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Risk due to heat during work in agriculture

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Summary
Work environments with high temperatures are defined severely hot environments, even if there is also a high level of humidity in the air, in relation to the characteristics of the type of work being carried out, and the clothes worn by the workers. In these environments in order to avoid accumulating heat, considerable care must be taken in the thermo-regulation system of the body, through perspiration and vasodilatation mechanisms.

Key words: *predict heat strain, severely hot environments, working in agriculture, thermoregulation*

Introduction

Working in agriculture behaves workers to be exposed to sundries risk factors e.g. chemical agents, noise, posture, loads heading etc. Among these the most peculiar and the least investigated is constituted by microclimatic conditions during the different work steps. Warm and cold thermal stresses are estimated by microclimatic index: in particular, in agriculture range a heat strain condition come strain high temperature presence during horto-fruit harvesting, on field or in greenhouses. Therefore we are talking about "severely hot environments" as laid down in UNI EN 27243.

In order to evaluate the risks for agricultural operators during the fruit and vegetable harvest, we have set parameters and collected data regarding air temperatures, average radiating temperatures, air velocity, by using instruments with characteristics conforming to the UNI EN ISO 7726 standard. These parameters as well as the subjective parameters, clothes and physical activity, were used to calculate the Predicted Heat Strain (PHS) of the exposed operators, according to the UNI EN ISO 7933:2005 standard. Furthermore, the environmental parameters and subjective parameters collected in greenhouses were used to calculate the WBGT (Wet Bulb Globe Temperature) according to the UNI EN 27243 standard.

Material and methods

PHS Model (Predict Heat Strain) and software realized.

The P.H.S. "Predict Heat Strain", takes as input environmental parameters as air temperature t_a, the average radiating temperature t_r and the speed of the air V_a. Besides subjective parameters which are related to the operators, are considered: metabolic rate (M_{et}), clothing insulation (I_{cl}), the duration of activity, weight and height of the operator, the speed with which the work is carried out in relation to the direction of the wind, and the acclimatization of the worker.

In exchange the P.H.S. model supplies us with some output which enables us to evaluate the probability of thermal collapse due to the environmental and personal conditions of operators working in severely hot environments.

The parameters of importance for this evaluation are mainly:

- $C\ res = 0,072\ cp * V * (t_{ex} - ta\ /ADU)$ (heat flow for respiratory convection);
- $E\ res = 0,072\ Ce* V* (W_{ex} - W_a/ADU)$ (heat flow for respiratory evaporation);
- $C = hcdyn * f_{cl}* (t_{sk} - t_a)$ (heat flow by convection to the skin surface);
- $R = hr * f_{cl} * (t_{sk} - t_r)$ (heat flow by radiation to the skin surface);
- $t_{sk} = 0,7165\ tsk,i\text{-}1 + 0,2835\ t_{sk}$, eq (temperature of the surface of the clothes).

The final parameters that are useful for calculating the predicted thermal load are:

- Rectal temperature t_{re} [°C]: represents the internal temperature of the operator with a maximum temperature of 38°C;
- Total water loss [g]: establishes a maximum water loss compatible with the maintenance of the normal physiological parameters of the individual, according to the work carried out;
- Dimloss50 [g]:is the maximum water loss for the average subject;
- Dimloss95 [g]: maximum water loss for 95% of the population of workers;
- Imposture [min]: represents the time after which the rectal temperature reaches its maximum limit.

The P.H.S. calculation is arduous; we can make it easy using software in "Visual Basic 6.0" programming language, inserting and modifying the analytic processes and the algorithm fixed by UNI EN ISO 7933:2005. The software was developed by the department GEMINI – Laboratory of Ergonomics and Occupational Safety and Health– of the University of Tuscia - Viterbo, by Andrea Colantoni and Massimiliano Bernini. In figure 1, you can see a data form, as well as the various instruments used for the experiment.

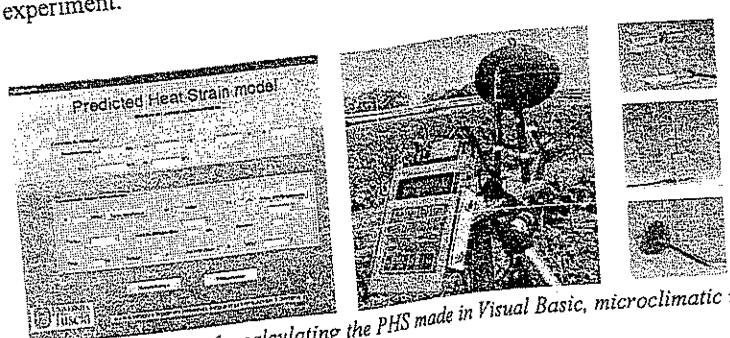

Figure 1. Software for calculating the PHS made in Visual Basic, microclimatic unit LSI Babuc, and probes for collecting environmental parameters.

WBGT index

Several different criteria can be used for the evaluation of thermal stress in hot environments, which are based on the elaboration of as many indexes. The UNI EN 27243:1996 standard refers to the W.B.G.T. (Wet Bulb Globe Temperature) index, whose scope is to keep excessive thermal stress of people working in hot environments under control, assuming a maximum limit which implies a limited increase (1°C) of the body temperature. According to the ACGIH the maximum limits of the WBGT index are calculable in relation to the work load and the work/rest alternation rate and presume light clothing is worn (0,4 ÷0,5 clo) with normal permeability to steam (table 1).

Table 1. Maximum values of the WBG index.

Work/rest	Work load 1		
	light	moderate	heavy
Continuous work	30,0	26,7	25,0
75% work - 25% rest	30,6	28,9	25,9
50%work - 50% rest	31,4	29,4	27,9
25% work -75% rest	32,2	31,1	30,0

[1]It is only possible to exceed the indicated limits following a medical check-up which confirmed the subject's tolerance for working in hot environments

The index is calculated with the following equations:

WBGT = 0,7 Tnw + 0,2 Tg + 0,1 Ta (external with exposure to sun);

WBGT = 0,7 Tnw + 0,3 Tg (internal and external without exposure to sun) having indicated with:

- T_{nw} the temperature (°C) measured with a bulb covered with muslin dampened with distilled water at room temperature, which is not subject to thermal radiation, and which is influenced by the natural ventilation of the environment;

- T_g the temperature(°C) measured with Vernon's globe thermometer, which consists in a bulb placed in the centre of a copper ball painted opaque black on the outside. The metal surface, heated through radiation, transmits a quantity of heat proportionate to the thermal radiation, the temperature and the speed of the air in the environment to the air contained in the inside of the sphere;

- T_a the temperature (°C) is the temperature of the air measured with a dry bulb which is not subject to thermal radiation and exposed to ventilation between 2 and 4 m/s;

The WBGT indexes calculated in this way, were compared to the limits of reference (table 2) considering the workers' metabolic expenditure between 130 and 200 W/m^2.

Table 2. Limits of WBGT on the base of the UNI-EN 27243.

Class	Metabolism, M		Reference value of WBGT [°C]			
			Acclimatized subject		Unacclimatized subject	
	[W/m2]	[W]				
0	M<65	M<117	33		32	
1	65<M<130	117<M<234	30		29	
2	130<M<200	234<M<360	28		26	
			stagnant air	moving air	stagnant air	moving air
3	200<M<260	360<M<468	25	26	22	23
4	M>260	M>468	23	25	18	20

Instruments

To survey environment sizes we have utilized unit LSI BABUC M with six inputs was used (figure 1), connected to 3 probes: a psychometric probe BSU102 with forced ventilation and a distilled water tank, used for measuring the air temperature (ta) and the temperature of the damp bulb (tw); an anemometric probe with hot wire BSV101, to measure the speed of the air (Va); a global thermometric probe BST131 in black opaque copper (reflexion < 2% ASTM 97-55) for measuring the average radiating temperature (try) (probes in compliance with regulation ISO 7726).

Monitored companies

A company situated on the Latium coastline was monitored, evaluating with the PHS model the risk of excessive thermal load for workers harvesting fruit and vegetables in the fields. Three greenhouses in Viterbo were examined with the aim of evaluating the microclimatic environment in protected places, and the consequent indexes of thermal stress for the people working therein. The greenhouses have carrying structures in steel with tunnel shaped sections covered with plastic film and openings for entry and ventilation. The work carried out in the greenhouses concerned the cultivation of vegetables (tomatoes, water melon, peppers).

Monitoring have been done from July to August, during the whole day (a work day), during the harvest period. Monitoring have been done in tree greenhouses near Viterbo. The work in the three greenhouses examined is split up in the course of the year, with a short break in the summer. Working hours are from 7.00 to 12.00 am and from 2.00 to 5.00 pm. The surveys were carried out from the beginning of February to the end of July.

During the hot season the workers go into the greenhouses at least once a day (more frequently twice a day) for a maximum of 40 minutes, with the task of watering the crops with sprinklers (also done during surveys regarding microclimatic parameters).

The workers' clothing varies considerably depending on the season: in the colder seasons clothing is heavier, with long trousers and sweaters, which are taken off on entering the greenhouse; in the hotter seasons clothing is very light.

Results

Risk valued through P.H.S. method during harvest period on field

In table 3 are pointed out input parameters, concerning the harvesting of crops in the fields. The tests were carried out on 8 workers taking into consideration their weight, height, type of work, insulation from clothes, their metabolic expenditure in relation to their work and lastly the state of acclimatization in relation to the environmental parameters.

The average values of environmental parameters, measured near workplaces, have been: t_a = 30°C; t_r = 42,3°C; p_a = 3,48 kPa, on fields and t_a= 30°C; t_r = 42,3°C; p_a = 3,48 kPa e t_a = 28,3°C; t_r = 39,9°C; V_a = 3,0 m/s; p_a = 2,06 kPa, during the melon harvest. Table 4 shows outputs data of PHS model.

Discussion and Conclusions

Analysed data of harvesting in the fields with the PHS model, don't show any particular risks for the workers (tre < 38°C). However we must consider that the experiment should be extended over a greater number of days or more seasons, as the risks are evidently correlated to the climatic conditions of the area. Furthermore we must remember to put plenty of drinking water at the workers' disposal.

Table 3. Input data for calculating the thermal load according to ISO 7933:2005 standard.

Worker 1	Personal information		A_{DU}	acclimatization	work position	I_{cl}	Met	Work
	weight	height						
	[kg]	[m]	[m^2]	[%]		[clo]	[W/m^2]	
A	58	1,70	1,67	100	standing	0,5	150	Harvesting peppers
B	80	1,75	1,95	100	standing	0,5	150	Harvesting peppers
C	62	1,69	1,71	100	standing	0,5	150	Harvesting aubergines
D	63	1,75	1,76	100	standing	0,5	150	Harvesting aubergines
E	78	1,80	1,97	100	standing	0,5	150	Harvesting tomatoes
F	90	1,70	2,01	0	standing	0,5	150	Harvesting melon
G	85	1,75	2,00	0	standing	0,5	150	Harvesting melon
H	70	1,65	1,77	0	standing	0,5	150	Harvesting melon

1 All workers can drink while working (DRINK= yes)

Table 4. Output values referring to the phases of harvesting in the fields.

	Workers							
	A	B	C	D	E	F	G	H
t_{sk} [°C]	35	34,9	34,23	34,23	34,25	34,8	34,1	34,1
C_{res} [W/m²]	0,96	0,96	0,96	0,96	0,96	1,10	1,10	1,10
E_{res} [W/m²]	6,62	6,62	6,62	6,62	6,62	9,60	9,60	9,60
C [W/m²K]	56,82	56,53	51,81	51,81	51,81	78,50	78,59	78,71
R [W/m²K]	-46,16	-46,29	-48,37	-48,37	-48,36	-43,41	-43,38	-43,34
t_{re} [°C]	37,6	37,5	37,6	37,6	37,5	37,5	37,5	37,5
Total water loss [g]	2946,3	3461,4	3.021,0	3118,4	3429,7	2669,9	2660,1	2345,5
$Dimloss_{50}$ [g]	4350	6000	4650	4725	5850	6750	6375	5250
$Dimloss_{95}$ [g]	2900	4000	3100	3150	3900	4500	4250	3500
$Dimloss\ t_{re}$ [min]	480	480	480	480	480	480	480	480

On the other hand the data gathered in the greenhouses shows that the microclimatic risks for workers must not be underestimated. In particular during the hottest hours of the day, from April onwards, hot temperatures can be reached to expose the workers to the risk of sun stroke (determined by using the WBGT index).

But even without adding to these levels of risk, the problem of sudden changes in temperature on entering or exiting greenhouses still remains.

In both cases the risks are amplified by the lack of acclimatization of the workplace. This factor seems to be a fundamental element of prevention. However this is not easy to accomplish, because the microclimatic conditions inside the greenhouses must be kept constant even in the workers' absence: therefore a gradual acclimatization inside the greenhouses is not possible. A possible solution to this problem could be through a more thorough examination with further research, or by building half-open places at the entrance of the already existing greenhouses: remaining in this area for a certain period of time before entering or exiting the greenhouse, it would allow for a better acclimatization and therefore fewer health risks for the worker.

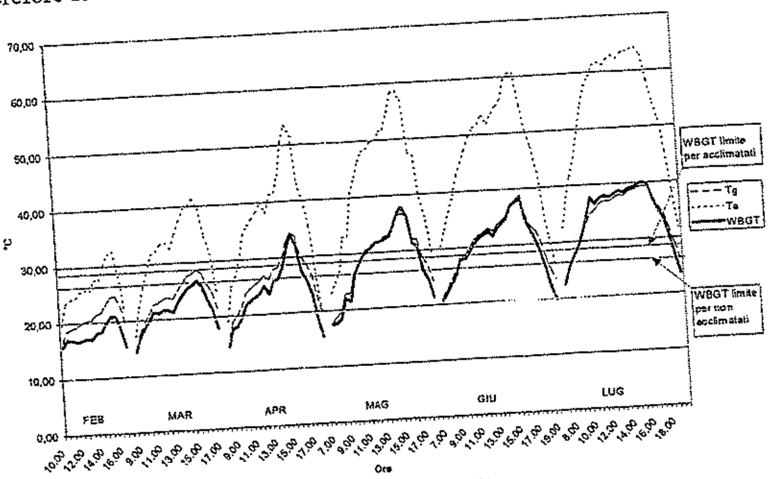

Figure 2. WBGT index over the year (greenhouse 1).

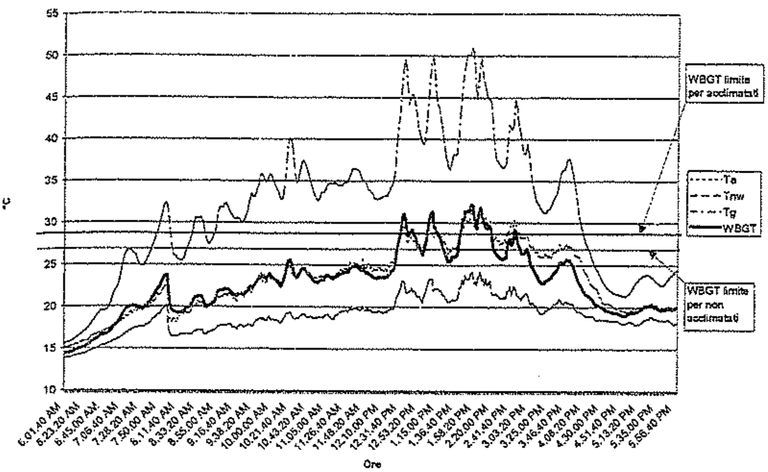

Figure 3. WBGT index on the 27th May (greenhouse 1).

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The authors' contribution in this paper can be considered equal.