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A concise review: edible mushroom and their medicinal significance

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Abstract

In many areas of human life, including food, health, culture, and religion, mushrooms have had a significant impact. Most people eat mushrooms for their flavor and texture. Recently, they have gained popularity as a protein source and a drug research tool. According to the phyla Ascomycota and Basidiomycota, mushrooms are fungi that produce spongy fruiting bodies, particularly those that possess a stalk and an envelope top. Mushrooms are composed of 90% water and 10% dry material. Additionally, it has a physicochemical composition that is important for nutrition. Edible mushrooms have been shown to offer therapeutic benefits, including anti-cancer, cardiovascular, hepatoprotective, neuroprotective, hypolipidemic, antiviral, antibacterial, and anti-diabetic actions. Mushrooms are a fantastic source of nourishment since they are rich in proteins, minerals, complex sugars, unsaturated fatty acids, and secondary metabolites. The composition and nutritional benefits of edible mushrooms have been carefully investigated in this review. Edible mushrooms have been used as potential therapeutic stand-ins, and bioactive components present in edible mushrooms, such as polyphenolic compounds and antioxidant activity, have also been studied. This review article may also help scientists, researchers, and medical professionals slow the advancement of some lifestyle diseases, neurological disorders, along autoimmune disorders.

Keywords

Mushroom, protein source, polyphenolic compounds, lifestyle diseases

Introduction

According to the phyla Ascomycota and Basidiomycota, mushrooms are fungi that produce spongy fruiting bodies, particularly those that possess a stalk and an envelope top. There are many different species of mushrooms on the earth, and people utilize them for their medicinal and dietary properties [1]. Since ancient times, it has been used for food and medicine. Due to its significance in human health, nutrition, and illness and its many medical characteristics, including cancer-preventing, antibiotic, antiviral in nature, immune-mediated, stimulating properties, and blood lipid-lowering effect, it is one of the most widely used food crops. Countless organizations nationwide have conducted countrywide assessments of species of fungi from various sources [2]. The nutritional value of professionally grown mushrooms is unknown, yet. The concept that the mushroom could be utilized as both food and medicine dates back to the belief of the ancient people that it maintained human wellness and good health, sustaining vitality as long as possible. The mushroom, in Greek mythology, gives heroes strength in battle. However, the Egyptians believed they were a true gift from the beneficent Orris. Because of this, Romans regarded fungi that were edible as divine foods and even consumed them [3].

Auricularia was the first mushroom ever created artificially. For the first time in 600, *Flammulina*, *Velulips*, and *Lentiluna* edodes were harvested. Growing mushrooms has benefited greatly from the assistance of the French. In the 1600s, *Pleurotus* spp. and *Agaricus bisporus* were originally raised for food. Since the turn of the century, only about thirty-five different kinds of mushrooms have been successfully cultivated in the United States; twenty-one out of them are currently grown commercially [2–3].

Biological importance and active ingredients of edible mushrooms

For millennia, medicinal mushrooms have been revered for their flavor, smooth texture, and therapeutic benefits. In general, mushrooms are composed of 90% water and 10% dry material. Additionally, it has a physicochemical composition that is important for nutrition. Mushrooms are nutrient-dense due to their high levels of protein, fiber, and minerals, as well as their low-fat content. All nine essential amino acids, which are all present in mushroom protein, are required by the human body. Due to their ease of digestion, mushrooms are being researched as a potential muscle protein substitute [4]. The vitamins thiamine, riboflavin, cyanocobalamin, ascorbic acid, ergosterol, and tocopherol, as well as some other nutrients, are also abundant in mushrooms. They are also a great source of iron, phosphorus, and vitamins like niacin. This is rare to find in those other foods, vitamin D is also present in mushrooms. Due to their high nutritional value and the positive effects of the bioactive substances they contain on health, mushrooms are regarded as a healthy food. Food bioactive ingredients that promote health and reduce the likelihood of disease are becoming more and more popular [5]. Mushrooms are an example of a food that serves both dietary and medicinal purposes. In addition to nutrients, the idea of “food supplements” was initially introduced as a factor to take into account while analyzing foods. In addition to being nutrient-dense foods, mushrooms also have therapeutic properties that may help avoid conditions including hypertension, diabetes, elevated cholesterol levels, and tumors. The existence of dietary fiber, notably chitin and beta-glucans, is what gives mushrooms their distinct functional characteristics. Some mushrooms may be able to lower blood glucose levels, and many mushrooms have cancer-fighting, antiviral, antithrombotic, and immunomodulatory effects [5–6].

Mushroom species, their components, and their biological significance

Polyunsaturated fatty acids are an active component of the *Laetiporus sulphureus* species of mushrooms, and they have antibacterial and antifungal properties [7]. Ganoderic acid and beta-glucan in *Ganoderma lucidum* have antioxidant and cytotoxic properties [8]. Lectins, ribotoxins, catechin, polysaccharides, galactomannan, beta-glucan, and fatty acids are present in the *Agaricus bisporous* species of mushroom, which also enhance insulin secretion activity and have antibacterial, antiviral, antifungal, antioxidant, and anti-diabetic properties [9–12]. Other species including *Pleurotusostreatus*, *Pleurotus* spp., and *Pleurotus sajor-caju* have lovastatin as an active ingredient, which can decrease cholesterol [13]. Some *Lentinus*

edodes species include lentinan and eritadenine, which can reduce cholesterol [14]. Species of *Grifolafrondosa* exhibit polysaccharides and lectins that act to increase insulin production and lower blood sugar [15]. The Cordyceps sinensis has cordyceptin active ingredient with hypoglycemic and anti-depressant activity [16], whereas the *Auricular* species have acidic polysaccharides that have analgesic effects [17]. *Trametes versicolor* also contains polysaccharide-K (Kresin), which has anti-cancer activity [18]. Fatty acids, polysaccharides, and amino acids are found in the *Pleurotus giganteus* mushroom with neuroprotective and antioxidant effects [19].

Significant pharmacological characteristics of edible mushrooms

Since antiquity, conventional medicine has valued edible fungus for its tremendous health benefits. A variety of ways that mushrooms can improve human well-being depend on their biological components. A growing number of people are interested in extracting bioactive components from mushrooms to create functional foods [20]. Traditional medicines have employed mushrooms for a very long time in many different forms. The use of phytochemicals or bioactive compounds from different mushroom species as antioxidants, anti-cancer, and anti-inflammatory agents to treat a range of human illnesses, such as cancer, diabetes mellitus, bacterial and fungal infections, coronary heart disease, and diabetes mellitus, is becoming more and more common around the world. However, numerous human experimental therapy studies including the use of mushrooms have been undertaken, and those studies have demonstrated that mushrooms with their preparations are typically well tolerated with little noticeable adverse effects [21]. The medicinal values of mushrooms are represented in Figure 1.

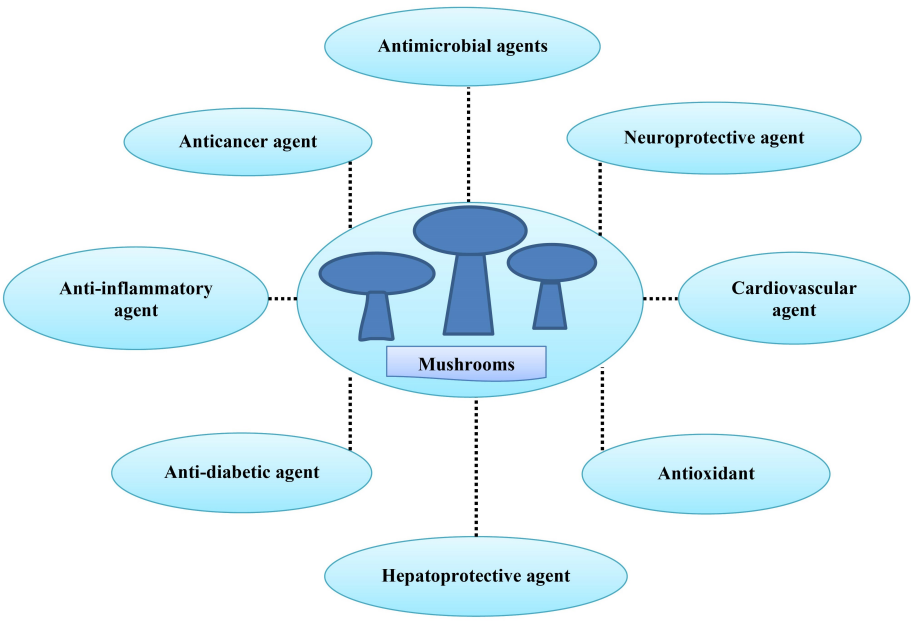

Figure 1. The medicinal properties of mushroom

Effectiveness of consumable mushrooms as an achievable cancer-prevention treatment

One of the deadliest illnesses on the earth is cancer. Recent research has revealed that polysaccharides present in mushrooms, which are naturally occurring plant active components, have potent anti-cancer effects on a range of cancer model organisms [22]. Furthermore, another polysaccharide, basidiomycota contains therapeutic capabilities that are connected to its glucan. Elements of the beta-glucan chemical family, polysaccharides are thought to enhance cellular immunity and possess anti-tumorigenic characteristics [23].

Agaricus bisporus contains bioactive substances that are equipped with immunomodulating as well as anticancer properties. The Canadian Cancer Society advises consuming *Agaricus bisporus* mushrooms due to their effectiveness against human illnesses. The study found that both *in vivo* and *in vitro*, the polysaccharide from *Agaricus bisporus* exhibits strong immunostimulatory and anticancer bioactivity [2, 24]. According to a literature review, the three main polysaccharides in *Agaricus bisporus* are alpha-glucan, beta-glucan, as well as galactomannan, with galactomannan making up 55.8% of the total [24]. The health and immunity of the mucosa can be enhanced by *Agaricus bisporus*. Consuming *Agaricus bisporus* in the diet considerably increases secretory immunoglobulin-A secretion [25].

The fruiting body extracts from *Agaricus bisporus* have an immunostimulant impact on activated peripheral blood mononuclear cells (PBMCs) and stimulate the production of interferon-gamma (IFN-γ). In HL-60 cells with leukaemia along with other leukemia lines from humans, *Agaricus bisporus* solutions have been shown to cause apoptosis, which inhibits cell proliferation. *Agaricus bisporus* fruitbodies contain arginine, which is utilized as a dietary supplement for cancer sufferers because it slows the growth and spread of cancer cells. Additionally, it was discovered that *Agaricus bisporus* does inhibit aromatase, reducing the incidence of breast cancer (BC). According to studies *in vivo*, phytochemicals produced from *Agaricus bisporus* limit aromatase activity, obstruct the proliferation of BC cells and lessen the size of breast tumors [26]. *Agaricus bisporus* is said to contain active compounds that include unsaturated lipids like linoleic acid, and linolenic acid (LINA), including conjugates of linoleic acid (CLA), that have been shown to inhibit aromatase activity [27]. A biologically acceptable method for influences on oestrogen receptor-positive tumors was also discovered, including suppression of aromatase function and subsequent reduction of oestrogen-using mushroom extracts. Although it has been demonstrated that regular use of mushrooms and their average frequency of use are adversely associated with the risk of BC, this relationship is most potent in post-menopausal women. It was found that eating mushrooms reduced the incidence of BC in premenopausal women [26, 28].

Effectiveness of consumable mushrooms as an effective anti-inflammatory drug

An extensive biological reaction to infections and serious injuries, inflammation helps to restore tissue function and structure. while chronic inflammation contributes to the onset of numerous inflammatory illnesses. Because they seem to be natural, safe medications with few, if any, side effects, alternative anti-inflammatory pharmaceuticals made from plants have drawn a lot of interest. Unprocessed *Flammulina velutipes* mushrooms were found to have anti-inflammatory characteristics, which prevented the production of nitric oxide (NO) and tumor necrosis factor-alpha (TNF-α) from murine macrophage RAW264.7 encouraged by lipopolysaccharides and IFN-γ. Furthermore, very few effective anti-inflammatory capabilities were found in shiitake that went through food processing steps such as boiling and heating, suggesting that the anti-inflammatory bioactive molecules of the treated mushroom had been eliminated. A different investigation revealed that *Flammulina velutipes* water and ethanol (EtOH) extracts significantly reduced the generation of NO as well as of inducible NO synthase (iNOS) and cyclooxygenase-2 (COX-2) in macrophages [29].

Effectiveness of medicinal mushrooms as a treatment for heart disease

Edible mushrooms are a great alternative for both heart disease patients and those exploring treatment for cardiovascular disorders because they are low in fat, have a greater amount of unsaturated fats, and contain no cholesterol. The mushroom's high potassium and low sodium content enhances blood circulation and salt balance in humans. Mushrooms are therefore advantageous for people with high blood pressure. Regular use of mushrooms like *Lentinula* and *Pleurotus* spp. was found to dramatically cut cholesterol levels [30].

High levels of triglycerides or cholesterol, or hyperlipidemia, are among the highly severe disorders that affect people and are a major risk factor for atherosclerosis and heart disease. By lowering blood

cholesterol levels, phytosterols can lower total cholesterol as well as low-density lipoprotein (LDL) cholesterol [31]. The sterols present in *Agaricus bisporus* (fungisterol) include ergosta-7,22-dienol, ergosta-5,7-dienol, and ergosta-7-enol. In several studies, it was found that *Agaricus bisporus* mushroom has both anti-glycemic and antihypercholesterolemic effects in rats fed a hypercholesterolemic diet (14% fat and 0.5% cholesterol) [32]. Daily consumption of *Agaricus bisporus* fruiting bodies helps to regulate anti-glycemic and anticholesterolemic responses in rats fed a hypercholesterolemic diet. Additionally, it enhances hepatic function and lipid homeostasis [32, 33].

Effectiveness of medicinal mushrooms as an excellent hepatoprotective substance

A variety of secondary metabolites, many of which have biological purposes, such as phenolic molecules, carbohydrates, terpenes, and steroids were produced as a result of the specific growth characteristics of mushrooms in ecology. A number of these processes work together to provide mushrooms with a great degree of potential as makers of bioactive chemicals that are advantageous to human health. This includes both their consumption as food and their significance in research facilities as producers of biomolecules with specific therapeutic properties [34]. A rat model of chemical hepatitis caused by paracetamol was used to test the hepatoprotective effects of water-based extracts of *Volvariella volvacea*, *Lentinula edodes*, *Flammulina velutipes*, *Auricularia auricular*, *Tremella fuciformis*, *Grifola frondosa*, and *Tricholoma lobayense* [35]. Animals were either fed whole shiitake or non-purified preparations to study the influence of nutritious and therapeutic mushroom bioactive elements on hepatic function, or hepatocyte preparations were incubated with complete or semi-purified extracts. Hydroalcoholic, alcohol-based, and water-based extracts of fungal mycelia and basidiomata have been studied [36].

Efficacy of mushrooms that are edible as a potential drug for the medical management of diabetes

Many people are affected with diabetes mellitus, a metabolic disease brought on by elevated blood glucose levels. If not properly regulated, it can have deadly results, organ failures, and life-altering effects. It has been demonstrated that ingesting mushrooms is a sort of herbal treatment with anti-diabetic characteristics which they have been employed for millennia to provide anti-diabetic, anti-oxidant, and anti-hyperlipidemic effects because they have largely natural compounds such as fibers, complex carbohydrates, phenolics, and alkaloids [37]. Additionally, the prebiotic properties of mushroom polysaccharides change the composition of the gut flora, which lowers insulin resistance. This review's objectives are to examine the connection between edible mushrooms and diabetes and to identify potential mushroom species that have antihyperglycemic capabilities. Numerous researchers have also examined the impact of various mushroom polysaccharides on the gut microbiome of diabetic animal models. *Agaricus bisporus* contains significant amounts of dietary fiber and antioxidants, including vitamin C, vitamin D, and vitamin B12, along with folates and polyphenols, which may be advantageous for diabetic people. *Agaricus bisporus* is said to contain several chemicals that may have anti-inflammatory in nature and antioxidant health benefits. These benefits may manifest with continued consumption over time in people at risk for type-2 diabetes. Animal studies found that high doses of *Agaricus bisporus* extract given orally to rodents lessened the effects of streptozotocin-induced diabetes [38]. Diabetic patients view mushrooms as a suitable diet because of their low-calorie count, lacking carbs, and low sugar and fat content. Lean proteins found in mushrooms assist the body in burning cholesterol. It is therefore the ideal diet for those attempting to lose calories [39].

Relevance of edible mushrooms as a successful antimicrobial agent

Globally, antimicrobial resistance poses a severe threat to public health, particularly with the emergence of multidrug-resistant organisms that are now almost immune to all antibiotics. Finding bioactive compounds from plants and animals that can be utilized as alternatives to conventional antimicrobials is therefore

becoming increasingly important. Several investigations have suggested that *Flammulina velutipes* mushrooms contain antimicrobials as well [40, 41]. Researchers looked into the antimicrobial properties of extracts from various *Flammulina velutipes* parts and found that mature *Flammulina velutipes* mushroom extracts from both methanol and chloroform demonstrated great antimicrobial properties, especially for staphylococcal infections and *Bacillus subtilis* [42]. Also discovered to have antimicrobial properties against Gram-positive and Gram-negative bacteria such as *Bacillus subtilis*, *Bacillus pumilus*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa* was a methanol extract of natural *Flammulina velutipes* fruiting body from Macedonia. A dual culture *in vitro* experiment that measured the adversarial interaction between the mushroom and the pathogens was used to study the pharmacological activity of *Flammulina velutipes* over plant pathogens [43, 44].

Enokipodins, a group of sesquiterpenoids of the cuparene type, were discovered in *Flammulina velutipes* and are now understood to be crucial elements in the plant's antibacterial activity. It was discovered that enokipodins A–D primarily have an antibacterial effect against Gram-positive bacteria like *Bacillus subtilis* and *Staphylococcus aureus* [45]. A greater understanding of their signalling pathways is necessary beforehand one of those substances can be employed as nutritional supplements or drugs in the food and drug sectors, even though numerous studies have shown the antimicrobial potential of *Flammulina velutipes*, such as the bioactive substances accountable for the socially constructed occurrence [46].

Considerable antioxidant effects of edible mushrooms

Due to its two deficient electrons, the oxygen molecule is a strong oxidant that can harm all organisms' cells by producing reactive oxygen species (ROS). Any chemical compound with at least one unpaired electron in molecular or molecular orbital structures is referred to be a free radical. ROS are produced by numerous external and biological sources. Although almost all species have antioxidant defense mechanisms, they are frequently not enough to completely ward off damage brought on by oxidative stress. Thus, the human body can be protected from oxidative damage by using antioxidant supplements or naturally occurring materials that contain antioxidants [47].

Oxidative stress is characterized by the increased accumulation and/or insufficient clearance of highly reactive molecules, especially the non-radical hydrogen peroxide (H_2O_2), hypobromous acid (HOBr), hypochlorous acid (HOCl), -ONOO, nitrous oxide (NO_2), and alkyl peroxy nitrates (RONOO), as well as the free radical reactive oxygen and nitrogen species (RONS) such as superoxide ($-O^{2-}$), hydroxyl (-OH), peroxyl ($-RO_2$), hydroperoxyl ($-HRO^{2-}$), -NO, and nitrogen dioxide ($-NO_2$) [48].

Numerous mushrooms have been found to have antioxidant properties. Each of the parts found in mushroom extracts is specific to a particular type of mushroom. Mushrooms have been a mainstay of the human diet for tens of thousands of years, and consumption of a wide variety of species has expanded recently. The primary bioactive components of mushrooms include phenolic compounds (phenolic acid and flavonoids), tocopherols, ascorbic acid, and carotenoids. Additionally, polysaccharides are physiologically active compounds. The increased antioxidant activity is reflected in the lower half maximal effective concentration (EC_{50}) value. *Austreus hygrometricus*, *Fistulina hepatica*, *Phellinus linteus*, *Pleorotus squarrosulus*, *Polyporus grammocephalus*, and *Macrocybe gigantea* are the plants with the highest antioxidant potential. With an emphasis on certain popular edible and medicinal mushrooms, this review will go over ROS, their detrimental effects on biological systems, antioxidant characteristics, and the comparative antioxidant activity of mushrooms. It has been demonstrated that phenolic compounds operate as metal inactivators, peroxide decomposers, free radical inhibitors, and oxygen scavengers in biological systems [49, 50]. The mushrooms all contain phenolic compounds. A nutritious food source of antioxidants, mushrooms are becoming more and more important to human health. Unexpectedly, mushrooms offer more antioxidant potential than the majority of fruits and vegetables. Consuming antioxidants will protect against damage caused by free radicals while preventing illnesses and aging. It is possible to manipulate fruit bodies or mycelium to produce active compounds in a relatively short amount

of time, which is a significant the ability to manipulate fruit bodies or mycelium to produce active molecules in a very short time is a key benefit when attempting to extract antioxidant nutrients from mushrooms. Mushrooms can be added to diet to help reduce oxidative damage in the human body, or antioxidant components can be extracted and used as functional additives [51]. *Pholiota adiposa*, *Pholiota lubrica*, and *Pholiota squarrosa* mushroom EtOH extracts were subjected to an oxidative stress (OSI) index and total oxidant status study by Sevindik et al. [52]. Total antioxidant capacity (TAS), total oxidant capacity (TOS), and OSI activity of different species of mushrooms were assessed by different researchers [53–64].

Mushrooms that can be eaten have the potential to act as a powerful neuroprotective agent

Neurological and neurodegenerative disorders are the most debilitating diseases and the biggest hazard to public health. Specific pathological alterations that affect simultaneously the peripheral and central nervous systems are the root cause of brain and nerve illnesses [65]. Additionally, these illnesses cause a decrease in neuron cell function, which affects the structure of the nervous system and causes degeneration or death of nerve cells throughout the body. Ataxia and dementia are the end outcomes, which are common symptoms of multiple sclerosis, Alzheimer's disease, Parkinson's disease, Huntington's disease, and amyotrophic lateral sclerosis [66]. Therapeutic mushrooms are a low-calorie, low-fat fungus that is more nutrient-rich. They contain a lot of nutrients and bioactive components, including vitamins, fiber, proteins, and carbohydrates, all of that has been traditionally used to treat a wide range of ailments. The globe over, therapeutic mushrooms including *Pleurotus giganteus*, as well as *Hericium erinaceus* are frequently used as pharmaceuticals and health supplements. In addition to lectins, the lactones terpenoids and alkaloid compounds, antibiotics, and metal-chelating elements, medicinal mushrooms, and their extracts also contain polysaccharide-glucan or polysaccharide-protein structures [67].

This review will focus on the therapeutic benefits of a few medicinal mushrooms that have been shown to have bioactive compounds that have a protective impact against neural dysfunction. These findings will help in the development of drugs to treat neurodegenerative diseases [68]. Some edible and medicinal mushrooms have the potential to increase the progression of neuritis in the brain by increasing nerve growth factor (NGF) results, mimicking NGF reactivity, or shielding neurons from neurotoxicant-induced death of cells. Such shiitake may have neuroprotective benefits against neurodegenerative illnesses like Alzheimer's and Parkinson's because of the fundamentals of the neurotrophic compounds found in the fungus. Regular eating of mushrooms may aid in preventing or delaying age-related neurodegeneration [69].

Conclusions

People are exerting more effort to find substances from nature that provide health benefits as they become more conscious of the potential negative effects of synthetic medicines and health supplements. *In vivo* and *in vitro* research has shown that mushrooms, a widely available fungus, offer amazing medicinal potential and excellent nutritional value. All kinds of mushrooms provide a good supply of carbs, protein, unsaturated fatty acids, some significant vitamins, and fiber from the diet, which are all nutritionally similar to vegetables. Although edible mushrooms are well known for their culinary and nutritional benefits, less is known about their medicinal potential. The bioactivities of edible mushrooms have been demonstrated to include cancer-fighting, anti-neurodegenerative, neuroprotective, antioxidative, anti-obesity, anti-diabetic, and antibacterial effects. Future studies should concentrate on determining the precise mode of action of several biochemical formulations and bioactive compounds. Researchers, healthcare professionals, and scientists working in the fields of pharmaceutical research and the development of drugs, as well as those working in the healthcare industry, will find this review paper to be of great use. A valuable source of bioactive compounds for medical and therapeutic uses, mushrooms additionally possess an abundance of applications as a nutritional and functional food. The information provided in this analysis may also act as a starting point for further study and experimentation as well as the commercialization of this unusual fungus.

Abbreviations

BC: breast cancer

NO: nitric oxide

ROS: reactive oxygen species

Declarations

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Author contributions

JPA: Conceptualization, Data curation, Writing—original draft, Supervision. VSA: Supervision, Writing—review & editing. SSR, AAT, and RSD: Data curation, Writing—review & editing. BAS: Data curation, Validation.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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Consent to participate

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