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RESEARCH ARTICLE

Sauna Bathing as an Alternative Adjunct Therapy in the Prevention and Treatment of Chronic Health Conditions Including Cardiovascular Disease, Neurodegenerative Disease, Metabolic Disease, and Mental Health Disorders

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ABSTRACT
Sauna bathing is a time-efficient, cost-effective health modality that has the potential to mimic the heat thermogenesis and cardiovascular effects of exercise. In recent years, researchers have been able to measure the benefits of sauna on human performance, endurance, and cardiovascular health. While many studies have investigated sauna use and its effect on athletic performance, fewer studies have investigated the use of sauna as a medical treatment for chronic health conditions. This review compiles the proven effects of sauna on human physiology and investigates its applications in the treatment of patients with chronic disease. Sauna use appears to be safe in most patient populations and is shown to be both tolerable and effective in patient populations with cardiovascular disease and late stages of congestive heart failure. Multiple cardiovascular benefits were demonstrated in the review including improved perfusion in peripheral arterial disease, decreased ventricular arrhythmias, 51% reduced annual cardiovascular mortality and 47% reduced annual risk of developing hypertension in men using the sauna 4-7 times per week. Finnish cohort studies have additionally exhibited reductions in lifetime annual risk of dementia by 66% in men using the sauna 4-7 times per week. It is suggested that increased heat shock protein expression through heat exposure may be responsible for the neuroprotective benefits of lifetime sauna use. Sauna has also displayed benefits in metabolic disease by reducing hemoglobin A1C and aiding heat acclimation in diabetics through improved thermoregulation. In mental health research, sauna use has shown potential in the treatment of depression by improving objective depression scores. Another study exhibited that sauna use was able to increase appetite in patients with severe depression and coexisting appetite suppression. Additionally, in cohort studies sauna is shown to be correlated to reduced annual risk of developing psychosis across the lifespan. By compiling and reviewing the current research on sauna bathing, education and guidance are provided to medical providers regarding the potential use of sauna as a treatment adjunct for patients with various conditions including cardiovascular disease, neurodegenerative disease, metabolic disease, and mental health disorders.

Introduction

Evidence of sauna use can be found as early as 2000 BCE in regions of Northern Europe.[1] It has long been utilized in Finnish culture primarily for its benefits to mental and spiritual well-being. Early sauna dwellings would be used as birthing places, morgues, and healing areas for the sick.[1] Centuries later, members of the scientific community began investigating the effects of sauna on human physiology. In American medicine, the earliest review of sauna literature dates to 1954.[2] As studies began to exhibit a connection to cardiovascular health, sauna research became focused on the positive effects of sauna on human performance. One groundbreaking, frequently referenced study utilized a three-week sauna protocol which improved run-time to exhaustion by 32% for a group of male distance runners.[3] If sauna use has a substantial, measurable effect on the performance of subjects at peak health, what benefits could it have for patients living with chronic disease and other physical impairments?

A useful example of the utility of sauna for chronic disease comes from various studies conducted in Japan.[4,12,21,23-25] The studies demonstrate the efficacy and the safety of sauna use in the treatment of patients with stage III heart failure.[4] Additionally, cohort studies on Finnish populations have connected lifetime sauna use to improved rates of cardiovascular mortality and disease prevention.[5] While there is a well-established link between sauna use and cardiovascular health, less research exists regarding sauna use and its benefits on other aspects of human health. Promising past studies on sauna use have demonstrated decreased incidence of neurodegenerative disease, improved insulin signaling in diabetics, and reductions in the clinical symptoms of depression.[6-8] This information is reviewed in more detail in later sections.

Despite the growing body of research demonstrating sauna bathing as a therapy to improve cardiovascular health, decrease mortality, and improve disease outcomes, clinical recommendations for physicians and medical providers are still lacking. The development of protocols and clinical recommendations require more research, particularly in specified disease populations. Additionally, sauna is not as widely available as other modalities of heat therapy. Therefore, other options such as hyperthermic bathing and heated blankets need to be explored in future research. Healthcare providers who are interested in augmenting patient treatment with sauna may refer to this article as a general resource for current information regarding its benefits and risks.

Methods

The Cochrane Handbook for Systematic Reviews of Interventions was referenced to guide the research and aid in assessing the quality of evidence in each study. Data collection was accomplished by using multiple online databases (i.e., ScienceDirect, PubMed, EBSCO Medline, Cochrane library, and Google Scholar) to procure experimental research, randomized controlled trials, and systematic reviews. Animal studies were excluded because of the differences in thermoregulatory mechanisms in animals and humans. Studies were limited to adult male and female subjects and excluded if containing data on children. The quality of evidence was evaluated based upon population demographics, inclusion of adverse effects, research design, and statistical analysis. If the study outcomes or conclusions were inconsistent with the data, they were omitted from the review. The Quality in Prognostic studies tool (QUIPS) was utilized to assess risk of bias in studies reaching an outcome based upon a prognostic factor. Trials and studies deemed high-risk by QUIPS criteria (selection, attrition, measurement, and outcome bias) were omitted from the review.[9] If conflicts of interest were stated in the research, results were not included in the review.

Results

Cardiovascular applications of sauna

Coronary artery disease (CAD) is the leading cause of death for both men and women in the United States.[10] CAD accounts for one in every four adult deaths, a total of 659,000 deaths per year, and a collective $363 billion dollars lost due to health care costs and the effect on productivity.[10] Current therapies for CAD are costly and are often instituted as secondary prevention after the onset of an acute cardiac event. The volume of deaths and excessive treatment costs necessitate the need for additional low-cost treatments that play a role in both primary and secondary prevention. Sauna bathing has been investigated as one such therapy with this potential. Studies have evaluated the relationship of sauna bathing on cardiovascular mortality, coronary artery disease, hypertension, and other areas of cardiovascular medicine.

Cardiovascular Mortality

The most comprehensive study conducted to date to evaluate the effect of sauna use on long-term cardiovascular mortality is the Kuopio Ischemic Heart Disease (KIHD) Risk Factor study.[11] This ongoing prospective cohort study was initiated in 1984 in Eastern Finland. In this region, saunas are commonplace, and multiple sauna bathing sessions

per week are common for many Finnish residents. The study conducted baseline examinations on 2,315 male participants and followed them for a mean time of 20.7 years to record four primary outcomes: sudden cardiac death (SCD), fatal coronary heart disease (CHD), fatal cardiovascular disease (CVD), and all-cause mortality. The study found that the frequency of sauna use was inversely associated to the risk of SCD, fatal CHD, fatal CVD, and all-cause mortality. For example, Finnish men who used the sauna 4-7 times per week decreased their annual relative risk of CVD mortality by 51% compared to men who used the sauna once per week.[11] The study implemented hazard ratio adjustments to account for confounding variables and lifestyle practices such as age, body mass index (BMI), systolic blood pressure, low-density lipoprotein (LDL), smoking, alcohol consumption, former comorbidities, and socioeconomic status.

Coronary artery disease

Waon therapy is a form of heat thermogenesis used in Japan that alternates infrared sauna with heat blankets to increase internal temperatures. The typical therapy protocol involves wrapping a patient in a blanket for 30 minutes immediately following 15 minutes of infrared sauna at 60°C.[12] A randomized controlled trial evaluated the effect of Waon therapy on 24 CAD patients who failed PCI or were not candidates for surgical intervention. A three-week protocol where patients completed five sessions per week was conducted and followed by myocardial perfusion scans. Summed stress scores (SSS) and summed difference scores (SDS) were utilized to measure the reversibility of ischemia measured on the scans. The treatment improved both SSS (16 ± 7 to 9 ± 6, $p < 0.01$) and SDS (7 ± 4 to 3 ± 2, $p < 0.01$).[13] The improvement in ischemia reversibility was proportional to the severity of occlusive disease which may suggest vascular modulation even in late disease. This study supports further research of the use of sauna as a treatment modality in patients who do not qualify for PCI.

Safety is a primary concern when subjecting CAD patients to cardiovascular stress such as sauna. One study evaluated the effect of sauna bathing on 16 patients with preexisting ST-segment depression on cardiac stress testing. After a 15-minute sauna session, the study evaluated patients using nuclear scintigraphy. While there were no adverse clinical symptoms across the treatment group, reversible ischemia was measured on scintigraphy in 14 of the 16 patients after sauna treatment.[14] The study exhibits that while sauna use was well tolerated in CAD patients, there was still myocardial ischemia occurring. While the ischemia was quickly resolved after therapy, there is still risk for developing myocardial infarction with rate dependent ischemia during sauna treatment. This should be considered before suggesting sauna bathing to patients with symptomatic and severe CAD.

Hypertension

The most convincing data on the effect of sauna use in patients with hypertension comes from the Kuopio Ischemic Heart Disease (KIHD) Risk Factor study. The hypertension arm of the study was conducted on a population of 1,621 men without baseline hypertension. The median time until follow-up was 24.7 years. The study identified a 17% reduced risk in developing hypertension in men who sauna bathed 2-3 times per week and a 47% reduced risk in men who used the sauna 4-7 times per week compared to men who only bathed once per week. The study again accounted for confounding lifestyle risk factors listed in the prior cardiovascular mortality section.[15] While these recent cohort data are suggestive of the preventative effects of sauna on hypertension, there are limited studies suggesting a lasting effect of sauna use on preexisting hypertension. For example, a meta-analysis of patients with CHF compiled the data from six studies that recorded systolic blood pressure. A mean difference in systolic pressure of -2.58 mmHg was calculated across the six studies.[16] The change in SBP was not deemed clinically or statistically significant. Studies evaluating the clinical effects of sauna on preexisting hypertension are lacking and warrant further investigation. The available studies were often fewer than four weeks and neglected to reassess blood pressure at a later interval. Additionally, primary hypertension was not the sole focus of the studies. The patients being studied typically had other comorbidities of focus such as heart failure and CAD. The promising results of the KIHD study on hypertension suggest the efficacy of sauna as primary prevention for hypertension, but more investigation is warranted before recommendations can be made regarding sauna use in the treatment of new or preexisting hypertension.

Peripheral arterial disease

Peripheral Arterial Disease (PAD) is a vascular pathological process that consists of partial or complete obstruction of the arteries exclusive of the intracranial and coronary vessels.[17] One experimental randomized controlled study established a change in vascular endothelial function by measuring flow-mediated dilation (FMD) of the brachial artery using ultrasound. The

FMD increased from 4.4% to 5.7% on average after two weeks of Waon therapy. No change was measured in the control group.[18] For comparison, Cilostazol, a vasodilator commonly used in the treatment of PAD, had no significant effect on brachial FMD in a randomized controlled trial.[19] The prior study exhibited a measurable change in peripheral vasodilation, but did not evaluate patients for clinical improvement. A separate experimental study was completed on 20 patients who fulfilled the criteria for PAD and evaluated several clinical parameters. After ten weeks of Waon therapy there was significant improvement of pain scores, six-minute walking distance, ankle-brachial index (ABI), and doppler perfusion in the lower extremities. In the seven patients with ischemic ulcers, four were completely healed, and three were significantly improved.[20] Ten of the subjects continued Waon therapy at least twice weekly and were followed up between six months and three years. Of the subjects who continued sauna-use, none exhibited worsening clinical signs of PAD, further suggesting the efficacy of sauna as maintenance therapy for PAD.

Arrhythmias

Promising evidence exists to suggest that sauna therapy can reduce the incidence of certain arrhythmias and ectopic beats. A randomized controlled study evaluated premature ventricular contractions in 20 heart failure patients after two weeks of sauna treatment. [21] The study reported a reduction in PVC count of more than 2,000 beats in a 24-hour period (3,161 ± 1,104 to 848 ± 415, $p<0.01$). The ten-patient control group saw no reduction in 24-hour PVC frequency. The same study exhibited no change in the number of premature atrial complexes between the experimental group and the control group. This study is valuable because a reduction in PVC frequency reduces the risk of sudden cardiac death in patients with structural heart disease.[22]

Congestive Heart failure

Evidence for the clinical applications of sauna use in patients with congestive heart failure is convincing. Most studies were completed by cardiologists in Japan, primarily utilizing Waon therapy protocols. [4,12,21,23-25] There are multiple clinical metrics and biomarkers that can be utilized to estimate the severity of heart failure. This section compiles the effects of sauna on few of these metrics including brain natriuretic peptide, ventricular ejection fraction, and clinical symptomology.

1.Brain natriuretic peptide

One metric with measurable improvement and clinically significant reduction was brain natriuretic peptide (BNP). A randomized controlled study with 40 participants utilized Waon therapy to evaluate BNP and oxidative stress in CHF patients. [23] Twenty CHF patients in the experimental group underwent Waon treatment for four weeks, and there was nearly a 200 pg/ml reduction in mean BNP (402±221 to 225±137 pg/ml, $p<0.001$). Another study recorded a similar mean reduction in 20 CHF patients after a shorter two-week protocol (441 ± 444 to 293 ± 302, $p=0.005$).[24] A systematic review conducted by Källström collected the data on five studies which reported BNP changes after sauna treatment and calculated a mean absolute difference of -124.62 (CI=95%, $p=0.0009$).[16] Studies have proven that BNP is an important prognostic factor in the management of chronic CHF patients, therefore the reduction in BNP in the Waon therapy groups prove clinically significant.[25]

2. Ejection Fraction

Ejection fraction is another objective measurement in the diagnosis and treatment of heart failure that directly correlates to disease severity.[26] One promising study using a Waon protocol five days per week for two weeks recorded an increased mean ejection fraction from 29% ± 2 to 33% ± 2 ($p<0.05$).[21] Another study with the same Waon protocol of a longer three-week duration, established a left ventricular ejection fraction change from 30.4% ± 12.6 to 32.5% ± 12.8 ($p = 0.023$). The systematic review conducted by Källström and colleagues compiled the data on ejection fraction changes in heart failure across six studies where patients were exposed to a form of sauna therapy. They found a mean absolute difference (MD) of +1.45% across all six studies.[16] The average length of the studies measuring EF were between two and four-week protocols. As a comparison, one meta-analysis of beta-blockers found that metoprolol, a beta-blocker proven to decrease myocardial remodeling and improve EF, improved EF by 7.4% over 9.5 months.[27] A statistically significant increase in ejection fraction over a short time in these studies is reassuring of the possible efficacy of sauna bathing in heart failure patients over time. Physiologic mechanisms suspected for the improved ejection fraction include reduction in arterial stiffness (afterload) and modulation of the autonomic nervous system.[61] A study of longer duration is required to measure clinically significant effects on ejection fraction.

3. Symptom improvement and New York Heart Association classification

While objective measures of sauna use such as BNP and ejection fraction are useful, they do not give information on how sauna use might affect the clinical symptoms of congestive heart failure. One of the Japanese trials measured 6-minute walking distance before and after 3 weeks of Waon therapy. The mean six-minute walking distance was increased from 337 meters to 379 meters ($p < 0.001$). The increase in exercise tolerance was positively correlated with increased peak VO2, improved LVEF, and improved endothelial function measured by increased flow-mediated dilation of the brachial artery.[18] Another experimental study placed patients into New York Heart Association functional classes prior to the study and retested them after a 2-week infrared protocol. Of 20 patients in the experimental group, there were 10 class III patients, 5 of whom improved to class II. Of the 10 class II patients one patient improved to class I.[24] To paraphrase, 30% of patients in the experimental group improved their NYHA classification when compared to the control. Additionally, a recent meta-analysis compounded sixteen studies on sauna treatment in heart failure and measured a pooled efficacy of NYHA class improvement.[28] They calculated a proportional reduction in class severity of 10.9% in class III patients and 12.2% in class IV patients across all studies. There was a total of 124 patients between the studies. These findings across multiple studies indicate that sauna use may be considered as an augmented therapy to improve clinical symptoms in class III heart failure.

Neurodegenerative disease

Dementia and Alzheimer's disease

A known association exists between Alzheimer's disease, dementia, and cardiovascular disease. A longitudinal cohort study looking at over 3,000 men and women established an increased risk of Alzheimer's disease in patients with cardiovascular disease. The risk was even more pronounced in subjects with PAD.[29] While most of the studies regarding sauna have focused on cardiovascular benefit, the association between CVD and neurodegenerative disease outcomes requires further investigation. The current studies on sauna for neurodegenerative disease demonstrate primary prevention and multiple physiologic mechanisms with potential to modify disease course.[29-37]

The Finnish KIHD prospective cohort study evaluated the effect of sauna use on the development of Alzheimer's disease and dementia. The results were adjusted for other confounding variables such as age, BMI, systolic blood pressure, LDL, smoking, alcohol consumption, former comorbidities, and socioeconomic status. The study established that there was a 22% reduced annual risk of dementia in men who used the sauna 2-3 times per week compared to those who did not use the sauna at all. In men who used the sauna 4-7 times per week, the annual incidence of dementia was decreased by 66% compared to non-users. The corresponding decreased annual risk for Alzheimer's disease was 20% and 65%, respectively.[29]

At present, the authors are not aware of any experimental studies that have evaluated the effect of sauna use on subjects with active Alzheimer's disease or dementia. Despite the paucity of evidence for sauna as a treatment for neurodegenerative disease, there are established physiological mechanisms that indicate the need for further investigation. Alzheimer's disease is marked by misfolded proteins and an overall reduction in cellular protein homeostasis. The defective system leads to the intracellular and extracellular accumulation of amyloid plaques and neurofibrillary tangles of phosphorylated tau proteins.[30] Heat shock proteins (HSPs) are often referenced in sauna literature and represent a new area of focus for many studies on Alzheimer's disease due to their proposed neuroprotective effects. HSPs can be described as cellular chaperones that police cellular function by recognizing these misfolded proteins and marking them for proteasomal autophagy.[31] An experimental study of 20 subjects recorded an increase in HSP70 and HSP90 of 45% and 38% after localized deep tissue heating of the vastus lateralis muscle.[32] The increased expression of HSPs in response to heat stress provides an explanation for the protective effects of sauna on Alzheimer's disease. Additional studies are required to evaluate sauna as a treatment for subjects with early symptoms of Alzheimer's disease and dementia.

Parkinson's Disease

There is also a scarcity of experimental trials evaluating the effect of sauna on patients with Parkinson's disease (PD). Parkinson's disease, like Alzheimer's disease, is a neurodegenerative disease of multifactorial etiology. The principle established mechanism leading to PD involves degeneration of the substantia nigra neurons from alpha-synuclein and Lewy body accumulation.[33] Treatment of PD typically involves dopamine replacement, but unfortunately disease-modifying options targeting the cause and progression of the disease are absent.[34] Heat shock proteins are a new

area in research of PD and are expected to play a role in the cause of disease. For example, there have been lab models and animal studies that exhibited reduced alpha-synuclein aggregation in response to increased HSP70 expression.[35-36] While the neurological deficits of PD are severe, they often are not the cause of death in these patients. Morbidity and mortality in PD are often due to the exacerbation of conditions that arise from chronic motor impairments, immobility, and decreased fitness over time.[37] Examples of these chronic conditions are CVD, osteoporosis, impaired cognition, muscle atrophy, and depression. While there is a scarcity of research on sauna and the treatment of PD, this patient population serves as an example of a group who cannot engage in exercise due to physical disability. Perhaps sauna could benefit these patients by mimicking exercise and preventing downstream negative health outcomes that result from chronic motor impairment.

Diabetes and Metabolic Disease

Diabetes mellitus comprises a group of metabolic disorders affecting the body's ability to process glucose because of an inability to produce insulin or a resistance to insulin.[38] In 2017, the CDC's Division of Diabetes Translation revealed that the percentage of the population with diagnosed diabetes increased from 0.91% in 1960 to 7.40% in 2015. That means there are 20 million more Americans living with diabetes today than there were 50 years ago.[39] While type I and type II diabetes are heterogenous disorders with different underlying pathophysiologic mechanisms, the chronic disease outcomes from long-term hyperglycemia are still remarkably similar. Examples of these end-point diseases include cardiovascular disease, chronic kidney disease, neuropathy, eye disease, and chronic infections of the skin and feet.[40]

The first human study to propose an effect of heat therapy on patients with metabolic disease was completed by Hooper in 1999. The study evaluated patients with type II diabetes after a protocol using hot-tub 30 minutes per day, six days per week, for three weeks. On average, their oral temperature increased by 0.8°C each session. The subjects had a mean decrease in HbA1C of 1% after three weeks.[41] Often as health care providers, we emphasize metrics such as HbA1C, but what matters to the patient is improvement of clinical symptoms and quality of life. One study used a 36-item quality of life questionnaire to evaluate the positive benefits of far-infrared sauna on subjects with type II diabetes.[42] The study found that subjects had less stress, decreased fatigue, improved physical and general health, and enhanced social functioning indices following three months of infrared sauna therapy.

Evidence exists to suggest that type II diabetes patients have impaired thermodynamic regulation of internal body heat due to reduced cutaneous vasodilation and impaired sweating.[43-44] An epidemiologic study revealed that type II diabetes patients have a 56% greater risk of mortality or hospitalization in the event of a heat wave.[45] While these data may suggest that sauna therapy or even exercise may be dangerous for patients with diabetes, there are other studies exhibiting that thermoregulation is improved in physically active individuals with diabetes.[46] One experimental study compared the whole-body heat loss (WBHL) in male patients with well-controlled type II diabetes against their healthy male counterparts.[47] The study revealed that after a seven-day period of heat acclimation, type II subjects whole-body heat loss was equivalent to that of their healthy counterparts who were not heat acclimated. While the heat acclimation protocol in the prior study did not utilize sauna, one study exhibited that blood pressure and heart rate changes during sauna use correlates to the stress of submaximal exercise.[48] This is comparable to the protocol utilized in the former study. Further investigation of sauna bathing's role in heat acclimation of diabetes patients is warranted. It has the potential to adapt diabetes patients to exercise and to reduce the risk of heat-related illness.

Various mechanisms may be responsible for the positive health effects of heat therapy on patients with type II diabetes. Conducted animal studies and in-vitro models have postulated chronic elevations in nitrous oxide (NO) as the primary catalyst. Elevations in NO lead to induction of HSP70 expression which increases the phosphorylation of enzymes that induce insulin signaling. The end-point outcomes of this process include reduced body fat, reduced inflammation, and improved glycemia.[8] More studies are required to further investigate the mechanisms behind sauna therapy for metabolic disease and its efficacy in this growing group of patients.

Behavioral Health

Depression is a pervasive disease in the United States. In 2018, the National Ambulatory Medical Care Survey found that 10.6% of physician office visits are related to depression.[49] A randomized controlled trial evaluated 28 patients with mild depression and found that after four weeks of far-infrared sauna, subjects had improved somatic complaints, relaxation scores, and hunger scores

when compared to control patients who had 30 minutes of bed rest. The study hypothesized that increased plasma ghrelin concentrations secondary to heat exposure may account for the stimulation of appetite.[50] This is pertinent because it may aid individuals with appetite dysregulation secondary to the physical symptoms of anhedonia. Additionally, it may suggest utility in patients with comorbid eating disorders. Another blinded randomized trial was conducted to evaluate the effectiveness of whole-body hyperthermia on patients with major depressive disorder. The study used water-cooled infrared lamps for a mean session time of 126.7 minutes. Following the session CES-D depression scores were completed and indicated a significant decrease in depression symptoms five days after therapy and lasting up to six weeks. The authors propose that the rapid heating and thermoregulatory cooling may sensitize physiological pathways implicated in mood regulation.[17] While the few studies completed to address the effect of heat therapy on depression are thought-provoking, the trial group sizes were small and sauna as a treatment for specific mental health disorders still requires further investigation. The KIHD Finnish longitudinal cohort study [51] was able to look at one subset of behavioral health disorders with important implications regarding sustained sauna therapy through a lifetime. They analyzed the risk of developing a psychotic disorder in 2,138 men without preexisting psychotic disorders. The study revealed that men who used the sauna 4-7 times per week were at a 77% reduced annual risk of psychosis when compared to men who used the sauna once per week. [51] When the model was adjusted for other risk factors and potential confounders the results remained the same. These findings call for additional studies evaluating sauna for behavioral health and warrant consideration by medical providers looking to augment treatment of individuals with these conditions.

Safety

If physicians and medical practitioners are to include sauna therapy as an alternative wellness modality for their patients, it is important that they consider each individual patient and their associated risk factors. Sauna appears to be tolerable across most patient populations, and while there are no established guidelines or absolute contraindications to sauna, the following information can help to guide medical practitioners in their decision-making process when patients are interested in sauna.

Impressively, there were very few adverse reactions to sauna in our review, even in patients with moderate heart failure.[24] Sauna does not appear to pose a risk to patients with hypertension, CAD, and CHF so long as the diseases are well controlled.[52] Conversely, sauna should be avoided in patients with recent myocardial infarction, unstable angina, severe aortic stenosis, decompensated heart failure, and cardiac arrhythmias. The acute drop in blood pressure during sauna bathing poses a risk to patients with orthostatic hypotension, valvular disease, and unstable cardiovascular conditions. There are a few reported cases of acute myocardial infarction and sudden cardiac death in the sauna, but all incidents were shown to be partly associated with alcohol intoxication.[53] Alcohol consumption has been shown to increase hypotension, arrhythmia, and risk for sudden death when using the sauna and should be strongly recommended against by healthcare providers.[54]

Sauna use should also be avoided in patients with conditions that cause anhidrosis and inability to regulate core temperature. Examples of these conditions include spinal cord injury, various autoimmune diseases, neuropathy in untreated diabetes and alcoholics, neurological disease, and certain drugs.[55] Many of these diseases exist on a spectrum, and providers should be aware if their patient suffers from impaired thermoregulation. While a lack of sweating can be problematic for some patients, [55] the occurrence of sweating can create problems for patients who are on transdermal medication patches. In vitro studies have exhibited that heat exposure may have a significant influence on the delivery of transdermal medications.[56] While an exploratory study was able to suggest a protective effect of sauna use on skin physiology, the research also recommended that patients with infectious skin conditions, urticaria, and open abrasions refrain from sauna use.[57]

There have been longstanding recommendations for pregnant women to avoid heat stress such as hot tubs and sauna. Emerging evidence suggests that the risk may not be as high as initially predicted. [58-59] A recent systematic review was published in the *British Journal of Sports Medicine* that evaluated the effect of exercise and passive heat stress on pregnant women. The study concluded that a pregnant female at any stage of pregnancy could tolerate 20 minutes of sauna at 70°C and 15% relative humidity without surpassing the teratogenic threshold of 39°C core body temperature.[58-59] However, it is important to note that the American College of Obstetricians and Gynecologists (ACOG) still recommends against the use of saunas

and hot tubs in pregnancy due to a study completed in 1992 exhibiting an increased risk for neural tube defects.[60] While ACOG now advocates for exercise in pregnancy, it has not updated its stance on passive heat stress such as sauna. This subject requires more investigation, and pregnant patients should be told to consult their obstetrician before considering sauna use.

Discussion

Underlying physiology of sauna use

The benefits of sauna to human health and physiology can be primarily attributed to the modulation of the cardiovascular system, the prevention of protein aggregation in neurodegenerative disease, and improved insulin signaling in metabolic disease. Cardiovascular modulation is evidenced by increased heart rate during sauna sessions, resulting in increased cardiac output, and improved ejection fraction.[16, 21] This mechanism begins with peripheral vasodilation which improves core temperature regulation through increased external heat exchange and diaphoresis. The reduction in preload from peripheral vasodilation triggers the increased heart rate and cardiac output to maintain systemic perfusion. Lasting compliance of the peripheral vasculature from sauna use is due to improvements in endothelial function as evidenced by increased flow mediated dilation of the brachial artery.[18] The prevention of neurogenerative disease is explained by increased expression of heat shock proteins that inhibit the aggregation of misfolded proteins responsible for Alzheimer's, dementia, and Parkinson's disease.[31-32, 35-63] Heat shock proteins are triggered by increased nitric oxide levels from sauna use. HSPs additionally induce insulin signaling which improves metabolic disease outcomes by inducing lipolysis, reducing glycemia, and improving inflammation.[8] While studies have evidenced improvements in behavioral health, no physiologic mechanisms have been established. Like exercise, there appears to be multiple underlying physiologic mechanisms responsible for the clinical improvements of patients who use sauna. With continued research, it is expected that more explanations for these benefits will be revealed.

Limitations

The sauna studies available often use differing sauna protocols which is important to note for providers interested in specific outcomes. There were often small experimental study groups which decreased the overall power and reliability of statistical conclusions. Many of the studies used correlations and did not conduct randomized controlled trials. Additionally, this review mostly omitted heat therapies that did not utilize traditional Finnish dry sauna or infrared sauna. While the most convincing research is coming from sauna bathing, there are additional studies exhibiting that other forms of heat thermogenesis, such as hyperthermic baths and blankets have similar effects to sauna. Further investigation of hyperthermic bathing is warranted because this modality is more accessible to the public. Furthermore, the primary limitation of sauna bathing as a treatment modality is patient access. In the United States, sauna access is limited to individuals with gym memberships or the financial means to buy and build their own. Despite the initial cost of entry to buy, build, or have access to a sauna, comparatively speaking, many individuals' annual medical expenses dwarf the cost of sauna ownership. It is our hope that continued research may lead to increased sauna access in medical domains such as physical medicine and rehabilitation, as well as in the private sector.

Clinical Applications

While more research is needed before formal recommendations can be made for medical providers, sufficient data are available to guide providers' decisions regarding sauna use. In the appropriate patient, the evidence supports the safe and effective use of sauna for congestive heart failure, peripheral arterial disease, and in healthy patients to reduce lifetime risk of cardiovascular mortality. The research supports the use of sauna for patients with well-controlled CAD, but special caution should be taken in high-risk patients. Insufficient evidence exists to support the use of sauna in patients with hypertension, but it may have a protective effect for normotensive patients over a lifetime. Additionally, a lack of evidence exists to support sauna use in patients with active Alzheimer's and dementia, but there are sufficient cohort data to indicate prevention of neurodegenerative disease in frequent sauna users. Sauna use should be considered in patients with diabetes, but should be avoided in patients with severe neuropathy, active skin ulcers, and infection. Sauna use decreases the clinical symptoms of depression and is low risk to patients without other comorbidities. Finally, because sauna use mimics mild to moderate intensity exercise, it can be recommended to patients who are unable to exercise due to pain, physical limitations, or who lack the desire to start an exercise regimen as recommended by their provider.

Conclusion

Sauna bathing is a safe and effective wellness modality that may be considered by medical professionals as an appropriate adjunct therapy to improve long-term health outcomes and to augment the treatment of chronic disease. Further studies are warranted to explore the use of sauna bathing and other hyperthermic treatments for various disease states.

Conflicts of Interest

The authors have no conflicts of interest to declare.

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