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Assessing rectal temperature with a novel non-invasive sensor

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ABSTRACT

Athletes, soldiers, and workers who perform intense physical activities under extreme hot conditions might encounter increased physiological thermal strain. Consequently, the increase in body core temperature (T_c) might result in heat exhaustion and heatstroke. Thus, continuously following changes in T_c is of utmost importance. Recently, the Tcore sensor (Dräger, Germany), which employs a unique dual-sensor heat flux technology, became commercially available to measure T_c, in a hospital-controlled environment. This study aimed to evaluate the possibility of using the Tcore sensor to accurately monitor rectal temperature (T_{re}), reflecting T_c, under exercise-heat stress. Thirteen healthy young males completed the study protocol, consisting of 90 min of moderate exercise (walking on a treadmill - 5 km/h, 4% elevation) under controlled hot/dry and hot/wet climatic conditions (30 °C/60% rh, 34 °C/40% rh, and 40 °C/40% rh). Tcore sensors were placed on the forehead and the left wrist. Temperatures from both Tcore sensors were recorded continuously together with T_{re} using a rectal thermistor. The original algorithm used by the company to estimate T_{re} from the Tcore sensor was found to be inadequate under the study's conditions and new models for the forehead and the wrist measurements were developed. Nearly 150,000 measurement sets (after filtering) were used to build independent MATLAB software algorithms and test their reliability according to the cross-validation algorithm. Bland-Altman analysis was used to compare between the results obtained by the new models to T_{re}. The database consisted of a large T_{re} range (36.5–38.9 °C). The mean errors of the models were close to zero, and the mean absolute errors were 0.20 ± 0.16 °C and 0.27 ± 0.20 °C for the forehead and wrist, respectively. 95% of the measurements from the forehead model and 86% from the wrist model were within ±0.5 °C of T_{re}, and 78% (forehead) and 64% (wrist) were within ±0.3 °C. Root Mean Square Deviation (RMSD) values were 0.29 °C and 0.40 °C for the forehead and wrist models, respectively. The developed models show the feasibility to use the Tcore sensor for assessing T_{re} under exercise-heat conditions. Furthermore, the sensor was found to be adequate for use on the wrist as well, which might be more practical for use in field conditions.

1. Introduction

Physical activity, especially when conducted under unfavorable hot climatic conditions, might result in hyperthermia and the associated risk of heat-related injury, which might be debilitating or even fatal (Epstein and Yanovich, 2019). One strategy of preventing these injuries is by continuously monitoring core body temperature (T_c) and ceasing exercise before it reaches a clinically significant condition (i.e. heat exhaustion, heat stroke) Overall, many methods and sensors exist to measure or assess T_c. They differ in their invasiveness, usage complexity, possible medical risks, and accuracy under varying conditions.

While invasive T_c measurement devices (e.g. rectal, esophageal, pulmonary artery, urinary bladder) are very accurate most of them are inconvenient. The two most commonly used minimally invasive

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measurements of T_c are esophageal and rectal temperatures. Esophagal temperature is characterized by rapid response time and close agreement with pulmonary artery temperature (Shiraki et al., 1986). Rectal temperature (T_{re}) has a slower response time to thermal transients but is widely used and simpler to apply (Sawka et al., 2011). One existing solution for T_c monitoring under field conditions is by measuring the temperature in the gastrointestinal track using a telemetric temperature sensor, which is an invasive method but highly comfortable and has low risks. The monitored temperature is relatively close to rectal or esophageal temperatures (Byrne and Lim, 2007). However, due to its dependency on the capsule's unknown position in the gastrointestinal track, it gives a reliable reading only a few hours after its consumption (Kolka, 1997; Lee et al., 2000).

Of interest for the present study are those technologies that are based on heat flux. The first technology, the Zero-Heat-Flux (ZHF), was introduced by Fox and Solman in 1971 (Fox and Solman, 1971). It assumes that heat flows from the body core to the skin and ceases when equilibrium between core and skin is achieved. The ZHF sensor is comprised of two thermistors, an active heating source and an insulation layer; T_c is extracted from continuously monitoring the temperature gradient across the insulation layer. Compared with the ZHF method, single or dual Heat Flux (HF) sensor technologies are more power-efficient, as they eliminate the need for an active heating source (Feng et al., 2017). The ZHF method usually consumes a substantial amount of energy and makes it uncomfortable for the user. Thus, despite the high accuracy of these devices, they are not very common (Teunissen et al., 2011). Previous studies compared the accuracy of ZHF sensors to other measurements reflecting core temperature (e.g. rectal, esophageal). (Kitamura et al., 2010; Dahyot-Fizelier et al., 2017; Mendt et al., 2017). They have found the ZHF method to be reliable and could possibly replace more invasive temperature sensors. Recently, a commercial device – Tcore by Dräger (Dräger, Germany), which utilizes the dual heat flux technology, was introduced for measuring T_c in hospital settings. Two studies, in which a prototype of the device had been tested showed promising results for its use under more stressful environmental conditions (Gunga et al., 2008; Mazgaoker et al., 2017). Based on these previous publications the present study was conducted to test the applicability of the Tcore commercial device for use under exercise-heat stress.

2. Methods

2.1. Tcore sensor

The Tcore device is a sensor system that estimates T_c from the skin surface based on HF technology (Sattler, 2010). The device consists of two temperature probes that are separated by an isolating layer, with a known heat conductivity. One temperature sensor measures the near-surface skin temperature under the insulator and the other temperature sensor is above the insulator. Assuming that the heat flux through the isolator corresponds to the heat flux through the skin, T_c can be extracted from the heat flux and be calculated by measuring the temperatures of both sensors. After thermal equilibrium is reached, the sensor can continuously measure core body temperature (Dräger Medical, 2014; Sattler, 2010).

2.2. Participants

Seventeen healthy young males were recruited for this study. Of the 17 subjects, 13 subjects completed the entire testing protocol, and one subject completed only one day of heat exposure. The general characteristics of the group were as follows: age: 25 ± 3 years old, weight 72 ± 10 kg, height 173 ± 5 cm, body fat percentage 19% ± 6%, BMI 24 ± 3 kg/cm^2, VO_{2max} 48 ± 5 ml/kg*min. Three subjects withdrew willingly from the study and their data were not included in the analysis.

2.3. Experimental protocol

Each subject visited the laboratory four times. Anthropometric measurements and maximal oxygen consumption (VO_{2max}) were measured on the first visit. The participants' VO_{2max} was measured according to the Bruce protocol by running on a motor-driven treadmill to exhaustion. Using a metabolic chart (ZAN600, nSpire Health Inc. Germany) VO_2 and VCO_2 were continuously monitored during the entire running session and established criteria have been used to determine a subject's VO_{2max}.

All experimental exposures have been conducted during the winter season to minimize the effect of heat acclimatization. To test the sensor's feasibility under various conditions and to obtain a larger database for the development of the required algorithm the testing protocol consisted of a 90 min exercise-heat stress exposure under three conditions: 30 °C/60% rh, 34 °C/40% rh, and 40 °C/40% rh. The exercise consisted of walking on a motor-driven treadmill at a pace of 5 km/h and 4% incline, which corresponded to work intensity of ~30% (30.2% ± 5.4%) of the participants VO_{2max}. During all testing, the subjects were dressed in military Battle Dress Uniform (BDU: long trousers and a long-sleeved shirt, 100% cotton), a cotton T-shirt, underwear, and sports shoes. Safety limits to terminate an exposure were set to $T_{re} = 39$ °C or HR (heart rate) = 180 bpm, or the study physician's decision.

Each participant was randomly exposed to the study protocol on three separate data collection days (2–7 days apart from each other). All testing exposures were conducted between 8:00 a.m. to 12:00 a.m. Participants were asked to refrain from strenuous exercise and alcohol consumption the day before every data collection day and from caffeine consumption and cigarette smoking for 12 h before the experimental session. They were also asked to complete 7 h of night sleep before each data collection day.

The study protocol and procedures were approved by the Institutional Review Board (IRB) of the Sheba Medical Center (2920-16-SMC) and the Israel Defense Forces Medical Corps (1639-2016-IDF) and by the ethical committee of Tel-Aviv University. All participants signed an informed consent form prior to their participation in the study.

2.4. Physiological measurements

Temperatures and HR were recorded continuously and simultaneously during the experimental exposures. T_{re} was monitored continuously using a rectal thermistor (YSI-401, Yellow Spring, USA) inserted ~10 cm beyond the anal sphincter. Tcore sensor measurements were taken at two body sites: (a) the right side of the subject's forehead on the vertical line above the eye, directly underneath the hairline (Fig. 1(a)), according to a former study by Gunga et al. (2009) and the manufacturer recommendations; (b) the subject's left-hand wrist (Fig. 1(b)). An elastic band secured the sensor position and ensured continuous contact with the skin. For safety reasons, HR was measured by an HR wristwatch and a transmitting chest belt (RS800, Polar, Finland).

T_{re} and the two temperatures from the Tcore device were monitored and recorded continuously using a computerized program (*AcqKnowledge*) at a rate of 1Hz; for data analysis, only the averaged values of every minute were used.

2.5. Data analysis

2.5.1. The development of the $T_{re(e)}$ models to reflect T_{re}

The two temperature outputs from the Tcore sensor were used for developing an algorithm that reflects T_{re}. The model that provides T_c according to the manufacturer (Drager Medical, 2014) was not effective in estimating T_{re} under the conditions of exercise-heat stress, as described in the *Results* section. Hence, a set of novel algorithms, one for the forehead and the other for the wrist, were developed to assess T_{re}. MATLAB's Curve Fitting Toolbox™, which enables fitting a curve to data according to provided or custom equations, compare optional

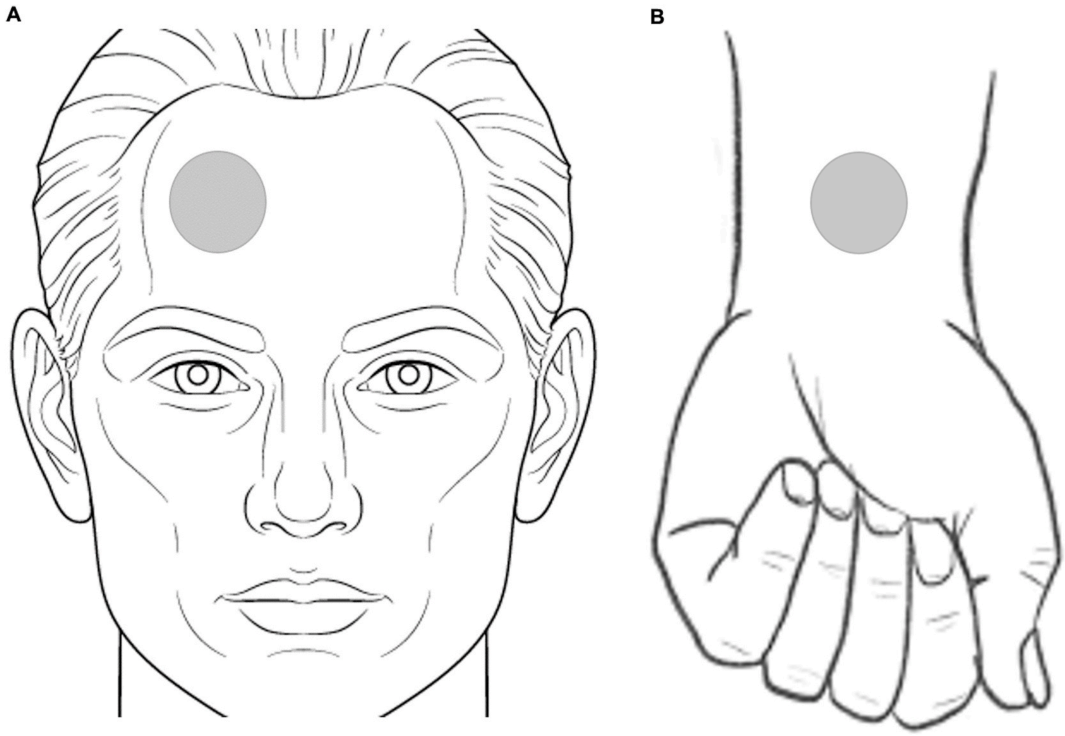

Fig. 1. The Tcore sensor location on a subject's forehead (a) and the wrist (b).

models, and perform data analysis including removal of outliers, was used to develop the new algorithms.

The Cross-Validation algorithm was implemented to choose the parameters that best fit the models. Thirteen iterations were performed. In each of them, one subject was the test set and the remaining 12 were the training set. The results of the 13 iterations were averaged and the average was taken as the chosen model.

The data used for the development and assessment of the new models were taken after eliminating the initial 1000 measurements (~15 min), allowing equilibrium to be achieved, as was usually done in similar studies (Feng et al., 2017; Huang et al., 2017; Kimberger et al., 2009; Sastre et al., 2018). To analyze reliable data, raw data artifacts were removed or replaced by interpolation based on existing valid data. Some of the collected data were unreliable - the measured T_{re} was not in a reasonable range (less than 36 °C for example) or lower than the temperature measured before entering the climate chamber. Occasionally, during a few seconds of measurement, the temperature of one of the thermistors was above or below the measurement in neighboring values. In these cases, data points were discarded when they were significantly outranged by more than 0.3 °C from the nearby other measurements. The data were then smoothed using a MATLAB filter function. In total, for the development and verification procedures of the models, 147,346 time-points were used from the wrist measurements and 135,039 time-points were used from the forehead measurements. Each time-point included data of T_{re} and two temperatures of each sensor. Each 60 measurements from 1 min were averaged. This process resulted in more smoothed, stable, and reliable data. Data from different climatic conditions were used altogether in the development of the model, in order to achieve $T_{re(e)}$ (the predicted temperature by the Tcore sensor using the new models), without the need to consider the environment, but only the subjects' physiological thermal strain. Ultimately, the averaged 1-min temperatures from all the participants and the experimental days were used to build and test the models.

2.5.2. Statistic and assessment of the results

For quantifying the deviation between T_{re} and $T_{re(e)}$ a Bland-Altman plot was constructed for all subjects under the exercise-heat stages. The percentage of measurement differences within the range of ±0.3 °C was counted, as well as for the range of ±0.5 °C . The mean error (*average*($T_{re(e)}$-T_{re}) and mean absolute error (*average*($|T_{re(e)}-T_{re}|$))were calculated for each of the two models. To assess the differences between the predicted values by a model and the actual observed values the root mean square deviation (RMSD) was calculated as $\text{RMSD} = \sqrt{\frac{1}{n}\sum_{i=1}^{n} d_i^2}$; where: d_i is the difference between observed and predicted measurements at 1-min intervals, and n is the number of time points; this gives a single value representing the accuracy of a model through various time points for a specific data set. The RMSD values were calculated for each participant from each experimental day and are reported as an average ±1SD of all subjects and days.Where appropriate, data are presented as mean ± standard deviation (SD). Statistical significance was accepted at the $p < 0.05$ level for an unpaired t-test.

3. Results

Measured T_{re} values during the experiment were in the range of 36.5-38.9 °C. Applying the data collected in the present study to the original

Table 1
Comparing the results produced using the original (Tcore) and newly developed models ($T_{re(e)}$) for assessing Tre.

		Tcore	$T_{re(e)}$
Forehead	Average error (°C)	−0.12 ± 0.38	0.00 ± 0.25
	Absolute error (°C)	0.31 ± 0.24	0.20 ± 0.16
	90th percentile (°C)	0.65	0.40
	Absolute errors < 0.3 °C (%)	55	78
	RMSD (°C)	0.34 ± 0.21	0.23 ± 0.10
Wrist	Average error (°C)	−1.57 ± 1.63	0.01 ± 0.33
	Absolute error (°C)	1.85 ± 1.31	0.27 ± 0.20
	90th percentile (°C)	3.10	0.58
	Absolute errors < 0.3 °C (%)	7	64
	RMSD (°C)	1.97 ± 1.26	0.31 ± 0.14

Dräger formula (Dräger Medical, 2014) was not satisfying in terms of validity either for the forehead or the wrist measurements (Table 1). Under the study's conditions the mean absolute error of the predicted temperature Tcore compared to the measured T_{re}, was 0.316 °C ± 0.242 °C for the forehead measurements and 1.847 °C ± 1.314 °C for the wrist measurements and RMSD was 0.406 °C and 2.596 °C of the forehead and wrist, respectively.

3.1. The developed algorithm

Several models have been tested to assess T_{re} from the Tcore's thermistors measurements. Different degrees of dependency between the thermistors and T_{re} were tested using the built-in MATLAB curve fitting tool. The temperatures of the sensor's thermistors and the T_{re} were uploaded, and the $T_{re(e)}$ formula was created according to the thermistors readings and the difference between them, with a power of −2, −1, 1, 2 and 3. For each model tested, MATLAB's curve fitting tool gave calculations describing the quality of the fit. The model which gave the best agreement with T_{re} was chosen accordingly. Then, the cross-validation method was applied. 13 iterations were performed; in each of them, one subject was the test set and the remaining 12 were the training set. The results of the 13 iterations were averaged and the average was taken as the chosen model.

The models which gave the best results were as follows:

For the forehead:

$$T_{re(e)} = 0.9943*Th1 - 0.3040*Th2 - \frac{3.0712e^{-0.5}}{Th1 - Th2} + 11.8807;$$

For the wrist sensor:

$$T_{re(e)} = -0.2010*Th1 + 0.4021*Th2 + 0.4308*(Th1 - Th2) + 30.5007;$$

Where: Th1 and Th2 are the temperatures at the two sides of the insulative layer.

The coefficients for (Th1–Th2) in the models express the temperature's dependency on the thermal conductivity coefficients (the ratio of the sensor and the body tissues coefficients). Dräger's thermal conductivity coefficients are commercially protected by the company.

3.2. Results

The estimates of T_{re} from the models that were developed ($T_{re(e)}$) is closer, as judged by all relevant parameters, to the measured T_{re} than the Tcore values (Table 1). The mean error of the new models were smaller than those of the original formula, as well as the mean absolute error, 90th percentile and RMSD. The percentage of absolute errors smaller than 0.3 °C was also higher for the new models than the original model suggested by the manufacturer.

135,039 measurement pairs for the forehead model determined an approximate average error of 0.00028 °C±0.255 °C between measured T_{re} and $T_{re(e)}$ and an average absolute error of, 0.202 °C±0.157 °C with 95% of the estimated values within ±0.5 °C and 78% of the values within ±0.3 °C from the measured T_{re}. 147,346 measurement pairs for the wrist model determined an approximate average error of 0.015 °C±0.335 °C between measured T_{re} and $T_{re(e)}$ and an average absolute error of 0.266 °C±0.205 °C , with 86% of the calculated values within ±0.5 °C and 64% of the values within ±0.3 °C from the measured T_{re}.

RMSD values used for goodness of fit comparisons indicated that overall, the model estimations were in close agreement with the measured values and met the criteria of 0.5 °C. The RMSD value for the forehead sensor is 0.235 °C±0.100 °C, and that for the wrist is 0.310 °C±0.139 °C. The values were close to the tighter limit of 0.3 °C.

The Bland-Altman plots for each of the two models are presented in Fig. 2.

According to these plots 95% of the measurements taken from the forehead and 85% of the measurements that were taken from the wrist were within ±0.5 °C. Furthermore, 78% and 64% for the forehead and wrist, respectively had an error smaller than the desired limit of ±0.3 °C . It should be noted that for the low T_{re} values the errors were positive and were negative for the higher T_{re} measurements, with a turning point of ~37.5 °C (Fig. 2). Hence, low T_c would be overestimating and high T_c would be underestimating actual values.

4. Discussion

The goal of this study was to examine the possibility of monitoring T_{re} as reflecting T_c under exercise-heat stress non-invasively by using the Tcore sensor. A large dataset was used for this analysis. There are two major novel findings from the study. The first, the Tcore device can potentially be used for workers who are exposed to harsh (hot) environmental conditions. This required to modify the original model suggested by the manufacturer. The second finding is that it is possible to obtain good results from measurements taken from the wrist and not only from the forehead. This is of great practical importance since for daily outdoor use it is more feasible to record data from the wrist than from the forehead. A device attached to the wrist can be less interfering during work than a device that is attached to the forehead; with a visionary sight such a device can also be implemented within a smart watch.

Both models that have been developed showed the applicability to reliably measure T_{re} under exercise-heat stress from the forehead and the wrist. The mean differences between measured T_{re} and $T_{re(e)}$ were almost zero. Both parameters, mean absolute differences and RMSD values, met the acceptance limit of 0.5 °C. The forehead model revealed

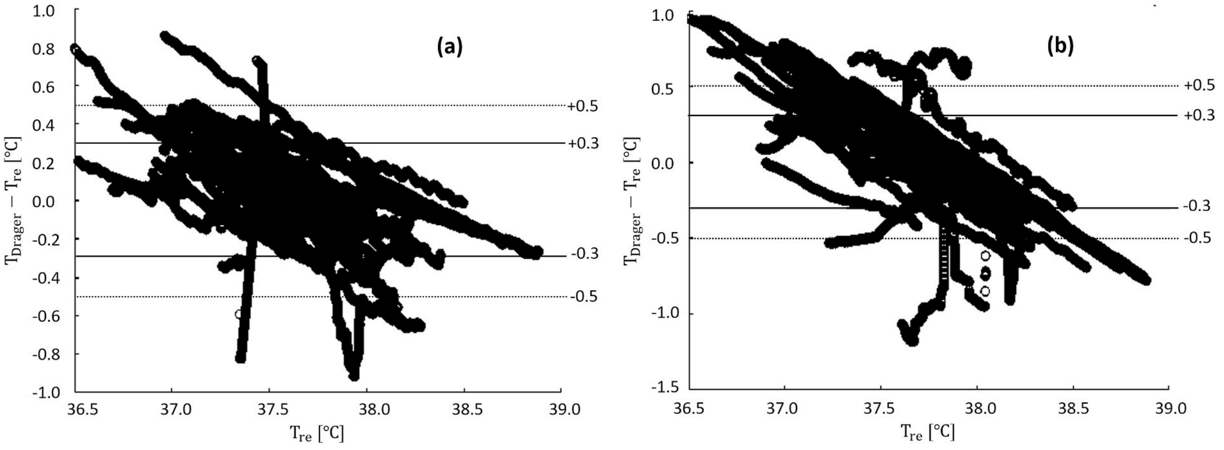

Fig. 2. Bland-Altman plots for the forehead (a) and wrist (b) sensors; T_{re} vs $T_{re(e)}$.

somewhat better results, which better met the tighter acceptance limit of 0.3 °C. A possible reason for the better accuracy of the forehead model could be the thickness of the tissue under the sensor. The forehead lacks significant subcutaneous tissue and thus there is less insulation between the blood vessels and the skin. In the wrist, the larger distance between the sensor to the core (blood vessels) might cause some distortion of the results and, thus, somewhat lower accuracy. Nevertheless, to the best of our knowledge, this is the first study in which reliable true results of T_{re} were obtained from the wrist using the HF technique.

Assessment of T_{re} with an error smaller than 0.5 °C is in accord with previous studies (Tayefeh et al., 1998). This level of error was considered sufficient in previous studies because it reflects the normal magnitude of human temperature variation (Tayefeh et al., 1998). However, an error of this size could result in misidentification of risky high values, which might be life-threatening. Therefore, we aimed at a tighter limit of 0.3 °C to lower the chances of missing significant hyperthermia. Under field conditions even a small change of 0.3 °C is significant and a deviation of 0.5 °C could be of clinical significance.

Even though our models presented overall good accuracy, we observed overestimation for lower temperatures and underestimation for higher temperatures when exceeding the threshold of about 37.5 °C, which is in accord with similar deviations that have been reported by others (Gunga et al., 2008; Mazgaoker et al., 2017). The overestimation in the lower range has less clinical significance for real-life use when assessing exercising or working individuals. However, the underestimation of T_{re} at the higher temperature range especially when approaching 39 °C should be considered since false-positive results might endanger the worker.

The data presented in this study are a hallmark in the field of using HF technologies to measure T_c since very few studies of exercising in hot climatic conditions were conducted using such sensors under similar conditions. In this regard, two pivotal studies, in which a prototype of the Tcore sensor attached to the forehead was used, are of relevance. Gunga and colleagues tested the Tcore prototype during treadmill activity reported a correlation coefficient of $r = 0.75$ between the measured T_{re} and the calculated T_c and an average error of -0.11 ± 0.34 °C under an ambient temperature of 40 °C, where 88.1% of the errors were within ±0.5 °C with (Gunga et al., 2008). The models that had been developed in the present study revealed, under all environmental conditions a much lower error for both the forehead and wrist than those reported by Gunga et al. Similar to our results, the Tcore prototype that was used by Gunga et al. gave an overestimation of T_{re} at lower core temperatures (approximately < 37.5 °C) and an underestimation for higher T_{re} (Gunga et al., 2008). More recently Mazgaoker et al. tested the Tcore prototype under an exercise-heat stress protocol, with a peak T_{re} of 38.0 °C. They showed a high correlation between T_{re} and the estimated temperature with a consistent underestimation of T_{re} (Mazgaoker et al., 2017). Only 51% of the differences in Mazgaoker et al.'s study were within ±0.3 °C of T_{re} with an average error of 0.23 ± 0.04 °C (greater bias with smaller deviation). Adjustment of the sensor's estimation improved the results to 73% within ±0.3 °C, which is still lower than the 78% (wrist) and 95% (forehead) in the current study. Noteworthy, however, is that in both studies with the Tcore prototype the original algorithm as was determined by the manufacturer was used. Overall, the current models allow better estimation of T_{re} than those presented in the former studies.

The results of the present study open the possibility to use the Tcore also under other stressful environmental conditions. This is supported by another study by Gunga et al. which revealed similar accuracy with T_{re} to ours, but under the conditions of 60 days of 6° head-down tilt bed rest - a mean error of 0.08 ± 0.32 °C have been reported (Gunga et al., 2009). Regarding the percentage of errors within ±0.5 °C, Gunga et al.'s results were somewhat better than our wrist data (72%) but worse than our forehead data (99%). Gunga had 73% errors within ±0.25 °C that are in accord with the 78% and 95% within ±0.3 °C (wrist and forehead, respectively) in our study. In contrast to our models, with increasing temperature, in Gunga and colleagues' study, the calculated values tended to overestimate T_{re}. In this study, Tcore values showed greater variability compared to T_{re} (the highest Tcore value was 38.0 °C while the highest T_{re} was 37.5 °C), which might make it harder to detect changes in T_c (Gunga et al., 2009). The reason for the opposite trend might be the different setting, the lower T_{re} values (maximum temperature of 37.5 °C was measured), and the position of the body in Gunga et al. study, where the head is lower than the rest of the body, and more blood flows to its direction.

5. Conclusions

In the current study, we managed to expand the use of an existing sensor to a new application - exercise under environmental heat stress and measuring temperature on the forehead and wrist, which is beyond its usual use as described by the manufacturer (comfort climate and low metabolic rate). This required the development of a model that enables the use of the sensor under conditions that are of great practical importance - preventing heat-related injuries. In addition to the original location of the sensor, we developed a model that adjusts for the use of the sensor on the wrist. This offers a new and maybe more convenient way of measuring T_c. Compared to other devices and models, the newly developed algorithms achieved satisfying results with low errors under the acceptable threshold of 0.5 °C and also under the desired threshold of 0.3 °C, although still only borderline for the wrist. Field experiments are still needed in order to verify these results outside of a laboratory setting.

Ethics

The work described has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. The study protocol and procedures were approved by the Institutional Review Board (IRB) of the Sheba Medical Center (2920-16-SMC) and the Israel Defense Forces Medical Corps (1639-2016-IDF) and by the ethical committee of Tel-Aviv University. All participants signed an informed consent form prior to their participation in the study.

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The funding source had no involvement in the study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

Authors' contribution statements

Idan Tsadok: This study was carried out by me, as part of my MSc thesis. I was responsible for recruiting the test subjects, adjusting the Tcore device to our Institute's data collecting system, conducting the experiment, and analyzing the data. I wrote the preliminary draft of the manuscript and prepared it according to the Journal's guidelines. Mickey Scheinowitz: Together with Prof Epstein I supervised Idan Tsadok in conducting the study. I read the darfts and co-author the final version of the manuscript. Sagi Spitzer: As the medical officer of the study I authorized the participation of the test subjects, informed them on the study's procedures and signed them on the consent form. I was actively involved in writing the manuscript drafts and its final version. Itai Ketko: Together with Prof Epstein I initialized the study and its procedures. I reviewed the manuscript and approved its final version. Ran Yanovich: I was involved in initializing the study and funding acquisition. I was responsible for all the project administrations, including purchasing the Tcore device. I reviewed the manuscript drafts and its final version. Yoram Epstein: I was involved directly in all the stages of the study starting with conceptualization, writing the study's protocol, supervising data collection and analysis, and writing the manuscript and editing its final version.

Disclosure

The interpretation of the data, the opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the IDF Medical Corps or the Israel MOD.

Declaration of competing interest

Declarations of interest: none.

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