THE INFLUENCE OF SAUNA TRAINING ON THE HORMONAL SYSTEM OF YOUNG WOMEN

by

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Since there are only a few papers concerning hormonal changes in people not accustomed to sauna exposure and even less with women as the subjects, the main goal of the research was to analyze the basic responses of the hormonal system in women. Women were subjected to single and repeated thermal stress in Finnish sauna. Ten healthy female between the ages of 19-21 volunteered to participate in the experiment. All selected volunteers shared similar anthropometrical parameters. Volunteers underwent a series of seven baths in Finnish sauna. Baths were taken seven times every second day, always in the morning. Each sauna treatment lasted 30 minutes. During the sauna bath the subjects rested in a half-lying down position. Average temperature in the sauna was 80.1^{o}C, and the relative humidity of the air was 26.6%. Significant decreases of body mass and plasma volume were observed both, after the first as well as after the last exposure to heat in sauna. However, the most pronounced changes in PV were observed after the last sauna. Increase of rectal and tympanic temperatures were milder after the last sauna compared with the first one which proves organism adaptation to high temperature of environment. Statistically significant decrease were observed in plasma TSH and T4 concentrations after the last sauna exposure, whereas more than twofold increase in hGH was observed after the first and the last sauna bath. There were a significant increases in ACTH and cortisol after each sauna bath, however the rise in cortisol concentration was less pronounced after the last sauna. Significant increases of prolactin concentration after bath sauna exposures were noted. Observed changes may be the result of acclimatization of the organism to repeated exposure to heat during sauna bath.

Key words: sauna, heat stress, hormonal changes, acclimatization

Introduction

The Finnish sauna has became a very popular heat therapy treatment, mainly used as a preventive and hygienic measure. Temperature of human

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body increases quickly in sauna. Most effective method of cooling a human body down in hot environment, is by sweating and evaporation of the sweat from the surface of the skin. Thermo-regulating system, however, is not an independent system. Responses to the heat depends on the capillary vessels in the skin and proper reaction of the cardiovascular system. (Kawashima, 1993). Hormonal system strongly affects the thermoregulatory system and there are several hormonal changes under thermal stress, particularly strong in people not used to sauna. Common responses to stress are activation of the hypothalamo–hypophyso-andrenal axis and activation of sympathetic system. There is an increase in production of Adrenocorticotropic hormone (ACTH) and increase of concentration of cortisol and its metabolites in blood or urine as a response to thermal stress (Kukkonen et al. 88, Mills 85).

Another hormone, whose secretion is increased by thermal stress, is the growth hormone. High increase of hGH was observed after sauna in previous papers (Ježova et al. 1985, Leppä luoto et al. 1986b, Opaszowski et al. 2001, Szygula et al. 1990).

Prolactin is the other hormone with increased secretion under stress conditions. Secretion of prolactin increases in both men and women under various stress factors such as physical exertion, hypoglycemia, surgery, or dehydration. (Frewin et al. 1976, Gala 1990, Galbo 1983, Mills 1985, Saini et al. 1990). Mills & Robertshaw (1981) and Christensen et al. (1985) suggested positive correlation between tympanic temperature and prolactin secretion. Decrease of sodium in the body during and after heat exposure in the sauna may be the other factor that increases prolactin secretion. (Lammintausta et al. 1976)

Hormones of the hypothalamic-pituitary-thyroid axis play an important role in the regulation of thyreotropine (TSH), main hormone of axis, selectively triggers the action of the thyroid gland. It regulates all stages of synthesis and secretion of the thyroid gland hormones – thyroxine (T_4) and triiodothyronine (T_3), (Klimek and Pawlikowski 1973, Szybinski 1974). When oxidative phosphorylation is disturbed, it may lead to the increase of heat production. Both T_3 and T_4 intensify catabolic processes (Szybinski 1974) and affect the metabolism of fats and carbohydrates.

Most research on thermal exposures in sauna that originated from Finland cannot be compared with other literature on this subject. This is affected by two factors. First, volunteers were accustomed to sauna since the early childhood. Secondly, research was done with male volunteers and in mixed groups in some cases. No attention was paid to the difference in the thermoregulatory responses between the two genders. Only comparative paper by Ježova et al. (1994) touches the problem of gender differences in hormonal reaction caused by sauna between men and women.

Therefore, the main goal of the study was to analyze the basic responses of endocrine system in women, subjected to single and repeated thermal stress in the Finnish sauna.

Material and methods

Ten healthy, non-smoking female volunteers, aged 19-21 yr participated in the study. No subject had any existing endocrinological problems on entering the study and all were eumenorrheic. Subjects never used the sauna prior to the experiment. Method was approved by the Ethics Committee, in the Department of Medicine at the Jagiellonian University in Krakow. Volunteers were fully informed regarding methods of experiment and gave their full consent in participating. All volunteers shared similar body anthropometrical parameters – anthropometrical measurements were performed before the study. Study begun with the women in their 1st (follicular) phase of the ovarian cycle. None of the female volunteers were using birth control pills.

Volunteers underwent a series of seven baths in Finnish sauna. Baths were taken every second day, always in the morning. Each sauna treatment lasted precisely 30 minutes. During the sauna bath the subject rested in a half-lying down position. The average temperature in sauna was 80.1^{o}C , and the relative humidity of air, at 26.6 % All physiological and biochemical data was collected during the first day and fourteenth day of study before and after the sauna. (i.e. before and after the first and the final sauna bath). On the first and the fourteenth day the subjects were fasting ten hours before the experiments (subjects did not eat or drink after 10 pm of the previous day).

Following physiological indexes were measured in the experiment:

– Tre – rectal temperature [^{o}C]
– Tty – tympanic temperature [^{o}C]
– BW – body weight (mass) [kg]

Rectal and tympanic temperatures were monitored using an Ellab (Dania) electrometer with accuracy of +/- 0,1 ^{o}C. Body mass, measured before entering the sauna and after the thermal exposition, using a Sarrtorius electronic scale with accuracy of +/- 1g. Blood samples (10 cm^3) were taken for biochemical testing, from the cubital vein after subjects' rest in supine position for 10 min before entering sauna room, and in the same position three minutes after sauna bath. From the full blood the following were measured:

– Hct – hematocrit; by the microhematocrit method,
– Hb – hemoglobine concentration; by the Drabkin method.

Changes of these indexes were subsequently used for calculations of variations of the plasma volume (? PV) according to the modified Dill-Costill formula modified by Harrison et al. (1982)

$$? PV = 100 \{ (Hb_1 / Hb_2) * [100 - (Hct_2 * 0{,}874)] / [100 - (Hct_1 * 0{,}874)] - 1 \}$$

where as: Hb_1, Hct_1 – initiated results; Hb_2, Hct_2 – the end results

The levels of the following hormones were determined in the blood plasma:

TSH (Thyroid Stimulating Hormone), by the immunoradiometric method using a Spectria TSH IRMA [^{125}I] set, Orion Diagnostica, Finland,

T_3 (triiodothyronine), **T_4** (thyroxine) and **hGH** (growth hormone), with the use of radioimmunological method, OPiDI RIA-HGH set, Radioimmunology Department OPiDI, Swierk, Poland,

ACTH (adrenocorticotropic hormone), by the radioimmunological method using an ACTHK-PR set, CIS Bio-International, France,

Cortisol (adrenal cortex hormone) and **Prolactin** (lactotropic hormone), with the use of the immunoradiometric method, Spectria Prolactin IRMA set, Orion Diagnostica, Finland.

The after sauna hormone concentrations were corrected for the changes of plasma volume.

Values of all measurements are presented as arithmetic averages (+ /-)SD. Statistical significance of the differences of the obtained results was checked by the Wilcoxon's test for dependent data. Differences at $p<0,05$ were considered as significant.

Results

Parameters of the selected physiological reactions as well as biochemical indices of the subjects exposed to a thermal stimulus are presented in table 1. The body mass after the first sauna decreased on average by 0,55 kg (0,94 % of the initial body mass) and after the final sauna by 0,56 kg (0,96 % of the initial body mass).

Table 1. Changes of the selected physiological reactions as well as biochemical indices under the influence of the 1st and the 7th sauna bath

	First sauna			Seventh sauna		
Variables	before	after	Δ	before	after	Δ
Body mass [kg]	58,36±5,8	57,8±5,8	0,55***	58,57±5,7	58,01±5,7	0,56***
Rectal temp. [ºC]	37,3±0,3	38,4±0,3	1,1 ***	37,1±0,3	38,1±0,4	1***
Tympanic temp. [ºC]	37,0±0,2	39,3±0,5	2,3 ***	36,8±0,3	38,7±0,3^^^	1,9***
Ht [l/l]	41,15±1,03	42,95±1,12	1,8 **	41,0±2,27	42,5±2,04	1,5***
Hb [g/l]	13,72±0,64	14,55±0,99	0,83***	13,86±1,04	15,02±0,89	1,16***
TSH [uIU/ml]	0,841±0,3	0,854±0,44	0,013	1,078±0,37	0,89±0,26	-0,188**
T3 [ng/ml	1,525±0,21	1,578±0,179	0,053	1,584±0,17	1,456±0,189	-0,128
T4 [ng%]	9,626±1,2	8,664±0,58	-0,962	8,46±0,73	7,983±0,84	-0,477*
HGH [ng/ml]	4,43±3,9	9,8±4,7	5,37**	7,33±6,5	16,10±4,73	8,771*
ACTH [pg/ml]	11,29±8,78	30,78±18.38	19,497**	7,72±7,9	28,56±15,81	20,842**
Cortisol [ng/ml]	112,22±42,81	200,47±65,19	88,25**	108,39±40,17	171,38±51,83	63*
Prolactin [uIU/ml]	153,7±58,76	1143,2±1075,7	989,57**	136,6±53,9	616,21±529,17	479,61**

*p<0,05; **p<0,01; ***p<0,005 after vs. before sauna bath; ^^^p<0,005 1st vs. 7th sauna session

The subjects always had normal rectal and tympanic temperatures before entering the first and the seventh sauna. The final (seventh) sauna occurred when the volunteers were in the lutheal phase, which explains why the average temperature after the seventh sauna varies from the average temperatures in the follicular phase. Average increases of the rectal and tympanic temperatures were larger after the first sauna than after the final one. After each sauna an increase in the hemoconcentration of circulating blood was observed. It manifested itself by an increase of hematocrit and by an increase of hemoglobin concentration. This effect was the most pronounced during the first sauna. Calculated changes in the plasma volume (ΔPV) indicate greater dehydration after the first exposure to heat than after the last one.

The initial values and the changes in levels of different hormones produced by a single and repetitive thermal stress are presented in the table 1. Concentration of the thyroid stimulates hormone (TSH) in plasma was increased after the first sauna and slightly decreased after the last one. This change was statistically significant ($p<0,01$). Changes in concentration of triiodothyronine (T_3) were small after both saunas. Statistically significant decrease ($p<0,05$) in the concentration of thyroxine (T_4) was observed after the 7-th sauna .

Increase in the concentration of the growth hormone (GH) was statistically significant after each sauna exposure. However, the increase was the biggest after the last exposure ($p<0,05$). Level of the adrenocorticotropic hormone (ACTH) increased almost three times after the first sauna, and more then 3.5 times after the 7-th sauna. Both increases were statistically significant ($p<0,01$). Concentration of cortisol increased after the first treatment almost twice ($p<0,01$), but the increase after the last treatment was much smaller ($p<0,05$). Increase in the concentration of prolactin by a factor of 7.5 was observed after the first sauna, a slightly smaller increase (by a factor of 4.5) after the last one (in both cases $p<0,01$).

Discussion

The only effective way the organism can give away its heat in hot environment of sauna is the loss of heat with sweat evaporating from the skin

surface. During a routine sauna bath, organism loses an average of 400-600 g. of water (Häninen 1986, Kaupinen and Vuori 1986). Similar loses of water were observed in our study. Dehydration of the organism, causes loss of body mass and decrease in plasma volume. If the exposure to high temperature is prolonged, it leads to accumulation of heat by the organism, even if the temperature regulatory system is the most effective. During a twenty minute sauna bath, temperature of the body may increase from 0.5 to 4.0^{o}C (Kaupinen & Vuori 1986). Both the rectal and tympanic temperatures increased significantly also in the present study. Less pronounced increase in both temperatures during the last sauna session, demonstrates that the organism adjusts itself during two-week exposure to repeated heat in sauna. Achieved results correspond with the results quoted by others (Ježova et al. 1994). Average rectal as well as tympanic temperatures before the first (follicular phase of the ovarian cycle) and the seventh sauna bath (luteal phase) were similar, although the interior temperature should increase by 0.4^{o}C in the luteal phase of ovarian cycle (Stephenson and Kolka 1993, Frascarolo et al. 1992). No difference in initiated results between temperatures in the follicular and luteal phase observed in this study can be explained as the result of temporarily disturbances of the ovulation cycle under the thermal stress. Temporarily disturbances of the ovulation cycle in overheated women may be caused by hyperprolactinemia (Kukkonen-Harjula 1989, Laatikainen et al. 1988, Väänänen and Leppäluoto 1983). Disturbances of the menstrual cycle may also be the effect of secretion of the β-endorphin under thermal stress (Laatikainen et al. 1988).

Thermal stress stimulates hormonal system, which increases hormonal secretion. ACTH increased three times after the first sauna bath, and almost four times after the last one. However, Scandinavian authors observed lower increase of ACTH after heat exposure in sauna (Kukkonen – Harjula et al. 1989, Laatikainen et al. 1988, Leppäluoto et al. 1987). Slovakian authors observed that ACTH hormone increased four times after sauna bath (Ježova et al. 1985, 1994). Those differences in our (as well as in Jezova's experiment) and Scandinavian data may be connected with the fact that Scandinavian participants were adapted to sauna thermal stress.

Less significant increase of cortisol secretion was observed after the last sauna bath, which suggests that body familiarizes to hot environment. Increase of cortisol is considered to be a sensitive indicator of stress reaction and intolerance of heat (Follenius et al. 1989). In stress conditions, the same factors stimulate secretion of ACTH and growth hormone (Mills 1985). Statistically significant increase of GH was observed after the 1st and the last sauna. Similar changes were observed by others. However, the higher increase of GH was observed in men than in women in our experiment (Leppäluoto et al. 1986 b, Opaszowski et al. 2001, Szygula et. al. 1990). Among the factors causing increased secretion of GH in hot environment are listed: stimulation of adrenenergic system, dehydration, and increased secretion of vasopressin and prolactin (Frevin et al. 1976, Jezova et al. 1985, Leppäluoto et al. 1986 b, Saini et al. 1990). Correlation between stimulation of GH secretion and increase of the internal temperature was observed by Christensen et al. (1984). However, the experiments by Dore and co-authors (1991) did not confirm these suggestions. There is also an interesting relationship between secretion of prolactin and the growth hormone. While intensive physical activity we deal mainly with stimulation of GH and only slightly prolactin stimulation whereas overheating in sauna significantly increases prolactin secretion (Mills 1985). In the experiment we noticed that concentration of prolactin increased in the peripheral blood twice after the first sauna bath comparing to its rise after the 7th bath. Similar changes were observed in both men and women by other authors (Christensen et al. 1985, Jezova et al. 1994, Laatikainen et al. 1988, Lammintausta et al. 1976, Leppäluoto et al. 1986a, Palat et al. 1983, Väänänen & Leppäluoto 1983). The meaning of increased secretion of prolactin in overheated body has not been explained. It is suggested that prolactin takes part in the regulation between the water and electrolytes balance (Kukkonen – Harjula 1989, Kaupinen & Vuori 1986). The increased secretion of prolactin, mainly observed in young women after the sauna baths, may be the reason of temporarily disturbances of the menstrual cycle. Though, it was not noticed that this caused persistent infertility in women taking sauna bath regularly for long time (Kukkonen – Harjula, Kaupinnen and Vuori1988, Laatikainen et al. 1988, Leppaluoto et al. 1986 b, Väänänen, Leppäluoto 1983).

The regulation of the thyroid activity is complicated and not completely recognized in the human during thermal stress. It is suggested that the activity of the TSH–thyroid system has significance in the modifying of the activity of the temperature regulatory center in the hypothalamus (Galbo 1983). In this experiment TSH level decreased after the 7^{th} sauna, and T4 concentration decreased after both the 1^{st} and 7^{th} sauna sessions. The increase of T4 leads to increase of heat production in the body and rise of the internal temperature. The decrease of T4 after sauna bath suggests the adaptation of TSH-thyroid axis to the thermal stress.

Conclusions

The acquired data and theoretical background allowed to formulate following conclusions:

1. Thermal stress in sauna stimulates the hypothalamo–hypophyso-andrenal axis, which makes a higher concentration of ACTH and cortisol.
2. After 2 weeks of taking sauna baths, increase of concentration of cortisol is diminished. That suggests organism adaptation to the thermal stress.
3. Observed changes in hypothalamic-pituitary-thyroid axis may also be the result of body acclimatization to repeated exposure to heat in sauna.

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