Physiological Thermal Strain of Rice Farmers in Thailand: A Pilot Study

Alisa Yuangnoon[1*], Kanokrat Kruekimsome[2], Chamaiporn Kaiyasit[2]
Pornkamon Thoicharoen[3], Pongjan Yoopat[2,3], Kamiel Vanwonterghem[3]

[1]Biomedical Sciences Graduate Program, Faculty of Science, Rangsit University, Pathumthani 12000, Thailand
[2]Research Institute Rangsit University, Pathumthani 12000, Thailand
[3] Ergonomics Division, Faculty of Science, Rangsit University, Pathumthani 12000, Thailand
[*]Corresponding author, e-mail: alias.y@rsu.ac.th

Abstract

Global climate changes affect both productivity and the health status of people. In Thailand rice farmers - working under solar radiation - are confronted with heat stress. The objective of this cross-sectional study was to compare the physiological responses of the rice farmers among four harvesting tasks performed over 1 hour under hot conditions. The sample selection was a purposive sampling. Twenty-five farmers (six males and nineteen females) aged 48 ± 11 years were voluntarily participating in the project. Their main tasks included harvesting, threshing, winnowing, and rice screening. The used assessment methods concerned the perceived work strain (Subjective Workload Index; SWI), and the objective measured physiological reactions – heart rate - the cardiovascular load -, body weight loss, and the evolution of body temperature. The assessment criteria included heat stress index Wet Bulb Globe Temperature (WBGT; ISO 7243), and the cardiac response (cardiovascular load; CVL). The analysis of the results presented in the descriptive statistics of means and standard error of means. The results showed that the most intensive effort was harvesting (45.27%CVL) the winnowing task was the lowest (27.35%CVL). The additional environmental factors noise and lighting were significantly different between tasks. According to ISO 7243 in this study sample, threshing (70% manual, 30% mechanized) worked in the upper stressful zone where performing job and resting schedule should be adjusted to 25% work and 75% rest, followed by rice screening with a work-rest schedule of 50/50%. Harvesting and winnowing were situated in the safe zone from heat stress.

Keywords*: Heat stress, Cardiovascular load, body temperature, rice farming*

บทคัดย่อ

การเปลี่ยนแปลงของสภาพภูมิอากาศโลกมีผลกระทบต่อทั้งผลผลิตและสุขภาพของคน ในประเทศไทย เกษตรกรที่ปลูกข้าวซึ่งทำงานกลางแจ้งและได้รับรังสีจากดวงอาทิตย์โดยตรง อาจเกิดปัญหาสุขภาพการมีภาวะความเครียดจากความร้อน วัตถุประสงค์ในการศึกษาแบบตัดขวางในครั้งนี้เพื่อเปรียบเทียบผลการตอบสนองทางสรีรวิทยาของร่างกายในเกษตรกร ขณะทำการเก็บเกี่ยวและจัดเก็บเมล็ดข้าวเปลือก ระหว่างการทำงานในระยะเวลา 1 ชั่วโมง ภายใต้สภาพอากาศร้อนชื้น การเลือกกลุ่มตัวอย่างในครั้งนี้เป็นการเลือกกลุ่มตัวอย่างแบบเฉพาะเจาะจง อาสาสมัครผู้เข้าร่วมโครงการวิจัยเป็นเกษตรกร จำนวน 25 คน (เพศชาย 6 เหญิง 19 คน) มีอายุเฉลี่ย 48 ± 11 ปี ลักษณะการทำงานแบ่งออกเป็น 4 กิจกรรม ได้แก่ เกี่ยวข้าว นวดข้าว ฝัดข้าว และคัดข้าว ทำการศึกษาการตอบสนองทางสรีรวิทยาของร่างกาย ซึ่งประกอบด้วย แบบสอบถามความรู้สึกล้าจากภาระงาน หรือ Subjective Workload Index (SWI) วัดอัตราการเต้นของหัวใจ ระบบการไหลเวียนเลือด (ภาระงานของหัวใจและหลอดเลือด) น้ำหนักตัวที่ลดลง และการเปลี่ยนแปลงอุณหภูมิกายอุณหภูมิของร่างกาย ทำการศึกษาสภาพแวดล้อมด้วยดัชนีความเครียดจากความร้อนตามมาตรฐาน ISO 7243 (WBGT) วัดอุณหภูมิสภาพแวดล้อมบริเวณที่ทำงาน ผลการศึกษาพบว่าระบบไหลเวียนเลือดของเกษตรกรในกิจกรรมเกี่ยวข้าวมีค่าสูงที่สุด (45.27%CVL) ขณะที่กิจกรรมคัดข้าวมีค่า %CVL ต่ำที่สุด (27.35%CVL) ทำการวิเคราะห์และนำเสนอด้วย ค่าเฉลี่ยและค่าคลาดเคลื่อนมาตรฐานของค่าเฉลี่ย ผลการศึกษาพบว่า สภาพแวดล้อมมีค่า สภาพอากาศ เสียง แสงสว่าง มีความแตกต่างอย่างมีนัยสำคัญ การประเมินความเครียดจากความร้อนโดยดัชนีตามมาตรฐาน ISO 7243 จากกลุ่มตัวอย่างนี้ พบว่า กิจกรรมนวดข้าว อยู่ในขอบเขตที่สูงเกินกว่ามาตรฐานที่กำหนดซึ่งควรลดระยะเวลาการทำงานเหลือ 25% พัก 75% กิจกรรมคัดข้าวอยู่ในขอบเขตที่สูงรองลงมา ควรลดระยะเวลาการทำงานเหลือ 50% พัก 50% ขณะที่กิจกรรมเกี่ยวข้าวและฝัดข้าวอยู่ในระดับค่ามาตรฐานการทำงานภายใต้สภาวะอากาศร้อนที่ปลอดภัย

คำสำคัญ *: ความเครียดจากความร้อน ภาระงานของหัวใจและหลอดเลือด อุณหภูมิกาย เกษตรกรปลูกข้าว*

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1. Introduction

In Thailand, rice export is one of the main income resources of the country. In 2011, 14.5 million people were occupied in agricultural work (Yodjun, 2011). The reports about health problems of farmers referred to working conditions as awkward postures, heat, noise, dust, working hours, unsafe work mechanized machinery. Furthermore, Buranatratrevedh and Sweatsriskul (2005) reported risks for musculoskeletal disorders in Thai farmers varying from 16.6% to 75.9% as mentioned (Gates, 2007; ILO, 2003) and the tropical climatic conditions might affect farmers' thermoregulation, causing a physiological fatigue (e.g. sweat loss) during the professional activities. It is expected that when the physiological strain reaches or exceeds some thresholds, health and safety will be under thread. Adverse signs of fatigue are marked by e.g. exhaustion of sweat glands, failing cardio-respiratory functioning and reduction in producing output. An efficient prevention program requires the recognition of pre-symptomatic signs via an assessment of the farmer's reactions to the work-related factors. The measurement includes the evaluation of tasks (physical effort, intensity), the work organization, (e.g. duration, exposure times), and the existing environmental conditions especially the solar radiation which is referring to heat stress. Furthermore, the assessment of noise, lighting, body postures, etc. that may affect the employee's physical integrity.

The impact on the farmer's concern:

Heat stress and thermo-regulation

The core body temperature of human beings has to be kept in equilibrium at around 37°C. Beyond the limits, some parts in the cells are damaged permanently either by crystallization (deep cooling) or injured by over-heating. The consequences of heating up the body may vary from feelings of discomfort up to weakness and dizziness, stomach distress, nausea, abundant sweating or to conditions. When cooled by sweating stops, the body temperature rises exponentially to high critical values (≥ 40°C) reaching life-threatening levels in a very short time.

Heat disorders classified into five categories (Leithead and Lind, 1964): 1) Heat stroke: there is an increase of body temperature to dangerous levels (more than 40°C); 2) Heat syncope: there are signs of dizziness, fainting, and unconsciousness due to strong vasodilatation and reduced oxygen supply to the brain; 3) Anhidrotic heat exchange, caused by water depletion, excessing thirst, fatigue and it is often a pre-phase to heat stroke; 4) Heat-exhaustion: there are an excessive fatigue and muscular weaknesses due to salt depletion, muscular cramp may occur as well as nausea and vomiting; 5) Heat edema: the symptoms may include swollen feet and ankles in non-acclimatized persons, though these may disappear after a few days back into normal conditions. Burning wounds may occur when prolonged exposure of the skin to an air temperature of about 43.5 °C.

Heat exchange: Physiological strategies

The human body was equipped with an efficient thermoregulatory system with a dual physiological strategy: a first- line defense is oriented to increase the heat flux from the core of the body to the periphery where convection, conduction, and radiation can become operative. It was realized by peripheral vasodilatation and an increase in cardiac output to transport the heated blood to the skin. A second defense system becomes operative when the first measures are failing and are related to the more efficient cooling phenomenon: evaporation that requires a liquid: sweat. The onset of moisturizing the skin is regulated by the hypothalamus and reacts to the increase in body temperature that stimulates the sweat glands to increase their productivity. Finally, a third possibility concerns behavioral actions, which include conscious/unconscious lowered heat production by reducing the physical activity and by clothing adaptations (e.g. reflecting clothing against radiant heat such as flames or ovens).

Thermoreceptors are distributed all over the whole body. The cold and hot receptors detect respectively the loss from the body (cold) or gain to the body (heat) depending on the environment by which the core temperature is set as a comparing threshold.

Heat stress and thermal strain assessment

The WBGT index is an index that is used for heavy physical activities whereas PPD/PMV (ISO 7730, 2005) based on Fangers' equation (1970), serves as the comfort index (used for office/administrative work). Even though many indices have developed, none can predict with some degree of accuracy the psychosomatic reactions of the exposed population because of the crucial intra-and inter-individual differences. It is evident that for extreme hot or cold conditions, the primary physiological reactions will be close to the average at 37°C + or - 5°C.

In Thailand, most of the research reports were publishing health problems in rice farmers that come from a perceived rating score, questionnaires, and objectified environmental data. There are not many published data on physiological responses during work of Thai rice farmer.

2. Objective

The purpose of this study was to assess the physiological strain over a 1-hour work period of 4 tasks that Thai farmers normally perform during their daily job under tropical working conditions.

3. Material and methods

Figure 1 Farmer 4 activities: (a) harvesting, (b) threshing, (c) winnowing and (d) rice screening

3.1 Subjects

This cross-sectional study was conducted at Klong Luang, Pathumthani, Thailand in December 2015**.** The Human Ethics Committee at Rangsit University certified the project proposal before beginning the research. The sample selection in this study was a purposive sampling with the following; criteria a) they are male or female, b) they have work experience of more than ten years, c) They have no health problem on heart, thyroid, and musculoskeletal diseases. Twenty-five farmers (6 males and 19 females), aged 48 ± 11 years, voluntarily participated in the project. Their work experience in farming was 13 ± 2 years. All participants had informed about the objectives of the project, and they signed an informed consent before starting the measurement procedure. They wore double-layer clothes: the inside with a short sleeve T-shirt covered by a long sleeve cotton shirt (Figure 1b) combined with long trousers, socks, sports shoes or plastic boots, gloves and hat. The harvest tasks include 4 manual activities: harvesting, threshing, winnowing and rice screening.

3.2 Tasks and type of work

Harvesting: Concerns manual work cutting the rice stalks by using sharp knives or sickles (http://www.madehow.com/Volume-5/Rice.html#ixzz4XXEJivN7) in a forward bend posture, collecting the spikes from the rice plants and put the bundle of spikes in a plastic bag (size 20x34 inches). A production cycle is about 15 bundles in 1 hour, and farmers harvest 3 to 4 times a day (Figure 1a).

Threshing (70% manual: 30% mechanized): The threshing task as shown in Figure 1b, includes two operations. *The first operation* performed the work manually: the farmers use their hands, hold the pen and push rice paddy out of the chaffs into a basket, then manually shake the basket to remove the chaff, and put the rice paddy into bags. The rice from this part will be using for next breeding. The productivity is about 33 plastic bags per hour. *The second operation* concerns a mechanical threshing process and manual process. 3-4 farmers perform the threshing process: one ship the bags of harvested rice from the field to the machine, a second one lift the bags and fills the machine, the third and fourth subjects finally fill the buckets. Their productivity is about four rice sacks in one hour (i.e. 25 small bags, each small bag take 1-2 minutes).

Winnowing (70% manual: 30 % mechanization): The winnowing operation (Figure 1c) is to separate waste from rice in the husks that passed the threshing process in the previous task. The first operator drives and lifts the packs of rice-sacks to a high-levelled platform, where the second operator (holding a hooker) waits and opens the bags to bring the materials down into the machine. The third operator (at floor level) waits and controls the goods falling into a bucket and fills the rice bags. The fourth operator brings the finished rice bags to a cart and brings them to a next station for a sorting process. The productivity for getting good paddy per one hour is about 19 sacks from a total of 22 prepared sacks. Each sack takes about 2-3 minutes.

Rice screening (70% manual: 30% when mechanized): The objective of the rice screening is to separate the rice qualitatively in the husks (good and bad) by a fine tuning machine that screens the end product. The tasks occupy 3-4 persons. The duties of these operators are almost identical to that of winnowing, although the machine has a different function. The first man, the driver; lifts the sacks from the winnowing station to the upper level. The second person, standing at a higher floor level, hooks the bags, to open and to pour into the machine. A third operator will stand at floor-level, waiting for the cleaned paddy falling into the bucket and fills the rice bags, and the fourth operator handles the finalized materials onto a cart and brings it to sort at the final station. The net production for getting 14 sacks of good paddy in one hour requires in total 26 bags of raw material. One bag takes about 2-3 minutes (Figure 1d).

3.3 Assessment criteria

The assessment is divided into two phases: before and after work and includes the measurement and evaluation of the stress-strain reactions. The variables included a heat stress index (effort and climatic conditions) and the physiological factors before, during and after the job. Heart rate was measuring (before, during and after) by the Polar equipment (Finland) from which the %CVL was calculated (Yoopat et al., 2002). The body weight and ear temperature (before and after) measured by a weight balance and an ear thermometer (Ellab A/S, Denmark) as well as the perceived work strain (after), obtained from the Subjective Workload Index (SWI; Yoopat et al., 2012). The climatic conditions obtained from temperature measurements and the WBGT-Index ($0.7\ t_w + 0.2\ t_g + 0.1\ t_a$) (ISO 7243, 1982; Quest equipment, USA), combined with the cardiac response during work. The noise during work measured by sound level meter (SLM's; Rion-NL-32, Japan). Lighting at workplaces measured in Lux by Lux meter (Digicon; LX-70 Japan) and in cd/m^2 unit by Spot Luminance (Minolta LS-110, Japan).

3.3.1 Subjective Workload Index (SWI)

The SWI questionnaire divided into three parts: a) personal information, b) details of the work activities and c) information on environmental factors relevant to the working conditions. The SWI used in the study by asking the farmers to rate their perceived level of discomfort related to work via six adverse work-related factors: fatigue, risk, concentration, complexity, work rhythm and responsibility; and from 2 compensating factors: (positive motivation) their interest in the job and the degree of autonomy. They rate from ‘0’ means no discomfort up to ‘10’ means the most discomfort level or the most favored for the positive factors. The SWI is calculated using the formula: [(sum of 6 negative factors - the sum of 2 positive factors)/8]. SWI values of 2-3 represent a moderate discomfort with some warning signs. If SWI values exceed 3 or more, the degree of discomfort increases and improvement measures should take into consideration with some necessity: the higher the score, the shorter the term for implementation (Vanwonterghem et al., 1985). From an SWI score of 2.5 or more, each farmer is asked to express the perceived discomfort for the part of the body that was the most affected.

3.3.2 Cardiovascular load (CVL) and the distributed impact of effort (M - metabolism) or climate (T - temperature) on the recovery heart rate (EPCM, EPCT)

The relative cardiovascular load (%CVL) was calculating by heart rate according to the formula: %CVL = 100[(HRwork-HRrest)]/HRmax8h)]. Where HRwork = average heart rate during work performance, HRrest = lowest heart rate registered during sitting and rest for 5 minutes, HRmax8h = maximum heart rate for an 8-hour work period that is 1/3(220-age) + HRrest. %CVL is classified as follows: < 30%CVL means no significant fatigue, no health risk and no action required. 30-60 %CVL means a moderate level of fatigue; peak loads should reduce within a period of months; 61-100% CVL means a high degree of fatigue, the workload should be reduced within a period of weeks (Yoopat et al., 2002).

The cardiovascular response was completing by calculating a distribution of heart rates influenced by climate: ECPT = increased of cardiac pulses due to temperature; or by metabolism ECPM = increased of cardiac pulses due to the metabolic effort (Vogt et al., 1973). ECPT and ECPM are calculated as follows: ECPT = [1/3(P3 + P4 + P5) – P0]; ECPM = (P1 + P2 - P3) – [1/3(P3 + P4 + P5)]. Where P 1…P5 are the recovery heart rate at minutes 1…to five after work; P0 = heart rate at rest before starting work as it reflects either the recovery from the effort (acidosis) or from the thermoregulating system (blood circulation to the periphery - skin- to cool down).

3.3.3 Body temperature

The aural temperature was measuring by a digital infrared ear thermometer (Microlife, Switzerland). The assessment criteria are according to Mairiaux and Malchaire (1990) - safe at an increase of the core body temperature of: < 1°C: safe; 1.0-1.3 ^{o}C is the alarm level; > 1.3 is a dangerous level.

3.3.4 Loss of body weight

Body weight was measured before and after finishing tasks by digital balance ‘Tanita’ with the accuracy of $\pm$0.1 gram. The amount of body mass loss (%) classified as the following thresholds (Brouha, 1960; Mairiaux, 1989): 0.0-1.9%, no risk, no action required; 2.0-2.5%, risk for dehydration, medium-term actions required to reduce workload.

3.4 Physical environment

3.4.1 Climate

Environmental conditions: WBGT Quest temp Area Heat thermometer was used to measure three types of temperatures (WBGT; ISO 7243, 1982):

- Dry – bulb (Td) thermometer measured the temperature of the surrounding air, sheltered against solar radiation
- Natural – wet – bulb (T_{wn}) thermometer measured the humidity level about humidity based on the eventual cooling from spontaneous water-evaporation at the supply tip of the wet bulb thermometer, wrapped with water-saturated cotton wool wetted by distilled water (evaporation capacity principle)
- Globe thermometer (Tg), a circular black-mat coated copper sphere, to assess the radiant heat (IR, UV) which depends on the direction of light or hot objects in the environment temperature sensor

3.4.2 Lighting

Two types of equipment measured light at the workplace. Illuminance was measured by lux meter in the unit of Lux; Luminance was measured by spot meter in the unit of cd/m^2.

3.4.3. Noise

In this study, the noise was measuring by a sound level meter (Rion NL-32, Japan). A level of more than 85 dB(A) over an exposure of 8 hours interpreted as the risk for hearing damage. The noise level of 85 dB(A) to 90 dB(A) was an exposure limit for the 8-hour work day. The level of more than 90 dB(A) over an exposure of 8 hours interpreted as the risk for hearing damage (https://www.ccohs.ca/oshanswers/phys_agents/exposure_ext.html) (14 February 2017).

3.5 Statistical analysis

The results were presenting in the descriptive statistics of means and standard error of the means.

4. Results

4.1 Physical characteristics

The anthropometric data of the participating farmers are summarized in Table 1. Their rest heart rate and body temperature were in the usual range of healthy persons. The body mass index ranged from 25.04 to 28.08 kg/m^2.

Table 1 Physical characteristics of the subjects

	Harvesting (Mean ± SE)	Threshing (Mean ± SE)	Winnowing (Mean ± SE)	Rice screening (Mean ± SE)	Total (Mean ± SE)
N	5	5	10	5	25
Age (years)	53.60 ± 2.93	44.80 ± 5.15	46.90 ± 4.09	46.00 ± 6.19	47.64 ± 2.31
Height (cm)	154.40 ± 2.64	156.20 ± 1.24	159.90 ± 3.32	158.60 ± 4.04	157.80 ± 1.64
Body weight (kg)	67.26 ± 6.71	61.74 ± 4.88	64.39 ± 3.75	69.84 ± 4.89	65.52 ± 2.35
BMI (kg/m^2)	28.08 ± 2.20	25.26 ± 1.81	25.04 ± 0.89	27.80 ± 1.81	26.25 ± 0.76
Experience (years)	16.00 ± 6.20	15.42 ± 6.63	11.66 ± 3.42	9.27 ± 3.93	12.80 ± 2.30
Body temperature (^{o}C)	37.14 ± 0.20	36.66 ± 0.09	36.63 ± 0.20	36.48 ± 0.05	36.71 ± 0.10
Resting heart rate (bpm)	75.60 ± 6.05	83.00 ± 7.15	82.90 ± 3.82	69.20 ± 6.45	78.72 ± 2.79

4.2 Physiological response

The physiological responses of farmers showed in Table 2. Their perceived SWI score was 2.18 ± 0.30; the lowest score was in the harvesting task, and the highest score was in the threshing task.

The average heart rate at rest was 78 ± 2.79 beats per minute. The average heart rate at work was 94.71 ± 3.11 beats per minute. According to cardiovascular load threshold limit, the harvesting task was 44.25 ± 10.49 %CVL, threshing was at the limit of 30.89 ± 5.45% and below the threshold in the winnowing and rice screening task.

The aural temperature after work increased with about 0.05^{o}C which was still in the safe zone. The body weight loss was 0.35 kg which situated in the safe zone. The recovery heart rate increased in ECPM (10.80 ± 2.12) more than ECPT (5.64 ± 1.77) indicated that the body needs blood to supply the manual muscle work.

Table 2 Physiological respondents in selected activity (Mean ± SE)

	Harvesting	Threshing	Winnowing	Rice screening	Total
N	5	5	10	5	25
Work heart rate (bpm)	94.42 ± 2.71	100.72 ± 9.84	97.63 ± 4.07	83.16 ± 8.08	94.71 ± 3.11
%CVL	44.25 ± 10.49	30.89 ± 5.45	27.71 ± 4.69	26.33 ± 3.14	31.38 ± 3.18
Aural temperature (^{o}C) Before	37.14 ± 0.20	36.66 ± 0.09	36.63 ± 0.20	36.48 ± 0.05	36.71 ± 0.10
Aural temperature (^{o}C) After	37.00 ± 0.26	37.00 ± 0.10	36.66 ± 0.12	36.40 ± 0.07	36.76 ± 0.09
Body weight loss (kg)	0.10 ± 0.27	0.39 ± 0.19	0.39 ± 0.15	0.47 ± 0.08	0.35 ± 0.09
SWI	1.25 ± 0.78	2.83 ± 0.49	2.14 ± 0.42	2.53 ± 0.88	2.18 ± 0.30
ECPT	9.67 ± 6.67	3.13 ± 0.72	5.74 ± 3.02	3.93 ± 1.26	5.64 ± 1.77
ECPM	12.93 ± 3.94	14.67 ± 7.53	7.26 ± 2.73	11.87 ± 4.20	10.80 ± 2.12

CVL reflects a rather low intensive work for winnowing and rice screening which explained as semi-mechanized work. Threshing is at the fatigue limit for 8 hours of work and can be explained by the repetitive movements of the upper limbs and obviously less influenced by the climatic conditions (low EPCT). The most stressful job is harvesting (CVL of 44.25%) which explained by an intensive work in the upper limbs (cutting, holding material) and a negative static postural load (bent during cutting). Additionally, workload comes from the solar radiation (EPCT) of which the back muscle is bent in a significant of the time (almost permanent bent) receiving the solar radiation. That can explain their importance on the EPCT (nearly 43%) - the highest EPCT ratio is for winnowing (47% EPCT) but at less than 30%CVL. Obviously, the radiant heat impact for winnowing comes from the radiation via the walls and ceiling (indirect), where the harvesters are subject to direct sunlight. However, for comparison between ECPM and ECPT, the results show that ECPM value is higher than ECPT values in all activities.

The maximum muscle workload found in manual threshing in which the ratio of metabolism to thermoregulation is the most intensive physical work, but have fewer problems with the climatic conditions (shadow of heat) although the ration for the energetic, dynamic workload is the highest of all jobs. The main risks for threshing are situating in the domain of musculoskeletal disorders in the upper limbs. Harvesting was done in the early morning (before reaching the highest thermal load), a threshing task performed in the early afternoon, winnowing and rice screening were done both in the late morning (but have a lower impact on heat stress). The values of body temperature seem to influence the drinking behavior (water intake) that affects the thermoreceptors in mouth-head. SWI is at an acceptable level for all, and none the least for harvesters which estimate their workload as very low. Threshing workload was higher than all other activities; SWI 2.83 is moderate discomfort with warning signs.

4.3 Physical environment

WBGT and its composing factors, noise and light at work show in Table 3. The highest WBGT was in the threshing task (33.00 ± 0.37 °C)) and the lowest was in harvesting (28.15 ± 0.06 °C) as they started work in the early morning before the sun-heat begin to burn, and lower heat-impact was during winnowing (interior building, no direct sun exposure). The relative humidity was the highest in harvesting (early morning mist) and the lowest in full sunshine (screening). Where harvesting produced the most physical effort (CVL) and the most endogenous heat, it has the profit of the lowest climatic conditions, and as such a logic behavioral work-management. However, attention should be aware whenever the morning conditions worsen.

Noise nearly reached the threshold limit in the threshing task, remaining below the 90 dB(A) limit in the other tasks, and a hearing protection (plugs) should provide to the ‘threshers.' Lighting did not affect the efficiency because the levels were high as work in the open air under solar radiation.

Table 3 Environment parameters of studied occupational outdoor environments

	Harvesting (Mean ± SE)	Threshing (Mean ± SE)	Winnowing (Mean ± SE)	Rice screening (Mean ± SE)	Total (Mean ± SE)
WBGT (°C)	28.15 ± 0.06	33.00 ±0.37	30.19 ± 0.06	31.96 ± 0.17	30.70 ± 0.35
Tw (°C)	27.96 ± 2.01	28.10 ± 0.37	25.96 ± 0.02	27.16 ± 0.04	27.03 ± 0.42
Td (°C)	28.78 ± 0.09	34.10 ± 0.37	31.32 ± 0.08	33.42 ± 0.11	31.79 ± 0.39
Tg (°C)	33.73 ± 0.11	44.18 ± 0.07	42.97 ± 0.01	48.08 ± 0.05	42.38 ± 0.96
%RH	69.60 ± 0.16	N/A	48.05 ± 0.03	44.08 ± 0.05	52.44 ± 2.30
Noise (AP)(Hz)	55.20 ± 0.12	84.40 ± 3.06	81.19 ± 0.09	74.63 ± 0.15	75.32 ± 2.23
Light (Lux)	706.20 ± 2.53	244.51 ± 11.61	829.88 ± 0.03	899.64 ± 0.15	702.02 ± 48.45
Light (Cd/m^2)	522.68 ± 9.26	1110.80 ± 171.13	829.88 ± 0.03	899.64 ± 0.15	702.02 ± 48.45

4.4 Heat stress

The result that represents the combination of heat stress and strain of the body was shown in Figure 2, that allow driving safe work-rest schedules. This result (adapted from ISO 7243, 1982) indicates that threshing was situating in the highest heat stress risk (work and rest schedule should be 25% work and 75% rest). Rice screening should distribute work and rest at 50% ratio. Harvesting and winnowing are in the safe zone.

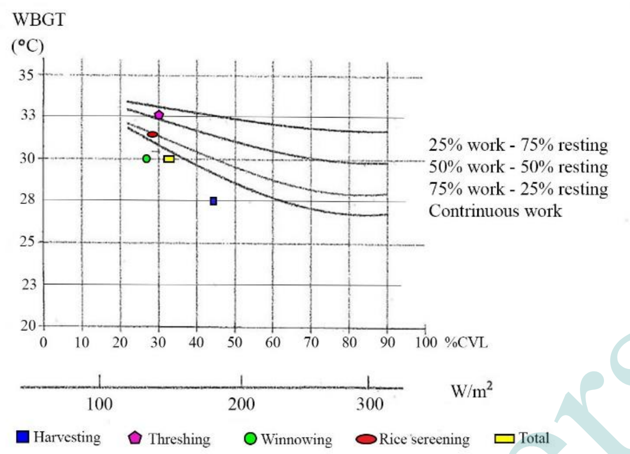

Figure 2 WBGT index when combined with the workload of cardiovascular system (%CVL)

4.5 Body discomfort

The result of body discomfort shows in Figure 3. Farmers rate their discomfort according to their farmer task mainly at the forearms as follows: harvesting (31.53%), threshing (39.13%), winnowing (36.84%), and rice screening (36.36%).

The highest perceived discomfort for the rice farmers during harvesting seasons is found in the upper arms (35.98%) whereas the lowest in the neck (2.26%). Calf muscle (20.40%), lower leg & low back (13.20%), shoulder (12.39%), upper back (10.85), and upper legs (5.25%) situated between the previous mentioned body parts.

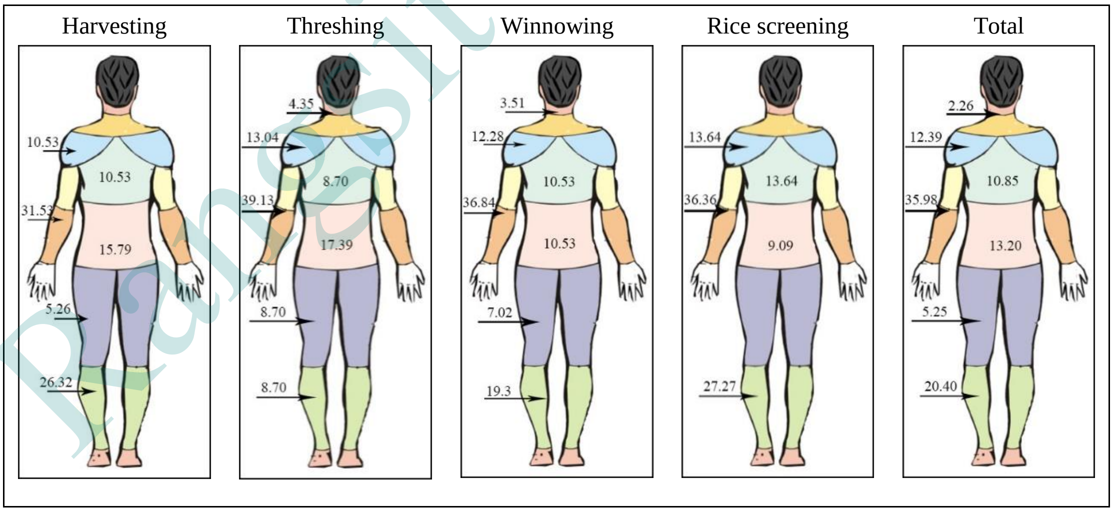

Figure 3 The farmers' body discomfort shown in percentage of parts of the body affected

5. Discussion

In taking into account that the data had been collecting during the cooler season (December), it may expect that in the hot-dry or more wet-humid periods the impact on the operators may evolve differently, although 'harvesting' (2 to 3 times a year) may vary following the season.

The physical efforts of the farmers are characterized by their functions. The manual harvesters - working in bend postures soliciting the upper limbs to collect and hold the cut materials - have to highest muscle load (almost 45% CVL where 30% is the 8 hours limit). However, they operated in the early morning when the climate was still moderate which corresponds to the peak heart rate of the rice harvesters reported in Sahu, Sett & Kjellstrom, (2013). In the study, the air temperature ranges were 31 - 33.5 ^{o}C (122 ± 9.5 beats per min, and 35 - 36 ^{o}C (132 ± 11.5 beats per min) and (119 ± 10.5 beats per min) at 28 - 30 ^{o}C (Sahu, Sett and Kjellstrom, 2013).

Threshing - Less physical intensive reach the 30% CVL limit - but according to the WBGT index - the combination of effort and heat exposure - falls under a more heat-stressing condition and requires a specific work-rest scheme (25% work, 75% rest). A job analysis with measurement of muscle load in the upper part of the body advised as it cumulates local fatigue in arms, shoulder, and trunk run into a condition where work-rest schemes should be adjusted. For winnowing and rice screening, the result corresponds with the findings of Lundgren, Kuklane, and Venugopal (2014) who classified the intensity of agricultural work as ‘moderate’ with a WBGT value of 29.6 ± 0.3 ^{o}C.

From the WBGT-graph ISO standard, ISO 7243 (1989), the post-harvesting process shows that the combination of the effort-climate reactions fit with the adjustment in work-rest schemes, mainly due to the heat stress (temperature-humidity) and solar radiation. A protective screen (reflecting) at about 1 m above head-height in a slope of about ’40-45 degrees, allows a spontaneous ventilation that could reduce the thermal impact of winnowing (nearby building) but mechanical ventilation could reduce the impact as well.

The physiological results ask for an adjustment in work-rest schemes in some tasks. Either because muscle fatigue (especially harvesters that cannot protect and the operational posture cannot change) merit resting periods to allow muscles to restore from the efforts (shoulders, back, and arms) as the impact of isotonic and isometric muscles affect the cardiac load.

The EPCM are in all jobs dominant but especially in harvesting which confirms the impression of the real workload seriousness in the farmers’ job.

Concerning the other measurements (weight loss and body temperature) no significant conclusion can be made because the ‘drinking’ behavior of the subjects, a behavior that is necessary to maintain the water-housekeeping in the body and that has to be respected. The drinking of water during work explains the low weight loss due to sweating (quantity of water volume intake) and the temperature of the water (lower than body temperature) that could have an effect on the inner-ear thermal condition (local cooling effect). For a correct interpretation of these effects, the quantity, temperature, the nature, and frequency of fluid intake should envisage.

The highest level of discomfort in the upper arm confirmed by the study of Vyas (2014) who reported severe to very severe pain in the upper arms, shoulders, and neck, thighs and lower back, and legs, because of repetitive movement and due to heavy material handling in harvesting activities. Discomfort related to **a loss** in productivity may affect harvesters’ income. As indicated in the previous study, the daily payments were related to the number of rice bundles the harvesters cut and assemble per day (Sahu, Sett and Kjellstrom, 2013).

6. Conclusion and recommendation

According to heat stress index (adapted WBGT ISO 7243), the physiological response in this study showed some risks in the working conditions combining ‘climate and effort.’ The cardiovascular system (CVL) in moderate weather (harvesters) remains in an acceptable work strain, whereas the other jobs in open air (threshing and rice screening) should modify the ‘effort and exposure time.’ Harvesting and winnowing in this study climatic condition are jobs that can be performed continuously safe: especially winnowing that happens in a sheltering building and is partly mechanized. even some parts performed under the shelter of the building and rice screening under full radiation load, threshing should - following the same standard - reduce the effort-rest schedule: a sun protector could improve the heat exposure, the impact on CVL is more effort related (EPCM ratio). Somewhat more critical for ‘harvesters’ CVL that for about 57% caused by effort (ECPM) but 43% by temperature, and this already in the fresher early morning condition. However, from the WBGT graph, the climate should not raise too much to become also critical for this evaluation criterion, and every interaction between the factors merit to be analyzed in depth and over more practical sessions before formulating binding conclusions.

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