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ORIGINAL RESEARCH

# Environmental Heat Stress Among Young Working Women: A Pilot Study

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**Abstract**

**BACKGROUND** Heat waves are increasing significantly in frequency and severity and threaten the health and income of outdoor workers. Pregnant women workers are particularly at risk due to their delicate physiological systems and accountabilities to future generations. Animal and human studies propose that elevated body temperatures during pregnancy can induce adverse pregnancy outcomes.

**OBJECTIVE** To measure the change in internal body temperature (Tcore) in young working women before, after, and during work (both outdoor and indoor) on hot humid days and relate threshold temperature to the upshot adverse effects of pregnancy (teratogenicity and related miscarriage).

**METHODS** Tympanic temperatures were measured using infrared ear thermometers and workplace temperatures were collected using Lascar Data Logger. Brief exploratory interviews were conducted to gather qualitative data, and content analysis was also carried out.

**FINDINGS** Body temperatures were found elevated among outdoor women workers compared with that of indoor women workers.

**CONCLUSIONS** The present study found that outdoor work during pregnancy in hot, humid days might increase body temperature up to levels that could induce fetal destruction or anomaly.

**KEY WORDS** heat stress, pregnancy, teratogenicity, women, climate change, outdoor worker

## INTRODUCTION

Heat stress is the consequence of imbalance between heat produced internally and heat lost to the environment. Heat stress can cause discomfort, fatigue, exhaustion, heat cramps, and heat stroke in humans.[1] These effects are classified as direct effects of climate change according to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.[2]

Heat stress in workplaces is considered especially hazardous, and risk depends on the intensity of the muscular work a person is performing. Individuals who are involved in outdoor work in hot conditions, without access to shade or sufficient water, are at especially elevated risk.[3] But heat stress is also an issue for those working indoors without cooling facilities, especially pregnant women who perform a considerable amount of physical work for daily survival (eg, collection of water and firewood) or as part of economic activities.[4,5] The Heatwave Early Warning Systems is used to assess heat risk to the elderly, the sick, children, and outdoor players and workers.[6]

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Women differ from men in terms of response to heat stress.[7,8] Women sweat less than men and have lower cardiorespiratory fitness, higher metabolic rate, higher percent of body fat, lower body weight, lower body surface area, and higher surface area—to—mass ratio, which put their thermoregulation at a significant disadvantage.[8,9] Furthermore, hormonal cycles (of those who do not use medicinal hormones) significantly affect temperature regulation.[10] Women's basal temperature (Tcore) is higher in the luteal phase and during pregnancy because of circulating progesterone.[7,11-13] Thus, women's physiology is less adaptive to any imposed heat stress, especially during pregnancy, which can place the developing fetus at considerable risk of distress.[11,14]

In recent years, heat waves have occurred with increasing frequency worldwide, threatening human health. It should be noted that in the absence of an exact definition of a heat wave, predictions of heat waves in the past were problematic and continue to be a global challenge.[15,16] However, the World Meteorological Organization defines a heat wave as an environmental condition when the daily maximum temperature of more than 5 consecutive days exceeds the average daily maximum temperature by 5°C.[17] Thus, the definition has different values for different regions. Yet the global temperature is predicted to increase and is predicted to rise 1°C-3°C until 2020 and 3°C-5°C until 2080 (up to 4°C) in many inland areas within the large continents where the maximum temperatures are already 40°C during the hottest part of the year.[18] A 7°C warming above current temperatures would create small land areas where metaboli heat dissipation would be impossible.[2]

Heat-related health impacts are of particular importance in tropical developing countries where climate change during this century is already prominent, and where the health system is burdened with other service and economic limitations.[19,20] Furthermore, a large proportion of the workforce in those countries, including women workers who are widely discriminated against, is deployed outdoors with little protection from heat.[2] These findings come from a study that was conducted in Bangladesh, a tropical developing country taken as a model for studying heat stress in outdoor women workers.

Climatically, Bangladesh belongs to the subtropical region where monsoon weather prevails throughout the year. The average temperature of the country ranges from 12.5°C-25.7°C during winter and 25.2°C-33.2°C during summer. However, in recent years some parts of the country have recorded highest temperature (42°C) during summer and lowest (2°C) in winter, which is a strong concern of climate change.[21] The average relative humidity for the whole year ranges from 71%-86%.[5,21] A recent investigation by the Bangladesh Meteorological Department on heat waves from March 1 to June 20 from 1991-2000 found that April was the hottest month and 1995 was the hottest year all over the country. It is worth noting that the Bangladesh Meteorological Department defines a heat wave based on the conditions that (i) the maximum temperature must be ≥36°C ($T_{max} \geq 36°C$), and (ii) $T_{max} \geq 36°C$ should apply over a wide region (ie, should be at more than 1 adjacent station). The total number of heat waves in Khulna was 1671, which was the maximum among all divisions of Bangladesh over the period of 1991-2000. Figure 1 shows the number of heat waves in different months of the period (1991-2000).

Rajshahi and Khulna divisions experienced extreme hot weather for prolonged periods, as shown in Figure 1. These 2 divisions experienced weather for 91 days and 61 days that was $42°C > Tmax \geq 40°C$, respectively, and weather for 29 days and 16 days that was $Tmax \geq 42°C$. In Dhaka division the weather for 281 days was $38°C > Tmax \geq 36°C$, and for 75 days it was $40°C > Tmax \geq 38°C$. Thus Dhaka division is the area with moderately long periods of hot weather.

For the Heat Index (HI) chart over this period, 1991-2000 had "very hot" weather typically occurring in March-April and November-December, whereas May-October was considered "hot." Another study in Bangladesh analyzed 20 stations for the period of 1961-2010, and the data revealed that mean HI value ranged from 42°C-50°C in summer, whereas the highest value surpassed 60°C in May in some parts of the country.[22] HI is the perceived temperature in the human body, which takes account of air temperature and relative humidity. It is widely used to warn vulnerable people worldwide. It indicates 35°C is the optimal temperature for human body functions.[23]

Considering these stated points, this pilot study was conducted in May 2014 in Dhaka, Bangladesh.

**Maternal Heat Stress During Pregnancy.** Heat stress in women has special clinical implications for infants in utero. Many studies have found an association between seasonal patterns and adverse birth outcomes. A retrospective study in Brisbane found that exposure to higher ambient temperature over the last 4 weeks before birth has an acute effect on gestational age and carries the risk of stillbirth.[24,25]

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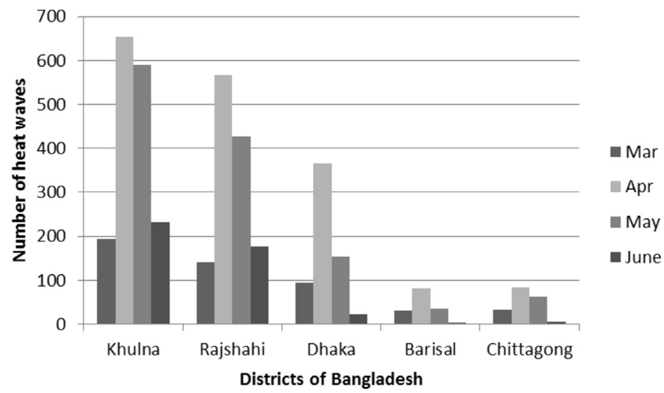


**Figure 1.** **Total number of heat waves in Bangladesh (1991-2000).**

The study did not consider miscarriage as a result of malformation or teratogenicity, which might indicate a substantial research gap.[20,26,27]

However, no exact temperature has been fixed yet that could be considered a threshold to teratogenic upshots in human embryos. Reviews of published reports have found that the threshold temperature varies from 0.5°C-2.5°C above the normal Tcore,[28] which would be 37.5°C-39.5°C in humans. Table 1 shows different estimated threshold temperatures for both humans and animals, as gathered from published reports.

## METHODS

**Hypothesis.** The null hypothesis of this research is that outdoor work of women on hot, humid days will not increase Tcore.

## OBJECTIVES

The aims of this research were to do the following:

**Table 1.** **Different Estimated Threshold Temperatures, Gathered From Published Reports**

| Suggested Threshold Temperature Above Normal Tcore (°C) | Animal | Reference |
|---|---|---|
| 1.5-2.5 | Human | Edwards[29] |
| 0.5 | Human | Zeqiri[30] |
| 2 | Humans | Andersen, Vastrup[26] |
| 2 | Rat | Kimmel, Cuff[31] |
| 2-2.5 | Mammals | Edwards, Walsh[32] |
| 2-2.5 | All species | Edwards, Shiota[33] |
| 2-2.5 | All species | Edwards[34] |

Tcore, internal body temperature.

- Measure the change of tympanic temperature in young working women before, after, and during work in both indoor and outdoor settings
- Calculate wet bulb globe temperature (WBGT) and core body temperature (calculated Tcore)
- Relate the maximum temperature range with the proposed threshold temperature to upshot adverse effects on the embryo.

**Study Overview.** This is cross-sectional comparative research, which was approved by the appropriate ethical committee of Bangladesh (Ethical Review Committee of the Center for Injury Prevention and Research Bangladesh) on October 28, 2014. The study was conducted at indoor and outdoor workplaces in Bangladesh during the mid-summer season (May) of 2014. The study days were selected when the outdoor temperature was ≥30°C and the relative humidity was >40%. The tympanic temperatures of the workers were measured with infrared ear thermometer before the start of work, during work, at the start and end of a break, and at the end of work. Workplace temperature data were calculated with Lascar Data Logger. The work metabolic rate was estimated from approximate values of occupational health guidelines. The work intensity can be described as follows:

L = Low intensity = approximately 200 W = sitting, standing, light hand/arm work
M = Medium intensity = approximately 300 W = walking, moderate lifting
H = High intensity = approximately 400 W = heavy materials handling

**Recruitment of Participants.** In both outdoor and indoor settings, the study populations were young working women (18-40 years). They were selected through a systematic random sampling. A total of 27 samples were recruited, among them 8 were from a construction field (outdoor) and 19 were from a garments factory (indoor). Eight outdoor workers were selected from among 15 workers by the simple random sampling method and 20 indoor workers were selected from among 50 workers (1 declined to continue later). The workers were assumed to be acclimatized to higher temperature. The inclusion and exclusion criteria are listed in Table 2.

**Description of the Study Places and Works.** *Workplace 1* was a building construction site located in a residential area in South Dhaka. The workers started their work at sunrise. They were assigned to complete the day's work before dusk in order to save electricity. The women workers carried sand, gravel, and brick chips to make mixtures for roof paving of the buildings under construction. They worked in 2 groups, each taking turn to shovel and fill up buckets and to carry them. Data collection was done during the hottest days of the year (ie, in May), when ambient temperature reached 36°C-39°C.

*Workplace 2* was the site of a ready-made garments industry housed in a five storied building without any air cooling facilities. More than 100 women worked on each floor, starting by 9 AM each day. They were assigned to sew cut pieces of dress materials, which they did in a sitting position through arm and hand movement. They performed the task in a relaxed manner unless strictly supervised. Data were collected the same as for workplace 1 (ie, during May, the hottest month of the year). The data logger recorded workplace temperature to be within 30°C-31°C.

## DATA COLLECTION

Eligible participants were examined before the survey was commenced. The field researchers reached the workplaces 1 hour before work began, after which baseline assessment was carried out. Field researchers, each assigned to 4 participants, performed the following tasks:

a. Explained the study aim and procedure to the participants and collected their signatures on the consent paper.
b. Noted down contact details of the participants, including mobile numbers (if any).
c. Found out if the participants were currently taking any medication, such as amphetamine or opium or any prescribed medication. In general, substance abuse is very common among those engaged in intense work.
d. Took the participants' medical histories, including weight and height, signs of hypertension (blood pressure was measured), shortness of breathing, allergies, or asthma. However, it was not expected that thorough and appropriate health information could be gathered given the level of the participants' health awareness.
e. Conducted ear examination. Observations of the external and middle ears were done to exclude any pathologic conditions of the ear that might affect records. Taking consent, 1 ear of each worker was examined, and the temperatures were recorded from a specific ear every time to avoid variations.

In-depth exploratory interviews were conducted during breaks using a pretested structured questionnaire. The questionnaire was written in Bengali, and the interviews were also conducted in Bengali. The questionnaire mainly focused on the type of work, duration of work, work output, frequency of rest, clothing, heat stress symptoms, and adaptive methods.

**Data Analysis.** Content analysis (both descriptive and interpretative) was done with qualitative data.

One-way analysis of variance (ANOVA) was done with the quantitative data from both workplaces. WBGT of both indoors and outdoors were calculated using the Excel analysis tool found at the ClimateCHIP website (http://www.climatechip.org/).

WBGT takes into account temperature, humidity, wind speed, sun angle, and cloud cover (solar radiation). For direct exposure to sunlight these are good elements to monitor. According to WBGT, the average human optimal Tcore is 38°C.[35]

Metabolic rates and calculated Tcore were deliberated from the model of Professor Richard de Dear (human heat balance). Metabolic rates were calculated to find out workers' muscular work, which is vital in calculating work-related heat stress. It is often used as a measuring unit for human body heat or power production. Because tympanic temperature does not represent actual core temperature, Tcore was calculated for each worker for 1 hour by this model to correlate with WBGT guidelines and the proposed threshold temperature of adverse pregnancy outcomes.

**Table 2. Inclusion and Exclusion Criteria**

| |
|---|
| Inclusion Criteria |
| a. Reproductive age |
| b. Ability to give informed consent |
| Exclusion Criteria |
| a. Current sickness that may affect Tcore |
| b. Current use of any medication what might increase body temperature |
| c. Any signs of substance abuse (especially amphetamines, marijuana, and opium) |

Tcore, internal body temperature.

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## RESULTS

The mean tympanic temperature of outdoor workers increased gradually with time. Figure 2 shows a comparison between the temperatures of outdoor and indoor workers at different times. At 7.30 AM the average temperature of outdoor workers was 36.9°C, and when they completed their work for the day it became 38.1°C. Maximum temperature of 38.3°C was observed commencing at rest time at 2:30 PM. For indoor workers, the maximum temperature was recorded at 37.3°C when they finished their rest/lunch at 2:05 PM.

Table 3 shows mean tympanic temperatures with standard deviation and ranges measured at different times during work as well as calculated WBGT, core temperature, and metabolic rate or power production. For calculating core temperature, clothing insulation was assumed to be 0.77 clo, and participant surface area was assumed to be 1.49 $m^2$.

Table 3 shows that the temperature of the outdoor participants before they started work was 36.9°C ± 0.4 and after work it was 37.2 ± 0.4. Highest mean body temperature, 37.3°C ± 0.4 (38.3-36.6), was before break at 2:30 PM, when air temperature was 39.5°C with relative humidity at 46.5%. Calculated core temperature for 1 hour of exposure time was 41.5°C. WBGTs at this time were highest as well, at 33.3°C. It is obvious that ear temperature always underestimates the core temperature. According to the WBGT scale, working or exercising in direct sunlight will stress the body after 15 minutes and at least 45 minutes of break each hour is recommended.

At the end of the day (6:45 PM), the work speed was accelerated without any breaks or rest in order to complete all tasks before sunset. The mean temperature was 37.2°C with a standard deviation of ±0.41 and calculated WBGT was 31°C. According to WBGT work/rest regimen per hour, they should rest 40 minutes, meaning rest 75% and work 25%.[36]

However, for the indoor workers, tympanic temperatures were comparatively at a comfortable level throughout the work time, and in the WBGT scale they were in continuous work limit. A one-way analysis of variance (ANOVA) was calculated for both outdoor and indoor workers body temperatures. The analysis were found statistically significant for

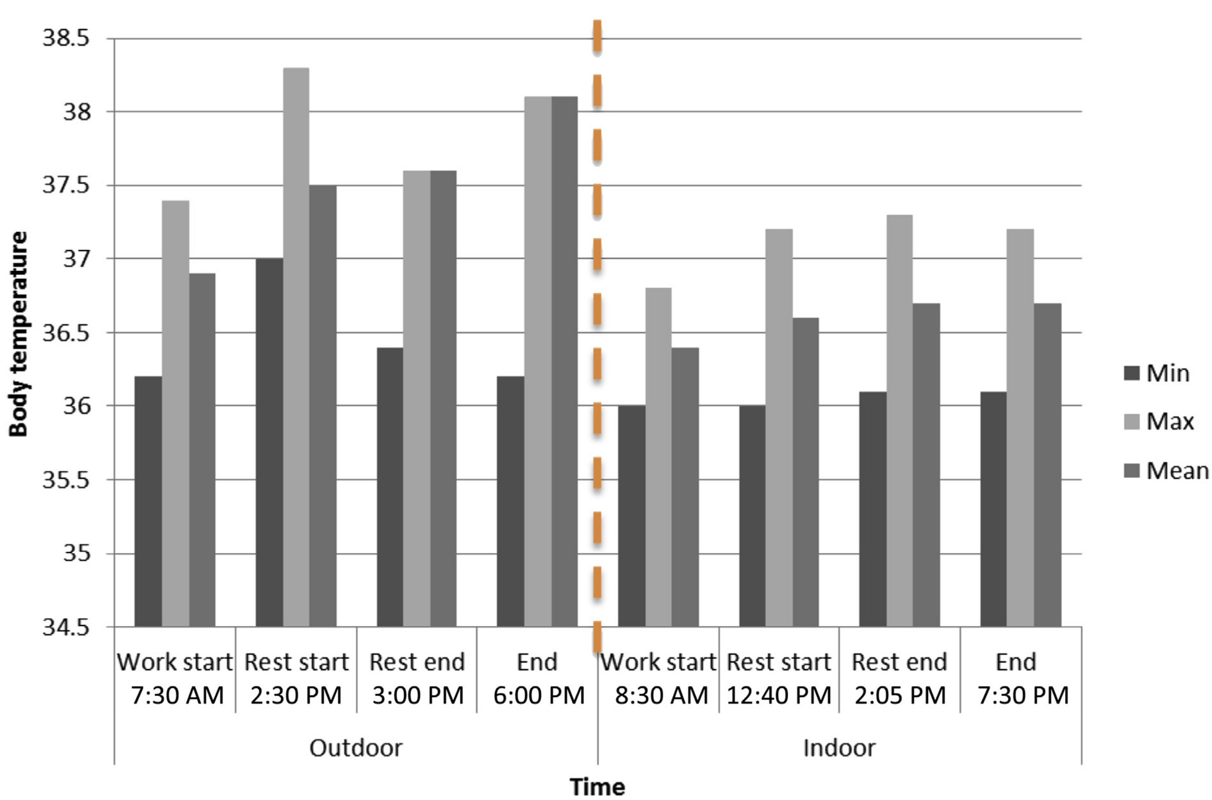


**Figure 2. Comparison between temperatures of outdoor and indoor workers at different times.**

**Table 3. Comparison Between Mean Temperatures With Standard Deviation, WBGT, and Calculated Tcore at Different Time**

| Outdoor Workers | Tympanic Temperature (range) | WBGT (°C) | Tcore (°C) | Metabolic Rates (W/m$^2$) |
|---|---|---|---|---|
| Before work (7:30 AM) | 36.9 ± 0.4 (37.4-36.2) | 30.7 | 40.6 | 280 |
| Before break (2:30 PM) | 37.3 ± 0.4 (38.3-36.6) | 33.3 | 41.3 | 280 |
| After lunch (3 PM) | 37.1 ± 0.4 (37.6-36.4) | 32.9 | 36.9 | 60 |
| At the end (6 PM) | 37.2 ± 0.4 (37.7-36.2) | 31.0 | 41.2 | 280 |
| Indoor Workers | | | | |
| Before work (8:30 AM) | 36.8 ± 0.3 (36.8-36.0) | 29.4 | 37.9 | 140 |
| Before break (12:40 PM) | 36.6 ± 0.3 (37.2-36.0) | 29.0 | 37.8 | 140 |
| After lunch (2 PM) | 36.7 ± 0.3 (37.3-36.1) | 28.3 | 36.8 | 60 |
| At the end (7:30 PM) | 36.7 ± 0.3 (37.2-36.1) | 25.7 | 37.2 | 140 |

Tcore, internal body temperature; WBGT, wet bulb globe temperature.

both cases, Outdoor $F(3,48)=5.20$, $p=0.003$ Indoor $F(3,68)=5.05$, $p=0.003$ (Tables 4 and 5).

## INFORMATION FROM WORKERS

The mean age of the respondents from both sites was 24 years (as shown in Table 6). They were questioned about how the production output was affected by heat, difference in the number of hours required to complete their work in hotter and cooler days, how many times they need to stop for a break, and what symptoms they experienced because of heat. Workers from both workplaces reported that it required a longer time to finish their tasks in hot days. Repeated breaks to take rest and slow speed were identified as the reasons why it took a longer time to finish work during those days. They also reported that they felt more tired in the hotter weather and experienced sweating and headaches that slowed them down. Outdoor workers simply stay absent from work when physically exhausted, but indoor workers have to apply for sick leave, sometimes without pay. All these severely affect their daily income, family health, and so on. During the interviews, 75% reported that they took breaks to rest every 10 minutes or less, whereas 25% stopped for rest every 10-20 minutes. In the case of indoor workers, they were observed to stop working each time they were done with a batch of dress materials in order to avoid boredom. They were found to be more relaxed and in better spirits than the outdoor workers. The majority of them (73.7%) took rest at more than 20-minute intervals and a few (26.5%) at 10- to 20-minute intervals.

The summary of the interview is presented in Table 6. On average, respondents worked 12 hours a day in their respective workplaces. A vast majority of the respondents (100%) drank water during work hours; 88.8% believed heat affected their work; 92.6% experienced excessive sweating, 70.4% felt extreme thirst, 55.5% felt exhausted, 48.1% experienced headaches or dizziness, and 14.8% had other symptoms like nausea, fainting, heat rash, and so on.

**Limitations of the Study.** The main constraints of this study were the very small sample size and limitations with regard to the accuracy of the Tcore measuring method. The sample size was only 27: 19 indoor workers and 8 outdoor workers. Lack of funding was also a core constraint in hiring skilled field researchers.

Use of the Tcore measuring method proved to be another limitation because ear or tympanic temperature does not provide the actual Tcore for various reasons, such as environmental factors, variations in ear anatomy, inconsistent user technique (ie, failing to position the thermometer at the same depth and angle in the ear canal for each measurement), and so on.[37] Hence, swallowing a temperature-sensitive radio pill might be a good choice but was found to be unrealistic for the Bangladesh setting, where lack of health education and health safety guidance among the general population hinders health-related studies. Nevertheless, the Occupational Safety and Health Service of the Labour Department in New Zealand recommends ear temperature to calculate WBGT at work.[38]

**Table 4. One Way ANOVA for Outdoor Workers**

| Source of Variation | SS | df | MS | F | *P*-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 2.77 | 3 | 0.92 | 5.20 | 0.003434 | 2.80 |
| Within Groups | 8.51 | 48 | 0.18 | | | |

**Table 5. One Way ANOVA for Indoor Workers**

| Source of Variation | SS | df | MS | F | *P*-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 2.77 | 3 | 0.92 | 5.20 | 0.003434 | 2.80 |
| Within Groups | 8.51 | 48 | 0.18 | | | |

**Table 6. Summary of Characteristics of Study Sample**

| Variables | Results |
|---|---|
| Age (y), M ± SD (range) | 24.67 ± 8.0 (18-40) |
| Weight (kg) M ± SD | 53.25 ± 3.5 |
| Height (cm) M ± SD | 150.12 ± 3.7 |
| Hours worked in a day M ± SD (range) | 12.05 ± 0.95 (11-14) |
| Breaks | |
| Outdoor | |
| <10 min | 6 (75%) |
| 10-20 min | 2 (25%) |
| >20 min | 0 |
| Indoor | |
| <10 min | 0 |
| 10-20 min | 5 (26.5%) |
| >20 min | 14 (73.7%) |
| Drink Water During Work | |
| Yes | 27 (100%) |
| No | 0 |
| Work Output Affected by Heat | |
| Yes | 24 (88.9%) |
| No | 3 (11.1%) |
| Different Symptoms of High Heat Exposure | |
| Excessive sweating | 92.6% |
| Exhaustion | 55.5% |
| Extreme thirst | 70.4% |
| Dizziness or headache | 48.1% |
| Others | 14.8% |

Least, but not negligible, workers might avoid reaching critical temperatures by taking very short rests, but it was not possible to measure that.

## DISCUSSION AND CONCLUSIONS

The first step in the study was to find out the changes of temperatures while working outdoors and indoors during hot, humid days. The second step was suggesting that such changes or elevations of Tcore could risk pregnancy outcomes.

The study found minor changes of Tcore among outdoor workers with the rise of air temperature and muscular activity. Among indoor workers Tcores did not change much, but rather remained at the comfortable level of WBGT throughout the work period. However in both cases the One-way Anova proved the hypothesis (p=0.003).

Maximum Tcore of outdoor workers at many points of work were up to 37.5°C or more, which might cause the onset of adverse effects on pregnancy, as discussed earlier. Maternal heat stress was first observed by Marshall Edwards. He found that pregnant guinea pigs had miscarriages after exposure to environmental heat waves (40 to 42°C) for 2 successive days.[33] Later, detailed research and reviews indicated that heat stress during the first months of pregnancy could increase the risk of congenital defects, particularly of the central nervous system, or spontaneous abortions as a result of anomaly: fetal growth, gestational age, or mental health or stillbirth during the second to third trimester.[39-42] Several mechanisms for this teratogenicity were identified, such as DNA fragmentation, nuclear chromatin clumping, arrested mitosis, alteration of the cytoskeleton, and disrupted circulation.[33,43-47] Hence, it is proposed from our study that outdoor strenuous work during pregnancy might cause miscarriages (from anomaly) or other adverse outcomes.

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