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DIFFERENCES BETWEEN FOREHEAD AND BACK OF THE HAND TEMPERATURE MEASUREMENTS USING NON-CONTACT INFRARED THERMOMETERS IN HEALTHY YOUNG ADULTS

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Abstract
The COVID-19 pandemic necessitated the implementation of rapid, safe, and non-invasive body temperature screening methods to facilitate early identification of potentially infectious individuals. Non-contact infrared thermometers have therefore been widely adopted for this purpose. However, concerns have been raised regarding the accuracy of temperature measurements obtained from different anatomical sites, particularly in the context of increased reliance on alternative measurement locations such as the back of the hand (dorsum manus regio). This study aimed to compare body temperature measurements obtained from the forehead and dorsum manus using a non-contact infrared thermometer, with axillary temperature measured by a digital thermometer as a reference. An analytical observational study with repeated measures was conducted among 70 third-year medical students at Universitas Baiturrahmah. Temperature measurements were performed at the forehead, dorsum manus, and axilla, and participants were divided into control and intervention groups based on environmental measurement conditions. Repeated measures ANOVA revealed significant differences between forehead temperature and both dorsum manus and axillary temperatures, while no significant difference was observed between dorsum manus and axillary measurements. Independent t-tests showed no significant differences between control and intervention groups. These findings suggest that dorsum manus temperature measurements may approximate axillary values under stable conditions in healthy young adults, although caution is required when generalizing to other populations or clinical settings.
Keywords: *Body temperature, COVID-19 screening, thermogun, digital thermometer, young adults*

INTRODUCTION

The Coronavirus Disease 2019 (COVID-19) pandemic has posed a major global health challenge due to its high human-to-human transmissibility. The disease is caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), which was first identified in Wuhan, China, and subsequently spread worldwide. Owing to its rapid transmission through respiratory droplets and its potential to cause severe respiratory complications and death, the World Health Organization (WHO) declared COVID-19 a global public health emergency. Fever, cough, and shortness of breath are among the most common clinical manifestations, overlapping with symptoms of influenza, thereby emphasizing the importance of rapid and accurate initial screening methods for COVID-19 detection.[1,2]

Body temperature measurement is a fundamental component of vital sign assessment and serves as an important indicator of physiological status. Elevated

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body temperature is commonly associated with infectious diseases, inflammatory conditions, and other pathological processes. Although individuals may subjectively report discomfort or fever, objective measurement by healthcare professionals remains essential, particularly in situations where patients are unable to communicate their symptoms effectively. Consequently, thermometer-based temperature measurement is a critical clinical tool for identifying abnormalities and supporting early clinical decision-making.[3]

During the COVID-19 pandemic, large-scale temperature screening necessitated measurement methods that are rapid, safe, comfortable, and practical. Several anatomical sites are commonly used to estimate body temperature, including the forehead, axilla, and peripheral regions such as the back of the hand (dorsum manus regio). Forehead temperature measurement has been widely adopted because of its non-invasive nature and its anatomical proximity to the temporal artery, which receives blood flow directly from the core circulation and plays a role in thermoregulation via the hypothalamus. Axillary temperature measurement is also commonly used and is considered to approximate internal body temperature due to its anatomical location near major blood vessels. In contrast, temperature measurements obtained from peripheral sites, such as the dorsum manus, may be more susceptible to variation due to environmental exposure and distance from the core temperature center.[4,5]

Various types of thermometers are available for clinical and public health use, including digital contact thermometers and non-contact infrared thermometers. Based on their mode of operation, thermometers can be classified as contact or non-contact devices. During the pandemic, non-contact infrared thermometers, commonly referred to as thermoguns, were extensively utilized to minimize physical contact and reduce the risk of viral transmission. These devices were primarily employed as screening tools to ensure that individuals entering public facilities had body temperatures within acceptable limits, typically below 37.5°C, in accordance with public health regulations.[6,7]

Despite their practicality, concerns remain regarding the accuracy of non-contact infrared thermometers when used at different anatomical sites. Previous studies have demonstrated that measurement location can influence temperature readings. A study conducted by Budi Sumanto et al. reported measurement errors when comparing an Arduino-based infrared thermometer with a digital thermometer, as well as discrepancies between measurements taken at the arm fold and the forehead, indicating that anatomical location contributes to temperature variability.[8] Similarly, Franconi et al. observed a mean difference of 0.41°C between forehead and axillary temperatures in children when comparing non-contact infrared thermometers with digital axillary devices.[9] Van den Bruel et al. also reported small but measurable differences between non-contact infrared and axillary temperature measurements in young children.[10]

During the COVID-19 pandemic in Indonesia, public concern emerged regarding the safety of thermogun use on the forehead, fueled by misinformation suggesting potential harm to the brain. As a result, temperature screening practices in some settings shifted toward alternative measurement sites, particularly the back of the hand (dorsum manus).[11] However, scientific evidence supporting the equivalence or reliability of dorsum manus temperature measurements compared with established measurement sites remains limited.

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Therefore, this study aims to compare body temperature measurements obtained from the forehead and the dorsum manus using a non-contact infrared thermometer, with axillary temperature measured by a digital thermometer as a reference, among third-year medical students at Universitas Baiturrahmah. This study was conducted as part of preventive efforts to support safe campus activities during offline learning and academic completion processes amid the COVID-19 pandemic.

METHODS

This study employed an analytical observational design with repeated measures to compare body temperature measurements obtained from different anatomical sites. The study was conducted at the Faculty of Medicine, Universitas Baiturrahmah, Padang, West Sumatra, Indonesia, between March-October 2021.

Primary data were obtained through direct measurement of body temperature at three anatomical sites: the forehead, back of the hand (dorsum manus regio), and axilla. A total of 70 third-year medical students from the Faculty of Medicine, Universitas Baiturrahmah, were recruited using simple random sampling. All participants underwent temperature measurements at all three anatomical locations. To assess the potential influence of environmental conditions, participants were allocated into two groups based on measurement setting. Control group: temperature measurements conducted under non-standardized environmental conditions. Intervention group: temperature measurements conducted under controlled room conditions. Each group consisted of 35 participants.

The inclusion criteria were male and female third-year medical students of Universitas Baiturrahmah who provided written informed consent to participate in the study. Participants were excluded if they reported symptoms of acute illness, including fever, cough, or influenza-like symptoms, at the time of data collection.

Prior to data collection, all thermometers were calibrated according to the manufacturer's instructions. Temperature measurements were conducted using a non-contact infrared thermometer (TaffOmicron AD801 IR Thermogun Thermometer) for the forehead and dorsum manus, and a digital contact thermometer (Omron Termometer Digital) for axillary measurements. All participants were instructed to stand in a comfortable position before measurement. Factors that could influence body temperature measurements, such as recent physical activity and environmental exposure, were explained briefly to each participant prior to data collection.

In the control group, temperature measurements were performed under routine environmental conditions without standardized room temperature control. Measurements were conducted as follows: (1) Forehead temperature was measured using a thermogun positioned approximately 5 cm from the center of the forehead. (2) Dorsum manus temperature was measured immediately afterward using the same thermogun aimed at the back of the hand.(3) Axillary temperature was then measured using a digital thermometer placed in the axilla until an audible signal indicated completion of measurement. (4) Temperature values from all three locations were recorded sequentially. (5) After each participant, thermometers were disinfected using cotton and alcohol prior to subsequent measurements. (6) For female participants, axillary temperature

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measurements were assisted by a designated female examiner to ensure participant comfort and privacy.

In the intervention group, measurements were conducted in a controlled environment. The examination room temperature was maintained at approximately 25°C with stable humidity. Participants were asked to remain in the room for at least 5 minutes prior to measurement to allow acclimatization. The measurement sequence and instruments used were identical to those applied in the control group: (1) Forehead temperature measurement using a thermogun positioned approximately 5 cm from the forehead. (2) Dorsum manus temperature measurement using the same thermogun. (3) Axillary temperature measurement using a digital thermometer until an audible signal was produced. (4) All temperature readings were recorded, and thermometers were disinfected after each measurement.

Descriptive statistics were used to summarize participant characteristics, including age and sex distribution. Continuous variables were presented as mean ± standard deviation (SD). Differences in temperature measurements among the forehead, dorsum manus, and axilla were analyzed using repeated measures analysis of variance (ANOVA), followed by Bonferroni post hoc tests for pairwise comparisons. To assess differences in temperature measurements between the control and intervention groups, an independent sample t-test was performed. Statistical significance was defined as a p-value < 0.05. All analyses were conducted using standard statistical software.

RESULTS AND DISCUSSION

A total of 70 participants were included in the analysis. The mean age of the participants was 20.5 ± 2.26 years, and the majority were female (46 participants, 65.7%). The mean body temperature measurements obtained from each anatomical site are presented in Table 1.

Table 1. Characteristics of the Study Population

Age (years)	20.5±2.26
Thermogun Forehead	36.4±0.35
Thermogun Dorsum Manus	35.8±0.50
Digital thermometer Axilla	35.9±0.66

Comparison of Temperature Measurement Locations

Repeated measures ANOVA demonstrated a significant difference in temperature measurements among the forehead, dorsum manus, and axilla ($p < 0.001$). Post hoc Bonferroni analysis showed that forehead temperature differed significantly from both dorsum manus and axillary temperatures. In contrast, no statistically significant difference was observed between dorsum manus and axillary temperature measurements ($p = 0.287$). Detailed pairwise comparisons are shown in Table 2.

Table 2. Comparison between temperature location

Forehead	Dorsum Manus	0,627*	0,050	0,001
	Axilla	0,507*	0,064	0,001
Dorsum Manus	Forehead	-0,627*	0,050	0,001
	Axilla	-0,120	0,071	0,287
Axilla	Forehead	-0,507*	0,064	0,001
	Dorsum Manus	0,120	0,071	0,287

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Comparison Between Control and Intervention Groups

Independent sample t-tests revealed no significant differences in temperature measurements at the forehead, dorsum manus, or axilla between the control and intervention groups ($p > 0.05$ for all comparisons). These findings indicate that environmental control during measurement did not significantly influence temperature values across all anatomical sites (Table 3).

Table 3. Comparison between control and Intervention Groups

Forehead	36.4 ± 0.32	36.4 ± 0.25	0,127
Dorsum Manus	35.7 ± 0.47	35.8 ± 0.34	0,209
Axilla	35.9 ± 0.49	35.9 ± 0.60	0,606

*Independent Sample T-Test

This study evaluated differences in body temperature measurements obtained from the forehead, dorsum manus, and axilla among healthy young adults. The mean age of participants was 20.5 ± 2.26 years, representing a relatively homogeneous and young population. Previous studies have demonstrated that age influences thermoregulation, with lower body temperatures observed in older adults due to reduced vascular responsiveness and metabolic activity.[12,14] However, the narrow age range in the present study likely minimized the impact of age-related thermoregulatory variation.

The majority of participants were female, consistent with demographic data reported among medical students in several regions. Although sex-related differences in body temperature have been suggested, existing evidence remains inconsistent. Studies by Dzien et al. and Malawi et al. reported no significant influence of sex on forehead, wrist, or core body temperature measurements, supporting the notion that sex-related effects were unlikely to confound the findings of the present study.[15,16] Nevertheless, physiological factors such as hormonal fluctuations and circadian rhythm may still contribute to intra-individual variability and warrant consideration in future studies.[17,18]

The primary finding of this study was the presence of significant differences between forehead temperature measurements and those obtained from the dorsum manus and axilla, whereas no significant difference was observed between dorsum manus and axillary temperatures. These results are consistent with previous studies reporting discrepancies between peripheral and core-adjacent measurement sites. Malawi et al. reported significant differences between wrist and forehead temperatures compared with core body temperature, highlighting the influence of anatomical location on infrared temperature measurements.[15]

The observed differences can be explained by physiological and anatomical factors. The forehead is supplied by branches of the temporal artery, which is closely connected to central circulation and the hypothalamic thermoregulatory center, allowing it to better reflect core body temperature under stable conditions.[19,20] In contrast, the dorsum manus represents a peripheral site with abundant arteriovenous anastomoses that facilitate heat dissipation, making it more susceptible to environmental and circulatory influences.[21,28]

Interestingly, no significant difference was found between dorsum manus and axillary temperature measurements. Axillary temperature is widely regarded as a surrogate for core body temperature due to its proximity to major blood

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vessels near the thoracic region.[27] The absence of a statistically significant difference between these two sites suggests that, under controlled and stable conditions, dorsum manus temperature measurements may approximate axillary values in healthy young adults. This finding aligns with reports indicating comparable peripheral and axillary measurements in specific populations and settings.[26]

The comparison between control and intervention groups revealed no significant differences in temperature measurements across all anatomical sites. These findings suggest that environmental temperature control, as applied in this study, did not substantially influence temperature readings. This observation is consistent with previous reports indicating minimal differences in axillary and forehead temperature measurements across varying environmental conditions.[29,30,31] However, other studies have shown that dorsum manus and wrist temperatures may exhibit diurnal variation, with lower values observed during morning measurements.[34] Such variability underscores the importance of standardized measurement conditions in clinical and screening contexts.

Despite these findings, several limitations should be acknowledged. The study population consisted exclusively of healthy young adults without fever, limiting the generalizability of the results to febrile patients, older individuals, or clinical populations. Additionally, the study focused on mean differences rather than agreement analysis, which limits conclusions regarding interchangeability between measurement methods.

CONCLUSION AND RECOMMENDATION

In conclusion, this study demonstrated significant differences between forehead temperature measurements and those obtained from the dorsum manus and axilla. However, no statistically significant difference was observed between dorsum manus and axillary temperature measurements among healthy young adults under stable environmental conditions. These findings suggest that dorsum manus temperature measurement using a non-contact infrared thermometer may provide values comparable to axillary measurements in this population. Nevertheless, caution is warranted in interpreting these results, as the findings cannot be generalized to febrile individuals, older populations, or varying environmental conditions. Further studies incorporating broader populations, febrile states, and agreement-based analyses are required to validate the clinical applicability of dorsum manus temperature measurement as an alternative screening site.

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