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Supraclavicular Skin Temperature as a Measure of Brown Adipose Tissue Temperature in Normal and Obese Young Adults of Male

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Abstract
Background: *Brown adipose tissue (BAT) takes part in non-shivering thermogenesis and plays an important role in regulating metabolism. Since direct measurements of BAT are often invasive or expensive, supraclavicular skin temperature (SCT) has been described in literature as a measure as BAT activity.*
Objective: *This study explored the supraclavicular skin temperature as a possible reflection of BAT activity in young lean and obese adult males*
Methods: *The study was conducted in 446 young adult males, grouped into, normal weight, overweight, and obese categories based on BMI. SCT was taken as a measure of BAT activity because of high accumulation of BAT in this zone in adults. Using thermistor probe which was attached to Fluke 17B+ multimeter, we measured both SCT (BAT region) and chest skin temperature (non-BAT region). Temperature was recorded in winter months at room temperature of 25-26 ^{0}C. Temperature values were compared across BMI groups.*
Results: *SCT and chest skin temperature were recorded in 446 subjects. The mean temperature recorded from supraclavicular and chest region were 33.3 ±0.8 ^{0}C, 32.8±1.0 ^{0}C (mean±SD) respectively. The SCT was significantly higher than the chest skin temperature. But when compared with normal weight group, the SCT in overweight and obese participants showed lower values (32.8±1°C and 32.6±0.6 °C, respectively) and were statistically significant ($p < 0.001$).*
Conclusion: *Our study shows that the skin temperature measured over the supraclavicular region is consistently higher than chest skin temperature, reflecting the activity of brown fat. Importantly, this temperature was highest in young men with a normal BMI and gradually declined in those who were overweight and obese. This suggests that BAT activity decreases with increasing BMI reflecting. Measuring SCT therefore offers a simple, non-invasive way to measure BAT activities indirectly in population studies to understand pathophysiology of obesity.*
Keywords- *Supraclavicular skin temperature; Brown adipose tissue; Non-shivering thermogenesis; Body mass index; Obesity; Young adult*

INTRODUCTION

The ability to maintain a stable internal body temperature is one of the most critical aspects of human physiology. Even slight deviations from the normal core temperature range can interfere with enzymatic reactions, cellular processes, and overall metabolic stability (Benzinger, 1969). The human body has evolved multiple mechanisms to achieve this thermoregulation, including behavioral adaptations, muscle activity such as shivering, and the role of adipose tissue. Non-shivering thermogenesis (NST) is a critical physiological process that enables the body to maintain thermal homeostasis in response to cold stress without muscular activity. The primary site of NST is brown adipose tissue (BAT), while white adipose tissue (WAT) does not directly produce heat; its metabolic role in supplying fuel makes it indispensable for sustaining shivering thermogenesis. (Cannon & Nedergaard, 2004).
BAT is rich in mitochondria containing uncoupling protein-1 (UCP-1), which allows energy from fatty acid oxidation to be released as heat rather than stored as ATP (Lowell & Spiegelman, 2000). This thermogenic capacity is vital in newborns, where BAT helps maintain body temperature in cold environments. For many years, BAT was assumed to regress and lose physiological relevance in adulthood. However, the discovery of metabolically active BAT in adults using 18F-fluorodeoxyglucose positron emission tomography–computed tomography (FDG-PET/CT) has transformed our understanding of human energy balance and thermoregulation (Cypess et al., 2009).
Despite the promise, one of the main challenges in BAT research has been the difficulty of measuring its activity in a safe, practical, and cost-effective way. PET/CT remains the gold standard for BAT imaging, but its reliance on radiation exposure and high cost limits its feasibility for repeated or large-scale

population studies (Symonds et al., 2012). Infrared thermography (IRT) has gained attention as one such tool. Since BAT deposits in adults are concentrated mainly in the supraclavicular region, surface skin temperature in this area has been proposed as a proxy for BAT activation (Law et al., 2018). Thermal imaging is quick, radiation-free, and relatively inexpensive, making it a practical option for both clinical and research applications.

Importantly, BAT activity is not uniform across individuals. Previous research suggests that younger, normal individuals tend to have more active BAT compared to those who are overweight or obese (Vosselman et al., 2013). Environmental factors such as cold exposure, diet, and circadian rhythm also modulate BAT activity (Nedergaard & Cannon, 2010). However, questions remain about how supraclavicular skin temperature varies with body composition in young obese adults male.

Given these considerations, studying supraclavicular skin temperature as a non-invasive marker of BAT activity offers an opportunity to better understand the relationship between body weight, and thermoregulation in young adults. This study aimed to assess SCT in a large sample of young adult males in winter months without any sympathetic stimulation and to provide a method to asses BAT activity in population -level metabolic health research.

MATERIALS AND METHODS

Study Design and Participants

The present investigation was designed as a cross-sectional, observational study aimed at exploring differences in supraclavicular brown adipose tissue and non-brown adipose tissue related skin temperature across BMI categories.

A total of 446 participants (aged 18–25 years) apparently healthy male were included.

The study was carried out in the Department of Physiology, Faculty of Medicine and Health Sciences, SGT (Shree Guru Gobind Singh Tricentenary) University, Gurugram, Haryana. The study protocol was approved by ethical committee of SGT Medical College and Hospital, Budhera, Gurugram, Haryana dated, 15.04.2022 with reference number- IEC/FMHS/MD/MS/2023-7

Prior to enrolment, all participants were provided with detailed information about the study's purpose and procedures, and written informed consent was obtained.

Inclusion criteria were:

(1) Age between 18 and 25 years of male

(2) Clinically healthy, with no history of chronic metabolic, endocrine, or cardiovascular disease; and

(3) Not on medications known to influence metabolism, thermoregulation, or body weight.

Exclusion criteria included:

(1) Acute illness, fever, or infection in the last two weeks;

(2) Smoking, alcohol, or drug dependence.

Anthropometric Measurements

To categorize participants into BMI groups, body weight was measured using a calibrated digital weighing scale with accuracy to the nearest 0.1 kg, while height was recorded using a stadiometer with accuracy to the nearest 0.1 cm. Participants were instructed to wear light clothing and no footwear during measurements.

BMI was calculated using the formula: (weight in Kg / height in M^2)

Based on World Health Organization (WHO, 2004) criteria, participants were classified into four categories:

- Underweight: <18.5 kg/m²
- Normal weight: 18.5–24.9 kg/m²
- Overweight: 25.0–29.9 kg/m²
- Obese: ≥30.0 kg/m²

Temperature Measurements

Supraclavicular region in adult is abundant in brown adipose tissues and present superficially offering a convenient site to measure skin BAT temperature. Skin temperature over this area was used as an indirect marker of BAT thermogenesis. The upper chest area skin temperature was also measured at a non-BAT region, where brown adipose depots are absent.

SCT and chest skin temperature (non-BAT) were recorded using a Fluke 17 B+ digital multimeter connected to a thermistor surface probe which had an accuracy of ±2 °C within the 0–50 °C. The probes

were securely placed on the skin surface at the designated anatomical regions and insulated with medical-grade tape and cotton padding to reduce heat loss and ambient interference.
Each measurement was taken after the participant had rested for 15 minutes in a thermo neutral room (ambient temperature maintained at 25–26 °C), during winter in the month (November to February) to ensure cold induced BAT activation.

Data Collection Protocol

The subjects were advised to avoid caffeine and strenuous physical activities 12 h prior to temperature measurement. To minimize diurnal variation, all measurements were carried out in the morning hours (9:00–12:00 AM), as previous research shows that BAT activity may follow a circadian rhythm (Lee et al., 2016).

Statistical Analysis

All data were entered into a database and checked for completeness before analysis. Continuous variables were expressed as mean ± standard deviation (SD).

1. Normality of data was tested using the Shapiro-Wilk test.
2. Paired t-tests were used to compare supraclavicular (BAT) and non-BAT skin temperatures within the same individuals.
3. One-way analysis of variance (ANOVA) was applied to compare temperature differences across BMI categories

A p-value <0.05 was considered statistically significant. All analyses were performed using SPSS software.

RESULT

The study was conducted in 446 healthy adults, comprising 323 with normal weight, 110 who were overweight, and 13 who were obese.
The range of SCT was (31.9 °C to 34.9 °C) in which the mean±SD were 33.3±0.9 °C and the range of chest skin temperature was (31.1°C to 34.7 °C) in which the mean±SD were 32.8±1.0 °C. The SCT was significantly higher than the chest skin temperature **(Fig 1).**

Figure-1

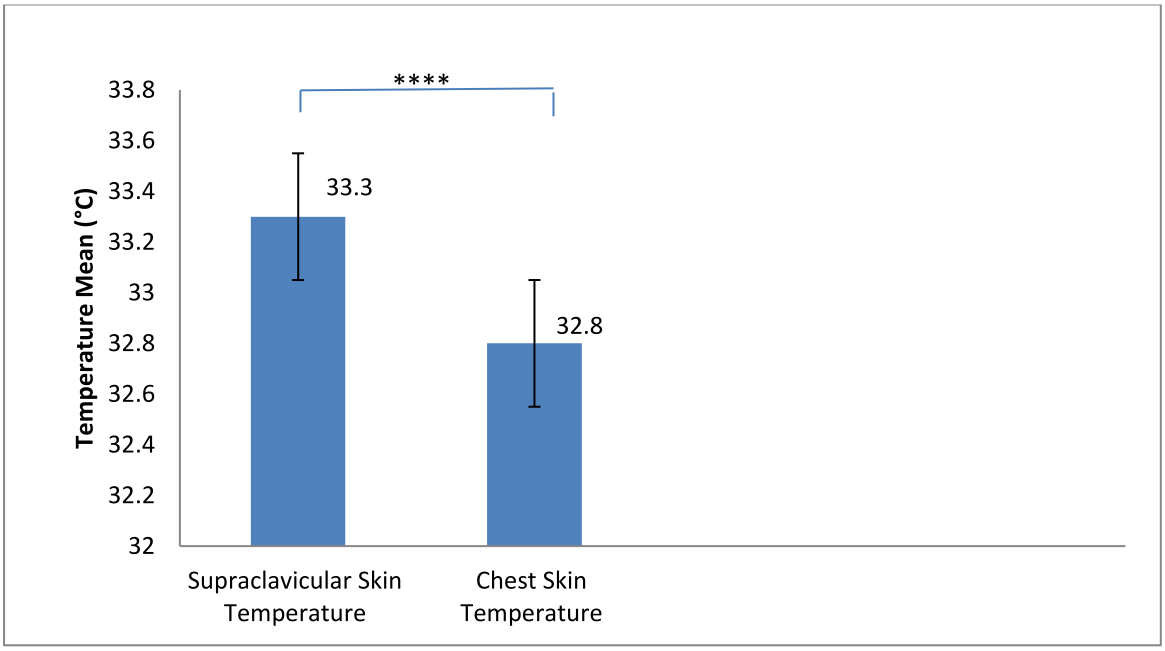

Figure1: Shows difference between supraclavicular skin temperature and chest skin temperature in healthy adult male (n=446). Significance difference was seen between supraclavicular skin temperature and chest skin temperature P< 0.0001****.

The difference between SCT and chest skin temperature across normal, overweight and obese categories are shown in Table 1. The SCT shows negative correlation with BMI (Figure 3). However there was no difference in chest skin temperature across BMI ranges.

Table-1. Temperature Variables across BMI Categories

	BMI (N=1000)			P-value
	Normal (N=323)	Overweight (N=110)	Obese (N=13)	
Supraclavicular Skin Temperature (°C)	33.5±0.7	32.8±1	32.6±0.6	**< 0.001**
Chest skin Temperature (°C)	32.9±0.8	32.3±1.0	32.7±1.4	**< 0.05**

Supraclavicular skin temperature was significantly higher in the normal BMI group (33.5 ± 0.7 °C) compared to the overweight (32.8 ± 1.0 °C) and obese groups (32.6 ± 0.6 °C), with overall group differences reaching strong statistical significance ($p < 0.001$).

Figure-2

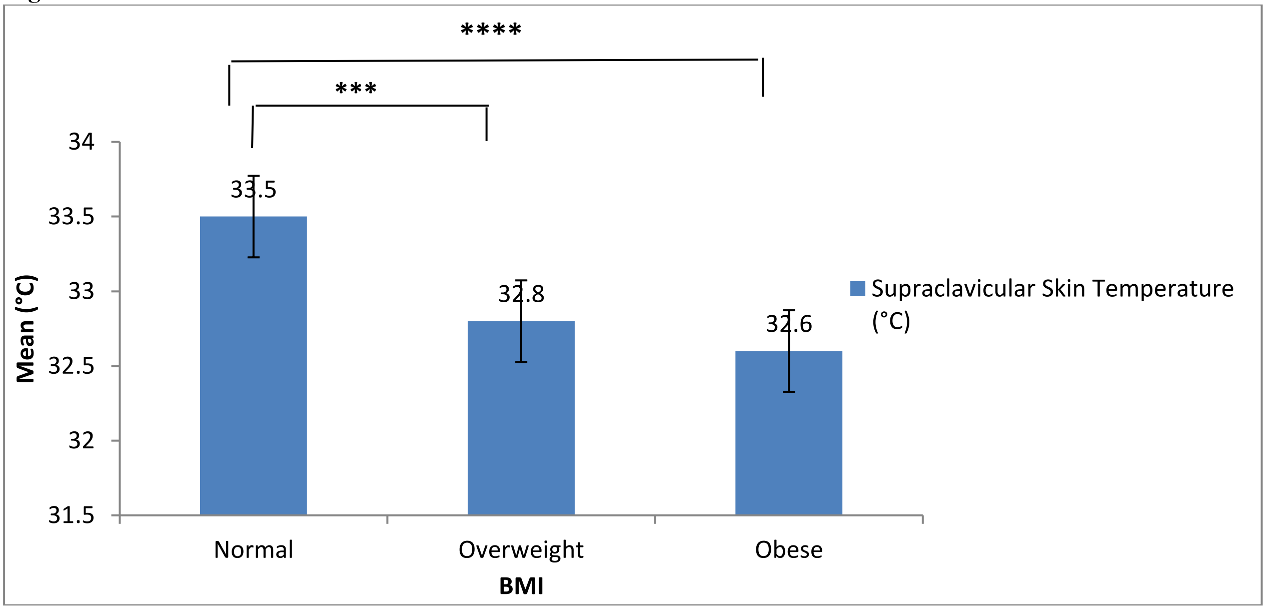

Figure 2: Supraclavicular skin temperatures show significant difference across BMI Categories. *** ($p < 0.001$), **** ($p < 0.0001$)

Figure-3

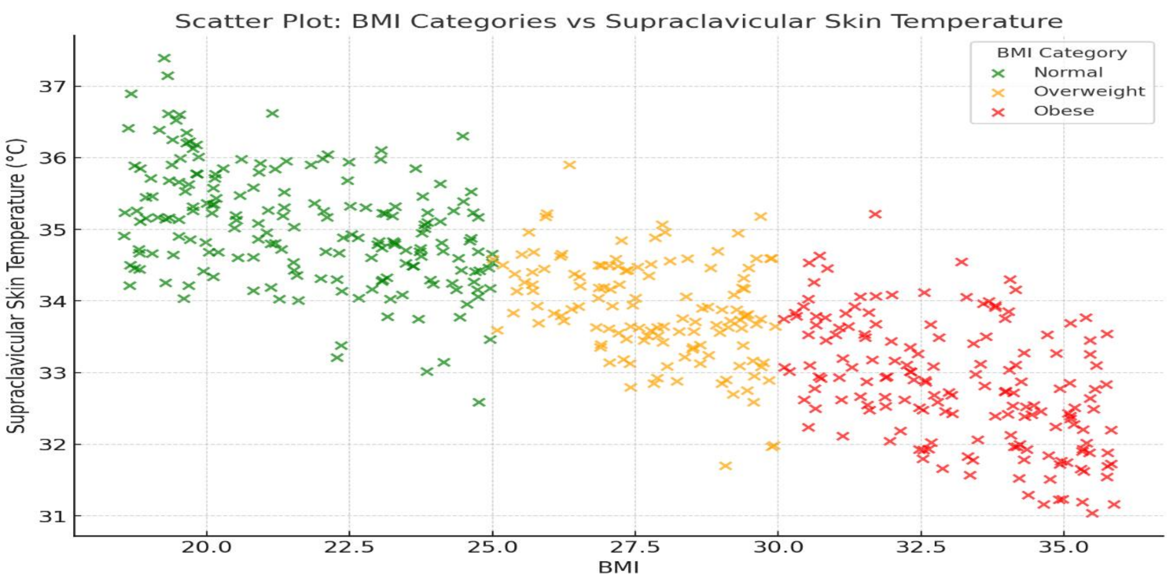

Figure3: The scatter diagram showing BMI categories plotted against supraclavicular skin temperature. Each colour represents a different BMI category (Normal (green), Overweight (yellow), Obese (red)).

DISCUSSION

In this study we have shown that the SCT is higher than nearby chest skin temperature measured noninvasively using a thermistor probe. The SCT is taken as an indirect measure of BAT activity because of the reason that this anatomical location has substantial presence of brown fat (Chondronikola et al., 2014). Moreover a significant positive correlation has been found between the change in the SCT with BAT activity, and the change in the SCT and non-shivering thermogenesis (Leitner et al, 2017, van der Lans, 2015) which will result in change in local skin temperature as a hot spot.

Thermogenic BAT has been frequently studied using deoxy-2-^{18}F-fluoro-d-glucose (^{18}F-FDG)–positron-emission tomography (PET), which provides quantitative information about the tissue's metabolic activity (1–3). This method is invasive, expensive and cannot be utilised in mass scale to assess pathogenesis of obesity. The heat production of BAT has also been studied using infrared thermal imaging of the skin overlaying the BAT depots (5–7). Measurement of supraclavicular skin temperature offers a promising method to study BAT activity noninvasively and can be utilised as a valuable tool for larger-scale studies and potentially even for clinical use in the future.

Our findings also showed that individuals with higher BMI tend to exhibit lower SCT, reflecting a potential reduction in thermogenic activity with increasing adiposity. There was a negative corelation between SCT and obesity. These findings are in line with previous work showing that BAT tends to be more active in normal individuals and less so in those with higher body fat (Cypess et al., 2009; Vosselman et al., 2013).

This finding also indicated that there is less BAT activity in overweight and obese contributing to the pathogenesis to obesity. Since BAT contributes to energy expenditure by burning glucose and fat, lower activity in these groups could partly explain the reduced metabolic flexibility seen in obesity. In other words, less active BAT may make it harder for the body to burn excess calories, which could contribute to further weight gain and increase the risk of metabolic diseases such as diabetes and cardiovascular problems (Virtanen et al., 2009; Chondronikola et al., 2014).

This study has several strengths, including its large sample size of 446 young adults and the use of a carefully controlled environment to reduce outside influences on body temperature. However, there are also some limitations. The use of skin temperature as a marker of BAT activity, while practical, is indirect. We did not activate BAT by cold induced sympathetic stimulation. However we recorded SCT during winter months where the subjects were chronically exposed to ambient cold. We did not confirm our findings against PET-CT scans, which remain the gold standard for BAT measurement. In addition, as this was a cross-sectional study, it cannot tell us whether changes in weight actually cause changes in BAT activity over time.

Despite these limitations, the results are encouraging. It suggests that a simple skin temperature measurement can provide useful insights into BAT activity and its relationship with body weight. This opens the door to further studies that could track BAT activity over time, explore lifestyle factors that might boost its function, and even test whether interventions such as cold exposure, diet, or exercise can meaningfully influence BAT activity in different groups of people.

CONCLUSION

Our study shows that the skin temperature check over the supraclavicular region can give useful clues about BAT activity in young adults male. We found that normal individuals had warmer supraclavicular temperatures, while those who were overweight or obese showed lower values. Results suggest that BAT activities play a crucial role in regulation of body body weight.

These findings highlight the potential of using a quick, non-invasive temperature measurement to better understand how BAT contributes to metabolism and body weight regulation. With further research and validation, this simple approach could become a practical tool for studying obesity, energy balance, and metabolic health in larger groups of people.

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