Heat stress assessment among workers in a Nicaraguan sugarcane farm

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***Background*:** Heat illness is a major cause of preventable morbidity worldwide. Workers exposed to intense heat can become unable to activate compensation mechanisms, putting their health at risk. Heat stress also has a direct impact on production by causing poor task performance and it increases the possibility of work-related morbidity and injuries. During the sugarcane harvest period, workers are exposed to excessive sunlight and heat from approximately 6 am to 3 pm. A first assessment of heat stress during the 2006/2007 harvesting season served to redesign the existing rehydration measures. In this project, sugarcane workers were provided with more rehydration solutions and water during their work schedule.
***Objective*:** To assess heat stress preventive measures in order to improve existing rehydration strategies as a means of increasing productivity.
***Methods*:** A small group of 22 workers were followed up for 15 days during working hours, from 6 am to 3 pm. Selection criteria were defined: to have worked more than 50% of the day's working schedule and to have worked for at least 10 days of the follow-up period. A simple data recollection sheet was used. Information regarding the amount of liquid intake was registered. Production output data was also registered. Temperature measurements were recorded by using a portable temperature monitoring device ('EasyLog', model EL-USB-2).
***Results*:** The average temperature measurements were above the Nicaraguan Ministry of Labour thresholds. Seven workers drank 7–8 L of liquid, improving their production. Output production increased significantly ($p = 0.005$) among those best hydrated, from 5.5 to 8 tons of cut sugarcane per worker per day.
***Conclusions*:** Productivity improved with the new rehydration measures. Awareness among workers concerning heat stress prevention was increased.

Keywords: *heat stress*; *climate measurements*; *hydration*; *sugarcane harvest*; *production output*

Received: 5 August 2009; Revised: 17 September 2009; Accepted: 18 September 2009; Published: 11 November 2009

The incidence of heat-related disorders increases with higher ambient temperatures (1). Internationally, different authors and Governmental institutions have assessed heat stress effects on workers and also have described different methods to measure its negative impact on productivity as well as mechanisms to control and diminish these effects (2–6). Heat stress in Nicaragua has not been given the importance it deserves, especially in relation to carrying out work in outdoor settings, such as agricultural activities.

In Nicaragua, sugarcane harvesting is done manually using machetes. Workers employed in the Montelimar farm are exposed to intense sunlight and heat while working on sugarcane plantations. Usually they work from 6 am to 2 or 3 pm, but some take more time and finish around 5 pm. This schedule starts on Monday and finishes on Sunday, so it can restart similarly the following week. Consequently on an average they have a high and/or very high metabolic rate. Traditionally, the average productivity rate per worker has been 5.5 tons per day.

Currently, the harvesting season lasts six months. During this time, every foreman is responsible for handing out to each farm worker three small bags of 250 mL of rehydration solution, every day for as long as the harvest period process lasts. However, there is a lack of properly designed policies or measures destined to guarantee an adequate distribution and consumption of the rehydration solutions.

In 1997, Perez Lopez et al. (7) evaluated hydro-electrolyte modifications in sugarcane workers in western Nicaragua after they were given rehydration solutions while harvesting sugarcane.

They designed a study in which they evaluated 15 workers supplied with an electrolyte-balanced rehydration

Citation: Global Health Action 2009. DOI: 10.3402/gha.v2i0.2069

solution and an equal number of workers given regular tap water. Some slight signs of dehydration were found in 80% and 73% of the two groups, respectively, while more severe dehydration was found in 33% of the tap water group and only among 20% of the rehydration solution group.

Ten years later, Dr. Solis Zepeda (8) conducted a controlled clinical trial on the same working population in western Nicaragua. His main objective was to evaluate the impact of preventive measures used to avoid damage to renal function caused by heat syncope (8). The analysed measures were rehydration solution (treated group) or regular water (control group) intake, provided by the company they work for. He evaluated 218 workers who drank rehydration solutions and 187 workers who drank regular water. Blood and urine samples were taken.

Serum electrolytes before beginning and after ending the day's work were monitored. The control group showed significant differences ($p = 0.002$) in serum electrolyte levels (5 mEq/L sodium difference; −0.5 mEq/L potassium difference) compared to the treated group (1 mEq/L sodium difference; −0.6 mEq/L potassium difference).

When it came to analysing diurnal differences in serum creatinine, the differences were greater in the control group (creatinine levels of 0.50 mg/dL initially and 0.55 mg/dL at the end of the working day) than among cases (creatinine levels of 0.85 mg/dL initially and 0.94 mg/dL at the end of the working day) ($p < 0.001$). Glomerular filtration rate was significantly impaired in the control group (−16 cc/min difference) compared with the treated group (−3.2 cc/min difference, $p < 0.001$).

The initial proposal for this project was to improve rehydration measures by increasing the amount of rehydration solutions and their distribution only in two farms (El Zapote and Montelimar) as a pilot intervention plan. Results were to be evaluated afterwards and if they were successful, then in the next harvesting season (2007/2008) these policies were to be implemented in all the other farms.

Sampling methods were used in order to properly evaluate the heat load to which sugarcane workers are exposed. Heat stress indexes such as WBGT were measured. A globe thermometer with a 15 cm diameter hollow copper sphere painted in black on the outside was used.

All measured values were above threshold limit values (TLV) considered normal by the Nicaraguan Ministry of Labour (9). It is important to mention that the Nicaraguan Ministry of Labour does not have its own TLVs and therefore it uses as national references those from the American Conference of Industrial Hygienists (ACGIH) and the National Institute for Occupational Safety and Health (NIOSH) (5).

The overall objective was to assess heat stress prevention measures in order to improve existing rehydration strategies as a means of increasing productivity.

Methods

Twenty-two workers were followed up from 15th April to 30th April 2008 during working hours, from approximately 6 am to 3 pm, for a total of 160 working hours. This included only workers who had worked more than 50% of each day's working period and had worked for at least 10 days of the follow-up period.

A simple data collection sheet was used. Information regarding the amount of liquid intake expressed (in litres, L) and daily productivity output (in tons) were recorded. The latter was facilitated through foremen's productivity data sheets.

The rehydration strategies were re-structured by decision makers participating in the project and the author of this paper. For an eight working hour schedule, all workers were instructed to drink 1 L of the rehydration solutions or tap water at least 30 minutes before they began to work. They were also encouraged to drink water and rehydration solutions (250 mL) every 30–45 minutes. In total, they were each asked to drink 10 L of liquid (tap water and rehydration solutions) per day.

In order to facilitate the monitoring of basic heat stress indexes during the 2007/2008 harvesting season, temperature, humidity and dew point were measured by using a portable temperature monitoring device ('EasyLog',

Table 1. Wet bulb globe temperature (WBGT) values during the 2007 harvest season at Montelimar farm

Time	Globe temperature	Dry bulb	Natural wet bulb	Measured WBGT	Permitted WBGT	Heat stress (%)
7:40 am	41	29.5	24.0	28.0	30.6	91.3
8:40 am	42	31.5	23.5	28.0	30.6	91.5
9:40 am	40	32.0	24.0	28.0	30.6	91.5
10:40 am	45	33.0	24.0	29.1	30.6	95.1
11:40 am	49	34.5	24.5	30.4	30.6	99.3
12:40 pm	45	34.0	25.0	29.9	30.6	97.7
1:40 pm	45	34.5	25.0	30.0	30.6	97.9

model EL-USB-2). This device was used to make hourly measurements. The data collected were downloaded to a PC for later analysis.

Variables such as heart rate and weight were evaluated at the beginning and at the end of the working day. Neither the amount of liquid intake nor productivity was validated.

Wet bulb globe temperature measurements recorded at Montelimar farm are shown in Table 1. Wind velocity was not evaluated due to the lack of proper equipment for measurement.

Statistical analysis

Descriptive statistics were used to analyse climate data (temperature (°C); relative humidity (%); dew point (°C)); liquid intake and output production. Chi-squared test was used to evaluate liquid intake versus output production by using SPSS version 13.

Results

Fig. 1 shows *in situ* hourly climate variation direct from the sugarcane fields while workers harvested the crop. As can be seen, temperature and relative humidity values oscillated from 23.5 to 34.5°C and from 40% to 64%, respectively, reaching maximum values as early as 8–10 am. This meant that water distribution had to be started at around that time on an hourly basis.

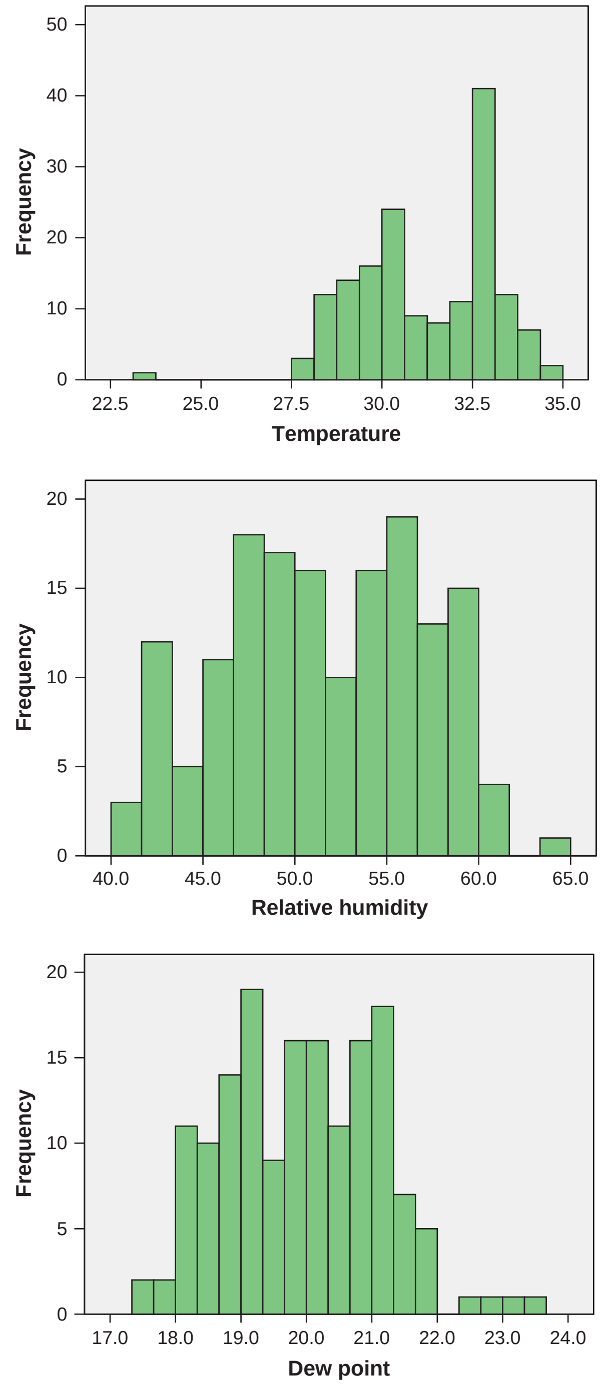
Table 2 shows the amount of liquid intake (including both regular tap water and specially formulated rehydration drinks). Seven workers drank from 7 to 8 L as temperature increased. What is of great concern is that, although temperature increased to maximum values early in the morning, many workers did not follow the rehydration measures and drank less than 6 L, a potentially dangerously low volume.

Fig. 2 shows relationships between daily production output and liquid intake. This showed that 13 workers who had the highest production output (range 6–8 tons, average 7.45 tons) were those who drank more than 6 L of liquid (regular tap water and/or specially formulated rehydration solutions) in comparison to those who drank less liquid and had a smaller production output. This finding is statistically significant ($p = 0.005$).

Measurements of heart rate and body weight at the start and end of the working day showed that workers experienced increases in heart rate and loss of body weight as they worked in these hot conditions.

Discussion

Historically, monitoring of toxins in the work environment has been the primary focus for identifying risks. Some potential biomarkers linked to cell injury are immunological factors, lymphokines, growth factors, prostaglandins, endothelins, collagen, adhesion mole-



	Temperature (°C)	Relative Humidity (%)	Dew point (°C)
Mean	31.2	51.5	19.9
Standard deviation	1.9	5.4	1.2

Fig. 1. Climate measurements during 160 working hours of follow-up for 22 sugarcane workers at the Montelimar farm. San Rafael del Sur, Managua, Nicaragua, April 2008.

Table 2. Comparison between temperature measurements and daily water intake for 22 sugarcane workers at the Montelimar farm. San Rafael del Sur, Managua, Nicaragua, April 2008

	Daily water intake		
	Less than 6 L	6–7 L	7–8 L
Temperature (°C)	*N*	*N*	*N*
23.5–27.2	1	0	0
27.2–30.8	3	5	2
>30.8	5	1	5

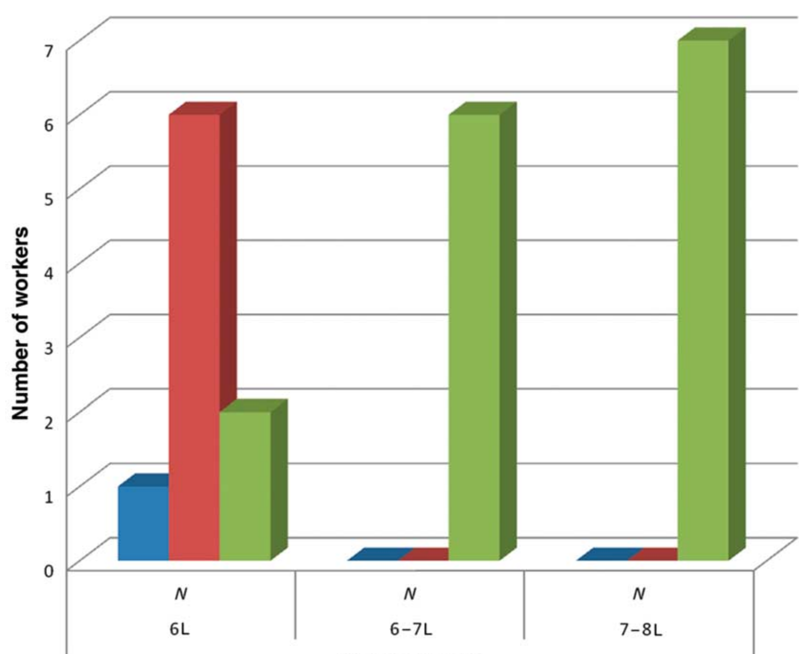
cules, thromboxanes, leukotrienes, platelet activating factors and heat shock proteins (10).

As mentioned earlier, heat illness is a major cause of preventable morbidity worldwide (1) and although human beings possess considerable ability to compensate for naturally occurring heat stress, many occupational environments and/or physical activities expose workers to heat loads which are so excessive as to threaten their health and productivity (11). It is important to remember that the normal human body contains approximately 60% of water, about 34–40 L in an adult person (12).

The present project evaluated climatic conditions at sugarcane plantations located at sea level, on the southwest coast of Nicaragua. Monitored climate indices (temperature and relative humidity) values varied from 23.5 to 34.5°C and from 40% to 64%, respectively, reaching maximum values as early as 8 am.

According to the Nicaraguan Institute of Territorial Studies (INETER) (13), relative humidity values for the whole month of April varied between 69 and 79% all along Nicaragua's Pacific coastline from San Juan del Sur (Southern Region) to Chinandega (Western Region). All sugarcane mills are located along the Pacific coastline. Managua lies between the two regions; the Montelimar sugar farm is located 62 km from Managua. However, the INETER humidity data are quite different from the relative humidity registered on the farm located in western Managua. Perhaps the fact that only 15 days were registered influenced this variation. Temperature data were not available at INETER's website.

Although only 22 subjects were followed-up for a short period of time in this study, important results were obtained. Other authors have shown the relationship between heat stress health effects and the ability to perform different tasks, as well as the increased risk of suffering work-related injuries (14). In this study, the workers drank more liquid as temperature values



	6L	6–7L	7–8L
< 4 tons	1	0	0
4–6 tons	6	0	0
6–8 tons	2	6	7

Fig. 2. Relationship between production output and daily water intake for 22 sugarcane workers at the Montelimar farm. San Rafael del Sur, Managua, Nicaragua, April 2008.

increased to maximum peaks. This was part of a rehydration process which was well planned in advance by the company's decision makers. Unlike during past harvesting seasons, when water and rehydration solutions were distributed quite randomly, during this harvesting season cool water and specially formulated drinks were distributed or intended to be distributed to workers, who received 1 L just before they began their working day and then 500 mL every 30 minutes.

The basis of this principle is that drinking to satisfy thirst is not enough to keep a person well hydrated. Most of the people become aware of thirst once they have lost 1–2 L of body water and persons highly motivated to perform hard work may incur losses of 3–4 L before serious thirst forces them to stop and drink. Since dehydration reduces the capacity for absorption from the gut, workers must be educated regarding the importance of drinking enough water during work and continuing generous rehydration during off-duty hours (14).

Productivity was positively influenced by the new rehydration measures. There was a significant increase of production, with up to 8 tons per worker during the follow-up period compared to the normal 5.5 tons per worker prior to the change in rehydration measures.

This important change in rehydration policies and increase in production output is the result of various efforts of training workers, foremen and managers on heat stress prevention, proper hydration measures and quality of (working) life carried out by occupational health and safety professionals (physicians and engineers), human resources departments and top management at sugarcane farms.

However, this was not an easy task. Often workers rejected the new rehydration measures, most of the time because it was difficult for them to understand thoroughly the dehydration and physiological compensatory mechanisms. Some of the reasons for this can be attributed to their low educational level, and feeling that 'nothing bad has ever happened to me before', etc.

Certainly more effort in terms of intervention strategies and scientific investigation needs to be carried out among workers in Nicaragua who perform jobs in which they are exposed to high ambient temperatures. These include farm workers, construction workers, miners and fishermen, especially those employed in the informal sector, which occupies about half of Nicaragua's economically active population.

More funds should also be designated by companies' decision makers for improving basic working conditions, in order to increase overall productivity (and workers' satisfaction in terms of better wages). This would also translate into safer and healthier workers, less absenteeism from sick leave, fewer accidents and other incidents.

Acknowledgements

I would like to thank all personnel from the Montelimar sugarcane company whose support was determinant for carrying out this project. I would also like to thank colleagues and professors from the Centre for Research on Health, Work and Environment at the National Autonomous University of Nicaragua (UNAN-Leon), Professor Staffan Marklund in the Department of Clinical Neuroscience at Karolinska Institutet, Stockholm, Sweden and last but not least to Professor Tord Kjellström from the Health and Environmental International Trust, Mapua, Nelson, New Zealand for their kind support and cooperation.

Conflict of interest and funding

The author has not received any funding or benefits from industry to conduct this study.

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