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Endocrine effects of sauna bath

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Abstract

Sauna bath brings about numerous acute changes in hormone levels, partly akin to other stressful situations, partly specific for sauna. Norepinephrine increases in those accustomed to sauna bath. Sweating increases the production of antidiuretic hormone, and the renin-angiotensin system becomes activated. Of the anterior pituitary hormones, growth hormone (GH) and prolactin (PRL) secretion is increased. Also β-endorphin has been frequently reported to increase, whereas the responses of ACTH and cortisol are variable, probably depending on the type of sauna exposure. Sperm production decreases in particular in sauna-naïve men, but reduced fertility has not been associated with regular sauna habits. Minor sex differences exist, the hormonal responses being somewhat greater in women. Sauna-naïve women may experience mild disturbances in menstrual cycle, but no effects of fertility have been reported. The hormone responses are short-lived, normalizing soon after sauna exposure during the recovery. Adaptation to regular sauna use plays an important role in the responses, which attenuate upon frequent exposure.

Key words: heat stress, hot bath, hyperthermia, norepinephrine, growth hormone (GH), prolactin (PRL), cortisol, β-endorphin, renin-angiotensin, spermatogenesis, adaptation

1. Introduction

Heat stress in the passive (hot baths and sauna) or active (exercise) form evokes multiple physiological responses, some of them involving the endocrine system. Sauna bathing, a common life-style habit used mainly for relaxation, cleaning, pleasure, and to release bodily stress, has modulating effects on the hormonal and autonomic nervous system activity (1). The purpose of this review is to summarize the current knowledge about the endocrine effects of sauna. Besides the Finnish sauna-type exposure to dry heat, rather similar endocrine responses have been observed upon immersion in hot water. A wealth of information is available on effects of sauna (and hot bath) on hormones from older studies carried out 20-30 years ago, but additional novel information about sauna and hormones is rather scarce. Some older reviews exist on the topic (e.g. 2,3), but in recent years the endocrine effects of sauna have not been addressed comprehensively. We therefore summarize the key information available from older literature with the more recent findings. A summary of the hormone responses detected upon sauna bath is presented in Table 1.

2. Neuroendocrine and pituitary hormones

The neuroendocrine responses to sauna have concentrated on stress hormones such as β-endorphin and ACTH, which respond variably, ranging from decrease to no change to increase (4-8). When the heat exposure reaches level of subjective discomfort the ACTH/β-endorphin increase is more consistent (9). The increase in β-endorphin may play a role in the feeling of wellbeing after sauna. The thermal stress response of these hormones is abolished in alcohol, cocaine and heroin addicts, which is explained by the disruption of hypothalamic opioid neurotransmission upon chronic addiction (7,10).

No effect of sauna on gonadotropins has been found in either sex (4,6). Findings on TSH are conflicting with reports ranging from increase (11) to no change (4,12) to decrease (both TSH and T4)(13,14).

The two anterior pituitary hormones with the most consistent responses during exposure to sauna are GH and PRL. GH increase has been documented in numerous studies (4,9,15). Leppäluoto et al. (16) documented that the GH response was under control of the hypothlalamic GH-releasing hormone (GHRH). Furthermore, an intriguing age difference was found: while GHRH and GH responded with significant increase in younger men (31-46 yrs), no increase of either was found in older men (49-66 yrs). The same investigators detected attenuation of the GH responses following repeated sauna exposure in men (7 days twice daily) (4). The attenuation of GH response was not reproduced in young women (13). Stimulation of peripheral thermoregulators (heating of arm) was found sufficient to increase the GH levels (17).

The other consistent endocrine response to sauna is the increase in PRL levels (4,5,9). The increase is brisk (up to > 10-fold), remained similar in men upon repeated sauna exposure (4), but attenuated in women (13). As an attempt to study the mechanism of PRL increase upon hyperthermia, Low et al. (18) subjected men to exhaustive bicycle exercise at 33 °C temperature, and to passive heating in a 41.5 °C water bath. Similar increase in body core temperature (to 38.8 °C) and a 2-fold PRL response was observed. It was concluded that the thermoregulatory afferents, rather than cardiovascular, provide the stimulus for PRL increase, probably through changes in serotoninergic and dopaminergic activation, in agreement with the response to sauna. However, it remains controversial whether the body core (17) or skin (19) temperature rise is more important in the PRL rise. Another study showed that facial cooling prevented the PRL increase and increased thermal comfort during sauna bath, indicating that a small part of total skin area (10%) can have a disproportionate role in the PRL response (20).

3. Cortisol

Findings on the acute effects of sauna bathing on the distal response of the hypothalamic-pituitary-adrenal axis, i.e. serum cortisol, are variable. In some studies cortisol levels have increased (21), in some an initial decrease was followed by an increase (8), and also unchanged levels have been reported (9). Similar variable findings have been made during the post-sauna cooling period (5,8,9,22). The differing responses are best explained by differences in the duration and temperature of sauna bath. A general trend is that higher humidity and temperature evoke higher increase in cortisol (9,22). Excessive sauna exposure of men (twice a day for 7 days) suppressed the GH, ACTH and cortisol responses at the end of the experiment (4).

A very recent study examined the effects of various types of physical exercise (endurance, strength, combined), followed by sauna, on serum hormone levels (GH, testosterone, cortisol) in men (23). The expected increases in the levels of the three hormones were found when studied in the afternoon, but not in the morning - a confounding factor not taken into account in all sauna studies. Sauna after the exercise enhanced neuromuscular fatigue, but did not change the hormonal responses evoked by exercise.

4. Effects on stress and cardiovascular hormones

Responses to sauna of the cardiovascular system, with its essential regulatory hormones related to hemodynamic consequences of heat exposure, have been studied in recent years. Regular sauna bathing has been suggested to exert a potential therapeutic effect on elevated blood pressure, which may be partly explained via favorable effects on the cardiac autonomic nervous system balance, improved vascular function and increased excessive fluid loss (24).

Sauna baths have shown to increase the demands of cardiovascular function (25). Sauna bathing leads to an increase in heart rate (HR), thereby imitating effects of moderate physical activity on cardiovascular system without active skeletal muscle work. Sauna bathing causes an increase in HR and heart rate variability (HRV), which is a marker of autonomic nervous system balance. HRV analysis provides an insight into cardiovascular responses to sauna baths. One recent study showed the effects of a typical Finnish sauna on HR and HRV in a population with cardiovascular risk factors among regular sauna bathers (26). The results indicate that sauna bathing improves cardiac autonomic nervous system balance, leading to increase in vagal tone and decrease in sympathetic tone, with favorable modulations in blood pressure during the recovery from sauna which may also be related to a lowered cardiovascular event risk (27).

Increased sweating during sauna bathing is accompanied by reduction in blood pressure and a higher HR, whilst cardiac stroke volume is largely maintained; although a part of blood volume is diverted from the internal organs to peripheral body parts with decreasing venous return which is not facilitated by active skeletal muscle work (1). Indeed, comparable with exercise-induced adaptations, heat stress could increase HR up to 150 per minute (26). During the hot sauna bath HR increases gradually from the beginning of sauna bath until the end, corresponding with an increase in body temperature and heat load. An earlier study conducted in young healthy men showed that the plasma norepinephrine concentrations increased approximately 2-fold during bath sessions with a mean temperature of 88 °C whereas there were no substantial changes in plasma epinephrine and serum thromboxane concentrations (28).

The effectiveness and safety of sauna bath as an additional diaphoretic or diuretic therapy requires more studies. Although intensive sweating, induced by sauna with dry or wet heat usually increases losses of water, urea, sodium, potassium and chloride, a single sauna bath session does not cause significant longer-term changes in serum electrolyte or creatinine levels (25). Ohori et al. (29) demonstrated that 3 weeks of repeated thermal treatment (Waon therapy) in patients with chronic heart failure was associated with decreases in levels of brain natriuretic peptides (BNPs) and plasma norepinephrine. However, there is only moderate evidence that sauna bath improves left ventricular ejection fraction and decreases BNP levels (30). Some other studies in which patients with heart failure were treated with infrared-ray sauna therapy for several weeks, decreases in concentrations of BNPs were demonstrated (31). A Finnish study on sauna and biomarkers (a single 30-min exposure) shows that there was an elevation in NTproBNP levels after sauna bathing, which may be associated with an increased workload of the cardiovascular system and heart muscle (25).

5. Reproductive function

5.1. Men

No differences in relevant reproductive hormone levels occurred after sauna exposure (FSH, LH, testosterone, estradiol, inhibin B, sex hormone-binding globulin), which seems to be the finding in several sauna studies (2,3).

Scrotal temperature is 2-3 °C lower than body core temperature (32,33), and it is considered quintessential for spermatogenesis. It is disturbed when testicular temperature is elevated, e.g. in cryptorchidism, fever, varicocele, or even obesity (34). Lifestyle conditions with increased testicular temperature, such as tight clothing and prolonged sitting position, increase scrotal temperature sufficiently to reduce spermatogenesis (35,36). Because sauna bath increases scrotal temperature to about 37.5 °C (37), negative effect on spermatogenesis is a relevant concern. On the positive side, intensive heat exposure in hot baths or by using tight underware for weeks-months can lead to reversible profound oligozoospermia – azoospermia, which has been proposed for male contraception (38,39).

There is ample information on adverse effects of various types of hyperthermia, including sauna and hot baths, on spermatogenesis in man and experimental animals (for references, see 37). A single exposure of sauna-naïve men to 86 °C for 20 min suppressed the sperm number per ejaculate from a mean of 250 to 160 x 10^6 in one week ($p < 0.05$), and the numbers returned to normal in 5 weeks (40). Immediate increases after sauna were found in sperm motility, glucose utilization and lactic acid accumulation. Ultrastructural alterations in sperm included swelling of plasma membrane, increase in immature forms and disorganization of arrangement of mitochondria. Another sauna study for 2 weeks demonstrated a significant reversible decrease in sperm motility parameters, but not in numbers (41).

A longer 3-month twice per week exposure to sauna brought about a 50% decline is sperm number per ejaculate and quality at the end of exposure (36 7), with gradual reversal to pre-exposure levels in 6 months. Similar reduction occurred in the percentage of progressively motile sperm, whereas no changes occurred in semen volume, sperm morphology, DNA integrity or viability. Slight reduction in histamine-protamine replacement, chromatin condensation and mitochondrial function also occurred. There was in sperm an increase of hypoxia-induced factors, vascular endothelial growth factor (VEGF) and heat shock proteins.

In all studies, the changes in sperm induced by sauna were reversible in weeks-months after cessation of exposure. Clearest negative effects of sauna on spermatogenesis have been found in sauna-naïve men (see above), whereas studies on chronic exposure to heat in various lifestyle conditions (professional exposure, sitting, tight underware, habitual sauna or hot baths) have largely remained inconclusive (35). Although no controlled studies exist, sperm counts in countries with habitual frequent use of sauna or hot baths, Finland and Japan, no evidence exists on lower sperm counts that in other countries (42,43). Neither is there epidemiological evidence for harmful influence of hyperthermia (or sauna) on male fertility (2,44). However, it remains unknown whether men with poor spermatogenesis would be more sensitive to sauna.

In conclusion, there is rather strong evidence that acute exposure of men to hyperthermia, such as sauna, has reversible negative effect on spermatogenesis, whereas effects of various forms chronic hyperthermia (including sauna) are less convincing. We may speculate that upon prolonged exposure adaptation mechanisms reduce the suppressive effects of acute heat exposure. Comparative studies on spermatogenic effects of acute and chronic sauna exposure would be needed to test this hypothesis.

5.2. Women

Some sex-related differences have been shown in the hormone responses to sauna. Despite similar increase in body temperature (2 °C), the increases of ACTH, cortisol and PRL were more pronounced in women, whereas those of catehcolaminens (epinephrine, norepinephrine) were similar despite higher increase of heart rate in women (8). Laatikainen et al. (5) found in women significant increases in β-endorphin and norepinephrine secretion, whereas the responses of epinephrine, ACTH and cortisol were variable. The adaptation of some of the hormonal responses to sauna also seems to differ between men and women (see above). Menstrual disturbances in women upon frequent sauna exposure have been ascribed to elevated PRL and β-endorphine (4). However, no effects of sauna on fertility have been reported.

Pilch et al. (14) studied the endocrine responses in women with no previous experience in sauna bathing. Tests were carried out on the 1st and 14th sauna day (30 or 45 min every other day). The expected elevations of GH, ACTH and cortisol were observed, and a clear adaptation of the responses was found in the group where sauna exposure was 45 min with a 5 min cooling period in between, as compared to 30 min continuous sauna exposure. The hormone responses appeared to be larger than in women accustomed to sauna, and the adaptation was also found in this study. Vähä-Eskeli et al. (45) observed that the PRL response to sauna was abolished during pregnancy, whereas it did not influence the responses of AVP and cortisol. No harmful effects of sauna have been found in healthy pregnant women (9). The hormonal responses were found to be similar in children and adults (46).

A very recent study (47) reported favorable effects of hot water immersion therapy on cardiovascular status of obese women with polycystic ovary syndrome. The therapy included a 8- to 10-week period of passive hot water immersion (1 hr at 40.5 °C) 3-4 times per week. Significant cardiovascular, endocrine and metabolic effects were observed at the end of the treatment period: decreased systolic and diastolic blood pressure, decreased total and LDL-cholesterol, and decreased fasting glucose, testosterone and C-reactive protein. The authors proposed reduced sympathetic nerve activity as the mechanism of the positive effects.

6. Metabolic hormone

Positive effects of frequent sauna visits (10 sessions every 1-2 days) have been reported in both sexes on blood lipids in the form of suppressed total cholesterol, LDL-cholesterol and triglycerides, and the responses were considered similar to those caused by moderate-intensive physical training (22,48). Some of the brain-gut peptides respond to sauna bathing. There was in women a significant increase in vasoactive intestinal polypeptide (VIP) during heat exposure, and an increase in motilin thereafter, whereas insulin, cholecystokinin (CKK) and somatostatin remained unaltered (49). The VIP increase was suggested to be related to a compensatory mechanism of simultaneous vasodilation and heat loss.

Hyperthermia increases the levels of several glucoregulatory hormones. In an experiment carried out on men in hot bath, the levels of glucose, GH, β-endorphin and glucagon increased, whereas those of insulin remained unaltered (50,51). The increase in blood glucose can be explained by combined GH and catecholamine effects in the face of unaltered insulin. These findings are not entirely consistent, because in another study, during a 3-h exposure to hot bath (52), there were increases in GH, epinephrine, glucagon and cortisol together with a slight hyperinsulinemia in the face of unaltered glucose. In an intravenous glucose tolerance test during the last hour of hyperthermia, signs of impaired first phase (probably caused by inhibition of insulin secretion by elevated epinephrine) and enhanced second phase (reaction to relative hyperglycemia) insulin responses were recorded. The increase of insulin in this study was explained by effects of increased glucagon and lipid intermediates. Of clinical significance is the observation that sauna accelerates the absorption of subcutaneously injected insulin (53).

Sauna (54) and hot bath (55) also increase the level of leptin, a hormone mediating the feeling of satiety. A Japanese study found in normal-weight individuals after prolonged sauna exposure an increase in caloric intake, associated with increase in levels of the orexigenic hormone ghrelin, whereas no change occurred in the satiety hormone leptin (56). The increased energy expenditure might suggest sauna baths as a potential lifestyle modification upon weight reduction (57). Altered leptin/ghrelin balance might play a role in the weight effects of frequent sauna exposure. The elevation of leptin was boosted by caffeine ingestion before the heat exposure (58). Whether a cup of coffee would improve the weight reduction effect of sauna is therefore a relevant question.

7. Conclusions and future perspectives

Sauna bath evokes a number of hormonal responses (Table 1). They are mostly temporary and subside soon after the heat exposure. The responses differ between individuals who are accustomed to sauna, often abating with experience. This is one apparent reason for many differences between individual observations, along with other variables such as the level of heat, duration of exposure, time of day, and age, sex and body composition of the participating individuals. The adaptation mechanisms are still poorly investigated, including the variable effects of sauna on spermatogenesis. Likewise, the mechanisms of the subjective feeling of wellbeing upon sauna bath remain largely unknown. The transient hormonal responses observed cannot be considered harmful for individuals in good health, but they may represent a burden for those in suboptimal health status – an issue deserving more detailed study in the future.

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Table 1. Documented changes in hormone levels during sauna bath, compiled from ref. 2 and papers published thereafter (as listed in the references).

Hormone	Change
Adiponectin	↔
Adrenocorticotropic hormone	↔,↑*
Aldosterone	↑
Angiotensin II	↑
Arginine vasopressin	↑
Atrial natriuretic peptide	↑
Beta-endorphin	↑
Brain natriuretic peptide	↑,↓
Cholecystokinin	↔
Costisol	↔,↑,↓
Epinephrine	↔,↑
Follicle-stimulating hormone	↔
Ghrelin	↑
Glucagon	↑
Growth hormone	↑
Growth hormone-releasing hormone	↑
Insulin	↔
Leptin	↑
Luteinizing hormone	↔
Melatonin	↔
Motilin	↑
Norepinephrine	↑
Prolactin	↑
Renin	↑
Somatostatin	↔
Testosterone	↔, ↑
Thyroxine	↔, ↑
Thyroid-stimulating hormone	↔, ↑
Vasoactive intestinal polypeptide	↑

* ↔, no change: ↑, increase; ↓, decrease