Reduction in body measurements after use of a garment made with synthetic fibers embedded with ceramic nanoparticles

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Summary

Background Therapeutic effects have been attributed to far-infrared (FIR) radiation emitted from different types of sources. One class of such infrared emitters consists of ceramics in a powdered form, which allows for its incorporation into creams and fabrics. Such ceramic materials emit in the FIR when subjected to body temperature. Published literature reports significant improvement in both pathological conditions, such as pain and blood dyscrasias, and cellulite upon use of accessories containing ceramic emitters.
Objectives In this study, we investigated whether the use of a garment made with synthetic fibers embedded with powdered ceramic led to a reduction in body measurements.
Methods The study population comprised 42 women divided into two groups: active and placebo. The volunteers used clothing either impregnated or not impregnated with ceramic powder for at least 8 h/day for 30 days.
Results The experimental data showed a reduction in body measurements, which may be a consequence of an increment in microcirculation and peripheral blood flow, and these changes might promote improved general health.
Conclusions Objective indicators were identified which showed that the reported ceramic accessories actually were capable of biological modulation.

Keywords: bioceramics, ceramic nanoparticle, far-infrared, infrared therapy, light therapy

Introduction

It has been reported that some types of ceramics emit light in the far-infrared (FIR) region of the electromagnetic spectrum when placed in thermal equilibrium with body temperature. The emitted infrared spectrum is a result of two contributions: the thermal radiation generated when heat from the movement of charges in the material (electrons and protons in common forms of matter) is converted to electromagnetic radiation and by photons emitted through transitions between different vibrational and/or rotational energy states. Therapeutic properties have been attributed to creams and garments that include ceramic FIR emitters in their composition.[1–4] Small pieces of ceramic have also been placed onto the skin[5,6] or embedded in bedclothes[7] to achieve the claimed therapeutic effects. The reported biological effects of the FIR light emitted by diverse sources include vasodilatation, increase in local temperature, and analgesic and anti-inflammatory action,[8] among others. Even though the infrared light intensities emitted by ceramic devices exposed to human body temperature are much smaller than those emitted by electrically heated plates, published literature reports significant improvement in both pathological conditions, such as pain and blood dyscrasias,[3] and cellulite[4] when

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accessories containing ceramics are used. The published literature on this issue is scant, and most of the work makes use of subjective analyses. For this reason, we assert that additional investigations are necessary to provide a better insight into the ongoing phenomena.

The present investigation is motivated by the hypothesis that ceramic-impregnated garments can modulate biological parameters such as body temperature and peripheral blood flow, thus modifying the general body condition of health with important consequences on skin health. In this work, the biomodulation effects promoted by ceramic-impregnated clothing were evaluated by quantifying the reduction in body measurements after daily use of a garment made with 90% polyamide and 10% elastane fibers with embedded ceramic particles.

Material and methods

The study protocol and consent form for participation were approved by an ethics committee. All subjects provided written informed consent for their participation in the study.

Ceramic powder, composed basically of alumina, magnesium oxide, titanium oxide, and silica, was incorporated into the polymer (90% polyamide and 10% elastane) from which the fabric was manufactured. In the manufacturing process, an amount of ceramic nanoparticles was added to the fused polymer in such a way that the nanoparticles became embedded in the tread after extrusion. This polymer was then sewn without mends and with different fiber types on the same piece of clothing. Wearable accessories, such as gloves, short trousers, T-shirts, socks, and others, can then be manufactured to have therapeutic properties. The great advantage of this tested fabrication method, when compared with the technique of gluing the particles to the surface of the fabric fibers, is that the loss of particles by detachment when the therapeutic accessories are washed in a conventional manner or put into an autoclave should be greatly reduced because the localization of the particles is not restricted to the surface but distributed in the bulk of the fibers. It is also possible to create different mechanical compression factors in different regions of the same piece of ceramic-impregnated clothing to preclude skin distention and produce a progressive drainage effect. Figure 1 shows the piece of clothing that was used in this study.

The subjects of this research were 42 sedentary female volunteers who ranged from 20 to 60 years old and were not undergoing any kind of treatment or diet. We refer herein to sedentary as those people with daily professional activities that do not practice any type of sport activities. Sedentary patients with regular everyday activities and no sportive practice were chosen because they often present some degree of overweight, matching the requirements for this study.

Figure 1 The therapeutic accessory used in this work was made of synthetic fibers embedded with far-infrared-emitting ceramic nanoparticles.

Table 1 Body mass index (BMI) statistics for treatment and placebo groups

	N	Minimum	Maximum	Mean (±standard deviation)
Active	22	22.6	33.3	27.4 (±2.5)
Placebo	20	22.6	31.2	26.5 (±2.5)

In this study, the study subjects were divided into two groups: the active group ($n = 22$) and the placebo group ($n = 20$). Table 1 shows the statistical parameters that characterize the population under study. Patients of the active group used ceramic-impregnated clothing, while patients of the placebo group used similar clothing containing no ceramic particles. The clothing used was manufactured by Scala Bio-fir. The participants of both study groups were requested to wear the respective

Table 2 Anatomical references for the metric measurements

Variable	Anatomical reference
C1	Umbilicus
C2	5 cm above umbilicus
C3	5 cm below umbilicus
H	Hip (iliac crest reference)
B	Breech (greatest diameter reference)
LT	Left thigh
RT	Right thigh
T	Thigh

clothing for at least 8 h/day or even to wear it while sleeping.

The list of exclusion criteria includes pregnancy, lactation, endocrine disease (hypothyroidism, diabetes mellitus), respiratory and circulatory diseases, osteoporosis, severe obesity, silicone prosthesis, use of anabolizant steroids, events of diarrhea during the experimental period, and the presence of dermatitis.

The biomodulation effects promoted by the employed ceramic-impregnated clothes were evaluated by measuring the change in the metric measurements of the body perimeters at the anatomical regions listed in Table 2 and the change in the subject's mass from before treatment to after treatment.

Results

Table 3 discloses the statistical parameters obtained for the dimensional variations in body circumferences taken at the anatomical positions defined in Table 2 and the change in body mass after the 30-day experimental period. The statistical plots for the data obtained for the different variables are shown in Figure 2 and in Figure 3. The summary of the statistical analysis comparing the differences among the mean values of the studied variables for the active and placebo groups after 30 days' treatment, with the applied statistical test in each case, is shown in Table 4.

Discussion

Our results show that clothing made of ceramic-impregnated fabric does interact with the human body through light radiation and promotes measurable effects on body circumferences at diverse anatomical positions and on the body mass. Those measurable effects are

Table 3 Statistical parameters for the dimensional variations (cm) in body circumferences taken at different anatomical positions and for the body mass (kg) after 30 days of treatment. The number of points (subjects) was 22 for the active group and 20 for the placebo group

	C1		C2		C3		Hip	
Parameter	Active	Placebo	Active	Placebo	Active	Placebo	Active	Placebo
Mean difference	−2.64	−0.40	−2.68	−0.75	−2.55	0.30	−2.00	−0.50
Std deviation	1.76	1.73	2.17	1.94	1.87	1.59	1.88	1.40
Std error	0.38	0.39	0.46	0.44	0.40	0.36	0.40	0.31
Minimum	−5.00	−3.00	−9.00	−5.00	−5.00	−2.00	−7.00	−4.00
Maximum	0.00	4.00	0.00	4.00	2.00	5.00	0.00	2.00
Median	−3.00	0.00	−2.00	−1.00	−3.00	0.00	−1.50	0.00
Lower 95% CI	−3.42	−1.21	−3.64	−1.66	−3.38	−0.45	−2.83	−1.15
Upper 95% CI	−1.86	0.41	−1.72	0.16	−1.72	1.05	−1.17	0.15

	Breech		Thigh*		Body mass (BM)	
Parameter	Active	Placebo	Active	Placebo	Active	Placebo
Mean difference	−2.32	−0.90	−2.27	−0.48	−0.94	0.12
Std deviation	2.44	1.07	1.70	0.82	1.58	1.03
Std error	0.52	0.24	0.26	0.13	0.34	0.23
Minimum	−8.00	−4.00	−7.00	−2.00	−5.00	−1.5
Maximum	1.00	0.00	0.00	1.00	2.00	3.5
Median	−1.50	−1.00	−2.00	0.00	−1.00	0.00
Lower 95% CI	−3.4	−1.40	−2.79	−0.74	−1.64	−0.37
Upper 95% CI	−1.24	−0.40	−1.76	−0.21	−0.24	0.60

*The data for the left thigh (LT) were merged with those for the right thigh (RT) composing the variable thigh (T) such that, in this case, $n = 44$ for the active and $n = 40$ for the passive group. The choice to merge the data was based upon the similarity of data obtained for the left and right thighs.

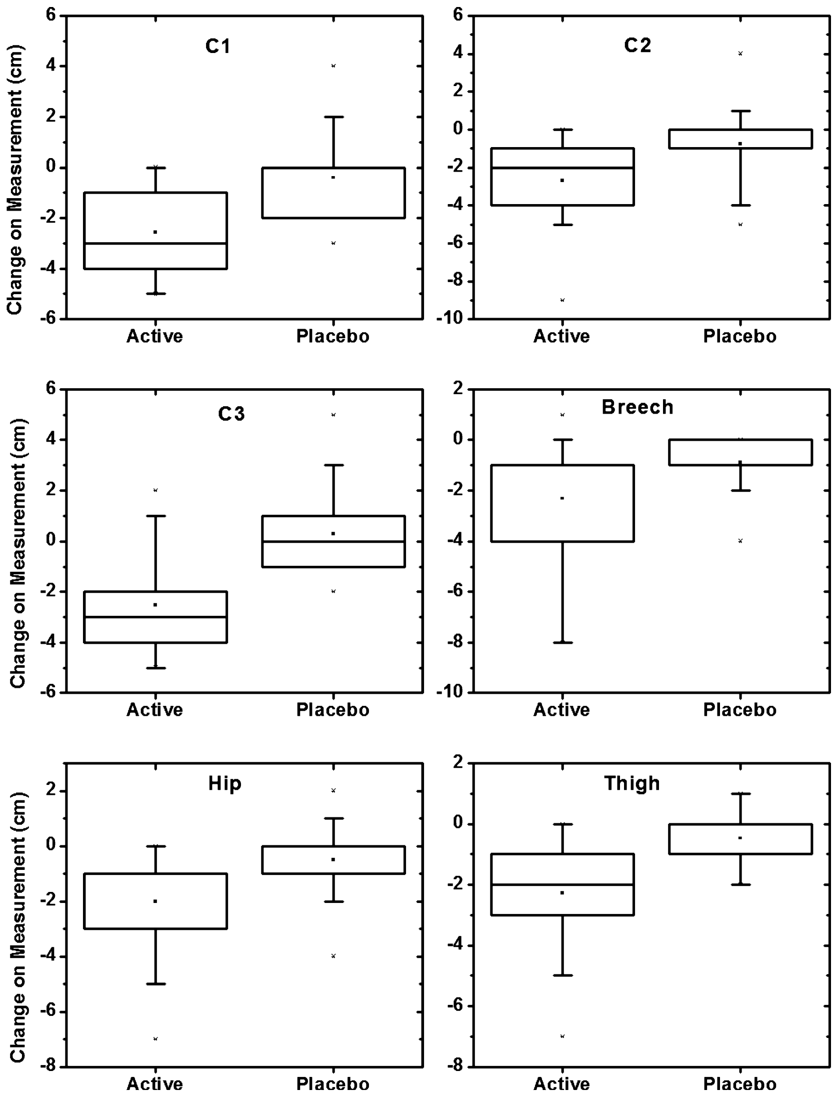

Figure 2 Statistical plots of the changes in body measurements for the active and placebo groups. The horizontal lines in the box plot denote the 25th, 50th, and 75th percentile values. The error bars denote the 5th and 95th percentile values. The symbol below the 5th percentile value denotes the 0th percentile value, and the symbol above the 95th percentile value denotes the 100th percentile value.

possibly because of an improvement in blood perfusion and stimulation in lymphatic drainage, which may be primarily a consequence of an increment in the local temperature. Indeed, published works report a temperature increase induced by topical use of infrared-emitting powders. Yoo *et al.*[1] prepared emulsion creams containing powdered tourmaline or jade. On one side of the studied subjects' faces, they applied the sample creams containing the jewelry powder, and on the other side of the face, they applied a control cream containing no jewelry powder. Using thermal imaging, they measured a temperature increase of 1 °C on the side of the face that received the cream containing jewelry powder. They suggested that such temperature elevation arises from the augmented microcirculation induced by the treatment. That hypothesis is strengthened by the work reported by Gordon and Berbrayer,[3] who experimented with ceramic-impregnated gloves on patients with Raynaud's syndrome. They found that the gloves, made active by the incorporated ceramic, were beneficial in the management of Raynaud's symptoms. This conclusion was documented by subjective measures of pain and discomfort as well as by objective measures of temperature. They measured a mean temperature increment of 1 °C in the finger dorsum of the patients who made use of active gloves.

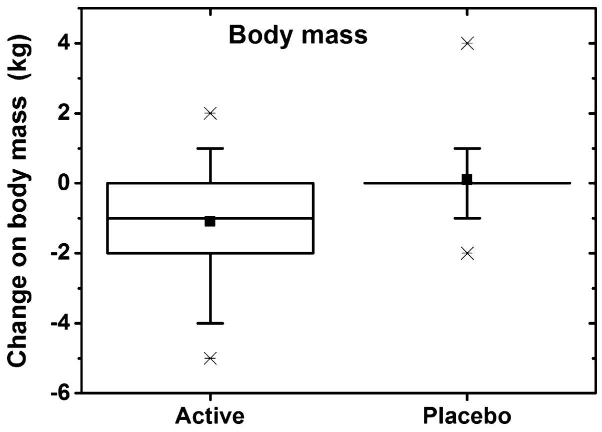

Figure 3 Statistical plot of the changes of the body mass measured for the active and placebo groups.

Table 4 Summary of the statistical analysis comparing the mean values of the studied variables for the active and placebo groups after 30 days treatment

Variable	*P* value	Significance*	Applied test
C1	0.0002	ES	Unpaired *t* test
C2	0.0043	VS	Unpaired *t* test
C3	<0.0001	ES	Unpaired *t* test
Q	0.0058	VS	Unpaired *t* test
CL	0.0193	S	Unpaired *t* test with Welch correction
CXE	<0.0001	ES	Mann–Whitney test
CXD	0.0003	ES	Unpaired *t* test with Welch correction
CX	<0.0001	ES	Unpaired *t* test with Welch correction
BM	0.0141	S	Unpaired *t* test with Welch correction

*S, significant; VS, very significant; ES, extremely significant.

The mechanism of action of ceramics placed in close contact with the human skin is not yet known, as there are neither enough experimental data nor specific experiments performed to give support to any hypothesis. In addition to their intrinsic infrared emission capability, ceramics possess high reflection coefficients for infrared radiation. In a wearable piece like the one used in this work, a high reflection coefficient would work as a radiation trap sending some amount of infrared rays back toward the body. Because of the high reflectivity, we must consider which source of infrared radiation is dominating the process: the ceramic FIR emitter or the body itself. In the latter case, the so-called bioceramic would play a passive role.

Inoué and Kabaya[5] reported the emissive power of a ceramic disk of 40 mm diameter, 5 mm thickness, and 10 g weight as being as much as 71.5 kcal/m^2/h (≈300 kJ/m^2/h = 30 J/cm^2/h) at 60 °C. If the formulae for a black-body radiator can be applied in the first approximation of the given case, the Stefan–Boltzmann law says that the total energy radiated per unit of surface area per unit of time is directly proportional to the fourth power of the black body's absolute temperature. Therefore, a significant correction should be applied for a ceramic piece at the human body temperature of 36.5 °C, which decreases the above given 300 kJ/m^2/h to ≈200 kJ/m^2/h. Dividing this number by two (because only one face of the disk is in contact with the subject's skin), the dose delivered to the subject by the ceramic disk would be 100 kJ/m^2/h. By comparison, a person with a daily ingestion of 2000 kcal (8.36 MJ) returns to the environment of 100 W of average power. That delivered (mean) power can be calculated by dividing the energy ingestion by the amount of seconds in 24 h. To calculate an estimate, let us disregard conductive and convective heat transfer and consider 100 W as the radiant heat flux. A woman 1.73 m tall has an approximate body surface area of 1.6 m^2.[9] This simplified calculation shows that 225 kJ/m^2/h of energy is radiated per unit of surface area per hour from the hypothetical subject's body. This amount of energy is comparable to that emitted by the ceramic disk reported by Inoué and Kabaya[5] and can be partially reflected back to the body by the ceramic disk.

The above-simplified calculation suggests that emission and reflection may both be relevant optical properties in the present application of ceramics and that both might be participating in the mechanism that leads to the modulation of biological processes by FIR radiation. Further experiments are required for a better evaluation of which factor is the dominant contributor.

Conclusion

The biomodulation effects promoted by a piece of clothing made with ceramic-impregnated polyamide and elastane fibers were evaluated. Reductions in body measurements and body mass could be observed in the experimental group that used clothing impregnated with ceramic particles for a 30-day experimental period. In the present work, a short-term evaluation was performed, and objective indicators were identified that showed the employed ceramic accessories actually were capable of biological modulation. Our results are important to skin health because excess body mass with large body circumferences correlates with the occurrence of cellulite and striae distensae. A long-term evaluation is now being carried out by our research group.

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