Variation of Forehead Temperature during Routine Working Shift in Hospital Laboratory Personnel: Implications for SARS-CoV-2 Screening

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Background: Scarce information is available on circadian body temperature fluctuation in healthy healthcare workers.

Methods: Forehead temperature was measured with an infrared thermometer in 33 ostensibly healthy laboratory professionals (mean age, 43 ± 13 years; 76% females) throughout a regular working shift, from 8:00 AM to 3:00 PM, at 1-hour intervals.

Results: A significant difference was found at different times of the day by 1-way analysis of variance (F statistics, 13.79; $p < 0.001$). The lowest mean forehead temperature was 36.2 ± 0.3 °C, recorded at 1:00 PM, whilst the highest was 36.7 ± 0.3 °C, at 9:00 AM. The mean difference between forehead temperature at acrophase and nadir was 0.5 °C (95% CI, 0.3-0.6 °C; $p < 0.001$). The forehead temperature measured between 9:00-12:00 AM was also significantly higher than that measured between 1:00-3:00 PM (0.3 °C; 95% CI, 0.2-0.4 °C; $p < 0.001$). The mean intra-individual variation of forehead temperature was higher but not significantly different in men (1.0 ± 0.2%) compared to women (0.8 ± 0.3%; $p = 0.112$).

Conclusion: Fever screening protocols for purposes of coronavirus disease 2019 (COVID-19) and other infectious diseases monitoring should consider normal daily fluctuations in forehead temperature.

Key Words: COVID-19, SARS-CoV-2, Body temperature, Circadian rhythm

INTRODUCTION

Fever is considered one of the most frequent symptoms in patients with symptomatic severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection. A meta-analysis

including 76 studies with 11,028 coronavirus disease 2019 (COVID-19) patients demonstrated that fever may be present in ~72% of all patients [1]. In a recent meta-analysis performed by the Cochrane COVID-19 Diagnostic Test Accuracy Group, fever was found to have 54% sensitivity and 67% specificity for establishing whether or not outpatients/primary care patients were infected with SARS-CoV-2 [2].

Consequent to the fact that most patients with SARS-CoV-2 infection present with pyrexia, a widespread practice of screening body temperature with thermal scanners or infrared thermometers at the entrance to many public places, including healthcare facilities, has been initiated [3]. None-

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theless, this practice carries some important drawbacks that impair its diagnostic performance, and which may cause important clinical and epidemiologic consequences. Briefly, a false negative reading would impair the timely and accurate identification of patients with symptomatic SARS-CoV-2 infection, who certainly need urgent care or isolation to limit potential transmission. On the contrary, a false positive reading may improperly limit personal freedom or access to public places, and would be followed by the need of performing unjustified SARS-CoV-2 diagnostic testing [4].

Among the various caveats of body temperature screening, which encompass device inaccuracy, the influence of extremes of environmental air temperature, use of antipyretic medications and high prevalence of asymptomatic SARS-CoV-2 infections [5], temperature readings are known to vary according to the body district [6], and follow a typical circadian rhythm, with daily rectal and axillary temperatures reaching nadir between 3:00 and 6:00 AM and acrophase between 4:00-9:00 PM [7]. The recognition of peculiar patterns of body temperature fluctuations using mass screening devices in healthcare workers has paramount importance, since this would enable a reduction in the risk that potentially infected people would be admitted to spread SARS-CoV-2 infection within healthcare environments (i.e., false negatives), as well as also avoiding hospital staff from being inappropriately stopped before entering the workplace with consequent shortage in personnel for patient care (i.e., false positives) [8]. We thus planned an observational study, aimed to determine whether forehead temperature may fluctuate significantly during a working shift within a laboratory medicine service.

MATERIALS AND METHODS

This study was performed at the Laboratory Medicine Service of the University Hospital of Verona in Italy, where the local administration has mandated an obligatory procedure of repeating body temperature screening in all healthcare workers throughout their working shift. After indoor temperature acclimatization, the forehead temperature was measured in 33 ostensibly healthy laboratory professionals throughout their working shift (from 8:00 AM to 3:00 PM), with 1-hour intervals of measurements. Forehead temper-

ature was measured in duplicate at each timepoint using the non-contact, dual mode infrared thermometer Jumper JPD-FR300 (Jumper Medical, Shenzhen, China; measuring range 35.0-42.2°C; mean inaccuracy, $\pm 0.2^\circ\text{C}$; mean imprecision, $0.6 \pm 0.3\%$) [9]. No subject used antipyretic medications before or during the study, and no specific indications were given as concerns routine workday activity (i.e., all subjects carried out their routine work within the laboratory service, including intake of foods and beverages, as for normal habits). The mean individual forehead temperature was calculated from the duplicate measures, and the final cumulative data at the eight time points were reported as mean $\pm$ standard deviation (SD). Repeated forehead temperatures values were compared with 1-way analysis of variance (ANOVA) or Mann-Whitney U test (when appropriate), whilst the mean forehead temperature difference between time points was estimated using Bland-Altman plots. The statistical analysis was performed with Analyse-it (Analyse-it Software Ltd, Leeds, UK). As repeated forehead temperature screening is a mandatory practice at our institution when healthcare professionals move among different sections or laboratories, the institutional ethics board cleared the research and granted a waiver for informed consent from the subjects in this study.

RESULTS

The local indoor temperature on the day of the investigation slightly increased during the study period, from 26.6°C at 9:00 AM to 28.0°C at 3:00 PM (Fig. 1a). The kinetics of forehead temperature in the entire study cohort (mean age, 43 ± 13 years; age range, 19-61 years; 76% females) is shown in Fig. 1a. A significant difference was found throughout the different times of the day by 1-way ANOVA (F statistics, 13.79; $p < 0.001$). No significant correlation was found between indoor and mean forehead temperatures recorded at the different time points (Spearman's correlation, -0.34 ; 95 CI, -0.84 to 0.48 ; $p = 0.403$). The lowest mean forehead temperature was $36.2 \pm 0.3^\circ\text{C}$, recorded at 1:00 PM, whilst the highest was $36.7 \pm 0.3^\circ\text{C}$, at 9:00 AM, with mean difference between acrophase and nadir of 0.5°C (95% CI, 0.3 - 0.6°C ; $p < 0.001$). The forehead temperature measured between 9:00-12:00 AM was al-

Fig. 1. Fluctuation of mean forehead temperature ($\pm$ standard deviation) measured during a routine working shift (between 8:00 AM and 3:00 PM) in 33 laboratory professionals. (a) entire cohort; (b) stratified by sex.

so significantly higher than that measured between 1:00-3:00 PM (0.3°C ; 95% CI, $0.2\text{--}0.4^{\circ}\text{C}$; $p < 0.001$). The mean intra-individual variation of forehead temperature recorded throughout the 7-hour study period and expressed as coefficient of variation (CV%) was $0.9 \pm 0.3\%$, higher but not significantly different in men compared to women ($1.0 \pm 0.2\%$ vs. $0.8 \pm 0.3\%$; $p = 0.112$). The specific variation of forehead temperature over the course of the daily shift in the two sexes is shown in Fig. 1b, demonstrating that the fluctuation is mostly overlapping between sexes.

DISCUSSION

Data on circadian variation of forehead temperature is relatively scarce in the current scientific literature. More-

over, to the best knowledge of the authors, data on circadian fluctuation in healthcare workers during a routine working shift is completely absent. Sharma et al. assessed the kinetics of body temperature taken in different body districts in eight healthy university students (mean age, 23 ± 1 years; 50% females), and reported that the forehead temperature measured with a digital ear and forehead thermometer increased by nearly 1.5°C from 8:00 AM to 2:00 PM [10]. Rather different results were published by Zheng et al., who studied 10 healthy young subjects (mean age, 23 ± 2 years; 50% females) exposed to median-high air temperature (i.e., 28°C), and observed only a modest and clinically meaningless variation of forehead temperature between 9:00 AM and 3:00 PM (i.e., $\sim 0.1^{\circ}\text{C}$) [11]. In a recent preprint, Shajkofci reported a progressive increase of $\sim 1^{\circ}\text{C}$ in mean forehead temperature from 8:00 AM to 1:00 PM in 19,392 subjects of unspecified age and sex [12].

Taken together, the results of our study show that there is a significant variation in forehead temperature measured with an infrared thermometer during a working shift in laboratory professionals, with a maximum bias as high as $+0.5^{\circ}\text{C}$ recorded between 9:00 AM and 1:00 PM. Unlike previous studies in different settings [10,11], we then found that the middle morning temperature (i.e., between 9:00-12:00 AM) was on average $0.2\text{--}0.4^{\circ}\text{C}$ higher than in early afternoon (i.e., between 1:00-3:00 PM). These findings may have important implications for systematic temperature monitoring in healthcare workers for purposes of screening infectious diseases (including COVID-19), whereby it may be advisable to adapt different ranges of “normal” forehead temperatures according to different periods of the day. Interestingly, Shajkofci reported a mean inter-individual forehead temperature variation between 1.9% and 2.3% with or without correction for environmental perturbations [12], which is nearly double than that found in our investigation (i.e., $0.9 \pm 0.3\%$). We suspect this may be due to either the narrower period of forehead temperature monitoring in our study, or the more standardized environment, which suffered only modest indoor temperature variations (i.e., 1.4°C).

In conclusion, the results of our investigation in a cohort of healthcare workers that was larger ($n = 33$) and more representative in terms of age distribution (19-61 years)

compared to previously published studies [10,11], suggests that fever screening protocols for purposes of infectious diseases monitoring should consider normal daily fluctuations of forehead temperature.

CONFLICTS OF INTERESTS

The authors declare no conflict of interest relating to the material presented in this article. Its contents, including any opinions and/or conclusions expressed, are solely those of the authors. The study data are available upon request from the corresponding author.

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