

Thermalism practices: benefits, gut-brain axis and unexplored microorganisms

Abstract

Since the dawn of humanity, the benefits of using thermal waters in various practices are evidenced, as well as its aid in the healing of injuries and improvement of metabolism. Currently, new approaches to the study of thermalism are applicable, such as the presence of microorganisms of sulfur and volcanic origin. In Latin America, studies indicate the presence of a diverse microbial ecosystem called Baregina, which is described as a type of sulfide. In this literature review, it is possible to understand the history of thermalism around the world and its implementation until today. Furthermore, the benefits of baths with sulfurous waters can be explained by the presence of distinct microbial consortiums, such as Bioglea. Benefits such as blood circulation, improvement in the lymphatic and endocrine system, tissue healing, recovery of injuries to the bones, muscles, and joints, also, performance in the gut-brain axis through microorganisms' presence. Moreover, new approaches and applications are highlighted.

Keywords: thermalism, microbial ecosystem, etruscans, gut-brain, tissue healing

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Introduction

Thermalism, briefly definable as a complementary therapy that includes the different ways of using mineral, sulfurous, and thermal water for application in health and healing treatments, is a practice known in humanity for the benefits found in waters with biochemical characteristics beneficial to the skin, organs, and systems. Since the dawn of mankind, the benefits of sulfurous, mineral, and volcanic waters have been emphasized in society, being used in rituals, local traditions, and religious practices. The first written reports of the use of waters with "miraculous" properties were in ancient Egypt, later by the Roman era, in which it had its great peak with the public baths.^{1,2}

Local people in Latin America used the benefits of hot springs even before the Egyptians. The buildings date back to the end of the last ice age and contained water reservoirs for bathing and rituals. In addition, their primitive dwellings were located near volcanic wells of hot water suitable for bathing. Water was seen as a sacred entity, and its use was made consciously and rationally.³

It is notorious that the benefits of thermal waters have been used in humanity for millennia, however, their biochemical and physical properties can reveal much more than a popular myth can tell. Beneficial microorganisms from hot springs are highlighted in the literature, acting on metabolism, immune system, and tissue regeneration properties.⁴

In water samples analyzed in Latin American territory, specific microorganisms of the genus Baregina can be found. With abundant sulfur-oxidizing bacteria and a gelatinous microbial mass (Bioglea), Baregina is characterized by being an associated microbial ecosystem, which is a type of sulfide.⁵ The "magical" benefits of the thermal waters of Latin America can be explained by the abundance of beneficial non-pathogenic microorganisms in their constitution, moreover, the metabolomics of this diverse ecosystem is evidenced.

Methodology

The present study has a descriptive-discursive character, emphasizing mainly the theme of thermalism and its benefits, as well as the microorganisms present in sulfurous waters, in addition, to

emphasizing the history of thermalism and the practices of ancient peoples that involved the use of water, as well as the gut-brain axis and the health and healing practices of thermalism. Intending to carry out an accurate and critical review of thermalism practices, it is noteworthy that microorganisms of sulfurous origin have not yet been fully cataloged. In view of this, the present study focuses on the benefits of baths and the use of sulfurous waters, as well as their microorganisms for the treatment of skin, joint, muscle, and skin diseases. Thus, objective searches were performed in the databases: PUBMED, SCIELO, and Google Scholar. In the search for the articles used in this bibliographic research, the terms "thermalism", "sulfurous waters" and "baregina" were used, without exclusion criteria.

Results and discussion

Thermalism in the World

The ancient Olmecs (1500 BC-400 BC) are considered one of the first known peoples who formed a great civilization in Latin America. Their farming practices are known for the clever use of drainage systems, canals, and dikes to control the flow of water and irrigate their crops.⁶ In addition, they believed that water was a sacred element, associated with life, fertility, and purification. The presence of water sources at many Olmec archaeological sites suggests that these sites were important for rituals and ceremonies.⁷

In the Mayan civilization, cenotes, natural freshwater wells, were considered portals to the world of the gods and used for religious rituals and ceremonies. In addition, the cenotes also provided drinking water to the Maya communities.⁸ In which they built cisterns and reservoirs to store water during rainy seasons. These structures were important for providing water during periods of drought or for use in times of war, when access to water sources may be limited. In addition to buildings located directly with the stars, the Maya also built near sulfurous sources of water.⁹

People originally from Italy called the Etruscans, used complex systems of conservation and use of water even before the Romans. The Etruscans were people who lived in Etruria, on the Italian peninsula, south of the Arno River and north of the Tiber.¹⁰ The hydro technology of the Etruscans was quite advanced and included the use of cisterns

and pipes, especially in urban areas, developing systems that distinguish between public and private use of water. Its architecture is considered extremely modern, and its city-states contained a large system of aqueducts, which inspired the great Roman constructions.¹¹

The Minoans also stand out as an ancient civilization that masterfully dominated water resources. Minoan buildings, especially their palaces, implemented water and sewage drainage strategies using open terracotta channels or stone masonry pipes. Their systems were so complex and advanced that their cisterns are used to this day in Crete (Greece), having their techniques preserved by locals.¹²

During Homeric times, around the ninth century B.C., people used hot baths as a way to cleanse the body, relieve pain, and perform home treatments such as hot compresses. There were purification rituals called “lustration,” in which people bathed in rivers or sacred springs, seeking the purification of their souls before religious ceremonies. Hippocrates, a Greek physician who lived between 460 and 377 B.C., was the first to observe and recommend the use of water in his work “Air, Water, and Places.” He highlighted the importance of water in therapy.¹³

The Roman tradition of thermal baths thrived especially during the reign of Emperor Trajan, and continued until the early Byzantine period, around the sixth century AD. Hot springs were popular places where people could bathe in hot and cold-water pools, as well as enjoy saunas and massages.¹⁴ The Romans believed that heated water had the power to relieve muscle aches, improve circulation, and promote overall well-being. Roman cities were equipped with hydraulic systems that allowed them to channel thermal water to public baths and private residences. The bathhouses in Baia and Campi Flegrei, in particular, gained prominence because of the volcanic origin of the water, which gave them unique properties.¹⁵

In ancient Egypt, there was also a strong therapeutic use of water. The Egyptians believed that water had healing properties and used it to treat a variety of ailments. Baths with flavored water and essential oils were common, and Egyptian priests were known for their knowledge of hydrotherapy.¹⁶ They developed massage techniques and medicinal baths to treat skin problems, localized pain, and joint problems.¹⁷

In Christian culture, various rituals of purification through water were used. The best known of these is called baptism and is used in various religions from Christianity to the present day.¹⁸ In addition, in biblical texts, wound healing, eye diseases, and even paralysis are described with the use of river and tank waters.¹⁹ However, in the medieval era, the use of spas was limited only in the Christian Roman Empire (Byzantine) and was considered an offensive practice.

In the modern era, sulfurous water treatment is categorized as beneficial to local tourism. The traditional idea of thermal tourism changed substantially in the 1980s, including massage, fitness, marine therapies, dietary therapies, physiotherapy, aesthetic treatments, detoxification treatments, sports and exercise, steam baths, hydrotherapies, health education, and relaxation techniques.²⁰

Benefits of thermalism

In addition to the mystical tales and epic stories that involve thermalism, its benefits are scientifically proven. Sulphureous waters as well as their in-depth and characteristic study depend on divisional arrangements based on temperature, chemical properties, and their osmotic characteristics.²¹

- a. Isotonic: They have a concentration of mineral salts similar to that of human blood. These waters are considered balanced and can be beneficial for hydration because they do not cause a significant change in the osmolarity of the body.

- b. Hypotonic: have a low concentration of mineral salts in relation to human blood, and lower osmolarity than the body, which means that they can be absorbed more quickly. They are often used for hydration after intense exercise or in cases of dehydration.
- c. Hypertonic: high concentration of mineral salts in relation to human blood, higher osmolarity than the body, which can result in slower absorption.
- d. Hypothermal: These waters have a lower temperature than body temperature, between 20°C and 30°C, and can be considered fresh waters, common in hot springs, pools, and spas.
- e. Hyperthermal: generally warmer, with temperatures above 39°C, they are known to be of volcanic origin and present a wide variety of microorganisms in their composition.

Vasodilation and vasoconstriction

The temperature of the thermal waters can influence physiological and biochemical processes in the human body, as well as in vasodilation, which consists of the relaxation of blood vessels, causing a redistribution of blood flow and vasoconstriction, being the process of contraction of erythrocytes.²² The mineral composition of sulfurous waters, such as calcium, magnesium, and sulfur are chemical indicators of vasodilation and vasoconstriction processes, in addition to temperature. It is also important to point out that the response of each organism is different to an external stimulus, whether physical or chemical.

In vivo, studies show the effects of vasodilation and vasoconstriction on the body mediated by the effects of thermal waters.²³ In the process of arterial hypertension, vasoconstriction contributes significantly to peripheral vascular stiffness, raising blood pressure. In this case, the process of vasodilation, promoted by hypothermal therapy can ensure the necessary change of blood flow, reducing arterial hypertension.²⁴ In this same perspective, in genetic or acquired diseases of coronary rigidity, vasoconstriction of the coronary vessels can cause reduced blood flow to the heart, triggering angina and, in more severe cases, a heart attack. Proper vasodilation is essential to maintain a blood and oxygen supply to the heart muscle.²⁵

Brain circulation requires high consumption of oxygen and glucose, and it is essential for the survival of an organism that the blood flow in the brain is in the correct volume.²⁶ Vascular diseases and complications, such as cerebral arteriovenous malformation, Reye’s syndrome, migraine disease, and cerebral amyloid angiopathy, are conditions interconnected to vasoconstriction and brain vasodilation, being conditions that can be aided by the benefits of thermalism.^{27,28}

The correct blood flow promotes the reduction of cortisol and is auxiliary in healing processes, as well as in the greater oxygenation of tissues and removal of toxins, that is, in toning the body, stimulating the immune system, and relieving pain or discomfort associated with deep muscles, joint or connective tissue diseases, and injuries or abnormalities.²⁹

Healing and regenerative processes

A study conducted in the city of Poços de Caldas (Minas Gerais state, Brazil) proved that the use of sulfurous waters had a significant change in osteoporosis in the knee region of 140 patients, who suffered from intense pain, minimized by the medicinal actions of thermal waters.³⁰ In addition, the use of sulfurous waters is correlated with the treatment of joint pain and in the regeneration of the joints, along with physiotherapeutic treatments, by the chemical elements such as calcium (in a concentration of 500-700mg/L) and magnesium

(50% less than calcium), the stimulation of collagen fibers, as well as their restoration process, happens slowly, but significant, reducing the tension between nerves and joints.³¹

Within the same perspective of tissue regeneration, sulfide balneotherapy is highlighted in the literature as an aid in healing processes in the dermis, considered a form of complementary treatment for certain dermatological conditions, such as psoriasis, eczema, seborrheic dermatitis, acne, and psoriasis.³² The sulfur present in sulfurous waters is believed to have anti-inflammatory, antimicrobial, and antioxidant effects. One study showed that the skin microbiota in 40 patients with psoriasis had a high change after treatment with thermal waters. Moreover, the bacterium Xanthomonadaceae, belonging to the phylum Proteobacteria, was associated with the clinical improvement observed after treatment of 3-week balneotherapy.³³

In addition, an in vivo study conducted in Japan proved that bathing sulfurous waters with carbondioxide (CO₂) accelerates the regeneration of skeletal muscle after injury, through an increase in myogenin expression. MyoD and myogenin are transcription factors belonging to the bHLH family of transcription factors. These proteins play important roles in the proliferation, differentiation, fusion, and myocyte formation of satellite cells.³⁴

Immune system and immune response

The heat of thermal baths stimulates the body to release β -endorphins and enkephalin, which are endogenous neuropeptides that influence pain perception through opioid receptor agonist activity. They also have immunosuppressive properties, such as decreased proliferation and activity of lymphocytes and natural killer cells.³⁵ In addition, sulfurous spring water can inhibit the proliferation of T cells and the production of inflammatory cytokines in a dose-dependent manner. Conventional detoxification leads to a stronger immune system, which can control infections, bacteria, and viruses more efficiently. It also helps overcome infections in early stages ranging from the common cold to deadly illnesses.³⁶ (Figure 1)

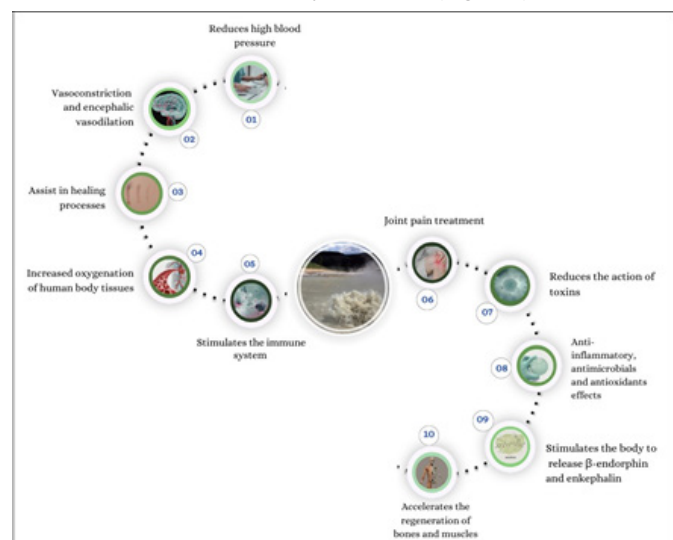


Figure 1 Proven benefits of Thermalism.

In several pathologies related to low-grade inflammation, especially in rheumatic diseases, balneotherapy, and mud therapy have been reported to cause a reduction in serum concentrations of pro-inflammatory cytokines TNF- α and regulatory cytokine IL-6. In addition, protein C-reactive levels decrease after balneotherapy

in patients with rheumatic and cardiovascular pathologies, acting directly on the immune system.³⁷ Given this, it is worth noting that a recent study showed that the practices of thermalism during the Covid-19 pandemic aided in the effectiveness of the immune response as well as the adaptive system.³⁸

In addition to psychic and immunological properties, thermalism also plays an important role in colon diseases, in which the intestinal mucosa loses its selective permeability, and the immune system reacts to absorb bacteria and metabolites, resulting in chronic inflammation. One of the treatments indicated for the replacement of the intestinal microbiota is hydrotherapy, assisting in the replacement of immunoglobulins (IgA and IgM) and T lymphocytes, present in the colon and acting on the gut-brain axis.³⁹

Moreover, a study conducted with young and elderly on the role of hydrotherapy with thermal waters in the regulation of lymphocytes and total leukocyte count showed, that in the younger group, the total number of leukocytes and granulocytes was significantly decreased. On the other hand, the total number of leukocytes and lymphocytes increased significantly after hydrotherapy in the older group, again emphasizing the great influence of thermalism on the immune system.⁴⁰

Gut-brain axis

The discovery of the axis so well-known today is closely linked with the practices of hydrotherapy. Since antiquity, Hippocrates has already described the routine of therapy, specifically mentioning: "... Bathing is good for many ailments, sometimes continuously or even sporadically and used the purification of the rectum to treat fevers febrile and diseases in general..."⁴¹ The gut-brain axis is described as the interconnection between two organs that communicate in the most diverse ways, correlated with the gut microbiota. The axis can regulate diseases and disorders in the neural system, such as Alzheimer's, autism, and Parkinson's.⁴²

The gut microbiome exerts various levels of control over the immune system, inflammation, and metabolism. Disruption in interactions between the microbiome and the host can lead to an increased risk of several diseases, including cancer, autoimmunity, diabetes, and other diseases. It is evidenced that at high temperatures, as observed in hyperthermal sources, they are active in the homeostatic control and regulation of the intestinal microbiota, assisting in the interactions with the microbiome of an individual.⁴³

Intestinal lavage with waters rich in minerals and microorganisms modifies the intestinal microbiota and can act positively on the neurological and immune system, still without precise scientific proof, colon hydrotherapy can promote antioxidant, anti-inflammatory, and detoxification effects.⁴⁴ Moreover, in the context of the gut-brain axis, thermalism may have relevant effects. Some studies suggest that immersion in hot springs may have beneficial effects in reducing stress and anxiety, possibly through the influence on the autonomic nervous system and the release of neurotransmitters related to relaxation, aiding in gastrointestinal disorders and neurological disorders.⁴⁵

Microorganisms present in sulfur waters

Sulfurous sources can contain various types of microorganisms, from beneficial to pathogenic ones such as ectoparasites and endoparasites. In greater numbers, there are bacteria, among them; *Pseudomonas*, *flavobacteria*, *Acinetobacter*, and other Gram-negative genera, as well as micrococci, endospore-forming bacilli, some *Actinomyces* and typical genera of soil bacteria.⁴⁶ The term "colorless sulfurous bacteria" refers to prokaryotes without photosynthesizing

pigments, capable of using reduced sulfur compounds for energy (including *Thiobacillus*, *Thiomicrospira*, *Sulfolobus*, *Beggiatoa*, *Thiobacterium*, and *Achromatium*). In addition, another type of classification is green and purple sulfur bacteria, which make anoxygenic photosynthesis. Among its main representatives are the genera: *Chromatium*, *Thiococcus*, *Thiospirillum*, *Halorhodospira* (purple), *Chlorobium*, *Prosthecochloris*, *Pelodictyon*, *Ancalochloris* and *Chloroherpeton*.⁴⁷

One of the most abundant microbial types of sulfites or sulfurous sources, especially at interfaces where H₂S and sulfides come into contact with atmospheric O₂ gas, is the sliding reduced sulfur-oxidizing bacteria of the genus *Beggiatoa*. The classification of a *Beggiatoa* is correlated with physical and chemical factors.⁴⁸ The source must contain more than 1 mg/L of divalent sulfur, in the forms of hydrogen sulfide and polysulfide acids. Such sources usually have organic matter, which is an additional sulfur element source: algae (baregin) and bacteria (sulfobacteria or sulfurs).⁴⁹ The part that is in suspension is called sulfuraria; The one that is dissolved has the name of Baregina. Sulfuria, which is only found in sulfurous waters, is formed by algae arranged in filaments that can harbor helminthes.⁵⁰

It is described in the literature that the microorganisms present in sulfurous waters can help in the performance of athletes, by the hematopoietic and antioxidant effect, being potentiators of the effects of thermal waters.⁵¹ In addition, they helped in tissue healing processes, being proven to improve the texture of the skin after constant use.

Conclusion

It is notorious that the practices of thermalism are very old, since the first civilizations, and that its benefit have been emphasized until the modern era. In addition, it was possible to prove that certain types of sulfurous waters are optimal for blood circulation, aid in tissue healing processes, stimulate the immune response, ensure greater oxygenation to the tissues, assist in the recovery of injuries to the bones, muscles, and joints, as well as ensures anti-inflammatory and antioxidant effects, in addition to benefiting the gut-brain axis. In short, various microorganisms can be found in thermal waters, depending on their intrinsic and extrinsic factors, potentiating the action properties of sulfurous sources. In the future, new studies could be carried out on the use of microorganisms of a sulfurous origin and thermal water as new approaches to product innovation, such as biomembranes and dressings, due to their ability to heal tissues and their great effect on the immune system. In addition, new approaches to treatments for neurodegenerative diseases are evidenced by the action of these microorganisms in the gut-brain axis. In view of this, it is worth pointing out that the use of these benefits and properties can be used in joint and muscle injuries, helping in the process of tissue regeneration. It is worth pointing out that thermal therapy is complementary, and can be of great help when used correctly and applied by qualified professionals. From current perspectives, this article highlights scientific evidence that proves the veracity of studies carried out recently and also highlights the importance of literature for the constantly evolving scientific base.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

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References

- Gianfaldoni S, Tchernev G, Wollina U, et al. History of the baths and thermal medicine. *Open Access Maced J Med Sci*. 2017;5(4):566.
- Fortuna S. History of medical thermalism in the Marche: the thermal baths in Sarnano. *Medicina Secoli*. 2009;21(3):1085–1103.
- Dailey M. *First peoples in a New World: colonizing ice age America*. 2nd ed. Cambridge University Press; 2012.
- Valverde A, Tuffin M, Cowan DA. Biogeography of bacterial communities in hot springs: a focus on the actinobacteria. *Extremophiles*. 2012;16:669–679.
- Mateu FT. The Baños of Montemayor (Cáceres): morphological and functional characteristics of the constituting microbial community. *Anales de Hidrología Médica*. 2006;1:61.
- Grove DC. Olmec archaeology: A half century of research and its accomplishments. *Journal of World Prehistory*. 1997;11:51–101.
- Pool C. *Olmec archaeology and early Mesoamerica*. Cambridge University Press; 2007.
- Wyatt AR. The scale and organization of ancient Maya water management. *Water*. 2014;1(5):449–467.
- Gill RB. The great Maya droughts: water, life, and death. UNM Press. 2000.
- Haynes S. *Etruscan civilization: a cultural history*. 2000.
- Bizzarri C, Soren D. Etruscan domestic architecture, hydraulic engineering, and water management technologies: innovations and Legacy to Rome. *A Companion to the Etruscans*. 2015;129–145.
- Angelakis AN, De Feo G, Laureano P, et al. Minoan and Etruscan hydro-technologies. *Water*. 2013;5(3):972–987.
- Voudouris K, Yapijakis C, Georgaki MN, et al. Historical issues of hydrotherapy in thermal–mineral springs of the Hellenic world. *Sustain Water Resour Manag*. 2023; 9(1):24.
- Zanetti C, Marcato M. The study of thermalism in the Roman age: Methodological proposal. 2015;381–385.
- Monti S, Claval P, Pagnini MP, et al. Thermalism between past and future. In Part VI: Tourism, sustainable development and culture turn. 2003.
- Bahadorfar M. A study of hydrotherapy and its health benefits. *International Journal of Research*. 2014;1(8):294–305.
- Juarez E. *Hydrotherapy Manual*. Weimar University. 2020.
- Hoss S. Baths and Bathing. The culture of bathing and the baths and thermae in Palestien from the Hasmoneans to the Moslem conquest. 2005.
- DeForest D. Baths, Christianity, and bathing culture in Late Antiquity. 2019:189–206.
- Boekstein M. Tourism, health and the changing role of thermal springs-should South Africa reposition its thermal spring tourism product? 2014.
- Queiroz ET. Diagnosis of mineral and drinking table waters in Brazil. *Águas Subterrâneas*. 2004.
- House JR, Tipton MJ. Using skin temperature gradients or skin heat flux measurements to determine thresholds of vasoconstriction and vasodilatation. *Eur J Appl Physiol*. 2002;88:141–145.
- Gardner CA, Webb RC. Cold-induced vasodilatation in isolated, perfused rat tail artery. *American Journal of Physiology-Heart and Circulatory Physiology*. 1986;251(1):H176–H181.
- Hansen PB, Hashimoto S, Oppermann M, et al. Vasoconstrictor and vasodilator effects of adenosine in the mouse kidney due to preferential activation of A1 or A2 adenosine receptors. *J Pharmacol Exp Ther*. 2005;315(3):1150–1157.

25. Josefsson A, Sigurdsson SB, Bang K, et al. Dorzolamide induces vasodilatation in isolated pre-contracted bovine retinal arteries. *Exp Eye Res.* 2004;78(2):215–221.
26. Bruzzone P, D'Andrea V, Motta C, et al. Occurrence of dopaminergic (D2) receptors within the rabbit pulmonary circulation. *Pulm Pharmacol Ther.* 2002;15(4):393–398.
27. Sun L, Li Q, Wang WT, et al. Enhancing hippocampal blood flow after cerebral ischemia and vasodilating basilar arteries: in vivo and in vitro neuroprotective effect of antihypertensive DDPH. *Neural Regeneration Research.* 2015;10(4):589–593.
28. Wang M, Hu Y, Fan Y, et al. Involvement of hydrogen sulfide in endothelium-derived relaxing factor-mediated responses in rat cerebral arteries. *Journal of Vascular Research.* 2016;53(3-4):172–185.
29. Maeda T, Mimori K, Suzuki S, et al. Preventive and promotive effects of habitual hot spa-bathing on the elderly in Japan. *Scientific reports.* 2018;8(1):133.
30. Branco M, Rego NN, Silva PH, et al. Bath thermal waters in the treatment of knee osteoarthritis: a randomized controlled clinical trial. *Eur J Phys Rehabil Med.* 2016;52(4):422–430.
31. Ziemka J, Szynal T, Mazanska M, et al. Natural medicinal resources and their therapeutic applications. *Roczniki Państwowego Zakładu Higieny.* 2019;70(4):407–413.
32. Huang A, Seité S, Adar T. The use of balneotherapy in dermatology. *Clin Dermatol.* 2018;36(3):363–368.
33. Martin R, Henley JB, Sarrazin P, et al. Skin microbiome in patients with psoriasis before and after balneotherapy at the thermal care center of la roche-posay. *J Drugs Dermatol.* 2015;14(12):1400–1405.
34. Nonaka K, Akiyama J, Tatsuta Net al. Carbon dioxide water bathing enhances myogenin but not MyoD protein expression after skeletal muscle injury. *J Phy Ther Sci.* 2013;25(6):709–711.
35. Yamaguchi N, Wan W, Sakamoto D, et al. Regulative effect for natural killer cell by hot spring hydrotherapy-Quantitative and qualitative discussion. *Open J Immunol.* 2013.
36. Chowdhury RS, Islam MD, Akter K, et al. Therapeutic aspects of hydrotherapy: a review. *Bangladesh J Med.* 2021;32(2):138–141.
37. Gálvez I, Torres Piles S, Ortega Rincón E. Balneotherapy, immune system, and stress response: a hormetic strategy? *Int J Mol Sci.* 2018;19(6):1687.
38. Masiero S, Maccarone MC, Magro G. Balneotherapy and human immune function in the era of COVID-19. *Int J Biometeorol.* 2020;64:1433–1434.
39. Kelvinson RC. Colonic hydrotherapy: a review of the available literature. *Complementary Therapies in Medicine.* 1995;3(2):88–92.
40. Yamaguchi N, Shimizu S, Izumi H. Hydrotherapy can modulate peripheral leukocytes: An approach to alternative medicine. 2004;546:239–251.
41. Bottalico L, Castellaneta F, Charitos IA. From hydrotherapy to the discovery of the gut microbiota: the historical gastrointestinal health concept. *Gut.* 2020;11(2):82–90.
42. Rodrigues SO, Pádua AG, Lima CMG. Gut-brain axis as a key aspect of clinical conditions. *Int J Fam Commun Med.* 2022;6(5):285–289.
43. Hylander BL, Repasky EA. Temperature as a modulator of the gut microbiome: what are the implications and opportunities for thermal medicine? *Int J Hyperthermia.* 2019;36(sup1):83–89.
44. Wardle J. Hydrotherapy: a forgotten Australian therapeutic modality. *Australian Journal of Herbal Medicine.* 2013;25(1):12–17.
45. Zhu H, Shen H, Xu J, et al. Comparative study on intestinal metabolism and absorption in vivo of ginsenosides in sulphur-fumigated and non-fumigated ginseng by ultra performance liquid chromatography quadruple time-of-flight mass spectrometry based chemical profiling approach. *Drug Test Anal.* 2015;7(4):320–330.
46. Mateus FT. The sulfur plants of Baños de Montemayor (Cáceres): morphological and functional characteristics of the constituent microbial community. *Annals of Medical Hydrology.* 2006;1:61.
47. Dias MF. Analysis of the microbial community in a biogas treatment system with high sulfide concentrations. 2015.
48. Avendano Sanchez A. Microbiological quality of a thermal water (Doctoral dissertation, Colombian School of Engineering Julio Garavito). 2016.
49. Martínez ER, Duarte MF, Maestre HP. Determination of the origin and composition of thermal waters located in the municipalities of Becerril (Cesar) and Ciénaga (Magdalena), Colombia. 2014.
50. Rosino Rosino J, Legido Soto JL, Mourelle Mosqueira ML, et al. Pelotherapy: history, characteristics and properties. *Water management in Spain, Mexico and Argentina.* 2021;17.
51. Fernández García V. Biomats from mineral-medicinal springs: applications in dermatology and cosmética hot mineral springs microbial mats: *Dermatol Cosm Applic.*