotillard *et al.* (2013) study suggests that people with weight disorders, who display a paucity of genetic variation in the gut microbiome, show little response to dietary interventions and commonly suffer from chronic inflammation (Druart 2014, Heczko 2005).

3. The effect of probiotics on normal body weight (which display the most beneficial influence)

Maintaining a healthy weight is not only dependent on the diet, but also on the overall body condition. Dietary intake can affect the composition of intestinal flora. Disorders of the intestinal flora ecosystem can manifest through various symptoms. The most common are bloating and diarrhea. Inflammatory conditions may also occur. A natural way to help restore the correct microbial balance is consumption of drinks derived from fermented milk (Clarke 2012, Grzymisławski 2017, Kobyliak 2016, Rouxinol-Diasa 2016).

Currently, scientific findings suggest that intestinal microbiota is involved in body weight modulation, energy homeostasis and influences inflammatory responses, thus playing an important role in the pathophysiology of obesity. Interest has arisen in both probiotics and prebiotics, as they have been shown to influence the diversity of intestinal microbiome composition, food intake, appetite, body weight, gastrointestinal metabolism, as well as the fluctuation of populations of intestinal bacteria (Ciborowska 2014, Kobyliak 2016, Till 2009).

In a multifocal study, focused on the beneficial effect of Lactobacillus gasseri on metabolic disorders, supplementation of a 12-week fermented dairy product containing Lactobacillus gasseri SBT2055 was utilized, and showed significant reductions in visceral and subcutaneous fat in the study group, resulting in weight loss and BMI reduction. In addition, a study conducted by Mazloom *et al*., involving a six-week prophylaxis with probiotics containing L. acidophilus, L. bulgaricus, L. bifidum and L. casei, led to a decrease in triglyceride levels, IL-6 levels and a decrease in insulin resistance in patients with type 2 diabetes. However, these changes were not statistically significant. Some clinical trials, including Loguercio *et al.* (2005), also show promising results of using probiotics in improving liver function, fat metabolism, and insulin resistance in obese patients with non-alcoholic fatty liver disease (NAFLD). Patients with histopathologically confirmed NAFLD, treated with a probiotic containing 500 million Lactobacillus bulgaricus and Streptococcus thermophilus microbes once daily for 3 months, showed reduced transaminase levels as compared to the placebo group (Kobyliak 2016, Szajewska 2010).

Some studies have shown that the use of yoghurts containing probiotic microorganisms (Enterococcus faecium, Streptococcus thermophilus L. acidophilus, Bifidobacterium longum, L. plantarum and/or B. lactis) significantly reduces total cholesterol and improves LDL/HDL ratio (Grzymisławski 2017, Kobyliak 2016).

In the analysis of A. L. Rouxinol-Dias *et al.* worldwide research and literature on the contribution of probiotics to maintaining a heathy weight or weight disorder therapy, many positive effects of selected species or strains on body weight have been demonstrated.

L. gasseri BNR17 was found to reduce weight gain in comparison to the control group. L. gasseri L66-5 which promotes weight gain. Meanwhile, L. rhamnosus GGMCC is the only strain that appears to promote weight loss in humans. In the case of L. plantarum LG42, L. gasseri SBT2055 and L. plantarum in combination with KY103 and L. curvatus HY7601, an anti-obesity effect was observed in animal models. In addition, treatments utilizing Lactobacillus acidophilus LA5 strains, Lactobacillus casei DN001 and Bifidobacterium lactis Bb12 showed modulating effects on the immune system in regards to inflammatory responses. It is suggested that some strains, e.g. L. rhamnosus CGMCC, promote weight gain while reducing leptin levels, reflecting an increase in susceptibility to this adipocytokine. This in turn, may indicate the potential usefulness of utilizing safer forms of this strain to induce weight gain. The effects of L. gasseri BNR17 seem to be of particular clinical significance, as they have shown to promote weight reduction and reduce visceral fat accumulation when used in animal model studies (in rats) (Weijui 2015, Granato 2010, Karasu 2010).

Dietary patterns have a significant impact on the intestinal microflora composition. Differences in inflammatory variables in the host and in the intestinal microflora were observed in the context of three significant dietary groups in overweight and obese subjects. It was found that those who displayed healthy eating patterns (higher consumption of fruit, yoghurt and lower sugar intake) were less likely to have metabolic abnormalities and had a more diverse intestinal microflora with a broader gene pool (Ciborowska 2014, Kobyliak 2016, Libudzisz 2006).

Scientific literature also suggests that the composition of tissue fatty acids can be modulated by enteric microflora. Beneficial bacteria, such as Lactobacillus sp. and Bifidobacterium sp., can synthesize bioactive isomers of conjugated linoleic acid which display anti-diabetic, anti-atherogenic, and immunomodulatory properties. These isomers are also believed to reduce the potential risk of developing pathologic weight gain

and obesity. Hence, a great deal of interest is raised by the question as to what extent the diversity of intestinal microflora plays a role in distinguishing obese, yet metabolically healthy phenotypes from those with metabolic disorders (Ciborowska 2014, Granato 2010, Kobyliak 2016).

Based on many analyses of probiotic microorganisms, mainly belonging to the genus Lactobacillus sp. and Bifidobacterium sp., preclinical evidence seems to confirm their contribution to counteracting obesity. Convincing evidence comes from reports on animal models suggesting that the use of probiotics may reduce, at least in part, the body weight resulting from the introduction of a high fat diet (HFD). It has been shown that supplementation with Lactobacillus curvatus HY7601 alone, or in combination with Lactobacillus plantarum KY1032, effectively inhibited weight gain and reduced the mass of fatty tissue in mice that received a high-fat/high-cholesterol diet during a 9-week period. In another double-blind study, a group of mice was placed on a HFD for a period of 18 weeks. After 8 weeks, randomly selected groups received supplementation of Lactobacillus curvatus HY7601 and Lactobacillus plantarum KY1032 or a placebo. It was found that a group of mice receiving probiotic supplementation showed an average body weight 38% lower than the placebo group. Other studies also show that a 12-week supplementation of Lactobacillus paracasei CNCM I-4270, Lactobacillus rhamnosus I-3690 or Bifidobacterium animalis subsp. lactis I-2494, significantly reduced weight gain induced by a HFD in mice. Similar results were obtained utilizing HFD-fed rats, supplemented with Bifidobacterium spp. (B. pseudocatenulatum SPM 1204, B. longum SPM 1205 and B. longum SPM 1207 or B. adolescentis). Anti-obesity properties in probiotic yeast were analyzed in a study done by Everard *et al.* (2014), demonstrating that a diet supplemented with Saccharomyces boulardii reduced body weight and fatty tissue mass in overweight mice and those suffering from type 2 diabetes (Ciborowska 2014, Granato 2010, Karasu 2010, Szajewska 2005).

Current scientific research aimed at the clinical implementation of probiotic microorganisms is not sufficient to provide a clear answer as to which strains directly affect human weight changes, and appropriate dosages for implementing this type of therapy. However, the utilization of probiotics in maintaining a healthy weight in the context of two alarming global "epidemics," including malnutrition and obesity, is becoming a very important topic and requires further analysis (Druart 2014, Rouxinol-Diasa 2016, Till 2009).

4. Probiotics in the athlete diet

Probiotics play a very important role in sports. Studies performed on athletes and physically active individuals, based on probiotic supplementation, show a moderate clinical benefit in terms of reducing the frequency, severity and/or duration of respiratory and digestive diseases. The probiotic mechanism of action most likely includes their direct interaction with the intestinal microflora, mucous membranes, immune system, and the immunological signaling of many organs and systems. The practical aspects which should be taken into account are: medical and dietary care for athletes seeking sources of recommended probiotics, appropriate microbial compositions for supplementation, dosage requirements for differentiated probiotic strains, guidelines for duration of therapy, appropriate storage and transport of products (Lamprecht 2013, Pyne 2015).

In the athletes subjected to intensive training, the occurrence of gastrointestinal symptoms such as cramps, diarrhea, nausea or bleeding is increased. These symptoms are believed to be associated with changes in intestinal permeability and decreased function as barriers. Responsible for maintaining these barriers are protein structures

located between the intestinal epithelial cells of the intestinal wall. The integrity of this system depends on the intricate interactions between intestinal microflora, intestinal epithelial cell metabolism, and the intestinal lymphatic system. Probiotic supplementation is an upcoming group of nutraceutics that can have a positive effect not only on the athlete's intestine, but on their overall health. Some research results show the promising benefits of probiotic action on the immune system (Elder 2009, Randy 2011). There is also evidence of beneficial effects of probiotic supplementation on the intestinal barrier integrity in serious conditions. However, further research needs to be performed in order to obtain clear results regarding the issues of gastric permeability as a consequence of intensive training and its consequences (Druart 2014, Lamprecht 2013, Pyne 2015). Most clinicians and also some athletes seem prone to ischemic colitis. This may stem from anatomic variations in the circulation of their colon and/or from medications or supplements they take (Randy 2011).

5. An overview of available probiotics

On the public market, probiotics can be found in foods as well as dietary supplements.

Products containing the Lactobacillus and Bifidobacterium strains usually contain the prefix "BIO" or "SANO" in their name. Manufacturers attempt to draw the buyer's attention by introducing newer and more appealing names. Examples of this include Bio Yogurt, acidophilic milk, products from the ACIDO and ACIDKO series, and bifidus milk (e.g. probifidus). Their common feature is compliance with the standard content of probiotic bacteria as specified for modified beverages (1 million microbes per $1cm^3$) (Ciborowska 2014, Duarte 2014, Floch 2008, Kobyliak 2016).

There is no known minimum effective dose of probiotics. Typically, the doses used in individual products and in studies utilizing probiotics range between 10^6 and 10^9 colony forming units (CFU). According to some authors, in most clinical situations the effective dose is 5–10x109 CFU, and in the case of S. boulardii, 250–500 mg/day (Szajewska 2005, Collado 2007, Everard 2014). Since no general dosing regimen is currently available, it seems reasonable to use a dose that has shown a beneficial effect in a human study with a specific probiotic strain (Ciborорwska 2014, Druart 2014, Grzymisławski 2017).

Various pharmaceutical companies produce a wide range of products containing different combinations of probiotic strains. Probiotics are also used in the manufacture of specific medical preparations. They come in numerous forms such as: drops, suspensions, tablets, capsules or sachets. It is not the number of strains in a given product, but their specific properties that ensures its effectiveness. Even the introduction of probiotic microbes into the intestine has a big impact on the effectiveness of a particular strain. Probiotic strains should have significant adherence ability to the intestinal mucosa. This function should prevent the pathogenic effects of other intestinal strains such as Escherichia coli.

Product nomenclature can often be misleading, as it is not uncommon to see companies using names or abbreviations that have nothing to do with the strains included in their products. It is quite common to combine probiotics with prebiotics. Prebiotics are non-digestible food ingredients that selectively stimulate the growth or activity of selected strains of intestinal bacteria. Prebiotics naturally occur in foods (onions, potatoes, bananas, chicory, leek) or they can be added to foods (e.g. bread or biscuits). The combinations of probiotics and prebiotics are referred to as synbiotics (Ciborowska 2014, Duarte 2014, Grzymisławski 2017, Kobyliak 2016).

Many probiotic strains are found naturally in milk, kefir, buttermilk and whey. Probiotic bacteria are also found in pickled cabbage and in pickled cucumber juice.

It is important to select the appropriate probiotic strains for treatment of particular conditions (Chatelier 2013, Ciborowska 2014, Granato 2010).

Conclusions

A diet rich in fat leads to a decrease in the amount of Bifidobacteria in the body. A proper personalized diet and probiotic supplementation can promote a beneficial biodiversity of intestinal microflora.

In summary, regular intake of probiotics provides a varied and well-functioning intestinal microflora that promotes integrity of the intestinal epithelium, improves intestinal barrier function, and aids in attaining a healthy weight (Kobyliak 2016, Lambrecht 2013).

Futher studies are neede to enlarge our understanding of manipulating the gut microbiota and the role of the gut microbiota in metabolic syndrome (MS). The MS comprise central obesity, increased hyperlipidemia, glucose levels, hypertension, and its incidence is increasing due to change in lifestyle and dietary structure in recent years (He and Shi 2017).

Probiotics are effective treatment for IBS but further evidence is required before the role of prebiotics or synbiotics in IBS. The efficacy of all three therapies pro-, pre-, synbiotics in CIC is also uncertain (Ford 2014).

REFERENCES

Barengolts E. (2016) *„Gut microbiota, prebiotics, probiotics, and synbiotics in management of obesity and prediabets: review of randomized controlled trials".* Endocrine practice Vol 22 No 10 pp.1224–1234.

Chatelier E.L., Nielsen T., Qin J., Prifti E., Hildebrand F., Falony G., Almeida M., Arumugam M., Batto J-M., Kennedy S., Leonard P., Li J., et al. (2013) *"Richness of human gut microbiome correlates with metabolic markers".* Nature 500, pp. 541–546

Ciborowska H., Rudnicka A. (2014) „*Dietetyka. Żywienie zdrowego i chorego człowieka*". PZWL, pp. 205.

Clarke S., Murhy E., Nilaweera K.(2012) "*The gut microbiota and its relationship to diet and obesity"* New insights. Gut microbes. May 1;3 (3) pp. 186–202.

Collado M.C., Meriluoto J., Salminem S. (2007) *"In vitro analysis of probiotic strain combinations to inhibit pathogen adhesion to human intestinal mucus".* Food Res. Int. 40, pp.629–639.

Cotillard A, Kennedy SP, Kong LC, Prifti E, Pons N, Le Chatelier E, Almeida M, Quinquis B, Levenez F, Galleron N, Gougis S, Rizkalla S, Batto JM, Renault P; ANR MicroObes consortium, Doré J, Zucker JD, Clément K, Ehrlich SD. (2013) "Dietary intervention impact on gut microbial gene richness". Nature. Aug 29;500(7464):585-8.

Druart C., Alligier M., Salazar N., Neyrinck A. M., Delzenne N. M. (2014) *"Modulation of the Gut Microbiota by Nutrients with Prebiotic and Probiotic Properties*" pp. 6245–6335

Elder K, Lashner BA, Al Solaiman F. (2009) "Clinical approach to colonic ischemia" Cleve. Clin. J. Med. pp. 401–409.

Everard A, Matamoros S, Geurts L, Delzenne NM, Cani PD. (2014) *„Saccharomyces boulardii administration changes gut microbiota and reduces hepatic steatosis, low-grade inflammation, and fat mass in obese and type 2 diabetic db/db mice".* MBio. 10;5(3), pp.1011–14.

Floch M. H., Walker W. A., Guandalini S. (2008) *"Recommendations for probiotic use",* J Clin Gastroenterol ;42 Suppl 2: pp.104–8.

Ford A. C., Quigley E. M., Lacy B., Lembo A. J. Saito Y.A., Schiller L.R., Soffer E.E., Spiegel B. M., Moayyedi P. (2014) *"Efficacy of prebiotics, probiotics and synbiotics in irritable bowel syndrome and Chronic Idiopatic Constipation: Systematic review and Meta-analysis".* The American Journal of Gastroenterology pp. 1547–1561.

Granato D., Branko G.F., Cruz A.G., de Assis Fonseca Faria J., Shah P.N. (2010) "*Probiotic dairy products as functional foods*". Comp. Rev. Food Science Food Safety, 9, pp. 455–470.

Grzymisławski M., Gawęcki J. (2017) *„Żywienie człowieka zdrowego i chorego".*

He M., Shi B. (2017) „Gut microbiota as a potential target of metabolic syndrome: the role of probiotics and prebiotics". Cell Biosci.

Heczko P.B., Strus M., Jawień M., Szymański H. (2005) *"Medical applications of probiotics".* Wiad. Lek. 58, pp. 640–646

Kailasapathy K., Chin J.(2000) "*Survival and terapeutic potential of probiotic organisms with reference to Lactobacillus acidophilus and Bifidobacteirum*" Immunol Cell. Biol. Feb; 78(1) pp. 80–8.

Karasu N., Simsek O., Con A.H. (2010) "*Technological and probiotic characteristics of Lactobacillus plantarum strains isolated form traditionally produced fermented vegetables".* Ann. Microbiol. 60, pp. 227–234

Kobyliak N., Conte C., Cammarota G., Haley A. P., Styriak I., Gaspar L., Fusek J., Rodrigo L., Kruzliak P. (2016), "*Probiotics in prevention and treatment of obesity"* a critical view, Nutrition and Metabolism.

Lamprecht M., Frauwallner A. (2013), "*Nutritional Interventions and Athlete's Health Acute Topics in Sport Nutrition"*. Med Sport Sci. "Exercise, Intestinal Barrier Dysfunction and Probiotic Supplementation".Basel, Karger, vol 59, pp. 47–56.

Libudzisz Z., Klewicka E. (2006), "*Lactic Acid Bacteria in Probiotics Products*". Zakażenia, zesz. 4, pp. 57–62.

Pyne D. B., West N. P., Cox A. J. & Allan W. (2015), "*European Journal of Sport Science*" Volume 15, Issue 1: Current controversies in sports nutrition Probiotics supplementation for athletes – Clinical and physiological effects. pp. 63–72.
Randy E.E. (2011) *"Ischemic colitis in athletes".* Current sports medicine reports, pp 242–243.
Rouxinol-Diasa,b A.L., Pintob A.R., Janeirob C., Rodriguesb D., Moreirab M., Diasb J., Pereirab P. (2016), *"Probiotics for the control of obesity – Its effect on weight change"*, Porto Biomedical Journal, pp. 12–24.
Szajewska H. (2005), *„Rola probiotyków w zapobieganiu i leczeniu chorób przewodu pokarmowego*". Pediatr. Współcz. (Gastroenterol. Hepatol. Żyw. Dziec.), 7, pp. 53–60
Szajewska H. (2010), *„Probiotyki w Polsce – kiedy, jakie i dlaczego?"* Gastr. Klin. 2, pp. 1–9
Tilg H., Moschen A.R., Kaser A. (2009), *"Obesity and the microbiota".* Gastroneterology. May; 136(5), pp. 1476–83.
Turnabaugh P.J., Ley R. E., Gordon J. I. (2006) *"An obesity – associated gut microbiome with increased capacity for energy harvest"*. Nature 444, pp. 1027–1031.
Weijun T., Teng Z. (2015) *"Probiotics inhibit immune fluctuation in the intestinal mucous layer in rats".* Surg. Today, pp 1553–1559.

Authors reported no source of funding.
Authors declared no conflict of interest.

Autorzy nie zgłosili źródła finansowania.
Autorzy nie deklarowali konfliktu interesów.

Author responsible for correspondence:
Izabela Chudzicka-Strugala
Department of Medical Microbiology
University of Medical Sciences

Wieniawskiego Street No 3
61-712 Poznań
Poland
ichudzicka@vp.pl

Autor odpowiedzialny za korespondencję:
Izabela Chudzicka-Strugała
Katedra i Zakład Mikrobiologii Lekarskiej
Uniwersytet Medyczny im. K. Marcinkowskiego w Poznaniu
ul. Wieniawskiego 3
61-712 Poznań
Polska
ichudzicka@vp.pl