Saunas: the facts, the myths, and the how-to

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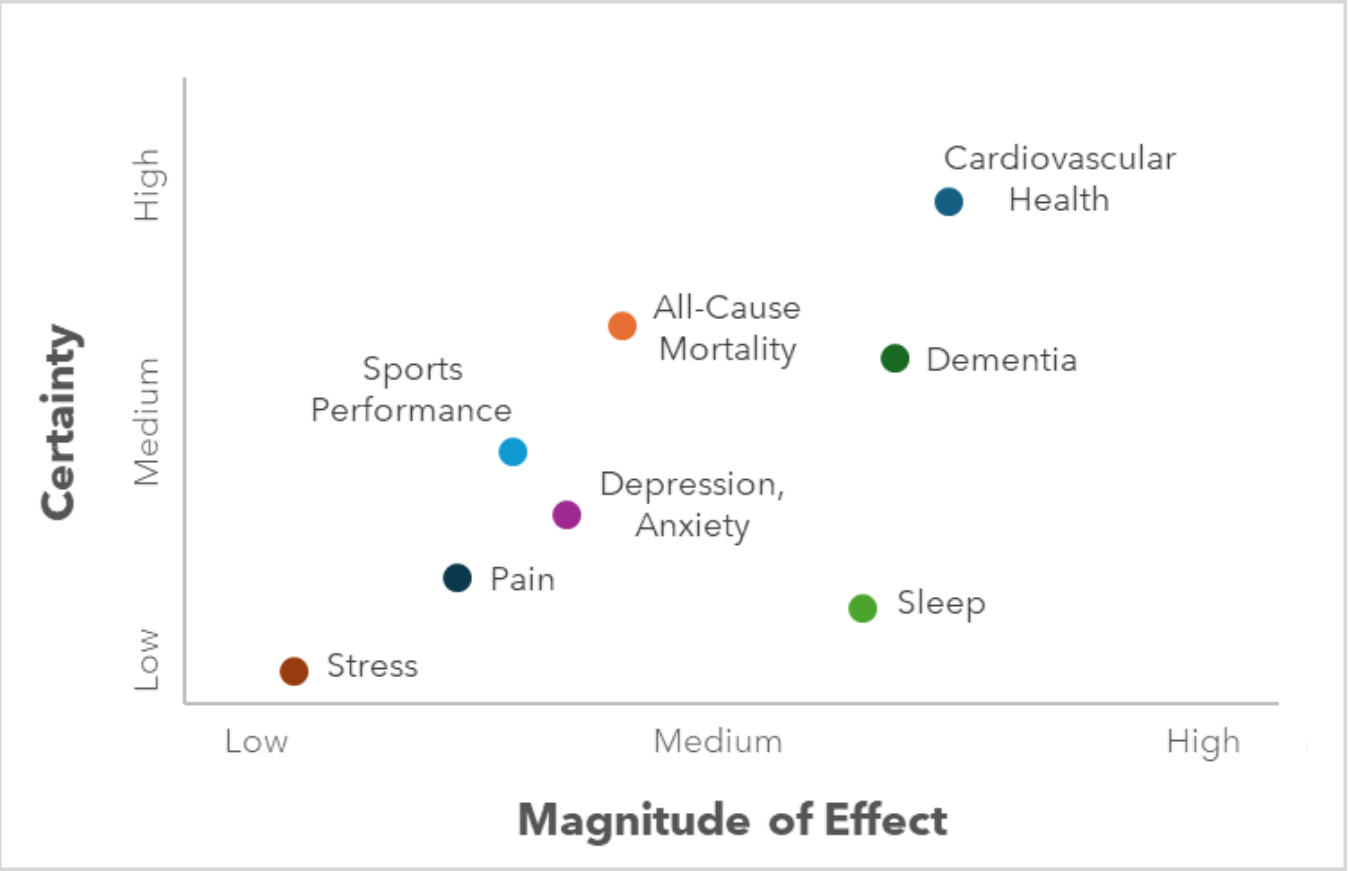

Figure 1: The benefits of sauna use, ranked by magnitude of effect and certainty of evidence. Magnitude and certainty for each benefit are assessed relative to the magnitude and certainty for other benefits of sauna use.

As far as healthy lifestyle practices go, few are quite so mystifying as that of sauna bathing. There is a long history of heat therapy in cultures all around the world, including Finnish dry saunas, sweat lodges pervasive among native american cultures in North America, and "banya" steam saunas in Russia. Sauna use and its equivalents have been around for thousands of years and are deeply rooted in relaxation and socialization for many cultures.

Popular media has recently fixated on sauna use and has touted the practice as a "longevity hack," claiming that saunas provide benefits across the health spectrum, ranging from better cardiovascular health to improved complexion. We've examined a few of the purported benefits over the years on the podcast (most recently on AMA #42 and a brief note on the five year anniversary post for *The Drive*), but given the sheer variety of claims, the topic deserves a deeper, more comprehensive look. Does current evidence support sauna as a panacea for human longevity?

Here, we will take a closer look at the strengths and weaknesses of existing evidence for a wide range of alleged benefits before exploring possible mechanisms behind the effects, and ultimately, the practical considerations and recommended protocols for sauna use.

Inferring causality from observational data

Most evidence for the plethora of purported benefits of sauna comes from observational studies, particularly those conducted in Finland, where sauna use is a common part of life across socioeconomic strata. Since observational studies (with the exception of those using Mendelian randomization) are only capable of identifying *correlations* between variables rather than *causal relationships*, we cannot be certain that many of the alleged "effects" of sauna use are, in fact, *caused* by sauna use. However, by evaluating correlative data for certain features and in the context of broader literature, we can estimate the likelihood that they represent cause-and-effect. A set of principles known as the Bradford Hill criteria have been developed for this purpose of deducing causal relationships from observational data, so before we dive into details on evidence linking sauna use to various benefits, we must first introduce these principles, as we will return to them throughout our discussion of the reliability of epidemiological associations between sauna and health.

The Bradford Hill criteria consist of nine principles:

Strength: How large is the effect? The larger it is, the more likely the relationship is causal.

Consistency: Are the findings consistent and reproducible across multiple studies and populations?

Specificity: How specific is the cause-effect relationship? If an exposure is associated with only one outcome or an outcome associated with only one exposure, a causal relationship is more likely.

Temporality: Does the exposure precede the reported benefits?

Biological Gradient: Does the observed benefit demonstrate dose dependency?

Plausibility: Is there a plausible biological mechanism by which the exposure might cause the apparent effect?

Coherence: How well do the observational human data align with *in vitro* or *in vivo* laboratory tests?

Experiment: Does any intervention-based evidence support the conclusions?

Analogy: Can we compare the current body of evidence to another, similar intervention with more established effects?

If you contrast the epidemiology implicating smoking as a causal driver of lung cancer (and many other cancers) with that of the epidemiology implicating various foods in the development of cancer, you'll see why no reasonable person would dispute the role of tobacco in cancer,

while there is no consensus whatsoever on the relationship between specific foods and cancer. To be clear, evidence does not need to fulfill all nine in order to make a strong case for causality, though generally speaking, the more criteria a body of evidence meets, the more confident we can be in deducing a causal relationship. In other words, if the literature supporting a given benefit of sauna can meet at least a few of these criteria, then it is more likely that sauna use is *directly producing* that particular benefit, rather than merely being incidentally associated, so we must keep these principles in mind as we explore evidence to date on the potential health effects of sauna use.

Evidence for the benefits of sauna use

Research has supported a list of benefits from sauna use that includes improved cardiovascular (CV) health, decreased all-cause mortality, decreased risk of dementia and Alzheimer's disease, improvements to sports performance, decreased stress, improved mental health, and better sleep. Below, we discuss each of these in turn, considering evidence from epidemiology and, where available, interventional and laboratory studies.

Cardiovascular health

Prospective cohort studies (non-randomized, mind you) have reported that more frequent sauna use decreases risk of CV-related death and other major adverse cardiac events after correcting for CV risk factors and several other potential confounders (such as age, BMI, blood pressure, etc). For instance, in a 2015 study conducted in an entirely male Finnish cohort (n=2,315) over a 20-year period, authors Laukkanen et al. reported a 63% reduction in risk of sudden cardiac death (SCD; HR=0.37; 95% CI: 0.18-0.75) among 4-7 sessions/week sauna bathers compared to once-weekly sauna bathers, as well as a 48% decrease in fatal coronary heart disease (CHD; HR=0.52, 95% CI: 0.31-0.88) and a 50% reduction in all cases of fatal cardiovascular disease (CVD; HR=0.50, 95% CI: 0.33-0.77). (Note: some SCD cases were also classified as fatal CHD, and fatal CVD cases included both SCD and fatal CHD cases). A 2018 follow-up by the same research group found that CV benefits remained consistent when examining a mixed male/female Finnish cohort (n=1,688, 51.4% female) over a 15-year period, in which those using a sauna 4-7 times per week had a 64% lower rate of cardiovascular disease-related death compared to those using a sauna only once per week (HR=0.36, 95% CI: 0.17-0.77). Sauna may additionally reduce risk of stroke, as shown in another 15-year study among Finnish men and women, in which those who used a sauna 4–7 times per week had a 62% lower chance of stroke (HR=0.38, 95% CI: 0.18-0.81) compared to once-weekly sauna bathers.

Increasing the *duration* of sauna sessions may also improve CV health. In their 2015 study, Laukkanen et al. also found that, relative to those who used a sauna for sessions lasting <11 minutes, individuals who engaged in sauna sessions lasting >19 minutes had a 52% lower risk of sudden cardiac death (HR=0.48, 95% CI: 0.31-0.75), a 36% lower risk of fatal CHD (HR=0.64, 95% CI: 0.46-0.88), and a 24% lower risk of other fatal CVD (HR=0.76, 95% CI: 0.59-0.97).

Additionally, Laukkanen et al.'s work indicates that the apparent protective effect may be dose dependent, as data from their 2015 study demonstrated that those using a sauna 2-3 times per week were at a level of risk between that of once-weekly and 4-7x weekly users, with risk of sudden cardiac death, fatal CHD, and fatal CVD all exhibiting statistically significant downward trends with increasing sauna frequency. The researchers observed a similar trend in their 2018 follow-up, though it did not achieve significance.

Impacts on endothelial function – specifically, improvements in dilation capability and decreases in arterial stiffness – has been proposed as a means by which sauna bathing may provide CV benefits. Indeed, experimental evidence of two weeks of sauna therapy in men with one or more coronary risk factors (hypertension, hypercholesterolemia, diabetes, obesity, smoking history) has been shown to result in an improvement to brachial artery diameter dilation following reactive hyperemia (4.0±1.7% to 5.8±1.3%), an indicator of endothelial health. Further, another investigation found that men and women at elevated CV risk who underwent sauna bathing for even a single 30-minute session showed an improvement in arterial compliance, as assessed by pulse wave velocity and left ventricular ejection time, two metrics which reflect arterial stiffness. These changes were maintained through the full 30-min surveillance period after the sauna session.

Together, the findings above offer persuasive evidence that sauna use benefits CV health. The data are consistent in showing strong, positive effects, and these effects appear to be related to sauna use in a dose-dependent manner. Sauna use may be even more beneficial for CV health when paired with exercise, as demonstrated by one study that showed that sauna use *plus* exercise led to better outcomes for CV-disease related deaths (and ACM, discussed below) than sauna use alone. Additionally, experimental evidence from studies of arterial compliance and dilation lend support to proposed mechanisms by which sauna use might cause reductions in CV risk.

Dementia and cognitive health

Sauna may also have cognitive benefits. Another study by Laukkanen et al. published in 2017 showed that Finnish men partaking in more frequent sauna baths (4-7x weekly) had a 66% lower risk for dementia compared to once-weekly users (HR=0.34, 95% CI: 0.16-0.71) over the median 20-year follow-up, after correction for several confounding variables. Similar results were reported for Alzheimer's disease (AD) specifically, with 4-7x weekly sauna users at 65% lower risk than once-weekly users (HR=0.35, 95% CI: 0.14-0.90). Use of sauna 2-3x weekly was associated with intermediate risk, though the differences in risk between this group and either the 4-7x weekly group or once weekly group did not achieve significance for either overall dementia or AD.

Considering that women have a significantly higher lifetime risk of dementia – and particularly AD – than men, it is important that we also evaluate how sauna might impact dementia risk in cohorts that include women. A study of 13,994 Finnish men and women showed that those using a sauna 9-12x/month (~2-3x/week) had a 53% reduction in the risk for dementia (HR=0.47, 95% CI: 0.25–0.88) in the first twenty years of follow up and an overall risk reduction of 19% over the entire 39-year study duration (HR=0.81, 95% CI: 0.69–0.97) compared to

those either not using a sauna or using a sauna <4x/month. Importantly, this association was not altered by corrections for participants' sex, indicating that sauna impacts dementia risk equivalently in men and women.
These findings are promising, but further studies are needed in order to determine how broadly this effect applies to different forms of dementia or whether it is specific to Alzheimer's disease.

All-cause mortality

Regular sauna use is also associated with a reduction in all-cause mortality (ACM). Evidence for this comes primarily from the 2015 study by Laukkanen et al. mentioned above, which reported a 40% reduction in ACM for men with 4-7 sauna baths per week compared to one per week (HR=0.60, 95% CI: 0.46-0.80). Again, reduction in risk appeared dose-dependent, as those using sauna 2-3 times per week were at intermediate risk. Given the strong effects on CV outcomes noted above, the reduction in risk of ACM was likely driven in part by CV-related deaths, but interestingly, in contrast to the CVD findings, the *duration* of sauna sessions was not associated with ACM risk.

Frequent sauna bathing has also been shown to offset at least some of the increased ACM risk associated with low socioeconomic status (SES) in Finnish men. Compared to those with high SES using sauna twice per week, low SES individuals using sauna twice per week had a 35% higher risk of ACM (HR: 1.35; 95% CI: 1.20–1.51), but those with low SES who used a sauna 3-7 time per week had only a non-significant 7% higher risk of ACM relative to those with high SES using sauna twice per week (HR: 1.07; 95% CI: 0.89–1.29). Since most deaths (54%) in this study were non-cardiovascular in nature, it's possible that the reduction in mortality risk extends beyond effects on CV health.

Exercise and sports performance

In contrast to most alleged benefits on this list, for which we must rely almost primarily on epidemiological evidence, the proposed positive effects of sauna on exercise performance – specifically, as a recovery modality – have been supported by interventional studies. For instance, a randomized crossover study in male runners by Scoon et al. demonstrated that 30 minutes of sauna use following training led to a 32% increase in time to exhaustion – a metric of endurance often used in runners and bikers – relative to the control recovery condition (90% CI: 21-43%). Another crossover study showed that the positive effects of post-training sauna use also include decreased muscle soreness and preservation of muscle function. Relative to those engaging in passive recovery, basketball players who used sauna for recovery reported less perceived post-workout soreness and were found to experience a smaller decrease from pre- to post-training in maximal countermovement jump (a test of lower body explosive power) 14 hours after resistance training (-1.1±4.5% vs. -5.0±3.8%, $P<0.01$).

One mechanism thought to underlie this benefit is increased plasma volume, which is associated with better circulation to muscles and improved cardiac function. Indeed, in the Scoon et al. study noted above, the sauna condition led to a 7.1% increase in plasma volume

compared to the control recovery condition (which did not entail any particular recovery practice; 90% CI: 5.6-8.7%), as measured by Evan's blue dye dilution, a finding which was also observed in prehypertensive non-athletes in a later study by Rissanen et al.

Heat exposure-related increases in plasma volume are likely due to adaptations resulting from transient water loss in the sauna. In support of this, dry sauna (which have higher rates of water loss via sweat compared to mist sauna) has been shown to cause greater plasma volume decreases, and slight dehydration prior to heat acclimation enhances plasma volume increases. This plasma volume loss is followed by an increase in plasma volume that is noted by 24 hours post-sauna. One study of exercise in a hot environment showed that these plasma volume increases occur mostly within the first day, but continue throughout the first week, peaking around 8 days of consistent heat exposure. This has also been observed in a sauna study, which showed five days of consistent sauna use results in a maintained higher plasma volume, indicating plasma volume changes as a result of sauna use are not transient given consistent heat exposure.

The Rissanen et al. study also reported that increases in plasma volume depended on the *type* of exercise preceding sauna use. While participants who used saunas following endurance or combined strength+endurance exercise had an increase in plasma volume 24 hours later relative to controls, this effect was not observed among participants who used saunas following strength training alone, suggesting that the positive impacts of sauna as a recovery modality may be specific to endurance training. Further, the benefits of sauna for exercise performance appear to rely on sauna being used *following*, rather than preceding, an exercise session, as 30 minutes of sauna use *prior* to exercise has been shown to lead to *worse* performance on tests of endurance (leg press and bench press) and strength (one rep-max leg press) relative to using no sauna pre-workout.

Sauna use has also been linked to improvements in VO_2 max and bone density, though these claims are based on more tenuous findings. For example, Kirby et al. demonstrated a marginal benefit to VO_2 max in runners that did not reach the level of statistical significance. Regarding bone density, a study by Toro et al. showed that, in a cohort of 23 young males, 12 sauna sessions resulted in statistically significant improvements in bone mineral content and bone mineral density relative to no-sauna controls. However, it's unclear if this represents a true, reliable effect, since the effect was small and only observed in the left leg (whole-body or right-leg bone metrics did not differ significantly between groups).

Taken together, compelling evidence supports sauna use in recovery after endurance exercise, though other claims regarding performance benefits do not have substantial support. It's worth noting that despite the controlled, interventional nature of some of these studies, placebo effects may have contributed to apparent benefits, as participants would have been aware of whether or not they were in the sauna recovery group.

Mental health

One of the most common beliefs regarding sauna use and other methods of whole-body heating concern their potential benefits for mental health, but research in this area has been very limited.

A small study conducted in 45 healthy volunteers in Japan indicated that sauna may decrease anxiety and improve mood and depressive symptoms, though, due to a lack of control group, we cannot ascertain whether these improvements are the result of a placebo effect. Effects on depression were also assessed in a randomized pilot intervention study in medically-stable patients with depression, in which two hyperthermic baths per week (40°C/104°F for a target of 30 minutes each) over a two-week period led to a 3.14-point decrease on the Hamilton Scale for Depression (on a scale of 52 possible points) relative to sham controls. Yet despite the inclusion of a control group, placebo effects may still have played a significant role, since it would have been impossible to blind participants as to whether or not they were receiving the hyperthermic bath. Further, it is unclear whether these results from hyperthermic baths would extrapolate to sauna use.

Further, a prospective cohort study in Finland showed an inverse association between frequency of sauna bathing and incident psychotic disorder diagnoses. Among men with no psychotic disorder history (or prior antipsychotic medication), those using saunas 4-7x weekly showed a 79% reduction in psychosis risk (HR=0.21; 95% CI: 0.08-0.52) over a 25-year follow up compared to those using sauna once weekly, an association that remained consistent across various models adjusting for different sets of confounds. However, those using saunas 2-3x weekly did not differ significantly from once-weekly users, and we have no additional data that might suggest causality.

Given the current lack of effective and widely accessible strategies to prevent and treat psychosis, depression, and anxiety, saunas may represent a promising option for those who have or are at risk for these conditions. The association between saunas and reduced psychosis risk is fairly strong, and some data suggest connections with reduced depression and anxiety, yet at present, we lack compelling evidence that these associations represent effects *caused* by sauna use. (For instance, the apparent effects may be due to the confounding variable of socialization, since saunas are often social environments. Or perhaps those who suffer from psychosis avoid saunas because they prefer to spend less time around others – in which case, causality is reversed.) However, although there may be too little evidence to conclude definitively that sauna use directly improves mental health, the possibility certainly exists – a possibility which may be worth exploring for those who suffer from these conditions in the absence of effective alternative treatments.

Sleep

Circadian rhythms in body temperature surrounding and during sleep suggest interventions for altering our body temperature may improve sleep quality. In preparation for sleep, our body temperature begins to decline, and the decline continues through most of the night until shortly (an hour or two) before waking, at which point temperature begins to rise again. The sharper

we can make the slope in our temperature decline before bed, the faster we fall asleep and the better our sleep quality is. Whole-body heating may also decrease insomnia, as older female participants in one study had improved sleep continuity and increased slow-wave sleep following hot baths administered 90 minutes before bed. These women also reported better subjective sleep, including “deeper” and “more restful” sleep.

Though these findings have not yet been replicated with saunas, it is fair to expect that this method of whole-body heating would have a similar impact on sleep as a bath or shower (see “Analogy” among the Bradford Hill criteria listed above). Indeed, in one survey study, 83.5% of respondents reported better sleep with sauna use.

Pain

Multiple forms of pain, including headaches, back pain, and other chronic pain types, have reportedly been abated through sauna use. In one randomized controlled study, individuals suffering from chronic tension-type headache were randomized into either sauna treatment (sauna use plus advice in management) or control (advice in management only) groups. The sauna group had a 1.27-point reduction (on a 0-11 scale) in subjectively reported headache pain compared to the control group following 8 weeks of treatment (95% CI: 0.48-2.07). The study identified no benefit to duration of headache, despite the significant change in pain rating. Importantly, sauna use in this study was used as a *preventative* measure rather than as a treatment modality, as sauna use could possibly result in increased headache intensity, so controlled conditions surrounding sauna practice for headaches are essential.

Regarding back pain, five consecutive days of twice-daily dry sauna use was found to decrease lower back pain by 2 points on the 0-10 verbal numerical rating scale and decrease disability score by 4 points on the 0-50 Oswestry disability index. This effect would be analogous to more widely studied pain relief associated with thermal baths – for instance, a meta-analysis of randomized trials found that thermal baths resulted in a mean decrease of 16.07 points (of 100; 95% CI: 9.57, 22.57) on a visual analog scale of back pain and a mean improvement of 7.12 points (of 50; 95% CI: 3.77, 10.47) in lumbar spine function (by the Oswestry disability index) relative to control subjects not using thermal baths.

Another study in individuals with somatoform pain disorder showed that 4 weeks of sauna use combined with cognitive behavioral therapy (CBT), rehabilitation, and exercise therapy improved pain behavior scores (based on complaints, requests for medication, etc.) slightly more than those undergoing CBT, rehabilitation, and exercise therapy without sauna, though results did not quite reach significance (-1.2 points, scale of 11, P=0.07), and the addition of sauna resulted in higher rates of return to work (77% vs 50%, P=0.05) However, given that *both* groups significantly improved, we can conclude that other elements of this three-pronged rehabilitation intervention also contributed to the overall effect, meaning that sauna use represents only one of many ways to improve pain.

There are some forms of chronic pain for which the evidence for sauna use is more conflicting. Specifically, though one study in people with rheumatoid arthritis and ankylosing spondylitis reported short-term reduction in pain and stiffness following sauna use, an older study reported

an exacerbation of pain symptoms in similar conditions.

Chronic pain is pervasive and can be highly debilitating, motivating interest in sauna as a treatment modality, but given the small effects and conflicting evidence, further studies are required to draw definitive conclusions about the impact of sauna on pain-related conditions. It appears likely that saunas may provide modest benefit in pain management in some cases, but other, better-established forms of pain management (e.g., medication, cognitive behavioral therapy, exercise, etc.) are available and may be more effective.

Stress

Popular media often describes sauna bathing as an excellent way to de-stress or otherwise become more stress-resilient, and these desired outcomes have been reported as primary motivations for many in using saunas. Further, socialization, which is known to impact stress, was reported as a motivating reason for sauna use in 85% of survey respondents in the same study. Though little concrete evidence currently exists to support benefits for stress, sauna use does act on many of the phenomena involved in how we experience stress. For example, the reduction in heart rate and blood pressure that occurs following a sauna bath could in part explain the calming effect many people report when using saunas. During the experience of acute stress, heart rate and blood pressure are transiently increased as a result of sympathetic nervous system activity, and the *opposite* (decreased heart rate and blood pressure) may thus have the effect of a “de-stressing” experience. Decreased stress benefits many bodily systems, including, but certainly not limited to, the cardiovascular and immune systems. Thus, decreased stress could have a powerful impact on health beyond the conscious perception of a lower-stress state.

Alleged benefits of sauna with limited scientific support

Two widely reported benefits of sauna use – “detoxification” and improvements in immune function – have little evidentiary support at present but deserve a brief note.

Sauna is thought to aid in detoxification, particularly regarding heavy metals such as mercury or lead, by promoting increased excretion of these metals through sweat. Sweating is indeed a major route of excretion of heavy metals, but it is unclear whether the *excess* sweating caused by sauna use would result in any *additional* metal excretion or if it would merely result in increased sweat volume with a correspondingly lower per-volume heavy metal concentration. Further, while research generally supports sweating as a strategy for eliminating toxic metals following high-level exposure (acute or chronic), very little evidence indicates that increased sweat output would significantly reduce heavy metal levels in the body for an average individual.

Improved immune function has also not been definitively confirmed, though sauna-related reduction in stress (as noted above) likely provides some immune system benefit. Further, the observation that sauna leads to an increase in white blood cells, lymphocytes, neutrophils, and

basophils might suggest an immune function boost, though it's uncertain whether the effect would translate to any long-term benefit to the immune system.The totality of evidence-backed sauna related benefits are summarized below, in **Figure 1**.

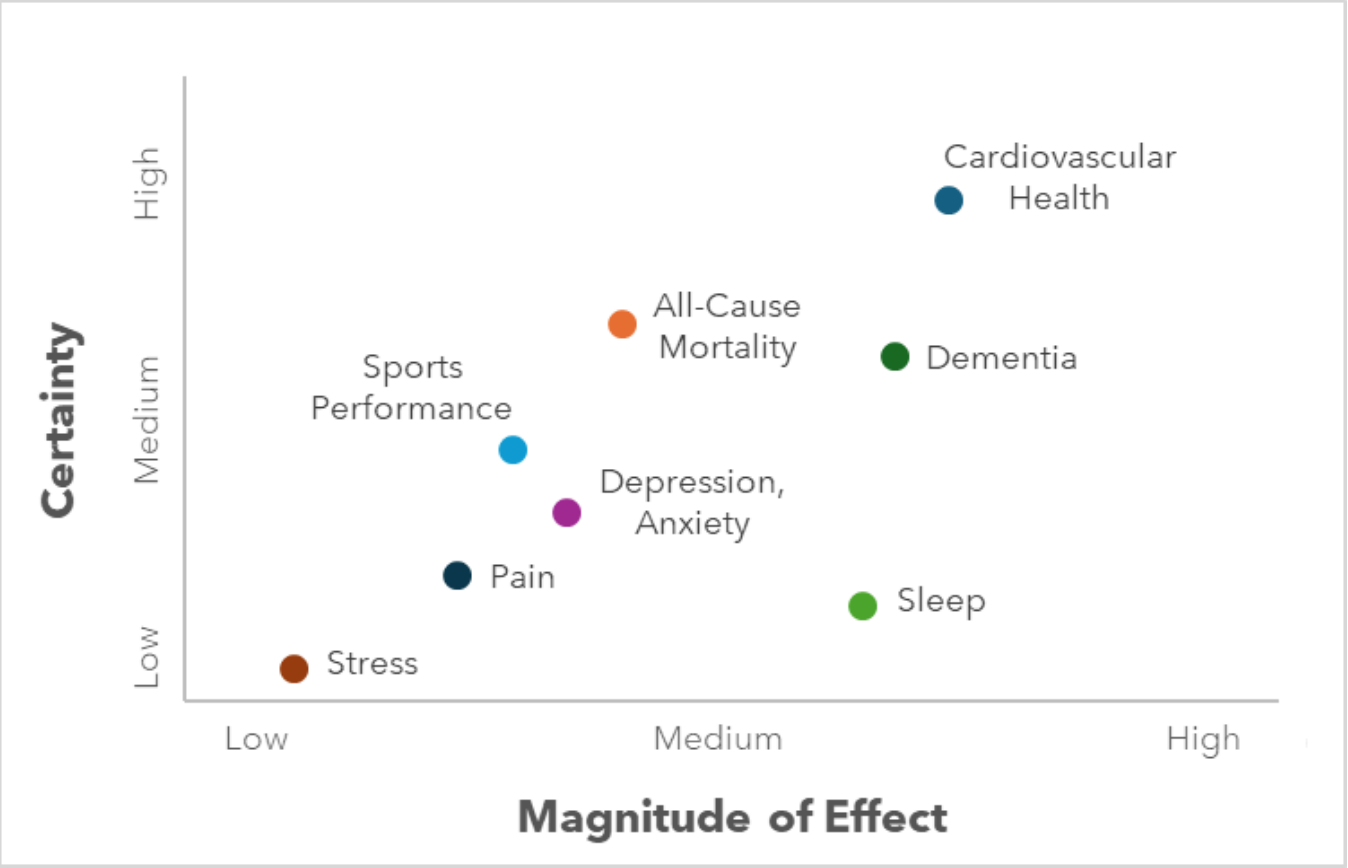

Figure 1: The benefits of sauna use, ranked by magnitude of effect and certainty of evidence. Magnitude and certainty for each benefit are assessed relative to the magnitude and certainty for other benefits of sauna use.

A wider look at the evidence

Apart from a handful of small experimental studies, most of the evidence detailed above is based on observational data, which we can place in the context of the Bradford Hill criteria for each specific benefit of sauna use (**Table 1**). But these effects do not exist in isolation – for instance, cardiovascular effects are likely to impact effects on all-cause mortality, as noted earlier. Thus, we must take a moment to consider the body of sauna literature as a *whole*, acknowledging a few points on how various threads might relate to each other and identifying limitations that apply to all.

Table 1: Benefits of Sauna Use, Scored per Bradford Hill Criteria*

	Cardiovascular Disease	All-Cause Mortality	Dementia	Sports Performance	Mental Health	Sleep	Pain	Stress
Strength	3+	3	3+	2	1	-	1	1
Consistency	3+	3	3	2	2	-	1	-
Specificity	0	0	0	0	0	0	0	0
Temporality	Y	Y	Y	Y	Y	Y	Y	-
Biological Gradient	3	2	2	-	1	-	-	-
Coherence	2	-	1	2	1	-	-	-
Experiment	2	-	-	3	1	-	2	-
Analogy	2	2	2	3+	3	3	3	1
Plausibility	3+	3	3	3+	2	2	3	1

*A 0-4 scale was used, with 0=negative/unconvincing data (data support no effect of sauna) and 4=very convincing data (data strongly support an effect of sauna). Y/N denotes yes/no for the temporality criterion. Dash (-) denotes a criterion for which there is little to no supporting data.

Many of the potential benefits of sauna use are interrelated. Improvements in circulation and cardiac function thought to underlie effects on exercise performance are clearly tied to CV health. Better sleep, lower stress, and a healthier cardiovascular system are all associated with lower dementia risk. Reduction in pain is likely to improve sleep quality and mental health. So although evidence supporting each of these effects individually may be relatively limited, the *consistency* (again, see the Bradford Hill criteria above) of the overall direction of all related effects *together* means that the whole body of sauna evidence is greater than the sum of its parts. This increases the confidence we can have in the idea that sauna is indeed *causing* at least some of these benefits, though it also complicates attempts to isolate any single effect to determine if it is a direct result of sauna use or is merely a covariate.

We must also be careful to consider the possible influence of a healthy user effect in pro-sauna literature. Many of the most compelling epidemiology studies were conducted in Finland, where regular use of saunas is typical across socioeconomic strata. With an estimated 60-90% of Finnish people using a sauna at least once per week, indicates two possible sources of bias: (i) people *not* using a sauna or using one far less frequently may be doing so because they have been told not to for health-related reasons, and (ii) people with the highest rates of sauna bathing may be far more health-conscious than other people, much like how those who exercise more frequently than average in the US are likely more health-conscious than average. If either of these conditions is true, the benefits associated with sauna use or the lack of benefits associated with less frequent sauna use could partially or fully be a result of other aspects of a healthy lifestyle – such as better diet, more exercise, etc – rather than a result of sauna itself.

Further, within Finnish culture, sauna bathing is a significant component of social life, and the purported benefits of sauna may therefore reflect the health benefits of socialization in addition to – or instead of – the use of sauna *per se*. This may be particularly true regarding the dementia, stress, and depression findings, as socialization or lack thereof can significantly impact all three. To determine whether any effects of sauna are a result of exposure to high temperatures, rather than the socialization typical of Finnish sauna use, a rather unusual experiment would have to be conducted. In this experiment, participants would be randomized into *hot temperature* and *ambient temperature* groups, and given specific conditions (time, frequency, socialization) under which the sauna should be used. Only then would we be able to determine whether the benefits of sauna use are specific to heat exposure.

Outside of Finland, sauna use is likely even *more* indicative of healthy users. In countries where saunas are less common and less publicly accessible, those who seek out sauna baths are likely to be of a higher socioeconomic status and/or may be particularly health-motivated. Many of the studies surrounding sauna use correct for a variety of health-related variables to mitigate the influence of a healthy user effect, but no amount of correction can take into account all possible factors.

All that said, particularly with regard to CV effects and improvements in exercise recovery, evidence supporting real benefits of sauna use are strong enough to conclude that a causal relationship is likely. Supporting literature stands up to scrutiny for several of the Bradford Hill principles described earlier, such as consistency, strength, biological gradient, and others (see **Table 1**) – decreasing the likelihood that the associations have been widely misinterpreted. But there is one criterion that we must explore in greater detail: **plausibility**. We've touched on this lightly across a few specific alleged effects, but to truly understand and evaluate the effects of sauna bathing, we need to understand more deeply how the body responds to heat stress.

What is thermoregulation?

Before getting into possible mechanisms behind the apparent effects of sauna use, we need to be familiar with the concept of "thermoregulation" – i.e., why and how our bodies maintain a steady temperature around 37±0.5°C (98.6±0.9°F).

This narrow temperature window is required to maintain the function of enzymes – the proteins that catalyze nearly every biochemical process within the body, from RNA synthesis (and subsequently, protein synthesis) to energy production. Though the biology underlying enzyme function is complex, in general, most enzymes in our bodies follow roughly the same functional curve, displaying low levels of activity at colder temperatures, reaching optimal function around 37°C (98.6°F), and displaying precipitous drops in function at higher temperatures. In fact, beyond 40°C (104°F), not only enzymes, but also all other proteins in our body (comprising virtually all cellular structures and processes), begin to denature (that is, they unfold, rendering them non-functional), so above this internal threshold, human life is a nonstarter. Hence, thermoregulation is a very, very robust, highly conserved part of human biology.

Temperature homeostasis, or the maintenance of body temperature within a window of 98.6±0.9°F, is regulated in large part by a brain region called the hypothalamus (specifically: the preoptic area of the hypothalamus). This region receives input from thermoreceptors in nerve endings throughout the skin (i.e., peripheral temperature sensors) and spinal cord/internal organs (i.e., central temperature sensors). Any variation in temperature is detected by these receptors and relayed to the hypothalamus, which in turn activates temperature control mechanisms in our bodies.

This leads to one of two results: **heat generation** or **heat loss.**

Heat generation occurs through a number of mechanisms. Activation of the sympathetic nervous system leads to vasoconstriction, causing the blood vessels closest to the skin (skin arterioles) to constrict, shunting blood away from the skin and leading to less heat lost to one's

surroundings. In addition, increased release of catecholamines (particularly norepinephrine, from the adrenal gland) and thyroid hormone (from the hypothalamus) leads to increased metabolism, which generates more heat. Within the brain, the primary motor center (within the posterior hypothalamus) is activated, which leads to increased muscle contraction, generating heat, and also leading to the shivering people experience when cold. Piloerection (i.e., body hair standing up) also helps to trap air at the surface of the skin, and enables the body to keep heated air in contact with skin for longer periods of time. Finally, the brain drives behavioral changes designed to warm the body, including adding clothing to increase heat retention, increasing movement to increase heat production (e.g., wiggling your toes and fingers in the cold), and assuming a closed body position to decrease the surface area from which heat is lost.

Heat loss, the element of thermoregulation relevant to sauna use, involves many of the same strategies as heat generation, but in reverse. Inhibition of the sympathetic nervous system leads to vasodilation, causing the blood vessels closest to the skin to dilate, thereby increasing the volume of blood passing close to the skin and, subsequently, heat lost to one's surroundings. In addition, decreased release of catecholamines and thyroid hormone leads to a reduction in metabolism, which decreases heat production. Activation of the cholinergic neurons responsible for sweat gland activity leads to increased sweat and heat loss through evaporation. And again, the brain triggers behavioral changes that help cool the body, including removing clothing to reduce heat retention, stopping movement to decrease heat production, and assuming an open body position to increase the surface area from which heat is lost.

Hormesis

So how might sauna bathing exert positive effects through effects on thermoregulation? The answer is believed to depend on a phenomenon known as "hormesis."

Hormesis is the adaptive response of cells following exposure to something harmful. Occasionally, in small doses or durations, such harmful things can be beneficial. Take, for example, the ubiquitous human experience of illness-induced fever. Viruses and bacteria thrive at body temperature. By transiently increasing your body temperature, your immune system is attempting to create, for a brief period, an unfavorable environment for these pathogens. After viruses or bacteria are detected, your hypothalamus increases the set point for your body temperature to create an environment more hostile towards the invaders, while kicking on a mechanism to protect the proteins and cells in our body. The result is that pathogens are eliminated, while we are protected. But the key feature of acute illness-related fever is that the elevation in body temperature is beneficial only in small doses. When we experience temperatures that are elevated for too long, severe consequences, including dehydration, protein denaturation, organ damage, and, ultimately, death can occur.

That brief periods of elevated body heat can kill off pathogens but maintain the integrity of our cells and proteins leads to another question: in the absence of pathogens, can temporarily raising body heat actually *benefit* us in any way?

Regarding sauna use, temporary heating in the absence of pathogenic threat not only leads to increases in body temperature (core temperature increases by 1-3°C and skin temperature by 6-8°C), but also alters our heart rate (increases to 100-150 beats per minute), cardiac output (increases by 60-70%), and blood pressure (systolic increases by ~15 mmHg). It is reasonable to expect that we may accrue benefits greater than our experience with fevers from the above results of sauna use given that these changes in aggregate closely mirror the physiological changes that occur during moderate exercise.

In response to this heat challenge, our "cool down" mechanism kicks on. We begin to sweat, and vascular changes occur to dilate blood vessels and let off more heat. The catecholamines (and other hormones) released to cool us down in response to elevated temperature may actually trigger mechanisms that offer broad benefits underlying many of the previously discussed. But how and why do these hormones provide benefits?

The reported underlying biology of sauna use

Exposure to high heat, triggering our sympathetic ("fight or flight") nervous system, leads to increased heart rate, blood pressure, and sweating, but also results in several hormonal changes.

Though high heat exposure (e.g., sauna use) impacts a large number of hormones , for the purpose of this newsletter, we will focus on the four that most likely underlie the reported benefits of sauna use: norepinephrine (a catecholamine), beta-endorphins, growth hormone, and prolactin.

The effects of hormones

Norepinephrine is released quickly in response to biological stress, and thus increases during the heat stress of a sauna bath. Though norepinephrine levels begin to fall quickly following the end of sauna use, levels do stay elevated even an hour afterwards. It is possible that the elevation in these hormones extends out even beyond this period, given that the final time assessed from the above study was an hour following the sauna. All three other hormones of interest follow similar patterns (beta-endorphins, prolactin, growth hormone), showing a dramatic increase during sauna bath and a gradual decrease afterwards.

Mechanistically, norepinephrine is the main hormone responsible for the physical sensation associated with sauna use, including increases in heart rate and blood pressure, which occurs as a result of norepinephrine-induced blood vessel constriction. Norepinephrine also leads to increases in heat shock proteins, reactive oxygen species, and brain-derived neurotrophic factor, which may contribute significantly to many of the beneficial effects, and will be discussed below.

Beta-endorphins are also secreted during the heat stress of sauna use. Endorphins are the body's endogenous pain killer, and heat stress-induced beta-endorphin release can lead to a sense of wellbeing or decreased stress by binding to mu opioid receptors in the brain. However, heat stress by means of sauna use can also lead to an increase in the release of *dynorphin*, which has the ability to modulate our endorphin system. Dynorphins, through their

binding to *kappa* opioid receptors, may be another element underlying the feelings of discomfort we experience *during* sauna use. However, long term, dynorphin activity leads to an upregulation of mu opioid receptors, essentially improving our ability to utilize beta-endorphins when they are released. It is through both of these mechanisms that the endorphin pathway triggered as a result of sauna use confers its multitude of benefits: decreased stress, improved mental health, pain modulation (particularly headache), and potentially even better sports performance (via higher pain tolerance/decreased pain experience).

Growth hormone (GH), again, released in response to heat stress, may also explain some of the benefits associated with sauna use. GH is implicated in recovery from exercise, particularly through its effects on tissue repair, and may also provide some benefit to mental health and cognition, as there is evidence to suggest growth hormone supplementation in GH-deficient individuals provides mood and cognitive benefits. GH could potentially underlie some of the cardiovascular benefits observed with exercise, through the upregulation of reactive oxygen species, which leads to improved endothelial health (detailed below).

Less convincingly, but worth noting, is prolactin. Prolactin, a hormone typically associated with pregnancy, is also upregulated in response to heat stress. Interestingly, prolactin may help promote white matter health and function in the brain, and may therefore play a role in the benefits of sauna related to mental health and dementia.

Heat shock proteins, brain-derived neurotrophic factor, and reactive oxygen species

As previously mentioned, the secretion of norepinephrine leads to increased production of heat shock proteins (HSPs, particularly HSP-70), which play an essential role in protecting the proteins in our body from damage via unfolding, misfolding, and aggregating, through their transient binding to and “chaperoning” of these proteins, particularly during times of cellular stress. HSPs may also repair or re-synthesize proteins that have already been damaged. Heat stress is known to robustly increase HSP expression in people, giving these proteins a plausible mechanistic role in sauna-related benefits.

HSPs may be particularly important for the sports recovery benefits of sauna use due to HSPs action on muscle proteins. HSP synthesis occurs over hours, with peak levels occurring around 3-5 hours following heat stress exposure, and levels declining by 8 hours, suggesting that the effects of HSPs may extend over a fairly long period.

The main regulator of HSP production, called heat shock factor 1, is also known to upregulate brain-derived neurotrophic factor (BDNF), a protein thought to play an essential role in mental health and cognitive function. Indeed, sauna use appears to increase circulating levels of BDNF. Mechanistically, BDNF supports neuroplasticity and promotes neuron survival and growth. This role may underlie several of the discussed sauna benefits, including mental health conditions and dementia.

One of the other effects of increased sympathetic nervous system activity is the generation of reactive oxygen species (ROS). Upon exposure to heat stress and activation of this branch of the nervous system, there is a greater demand for oxygen across multiple tissue types. As the

body breathes harder and takes in more oxygen, it begins to produce more reactive oxygen species. Further, growth hormone increases following sauna use may also increase ROS production. Though persistent high levels of ROS are known to increase oxidative damage to DNA and other cellular components, ROS in smaller doses are thought to provide benefit.

Though the evidence is not conclusive, this is one mechanism by which we think much of the cardiovascular benefit of sauna is conferred. There is evidence from individuals with chronic heart failure suggesting dysfunctional ROS production is a typical characteristic of the condition. Further, inhibition of nitric oxide synthesis (a key contributor to ROS production) leads to increased arterial stiffness, providing mechanistic evidence to suggest ROS play a role in endothelial health. Taken together, repeated low-dose exposure to ROS due to sauna use may improve endothelial health, and subsequently exert a protective effect across many domains of CV and cerebrovascular health.

All of these mechanisms (hormonal, HSP, and ROS) are summarized in **Figure 2**.

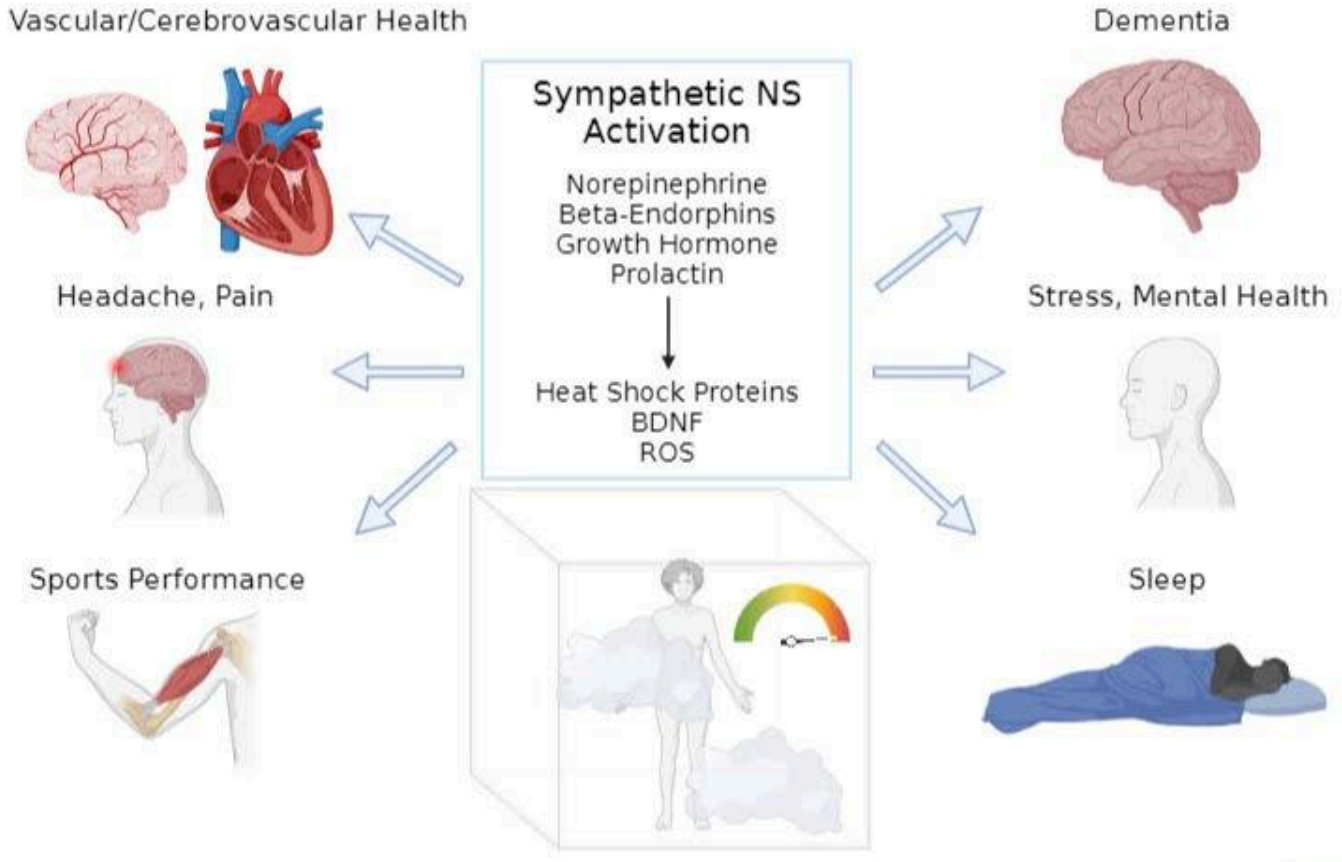

Figure 2: The mechanisms underlying sauna benefits include processes resulting from transient but reversible increases in norepinephrine, prolactin, growth hormone, heat shock proteins, Brain-Derived Neurotrophic Factor (BDNF), Reactive Oxygen Species (ROS) and beta-endorphins. Source: Internally created.

Though sauna use is also associated with decreased inflammation, this benefit may not be specific to or even provide substantial support for any particular reported benefit. Of course, decreased inflammation benefits health across a wide array of domains. However, an improved inflammatory profile does not appear to specifically or powerfully underlie any specific sauna-related benefit.

Notably, though cortisol is a popularly reported mechanism for sauna-related benefits, the evidence supporting this claim is not clear. Many studies have evaluated cortisol release in response to sauna use, and have conflicting results, with many reporting no significant change.

Of course, regardless of the physiological mechanisms of sauna bathing, we can only reap the benefits if we know the *practicalities* of sauna bathing. We've thus far examined the "why," and we must now address the "who," "what," "when," "where," and "how."

How to sauna

There are five key elements to consider in the practice of using a sauna: (i) the **type** of sauna to use, (ii) the **temperature** the sauna should be, (iii) the ideal **duration** of a sauna session, (iv) the ideal **timing** for sauna use, and (v) the optimal **frequency** of sauna use.

Type of sauna

There are three **types** of sauna: infrared, steam, and dry. Infrared saunas emit infrared light which we experience as heat after the light is absorbed by our skin. By contrast, steam saunas generate their heat by heating water to create pressurized steam which is then released within an enclosed space, while dry saunas are heated via air-warming generators, hot stones, or other mechanisms.

Though their heat generation mechanisms differ, all types of sauna are likely to provide similar benefits as long as sufficient heating, duration, and frequency are achieved. This also extends to other methods of heating, including hot tubs, thermal baths, and hot baths and showers. Even standing outside on a hot day would likely induce a level of heat stress. Though most of the studies discussed here used a dry sauna (15 were dry sauna studies, compared to 4 IR, 3 thermal bath, 2 steam, 2 comparing a variety of heating methods, and 2 with an unlisted type), several of the benefits were demonstrated across multiple heating modalities. For example, pain relief was observed with both dry sauna use and thermal baths, and while the risk reduction in CVD deaths was observed in dry saunas, some of the mechanisms possibly underlying the CV benefits were observed in IR saunas. Given the agreement between multiple methods of heating, it is reasonable to think that similar benefits to those of the dry sauna can be obtained using other heating modalities, given a similar degree of heating and duration are obtained.

With that said, extra caution should be employed when using infrared and steam saunas. Infrared saunas may use a variety of wavelengths, intensities, and locations for the light source, which could lead to differences in the degree or consistency of body heating. Steam saunas can more easily lead to overheating beyond what is recommended due to a faster rate of heating given the same duration of use, likely because of the inability of heat to escape the body as sweat (via evaporative cooling).

Older individuals using either steam saunas or infrared saunas, for which safe temperature ranges are less established, should be particularly careful, because overheating becomes more likely as our bodies become less efficient at regulating temperature with age. This would

also apply to anybody who has a difficult time regulating their body temperature due to other health conditions.

Sauna temperature

Regarding **temperature**, a vast majority of the studies listed above involved **dry** sauna conditions within the 80-100°C (176-212°F) range. Anything significantly above this temperature may not be safe, and since temperatures below this range have not been extensively studied, we cannot be sure that they would result in significant health benefits. In terms of **steam** saunas, because body temperature and heart rate both increase more even with lower temperature, caution should be exercised in keeping body temperature increases within the +6-8°C skin temperature range. Most recommendations for steam saunas fall within the 38-49°C (100-120°F) range. Due to our reduced ability to cool our bodies through evaporation in high humidity environments, the temperature required to maintain similar heating in these saunas is much cooler. Thus, using skin temperature increase would be a good indicator when using steam saunas, as humidity levels likely vary across models. A similar recommendation can be made for **infrared** saunas. Because different models may use a variety of light wavelengths, and these all have a different impact on body heating, following the recommendations of the manufacturer may be best in determining the temperature at which to use an IR sauna.

Sauna duration

In terms of **duration**, most studies using sauna as an intervention prescribed 15-30 minutes. This may represent an ideal goal for sauna session length in the long term but would likely not be feasible for individuals just beginning sauna use. For dry saunas, the recommendation for people new to saunas is that they begin with short sessions (e.g., 5 minutes) and incrementally work up to 20 minutes, and not necessarily exceed 30 minutes due to increased dehydration risk. In steam saunas, far shorter durations are suggested, with many guidelines recommending a maximum of 10-20 minutes. For infrared saunas, the studies above achieved results with sessions ranging from 15-30 minutes. As with temperature, which can lead to side effects if not maintained within an appropriate window, duration of sauna use should be carefully monitored, lest overheating and resultant serious side effects occur.

Sauna timing

Ideal **timing** of a sauna bath depends largely on the primary goal one wishes to achieve through sauna use.

For those hoping to use saunas to improve sleep quality, the optimal time would be an hour or two before sleep. This is because, as previously discussed, the more steeply body temperatures decline before bed, the better the quality of sleep. Entering a sauna shortly before bed is an easy way to increase the slope of this decline.

For those who want to use saunas to help with sports performance goals, a post-exercise sauna bath would likely be best, in order to capitalize on the protein support mechanisms (HSPs and growth hormone) that accompany sauna use.

A recent study suggests that for individuals using sauna bathing to improve cardiovascular health, pairing a sauna session very closely with exercise may increase the benefit above and beyond the effect of exercise alone. Though the studies of sauna use and cardiovascular health did not assess whether time of day was relevant to the benefits observed, it seems likely that the biological mechanisms underlying these benefits wouldn't be contingent upon what time the sauna session is, though future studies should explore this further.

Sauna frequency

Regarding **frequency**, the studies evaluated here suggest that more is better. People using a sauna four or more times per week consistently exhibited the greatest benefit. Though the difference was not always significant, people using a sauna twice or three times per week had greater benefits than those only using a sauna once.

However, though multiple sauna sessions per day has been used to increase growth hormone and may not necessarily be acutely dangerous, sauna use that is *too* frequent significantly increases the risk of dehydration and may be inadvisable in most cases. Further, even though using a sauna everyday is thought to be more beneficial than using a sauna once per week, if a higher frequency of sauna use comes at the expense of other health-supporting practices, particularly exercise, sauna bathing should be relegated to a lower priority.

For a summary of optimal sauna protocol parameters, see **Table 3** below.

Table 3: Optimal sauna use protocol.

	Dry Sauna	Steam Sauna*	Infrared Sauna*†
Temperature	80-100°C/176-212°F	38-49°C/100-120°F	38-49°C/100-120°F
Duration	20-30 minutes	10-20 minutes	20-30 minutes
Timing	For **sleep** benefit: Use 1-2 hours prior to bedtime. For **sports performance** benefit: Use following exercise to optimize recovery. For **cardiovascular** benefit: Pair closely with exercise for optimal benefit or use without accompanying exercise at any time of day.		
Frequency	Once per day, 4-7 days per week.		

*Recommendations for steam and infrared sauna use are based on safety rather than effectiveness, as few studies have been conducted using steam and infrared saunas.

†The temperature and duration recommendations for infrared saunas vary depending on the model being used.

Risks of sauna use

Some of the common side effects of sauna use include dehydration, dizziness, and headache. However, these are short-lived, and typically resolve once sauna use is discontinued.

Injuries do occasionally occur as a result of falls in the sauna usually resulting from slips or dizziness and passing out (one Finnish study reported approximately twelve sauna-related injuries per year at one hospital). Two easy precautions to avoid falls as a result of slipping or dizziness is to use slip-resistant slippers or shoes and maintain proper hydration.

Certain individuals should not use saunas, including those with uncontrolled cardiovascular disease (e.g., angina, congestive heart failure, recent heart attack), who may not be able to tolerate the increases in blood pressure (+15 mmHg systolic BP), heart rate (up to 100-150 beats per minute), and cardiac output (60-70% increase) accompanying sauna use. For individuals with controlled CVD and other CV risk factors, it may be advisable to consult with a doctor before using a sauna. However, in these cases, it is likely that saunas would be safe and well-tolerated, and could even confer significant cardiovascular benefit.

Additionally, as briefly mentioned, for individuals who have a difficult time regulating their body temperature due to underlying health conditions or age, overheating can occur more quickly and therefore sauna use should be approached with appropriate caution.

Women who are pregnant or nursing should also abstain from sauna use. Body temperatures above 38.3°C (101°F) can increase the risk of pregnancy-related complications and birth defects. Women who are actively nursing run a higher risk of overheating due to sauna use, as their bodies run at a warmer baseline temperature during breastfeeding.

Saunas may not be safe for people prone to dehydration or already dehydrated. The primary method by which our bodies cool us down in a sauna is through induced sweating, and this would further worsen dehydration in these individuals. In its most extreme form, dehydration can lead to kidney and brain damage, and even death, so it's best to avoid the possibility of exacerbating dehydration through sauna use altogether.

Finally, do not use a sauna if you are intoxicated. A *vast majority* of severe sauna-related injuries and deaths occur in people who use saunas while intoxicated. One study out of Korea found that of 103 deaths in a sauna over a seven year period, 76 had a blood alcohol concentration higher than 0.08.

Outside of these scenarios, sauna use is reasonably safe and reasonably well-tolerated at the recommended temperatures and durations, even in people who are not optimally healthy.

The bottom line

So do saunas really benefit your health? The answer seems to be: very likely, provided the protocols mirror those of the most robust studies outlined here. Considering the magnitude, consistency, and biologic plausibility of the evidence in support of sauna bathing, along with the other Bradford Hill criteria (**Table 1**), we can reasonably conclude that, most likely, sauna use is

causally linked to health benefits. This is particularly true regarding cardiovascular health (which remains the number one cause of death worldwide), which shows some of the largest and most consistent positive effect sizes of all of the discussed evidence. Regardless of whether some of the apparent effect of sauna use hinges on healthy user bias, paying more attention to your health and taking a more active role in promoting longevity is never a bad thing. The actual magnitude of effect is likely lower than the findings of vast epidemiology cited here, not only because of the inherent healthy user bias which can never fully be corrected for, but also because of the many social benefits that are equally baked into these studies.

There is one final point to make with respect to sauna use and it has to do with opportunity cost. Let's put the financial costs aside and focus instead on something more valuable than money: time. I've met people who spend 30 minutes a day in the sauna, but who rarely exercise because they say they are too busy. There is a clear order of operations that should be adhered to as you think about "stacking" more and more healthy behaviors, but the core of this remains: exercise, sleep, and nutrition. Consider these elements the foundation of your house. Be sure your house is in order before you venture off the property to pursue other things, such as sauna, despite the likely benefits.

Disclaimer: I have a dry sauna in my home and I spend 20 to 30 minutes at a temperature of 194 to 200 F, four to five times per week. I would do it every day, if time permitted. Most of those sessions are about 2 hours before bed, but at least once a week I try to get a session in following a workout or a long ruck. Above all else, though, I find the company I keep, usually with my wife, but also with friends, to be a special part of the experience.

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