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Apple cider vinegar in folk and modern medicine: a historical review and current scientific evidence

Anna Kiełb

5th Military Clinical Hospital in Krakow, Wrocławska 1-3, 30-901 Krakow, Poland

E-mail: akielb97@gmail.com

ORCID: https://orcid.org/0009-0005-3152-5429

Klaudia Perkowska

Military Medical Institute, Szaserów 128, 04-349 Warsaw, Poland

E-mail: dr.kperkowska@gmail.com

ORCID: https://orcid.org/0009-0001-7362-4995

Anna Kaźmierczak

4th Military Clinical Hospital in Wroclaw, Weigla 5, 53-114 Wroclaw, Poland

E-mail: a.kazmierczak.1998@o2.pl

ORCID: https://orcid.org/0009-0000-8435-6685

Wiktoria Izdebska

J. Gromkowski Regional Specialist Hospital in Wrocław, Koszarowa 5, 51-149 Wrocław, Poland

E-mail: wiktoriaxizdebska@gmail.com

ORCID: https://orcid.org/0009-0005-0242-141X

Patrycja Sornek

Military Medical Academy Memorial Teaching Hospital- Central Veteran Hospital, Stefana Żeromskiego 113, 90-549 Lodz, Poland

E-mail: sornekpatrycja5@gmail.com

ORCID: https://orcid.org/0009-0003-9630-055X

Agata Borkowska

Military Institute of Aviation Medicine, Zygmunta Krasińskiego 54/56, 01-755 Warsaw, Poland

E-mail: agata.borkowska.ab@wp.pl

ORCID: https://orcid.org/0009-0008-7347-7762

Igor Pawlak

Independent Public Hospital in Mińsk Mazowiecki, Szpitalna 37, 05-300 Mińsk Mazowiecki, Poland

E-mail: igor.a.pawlak@gmail.com

ORCID: https://orcid.org/0009-0003-1942-9296

Anna Mich

Independent Public Hospital in Mińsk Mazowiecki, Szpitalna 37, 05-300 Mińsk Mazowiecki, Poland

E-mail: aniamich97@icloud.com

ORCID: https://orcid.org/0009-0004-6299-5506

Radosław Ciesielski

Independent Public Hospital in Mińsk Mazowiecki, Szpitalna 37, 05-300 Mińsk Mazowiecki, Poland

E-mail: radoslaw.ciesielski@yahoo.com

ORCID: https://orcid.org/0000-0002-3458-2024

Jakub Stanek

Medical University of Lodz, Tadeusza Kościuszki 4, 90-419 Łódź

E-mail: jakubstanek22@gmail.com

ORCID: https://orcid.org/0000-0002-9450-7261

Abstract

Introduction and Aim of the Study: Apple cider vinegar (ACV) has been used for centuries in various cultural and medical contexts globally. This study seeks to explore ACV's traditional and contemporary applications, evaluating scientific evidence for its efficacy and safety.

Material and Methods: This review synthesizes information from PubMed, Google Scholar, and other scientific sources. Key search terms included "apple cider vinegar," "apple cider vinegar medical use," "apple cider vinegar antimicrobial effect," "apple cider vinegar lipid profile," "apple cider vinegar glucose level," "apple cider vinegar preparation," and "apple cider vinegar historical use."

Results: Research supports ACV's traditional role as a disinfectant, demonstrating effectiveness against a range of bacteria and fungi. Both animal and human studies suggest ACV may help lower cholesterol and triglyceride levels while boosting HDL cholesterol. Evidence indicates ACV can enhance insulin sensitivity and reduce blood glucose levels, offering benefits for type 2 diabetes management. ACV shows antioxidant properties, potential for lowering blood pressure, and use in certain skin diseases, though further research is needed to confirm these effects.

Conclusions: The historical use of ACV in traditional medicine finds partial support in modern scientific research. Its antimicrobial, lipid-modulating, and glucose-regulating properties are documented, suggesting potential benefits for cardiovascular health, weight management, and metabolic regulation. Nonetheless, the evidence for its cosmetic applications and impact on muscle cramps remains less definitive. Additional research involving larger, diverse populations is necessary to fully validate ACV's benefits and establish safe usage guidelines.

Key words: apple cider vinegar (ACV); antimicrobial effect; lipid profile; glucose regulation

Introduction

Apple cider vinegar has been known for thousands of years and is used in many cultures and medical traditions in many communities around the world. Its wide applications have been described both in ancient civilizations and in folk medicine, including Poland. In the 5th century BC Hippocrates allegedly used apple cider vinegar as a means of healing and disinfecting wounds, which indicates that it was considered an important agent in medical practices [1]. It had been mentioned also in the Bible. Ruth 2:14 tells of the maiden Ruth who was invited by

Boaz, the man on whose farm she worked, for a meal of bread dipped in vinegar [2]. It also found its place in traditional folk medicine, where it also served as a disinfectant, but was also used to support digestion or reduce fever [3]. In our home country, in the book "Polish Herbarium" from the 17th century by Szymon Syreniusz, can be found descriptions of the uses of vinegar, including apple cider vinegar, in the treatment of various diseases [4]. In his work "Gardening Applied to the Needs of the Polish Landowner" published in 1845 in Lviv, Franciszek Ksawery Giżycki also mentions apple vinegar [5]. In recent years, apple cider vinegar has been gaining popularity again because of the growing interest in natural treatments and a healthy lifestyle. Modern scientific researchers have undertaken a systematic review of its health properties, aiming to confirm or refute many myths related to its use. Numerous studies indicate the potential benefits of apple cider vinegar, such as beneficial effects on antimicrobial effects, cardiovascular health, improved blood glucose control, and support in weight loss [6,7,8].

Aim of the study

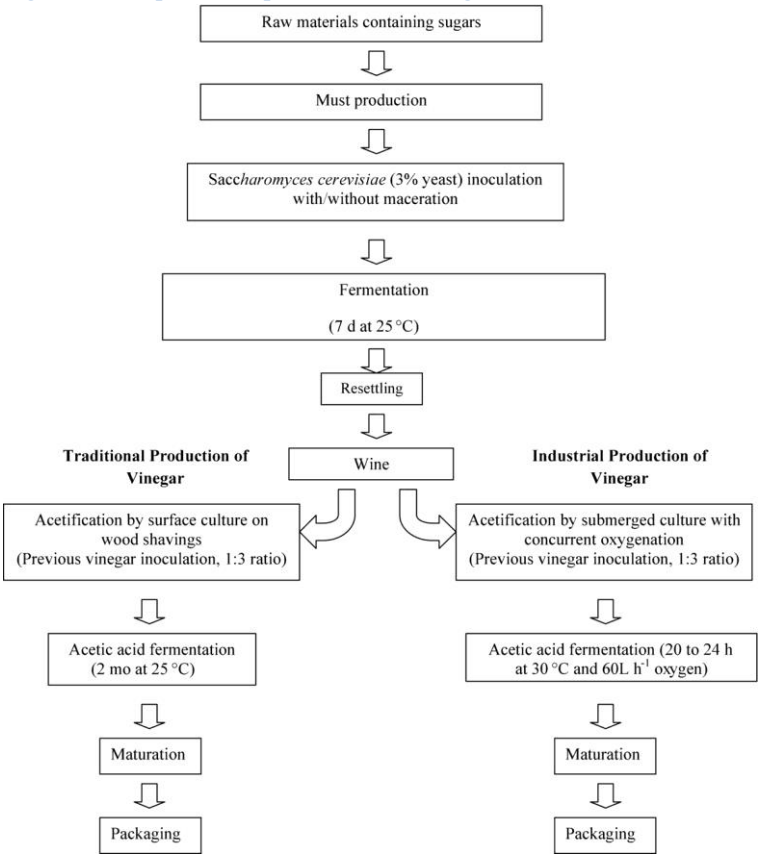
The purpose of this study is to review the uses of apple cider vinegar both in folk medicine and today, with an assessment of the current scientific evidence regarding its effectiveness and safety. By analyzing the available data, we try to answer which of the traditional uses of vinegar are supported by science and which are just myths.

Preparation and contents

Apple cider vinegar is made by fermenting apples or apple juice. The process consists of two main stages: alcoholic fermentation and acetic fermentation. The first stage is carried out using yeast and occurs under anaerobic conditions. The second is carried out using aerobic AAB (Acetic Acid Bacteria), which synthesizes acetic acid from the alcohol obtained in the first stage [9,11]. The general course of the process is shown in the *Fi*gure *1*. There are many different varieties of vinegar commercially produced in Poland, and some of them are even on the list of traditional products published by the Ministry of Agriculture and Rural Development [10]. Despite this, the trends of recent years have prompted consumers to pay special attention to the quality and organic origin of products, making homemade vinegar made from fruit pulp, without the use of yeast, increasingly popular [11,12]. The composition of apple cider vinegar and the percentage of individual ingredients will vary depending on the method of production and the origin of the fruit used. But regardless, in the composition, we can find malic acid, enzymes, pectin, antioxidant phenolic compounds (gallic acid, coffee acid, chlorogenic acid, catechins, epicatechins), elements (potassium, magnesium, sodium, iron, calcium, phosphorus),

amino acids and vitamins (C, E, A, P, B vitamins) [11,13]. These are essential components used in vital processes, in addition, many of them also show health-promoting effects [13].

Figure 1 - The process of production for vinegar



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Use in medicine

Antimicrobial effect

As mentioned earlier, one of the earliest uses of apple cider vinegar was for its antimicrobial properties [1]. In addition to Hippocrates, the ancient Babylonians also used apple cider vinegar as a disinfectant [14]. It was also well known to the ancient Chinese; Sung Tse, who is recognized for founding the field of forensic medicine in 10th century China, employed sulfur and vinegar as hand-washing solutions to ward off infections [12]. Its antibacterial properties are not in doubt due to the presence of acetic acid and other organic acids, which have properties that disintegrate the cell membrane of microorganisms, as demonstrated by numerous studies [12,14,15,16,17,18]. For example, in 2018, an article published in the journal Nature showed that it is reasonable to use apple cider vinegar as a disinfectant. The research investigated the antimicrobial and antifungal properties of apple cider vinegar (ACV) against E. coli, S. aureus,

and C. albicans. It was determined that undiluted ACV (5% acidity) was necessary to inhibit C. albicans growth, while a 1/2 dilution (2.5% acidity) was effective against S. aureus, and a 1/50 dilution (0.1% acidity) sufficed for E. coli. These inhibitory effects were confirmed through visual examination of inhibition zones on culture plates. The minimum inhibitory concentrations (MIC) for ACV tablets were identified as 62 μg/ml for E. coli, 125 μg/ml for S. aureus, and 250 μg/ml for C. albicans. ACV also significantly reduced the production of the inflammatory cytokines TNF-α and IL-6 from monocytes exposed to these microbes. Effective dilutions for this reduction were 1/50 for E. coli, 1/10 for S. aureus, and 1/2 for C. albicans. Notably, over 90% of monocytes survived after 24 hours of co-culturing with the microbes. Furthermore, ACV enhanced the phagocytic ability of monocytes, increasing their capacity to engulf and destroy microbial cells by 14.2% for E. coli, 13.7% for S. aureus, and 20.4% for C. albicans. Proteomic analysis showed that ACV-treated E. coli cultures lacked crucial enzymes and proteins necessary for metabolic processes and DNA protection. Similarly, S. aureus cultures did not express specific ribosomal proteins, enzymes, and cell division proteins. In C. albicans, essential enzymes for glycolysis and immune response were absent after ACV treatment. These results underscore the potent antimicrobial and anti-inflammatory effects of ACV, indicating its potential as a treatment for infections caused by these pathogens [14]. A slightly older study from 1998 showed a bacteriostatic and bactericidal effect of vinegar. The study examined the antibacterial properties of vinegar for food-borne pathogenic bacteria including Escherichia coli O157:H7, finding that 0.1% acetic acid inhibited all tested bacterial strains. This effect was usually enhanced by adding sodium chloride or glucose. Acetic acid's unique efficacy was highlighted as hydrochloric acid at the same pH did not inhibit growth. Vinegar solutions with 10%, 5%, and 2.5% acetic acid inactivated EHEC O157:H7 in 1 minute, 25 minutes, and 150 minutes, respectively, showing a linear relationship between acetic acid concentration and inactivation time. The bactericidal effect of vinegar was consistent across different inoculum sizes and was more effective on EHEC O157:H7 cells in the logarithmic growth phase than in the stationary phase. Higher temperatures also significantly reduced inactivation time, with faster inactivation observed at higher temperatures [17]. Another study published in 2015 analyzed the antifungal activity of apple cider vinegar on Candida species associated with denture stomatitis. It showed that apple cider vinegar (4%) had a minimum inhibitory concentration (MIC) of 2,500 μg/ml and minimum fungicidal concentrations (MFC) of 2,500, 5,000 and 10,000 μg/ml, depending on the strain. In contrast, nystatin had a MIC of 3.125 μg/ml and strain-dependent MFC values ranging from 3.125 to 12.5 μg/ml. A microbial kinetics study showed a significant difference between the effects of apple cider vinegar and

nystatin ($p < 0.0001$). After 30 minutes of exposure, apple cider vinegar showed fungicidal activity at four times the MIC, while nystatin retained fungistatic activity. In addition, apple cider vinegar significantly inhibited microbial adhesion ($p < 0.001$) compared to the control [18].

Effect on lipid profile

Lipid metabolism plays a crucial role in maintaining overall health, as it involves the breakdown, utilization, and storage of fats within the body. Various studies have explored how apple cider vinegar, with its unique composition of acetic acid and other bioactive compounds, may influence lipid profiles [8,12,19,20,21,22,23,24]. Most studies on the effects of apple cider vinegar (ACV) on lipid profiles have been conducted on animal models, specifically rats and mice, and have shown improvements in various health parameters. In studies involving high-cholesterol diets, animals given ACV exhibited significant reductions in serum total cholesterol and triacylglycerol levels compared to those on cholesterol-only diets. However, their total cholesterol levels remained higher than those in non-cholesterol groups. Liver cholesterol and triacylglycerol concentrations were also lower in the ACV groups [22]. For instance, a 2011 study showed that rats on a cholesterol-rich diet supplemented with ACV had decreased triglyceride and VLDL levels. Additionally, ACV increased total cholesterol, HDL, and LDL cholesterol levels, and improved liver function tests compared to the high-cholesterol diet without ACV. Another study confirmed similar findings, noting an increase in HDL-c and a reduction in triglycerides in healthy rats, as well as a reduction in LDL-c in diabetic rats [19,20]. Moreover, ACV supplementation in mice resulted in slightly lower body and liver weights, reduced body fat accumulation, and decreased hepatic lipids without affecting food intake or muscle weight. These mice also showed lower serum total cholesterol and triacylglycerol levels compared to those on cholesterol diets without ACV [21]. Overall, the consistent findings across these studies suggest that ACV can positively influence lipid metabolism by reducing serum and liver cholesterol and triacylglycerol levels, increasing beneficial HDL cholesterol, and improving liver function [19,20,21,22]. Several of the research on people was conducted on small groups of participants, which also showed a positive effect of apple cider vinegar on improving the lipid profile of people with obesity and patients suffering from type 2 diabetes and dyslipidemia. The study on the effects of vinegar consumption on lipid profiles from 2009 involved 155 obese Japanese participants who showed a reduction in triglyceride levels and total cholesterol [23]. Another study, in turn, conducted on patients with type 2 diabetes and

dyslipidemia showed a beneficial effect of regular consumption of small volumes of apple cider vinegar (20ml) on improving their vital parameters [24].

Effect on glucose level

Apple cider vinegar's effect on improving tissue insulin sensitivity was confirmed in several studies [8,12,20,21,22,25,26,27]. This is a particularly attractive property of vinegar, especially in recent years, where it is promoted to maintain or achieve a slim figure. Social media has had no small impact on the perception of one's body, especially among young people who are looking for various ways to get the right - in their perception - look. Therefore, consuming apple cider vinegar seems to be another magical way to achieve this goal. But is it? In a study conducted on an animal model, it was demonstrated that apple cider vinegar has several beneficial effects on glucose metabolism and insulin sensitivity. In diabetic rats, apple cider vinegar significantly decreased glycated hemoglobin (HbA1c) but did not change fasting blood glucose (FBG) [20]. In mice, vinegar consumption reduced body and liver weights, indicating less fat accumulation and potentially better metabolic processes. It inhibited body fat and liver lipid accumulation through the upregulation of fatty acid oxidation-related proteins, suggesting enhanced insulin sensitivity [21]. In a study involving cholesterol-fed groups, apple cider vinegar addition to food resulted in lower serum insulin levels, indicating improved insulin sensitivity. Vinegar also influences the expression of genes related to lipid metabolism, further enhancing insulin sensitivity and overall metabolic health [22]. Studies conducted on small clinical groups in humans, also show that apple cider vinegar has positive effects on glucose metabolism, blood glucose levels, tissue insulin sensitivity, and feelings of satiety. In one study, 70 participants with type 2 diabetes and hyperlipidemia were divided into an intervention group and a control group. In the intervention group, consumption of 20 ml of apple cider vinegar per day for 8 weeks significantly improved fasting glucose levels (FBS) reduced indices of insulin resistance (HOMA-IR), and improved beta cell function (HOMA-B) and insulin sensitivity index (QUICKI) [24]. In another study, healthy participants consumed meals with or without vinegar. The results showed that vinegar significantly lowered blood glucose and insulin responses after a meal and increased feelings of satiety. The higher the dose of vinegar, the greater the effect on lowering glucose and insulin levels and increasing satiety [25,26]. Further studies have confirmed that consuming vinegar before a meal increases insulin sensitivity in insulin-resistant people and those with type 2 diabetes, suggesting that vinegar may work similarly to some diabetes medications, such as acarbose or metformin [26,27]. In conclusion,

apple cider vinegar may effectively improve glucose control, insulin sensitivity, and satiety, which may be beneficial in managing type 2 diabetes and improving overall metabolic health.

Other health effects

Apple cider vinegar, thanks to its content of bioactive compounds such as polyphenols and vitamins, also affects other bodily functions. These compounds have a strong antioxidant effect, which helps protect cells from oxidative stress, which contributes to accelerated aging, cancer, and degenerative brain diseases [12,13,19,28]. Studies have shown that various types of vinegar, such as apple cider vinegar, wine vinegar, sherry vinegar, and balsamic vinegar, contain high concentrations of polyphenols that effectively neutralize reactive oxygen species, such as hydrogen peroxide and hydroxyl radicals. Wine and apple cider vinegar, for example, have high ORAC (Oxygen Radical Absorbance Capacity) and TEAC (Trolox Equivalent Antioxidant Capacity) values, confirming their strong antioxidant effects [19]. Phenolic compounds also exhibit anticancer effects. Studies on various cancer cell lines have shown that Kurosu Japanese rice vinegar, for example, inhibits their proliferation in a dose-dependent manner [29]. Vinegar, thanks to its acetic acid content, can also lower blood pressure, as shown in studies conducted on hypertensive rats and rat aortic endothelial cells [30,31]. The vinegar and acetic acid used reduced the activity of renin and angiotensin-converting enzyme (ACE), as well as lowered blood levels of angiotensin II and aldosterone in the test animals [30,31]. They also activated the AMPK pathway, leading to beneficial changes in the expression of proteins associated with blood pressure regulation. Studies have shown that the acetic acid in apple cider vinegar may be effective in lowering blood pressure and can be used in combination with antihypertensive drugs to increase their effectiveness [31]. Apple cider vinegar can also play a role in wound healing support (its antibacterial properties) and effects on brain function. In one study, researchers demonstrated that sphingolipid precursors produced by acetic acid bacteria may support cognitive function and improve mental abilities, which may be important in the treatment of dementia [32]. Another important feature of apple cider vinegar is its prevention of cardiovascular diseases. The polyphenols it contains, such as chlorogenic acid, can counteract the oxidation of LDL lipoproteins, which is crucial in preventing atherosclerosis [12]. Additionally, previously discussed properties such as beneficial effects on lipid profile and increased tissue sensitivity to insulin reduce the likelihood of cardiovascular diseases by influencing its significant risk factors [7]. The beneficial effect on weight loss has gained particular interest in recent years. Vinegar can support weight loss by increasing feelings of satiety and improving insulin sensitivity, resulting in lower calorie intake [23,24,26,27].

Previous studies on animal models have also shown that daily consumption of vinegar helps reduce liver fat in rats fed a high-fat diet [19,21,22]. Single studies also point to its positive effects in relieving muscle cramps in athletes [41].

Cosmetic use

In folk traditional uses of apple cider vinegar, its use in hair and skin care was very popular. From generation to generation, one could hear advice passed down on how to prepare a rinse with vinegar to improve the condition of hair, eliminate dandruff, and treat all sorts of inflammations and skin lesions [33]. Even today, browsing through Internet search engines, one gets the impression that apple cider vinegar can not only be a miracle weight-loss, anti-cancer, anti-hypertensive remedy but also a magic cure for skin diseases. However, these miraculous properties do not seem to be confirmed in reality. There are not enough studies to establish conclusively in which skin diseases apple cider vinegar can be used. The beneficial effect on the appearance and condition of hair and skin may be caused primarily by its antibacterial effect, and its acetic acid content to restore the skin's natural lower pH. But even this is not fully confirmed [34]. Studies examining the effect of apple cider vinegar use on skin conditions in patients with atopic dermatitis have even shown that it does not significantly improve patients' conditions and there is no rationale for its regular use [35,36]. Other studies showed that the use of a solution of garlic oil with apple cider vinegar can produce a beneficial effect in the treatment of alopecia areata as an adjunct to minoxidil treatment [37] or a mix of lemon juice and vinegar can inhibit the growth of fungi responsible for the formation of dandruff [39]. Other scientific sources indicate that there is no evidence to support its use in pruritus, removal of head lice, and treatment of pregnancy stretch marks [38]. Also, in the trend of conscious hair care in recent years, apple cider vinegar, due to its low pH, has gained great popularity, as a means of closing the hair cuticle and thus improving the appearance of the hair [40]. In addition, due to its bactericidal and bacteriostatic properties, to which one of the previous chapters is devoted, it seems reasonable to use it in the household as a natural cleaning agent for disinfecting and cleaning various surfaces. Such its use is also present in folk traditions.

Safety of use

To get the most out of the benefits of consuming apple cider vinegar, it is recommended to use it in dilution and moderation. Failure to take these precautions can cause gastrointestinal irritation, including heartburn, gastric reflux, and damage to the mucous membrane of the esophagus and stomach [42]. Prolonged consumption of large amounts can also lead to lower blood potassium levels (hypokalemia) and negatively affect bone health, increasing the risk of

osteoporosis. In addition, acetic acid in high concentrations can damage tooth enamel, leading to tooth decay and sensitivity [43,44,45]. The best solution to avoid side effects seems to be adding apple cider vinegar to everyday meals, for instance as an ingredient in salad dressings or marinades. Also, it is important to not forget about possible interactions of apple cider vinegar with medications, especially with some diuretics, digoxin, and insulin [43]. It is difficult to determine what daily amounts of vinegar produce the most beneficial health effects, there is not enough research on this topic. However, from the available sources, it can be indirectly concluded that the consumption of 15-30ml per day should not be exceeded, and already at this dose it is possible to enjoy the long-term benefits of its use [23,24,41,43]. As mentioned earlier, also in the application of vinegar for domestic usage as a cleaning agent, it should be remembered to dilute it with water beforehand.

Conclusion

A historical review and current scientific evidence on apple cider vinegar shows its long history of use in both folk and modern medicine. Apple cider vinegar was used as early as ancient times by figures such as Hippocrates, and its versatile uses included healing wounds, aiding digestion and weight loss, preserving food, and disinfecting skin and everyday objects. Modern scientific research supports many of these traditional uses, demonstrating health benefits associated with improved lipid profile, blood glucose control, reduced cardiovascular risk, indirect effects on weight loss, and lower blood pressure. Also, its high content of polyphenols and vitamins reduces oxidative stress on cells, which may help prevent cancer and degenerative brain diseases. A significant problem, however, may be the small number of studies conducted and the small clinical groups that constitute the subjects studied. Specifically, areas such as - particularly attractive - weight loss aided by the use of apple cider vinegar, use in the treatment of skin lesions, including the scalp, and aiding in the treatment of muscle spasms seem to require closer investigation with a larger number of subjects and different demographic groups in order to fully understand, confirm its efficacy, and verify the safe of usage.

Authors contributions

Conceptualization: Anna Kiełb, Anna Kaźmierczak

Methodology: Anna Kiełb, Anna Kaźmierczak and Klaudia Perkowska

Software: Jakub Stanek

Check: Radosław Ciesielski, Anna Mich and Igor Pawlak

Formal analysis: Patrycja Sornek

Investigation: Wiktoria Izdebska and Agata Borkowska

Resources: Klaudia Perkowska

Data curation: Agata Borkowska and Patrycja Sornek

Writing -rough preparation: Anna Kiełb, Anna Kaźmierczak and Wiktoria Izdebska

Writing -review and editing: Radosław Ciesielski, Anna Mich and Jakub Stanek

Visualization: Igor Pawlak

Supervision: Wiktoria Izdebska

Project administration: Anna Kiełb

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The authors report no conflict of interest.

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