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LED-bed therapy of cardiovascular disorders: a volunteer study

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ABSTRACT

Studies of the physiological response of human half-body illumination by a specially designed bed comprising large number of LEDs emitting in the red and near infrared spectral range were carried out in a group of 32 volunteers comprising healthy subjects and hypertension patients. Blood pressure, heart rate and arterial blood oxygen saturation, as well as the bed surface temperature were continuously monitored during the measurement sessions with and without aluminum foil cover on the bed surface. None of the volunteers exhibited any notable changes in the heart rate and blood oxygenation during the procedures. The LightStim LED-bed session did not produce changes of arterial pressure in normotensive group, while decreased blood pressure exhibited 2/3 of hypertensive patients. The thermal emission from the bed may serve as a dominant contributor to the observed effects on cardiovascular system.

Keywords: light-tissue interactions, photo- and thermo-stimulation, LED-bed therapy.

1. INTRODUCTION

Cardiovascular disease along the cancer is the leading cause of morbidity and mortality in the developed countries, responsible for annual 17.8 million deaths in the World (or 13.5% of all deaths worldwide[1]), including 1.83 million deaths in the European Union (according to Eurostat). One of the main risk factors for cardiovascular disease is high arterial pressure which may cause life threatening conditions – stroke and ischemic heart disease events. Hypertension is a condition of chronically elevated arterial pressure; according to the recent guidelines from the American Heart Association and the American College of Cardiology[2], it can be categorized as stage I hypertension (systolic:130-139mmHg / diastolic:80-89mmHg), stage II hypertension (systolic ≥140mmHg / diastolic:≥90 mmHg) and hypertensive crisis (systolic:>180mmHg/diastolic:>120mmHg). The latter can be very serious life threatening condition.

The pathophysiology of elevated arterial pressure is related to alterations in autonomic nervous system activity, abnormal levels of circulating and tissue angiotensin, altered vascular endothelial function, and abnormal calcium handling by vascular smooth muscle cells[1]. Various classes of antihypertensive medication are available acting on the aforementioned physiological mechanisms, such as angiotensin converting enzyme inhibitors, beta-blockers, calcium channel blockers, diuretics, centrally acting agents, and angiotensin receptor blockers. Hence, very often monotherapy is inefficient and patient requires combination of pharmacological agents. Such medication can cause different adverse effects as frequent micturition, dizziness, headaches and insomnia, which in turn decreases patient adherence to antihypertensive medication and may increase the risk of uncontrolled hypertension[3]. Medication is mandatory for stage II and hypertensive crisis patients, however very often patients without previous cardiovascular issues (such as heart attack) can improve situation without pharmacotherapy.

Recently several non-pharmacological approaches (complementary and alternative medicine) have gained popularity as they have less adverse effects and are more attractive to the patients. Most popular alternatives are medicines containing herbs, vitamins, minerals, nutritional supplements, homoeopathic medicines, aromatherapy products and non-ingestible modalities, such as osteopathy, massage, reiki, qigong, yoga and meditation[4]. Relatively new alternative approach to aforementioned modalities is photo-bio-modulation therapy[5] which may provide beneficial effect on cardiovascular

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system by stimulating angiogenesis and migration of endothelial cells[6], providing cardioprotection[7,8] and decrease of arterial stiffness and arterial pressure. In the recent past, advancements of LED technologies and contemporary studies of light effects on biological tissues encourage manufacturers to develop new LED-based light therapy devices. However, the wider use of this therapy requires more extensive clinical studies.

In the present pilot study we investigated the effects of LightStim professional LED bed[9,10] on the cardiovascular system of hypertensive patients and healthy middle age volunteers. The reference parameters were arterial blood pressure, pulse rate and arterial blood oxygenation level. The measurement methodology allowed separating the thermal and photo-induced effects.

2. METHODS

2.1. Subjects

The clinical measurements were taken from two different groups of subjects: ten healthy middle age volunteers (5 males and 5 females) and twenty two hypertensive patients (10 males and 12 females). The subject characteristics are listed in the Table 1.

Table1. The characteristics of volunteers involved in the study.

Characteristic	Normotensive (n=10)	Hypertensive (n=22)
Age (years)	44.8±17.9	55.3±20.0
BMI (kg/m^2)	24.4±2.8	31.5±5.8
Systolic arterial pressure (mmHg)	121.5±6.1	150.3±21.3
Diastolic arterial pressure (mmHg)	75.0±4.1	93.7±12.9
Heart rate (BPM)	60.1±3.8	75.0±12.9
Oxygen saturation (%)	96.9±1.2	95.3±1.5

Prior to study all subjects were informed about the procedures and associated risks and gave their informed written consent to participate. This study was conducted in accordance with the Declaration of Helsinki and was approved by the local Ethics Committee. Subjects were selected based on the arterial pressure measurement at seated position using automated oscillometric method. Normotensive subjects group comprised individuals with the systolic and diastolic pressure below 125/80 mmHg, while hypertensive patients consistently had blood pressure readings higher than 130/80-89 mmHg according to recent clinical guidelines[2]. The patients of this study either had never been treated for hypertension, or had their antihypertensive medications discontinued for at least 24h before the LightStim bed sessions. All procedures were performed in a well ventilated room (60 m^3/h) at 23°C and 50% humidity. To reduce emotional stress, participants upon arrival were rested and accustomed to all procedures for at least 10 minutes. Before each session, arterial pressure and heart rate were measured twice: at seated position and supine position by the automated oscillometric pressure monitor (UA-767PBT-CI, A&D).

2.2. Instrumentation and measurement protocol

The major component of the setup was light illuminating bed (LightStim Professional LED Bed, LED Intellectual Properties LLC)[9,10], which is FDA-approved over-the-counter device that emits energy in the visible and IR spectrum. LightStim bed is intended to provide topical heating for the purpose of elevating tissue temperature for a temporary relief of minor muscle and joint pain and stiffness, minor arthritis pain or muscle spasm, the temporary increase in local blood circulation, and the temporary relaxation of muscles. The recommended subject exposure time (session time) is 30 minutes[9,10]. The illuminator surface comprised 30 independent illuminator panels (19x32 LEDs, the total number of LEDs – 18,240) emitting at four wavelength bands peaked at 630nm, 660nm, 855nm and 940nm. The integral emission spectrum of illuminator panel was measured by a fiber optic spectrometer (Avaspec-2048, Avantes) and is presented on figure 1. The LEDs were arranged in the illuminator panel as shown in figure 2,B.

During entire procedure the subject was naked in the underwear (briefs and/or bra) in supine lying down position on the LightStim bed surface with the head supported by soft LightsStim had supporting pad; to prevent cooling, subject body was covered by a special LightStim towel (86x168 cm). The physiological signals during the session were acquired by

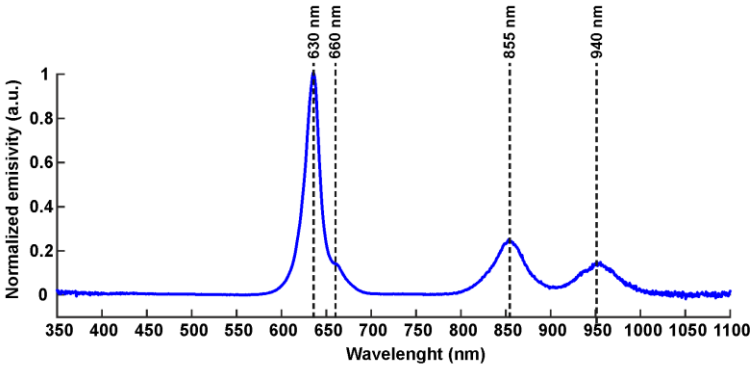

Fig.1. VIS-NIR emission spectrum of the LED-bed.

three sensor devices as shown in fig.2.A. (i) Arterial blood oxygen saturation was monitored in beat-to-beat manner by portable medical grade pulse oximeter (Onyx 3, Nonin Medical, Inc.) which was placed on the subject right index finger and paired with Apple Ipad 3 bluetooth, transmitting signal to NoninConnect application (Nonin Medical, Inc.). (ii) Continuous beat-to-beat recording of arterial pressure and heart rate was provided by non-invasive hemodynamic monitor (Finameter Midi, FMS Systems, AB), with the cuff sensor put on the subject's left middle finger. (iii) To insure reliability and calibration of continuous arterial pressure and heart rate measurement, oscillometric blood pressure monitor (UA-767PBT-CI, A&D) was utilized in parallel; its cuff was fixed over the subject right upper hand, providing data at two minute intervals during entire measurement session. To continuously control the temperature of bed's surface and the contacting part of the body, thermal probe (Termocouple, Extech Inc.) was attached in the site of tightest contact between the bed surface and subject tissue.

The protocol design was developed so that the heating and illumination effects were separated, which provided opportunity to study their short term effects on cardiovascular system. During the heating set, illumination was excluded by covering the operating LED-bed surface with 17 um thin aluminum foil, while during the illumination set Led bed surface was uncovered and subject body exposed to LED radiation as originally intended by the device manufacturer. To reveal cumulative effect of body heating, the measurement protocol consisted of two 30 minute sessions (two separate visits) each comprising two 15 minutes sets, with 3-5 minutes in-between break (to remove foil and allow cooling of subject body) as seen in fig.3. Temperature of the bed upper surface was kept within the interval 34-42°C during all measurement sets (with and without the foil).

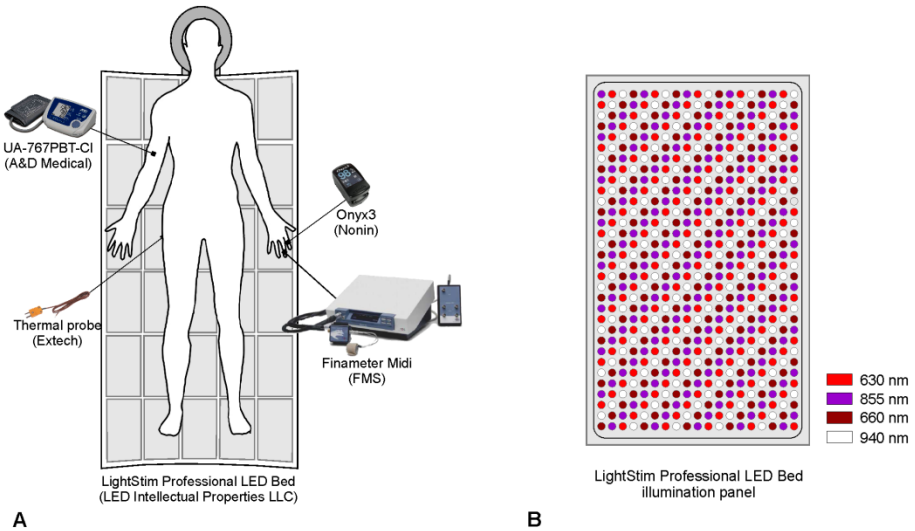

Fig.2. Experiment setup, showing subject position on the LightStim Bed, sensor placement sites on the body and measurement devices (A). Distribution of LEDs over the illumination panel (B).

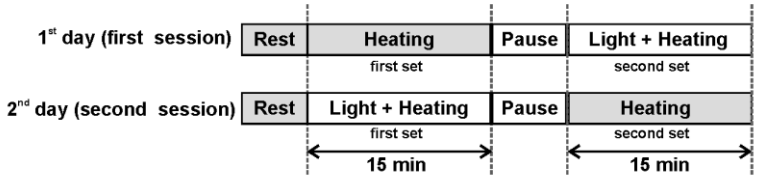

Fig.3. Diagram of measurement protocol depicting two 30 min. sessions, and four 15 minutes sets. During heating set the illumination surface was covered by foil, while during illumination set subject was exposed to LEDs.

After each session subject was asked to report subjective perception of heat during the illumination set and during the heating set. Investigator asked following questions: "Whether you felt some type of heat during the first set and the second set? (Yes/No)". And: "Please report in which set you felt more heat? (in the first or the second) ".

2.3. Evaluation of the heating effect by thermography

The LED bed heating effect was evaluated in separate pilot study on a single subject which had typical anthropometric parameters representing the healthy subject group. Two LightStim sessions (30 min each) were repeated at two different visits (at different days). In the first visit subject body was exposed to LightStim light for 30 minutes, while in the second session LED bed surface was covered by the reflective foil, shading body from the LED illumination.

Thermographic image of subject's back was acquired in standing position using high resolution FLIR camera (FLIR A655sc, FLIR Systems Inc.) 8 times: before the session, after lying on cold LED-bed surface (23°C) for five minutes, after 15 and 30 minutes of light session, and the same was repeated after covering LightStim bed surface with foil. Thermographic images were compared and distribution of temperature evaluated.

2.4. Data and statistical analyses

All beat-to beat recorded data was time averaged at 2 minute intervals to reduce the influence of respiratory variations, thus further analysis was performed on time averaged data. To assess the effect of LightStim LED bed on cardiovascular system, the differences between the baseline value during subject lying supine and the values at the fifteenth minute of each set were calculated for all subjects. Significant pressure differences from the baseline in all measurement sets (2 LightStim sessions x 2 sets per session=4 sets) were evaluated using One Way Repeated Measure Analyses of Variance, considering significance level at 0.05. The data is expressed as mean ± standard deviation.

3. RESULTS

3.1. LightStim bed effects on cardiovascular system

Hemodynamics during the change of body position

After lying supine for ~ 5 minutes, the arterial pressure and heart rate substantially decreased in almost all individuals in comparison to sitting position, while the oxygen saturation did not change notably. In the normotensive group systolic arterial pressure decreased for 5.6mmHg±1.1, diastolic for 4.6±3.5mmHg, and the heart rate for 7.0±4.2 bpm. In hypertensive group a few patients (18%) exhibited increase of arterial pressure after lying supine, the group average lowering of systolic arterial pressure was 4.4±10.1 mmHg, diastolic: 8.3±8.6 mmHg and heart rate 5.7±5.6 bpm.

Variations of the cardiovascular parameters

None of the examined subjects neither from normotensive, nor hypertensive group exhibited any oxygen saturation and heart rate changes from baseline out of the error range during or at the end of both LightStim sessions. The mean heart rate and hemoglobin saturation changes for normotensive and hypertensive groups are shown in in fig.4.C,D and fig.5.C and D. However, some subjects exhibited slight HR fluctuations for 1-2 beats per minute and SpO_2 changes for 1-2%; those were random in the nature and independent from the session set (exposed or covered illumination surface).

In the normotensive subject group, LightStim bed operation did not induce any noticeable changes of systolic and diastolic arterial pressure, as seen in figure.4.A and B. Hence, some individuals exhibited tendency for decrease of arterial pressure for 2-3 mmHg, which was within the measurement error.

The hypertensive patient group demonstrated different trend. Statistically significant reduction of systolic arterial pressure (exceeding the measurement error ±3 mmHg) was observed for 2/3 of all patients while the remaining 1/3 did not exhibit substantial changes in blood pressure during the procedures.

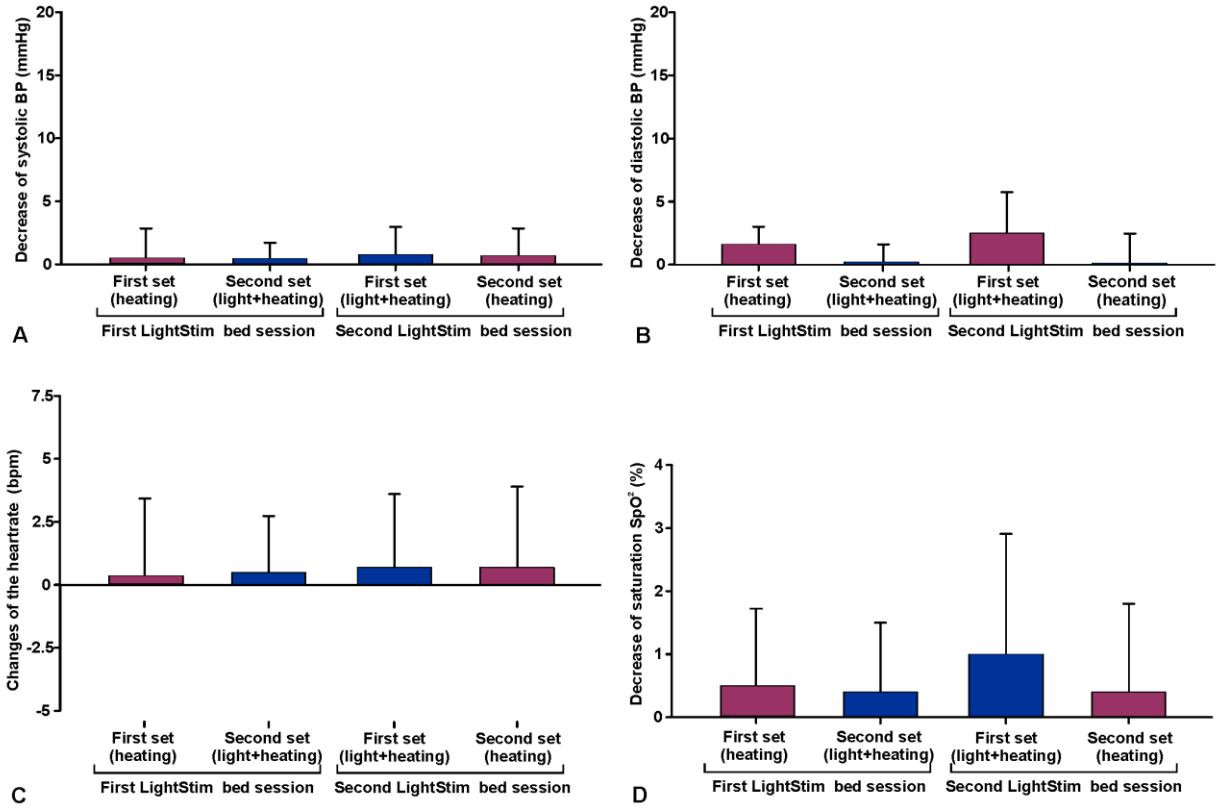

Fig.4. LightStim bed initiated variations of cardiovascular parameters from the baseline (supine position, mean ±standard deviation) in the group of normotensive subjects. A – systolic pressure, B – diastolic pressure; C - heart rate; D - saturation.

The patient group mean values are presented on fig.5.A and B

It has been observed that, decrease of arterial pressure started gradually 6-10 minutes following the onset of LightStim session, which (in time) corresponded to the increase of skin contact temperature above 37° C (Fig.6.B). It has been noticed that always during the first set of the first visit, lowering of systolic and diastolic arterial pressure was more pronounced regardless of exposure to the light or using the screen foil (LedStim bed illumination surface covered by foil) as seen in figure 5.A.

The typical example of cardiovascular parameters and temperature changes for normotensive subjects and hypertensive patients are presented on figure 6A and B.

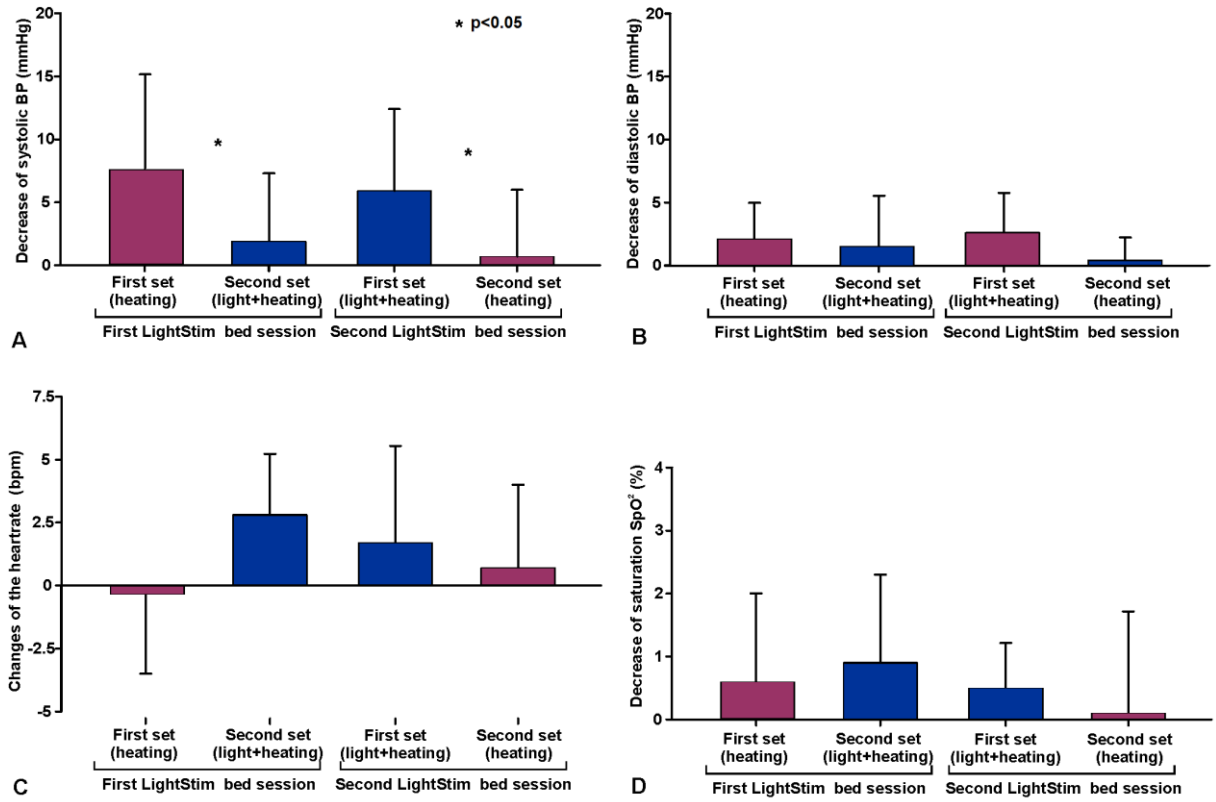

Fig.5. LightStim bed initiated variations of cardiovascular parameters from the baseline (supine position, mean ±standard deviation) in the group of hypertensive subjects. A – systolic pressure, B – diastolic pressure; C - heart rate; D - saturation.

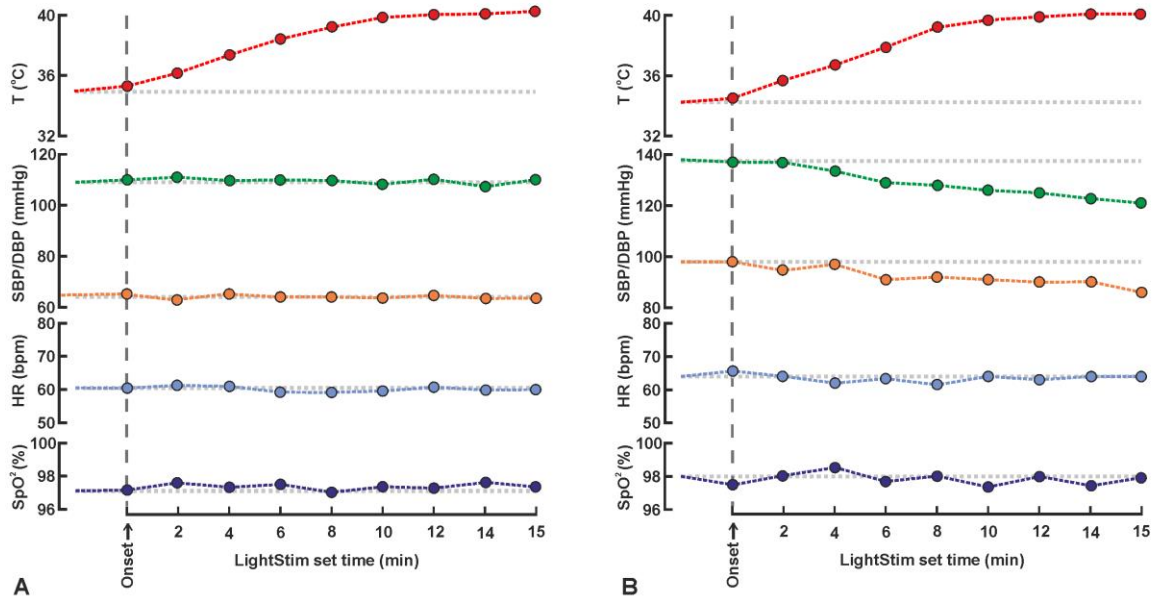

Fig.6. Representative example of data from one set of typical normotensive subject (A) and hypertensive patients (B), demonstrating changes of cardiovascular parameters and skin temperature during the session; SpO_2 – arterial blood oxygen saturation, HR - heart rate, SBP – systolic arterial blood pressure, DBP -diastolic arterial blood pressure, T- temperature. Circles represent 2 minutes averaged beat-to beat data; the baseline values of the parameters are marked with horizontal dotted lines.

3.2. Thermography-detected heating effects of the LightStim bed

Relatively uniform temperature distribution (32°C) was acquired on the subject's back during baseline conditions with lowered temperature regions (30°C) on the upper part of the limbs in the first and second visit (Fig.7A and E). In both visits the significant regional variance of temperature was observed following 5 minutes lying supine on the 32°C surface of non-operated LightStim bed (either uncovered glass or foil-covered). The skin contact surface showed decreased temperature regions, on the upper back (trapezius region) calves and upper limbs, particularly lower temperature were noticed after lying on bed covered with foil (29°C) as seen in (Fig.7, B and F). An interesting pattern of temperature distribution resembling the LED bed illumination panels and their boundaries was observed during LedStim bed illumination session, 15 (Fig.7, C and G) and 30 minutes (Fig.7, 4D and H) following exposure when body surface temperature reached 39°C (Fig.7, B and F).

Noticeable is the difference between the first visit (lying on warm foil) and the second visit (lying on the transparent plastic glass) demonstrating higher temperature at contact regions on foil, and more uniform heat distribution (particularly in non-contact regions) without foil. This indirectly confirms heating via radiation (either NIR or thermal emission), which was blocked by the foil, providing heat conduction directly from the warm foil to the body surface. The results of thermographic images were supported by the subject's answers - 97% of subjects reported difference between heating with and without foil, pointing on the perception of profound and more uniform heating when the LightStim bed illumination surface was exposed (without foil) and more localized heating at the contact point when surface was covered by foil.

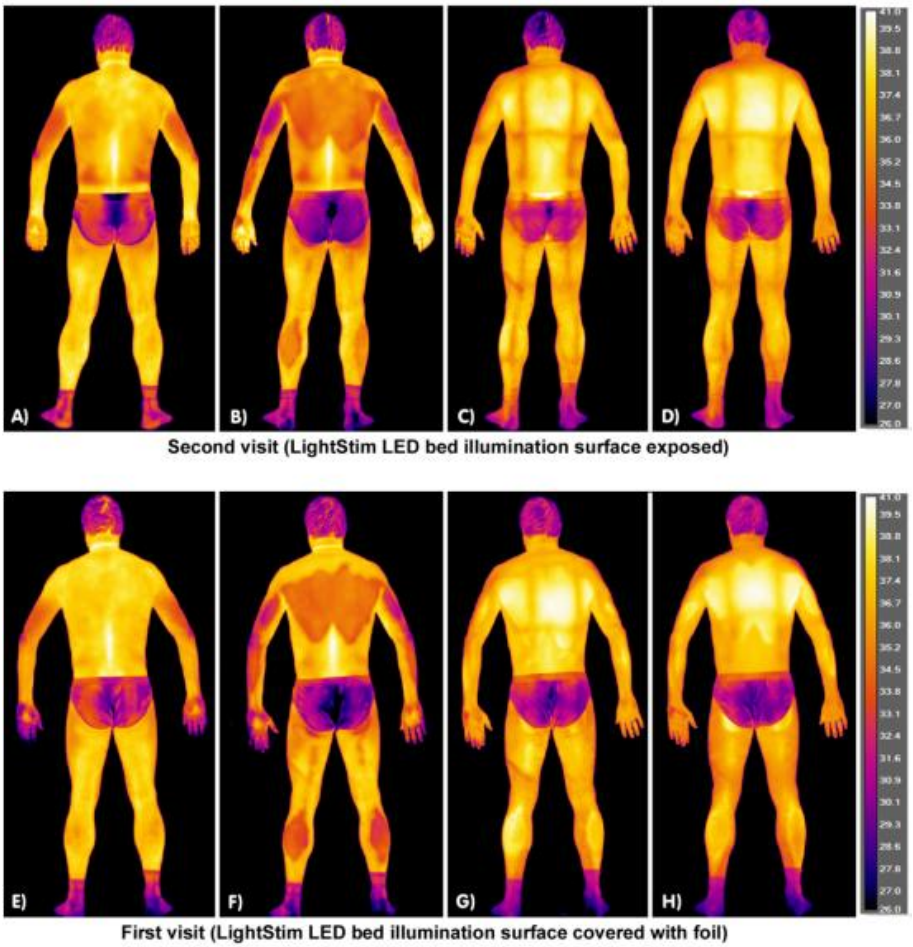

Fig.7. Thermographic images of typical subject at baseline - A and E; after lying supine on the 32°C LedStim bed surface – B and E; following 15 min and 30 LightStim session with (G and H) and without foil (C and D).

4. DISCUSSION

Our findings indicate that along the visible and NIR emission at four wavelength bands, LightStim bed illumination panel produces also substantial thermal emission which may contribute to effects on cardiovascular system even more efficiently than the photo-bio-modulation. Evidence from experimental and clinical studies implicates body heating (mostly in the sauna) to have an effect on blood pressure modulation[11]. Heating in the sauna may substantially decrease systolic and diastolic arterial pressure[12]. Hence sauna temperatures largely exceed body heating during LightStim led bed sessions. Nevertheless, some studies confirm decrease of arterial pressure and vasodilation evoked by passive body heating which is used during heat therapy (body heating up to 40° C)[13] Several physiological mechanisms were proposed to explain temperature effect on vasodilation, which is the general contributor to decrease of arterial pressure. Temperature exerts its vascular effects through thermosensitive signal transduction pathways, producing heat-induced sympatholysis of alpha adrenoreceptors through the activation of TRPV channels or ATP release with its potent vasodilatory and sympatholytic properties[14], or activation of release and synthesis of nitric oxide which is potent vasodilator of blood vessels[15].

It is difficult to comment the observed blood pressure changes due to the body position change as controversial results are reported in literature regarding the pressure differences during supine and sitting positions, pointing on decrease during supine[16], or decrease during sitting position[17]. However, in our study this question was secondary as the whole measurement series was performed during lying down supine position.

Another intriguing finding was different responses of patients to the LED-bed illumination where responsive and non-responsive patients were identified. Such situation is not unusual, as the clinical studies suggest on relatively large incidence rate of resistant hypertension among hypertensive patients ranging from 10-25% from all hypertensive subjects[18] and to achieve target pressure combining of different medication is required.

We also observed that after the break between the 15 minute sessions arterial pressure remained substantially lowered, in spite of return of skin temperature to the nearly baseline level (33-36°C). This may be explained by possible cumulative effect of the body heating, as the physiological mechanisms which were triggered by initial body heating, remained active during the following session, preventing from further decrease of blood pressure.

One limitation of the pilot experiment with thermal imaging was inability to measure temperature distribution in the depth of the tissue (volume), as existing conventional thermography provides temperature distribution only at the body surface and the modeling is difficult as the heat transfer within the body is complex process depending on several factors such as body composition, metabolic rate and microcirculation. Still unresolved question remains the elucidation of dominant mechanism that contributes to the reduction of blood pressure in hypertensive patients group – could it be photo-biostimulation, thermo-biostimulation or both?

5. CONCLUSIONS

Taken together, present study confirms the ability of the LightStim LED-bed to decrease blood pressure for 2/3 of the hypertensive patients. Our findings also indicate that along visible and NIR emission at four wavelength bands, LightStim bed produces substantial thermal emission which may serve as a dominant contributor to the observed effects on cardiovascular system. However, further studies with a larger number of subjects could provide more comprehensive information on the observed physiological effect.

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