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Intervention to reduce heat stress and improve efficiency among sugarcane workers in El Salvador: Phase 1

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ABSTRACT

Background Chronic heat stress and dehydration from strenuous work in hot environments is considered an essential component of the epidemic of chronic kidney disease in Central America.

Objective (1) To assess feasibility of providing an intervention modelled on OSHA's Water.Rest.Shade programme (WRS) during sugarcane cutting and (2) to prevent heat stress and dehydration without decreasing productivity.

Methods Midway through the 6-month harvest, the intervention introduced WRS practices. A 60-person cutting group was provided water supplied in individual backpacks, mobile shaded rest areas and scheduled rest periods. Ergonomically improved machetes and efficiency strategies were also implemented. Health data (anthropometric, blood, urine, questionnaires) were collected preharvest, preintervention, mid-intervention and at the end of harvest. A subsample participated in focus group discussions. Daily wet bulb globe temperatures (WBGT) were recorded. The employer provided individual production records.

Results Over the harvest WBGT was >26°C from 9:00 onwards reaching average maximum of 29.3±1.7°C, around 13:00. Postintervention self-reported water consumption increased 25%. Symptoms associated with heat stress and with dehydration decreased. Individual daily production increased from 5.1 to a high of 7.3 tons/person/day postintervention. This increase was greater than in other cutting groups at the company. Focus groups reported a positive perception of components of the WRS, and the new machete and cutting programmes.

Conclusions A WRS intervention is feasible in sugarcane fields, and appears to markedly reduce the impact of the heat stress conditions for the workforce. With proper attention to work practices, production can be maintained with less impact on worker health.

What this paper adds

- There is an epidemic of chronic kidney disease of unknown cause in Central America concentrated in sugarcane workers.
- Excessive heat exposure and dehydration combined with strenuous physical labour is suggested as the central element of the epidemic.
- Appropriate access to water, rest and shade during each workday offers important relief from the high level of heat stress experienced by sugarcane cutters.
- Added rest can be provided effectively while applying ergonomic principles to maintain adequate productivity.
- Physically demanding jobs in hot climates require appropriate access to water, rest and shade, especially in the context of global climate change.

BACKGROUND

Mesoamerican nephropathy (MeN), an epidemic of chronic kidney disease (CKD) unrelated to diabetes or hypertension, is taking a huge toll on agricultural communities throughout Central America.[1] El Salvador is one of the hotspots.[2–4] Though much remains to be learned about MeN, there is consensus that sugarcane workers are the most affected population, and that enough is known about some occupational risk factors to intervene and mitigate unnecessary death and suffering.[5]

Chronic heat stress and dehydration from strenuous work in hot environments is considered an essential component of the epidemic.[1 5 6] Heat exposure during sugarcane cutting is so extreme that, during part of the workday, workers should only labour 15 min out of each hour, according to OSHA guidelines.[7 8] The reality witnessed in Central America is very different.

Sugarcane cutting is work with high cardiovascular demand comparable to endurance athletes or elite soldiers during multiday operations or events, although sugarcane workers undertake such high-intensity work day after day throughout the harvest season.[9–11] The metabolic heat production from strenuous work in an uncompensated thermal environment determines that autonomic heat loss mechanisms (ie, sweating and skin blood flow) cannot maintain a thermal steady state.[12] Daily water needs due to loss of body water during vigorous exercise in hot climate can reach up to 12 L, and demands longer recovery periods (~24 h) with adequate fluid and nutrient (including electrolyte) replacement.[13,14] Insufficient fluid recovery causes dehydration which exacerbates heat strain.[14] Without appropriate responses (halting physical work, seeking shade, drinking fluids, etc), internal body temperature will rise, impairing performance (both mental and physical) and potentially leading to injury and to heat illness, heat stroke and even death.[10]

Recent animal studies have identified mechanistic pathways for how chronic recurrent dehydration and/or acute kidney disease may lead to CKD.[15,16] Additionally, epidemiological evidence for a causal association between MeN and chronic heat stress and dehydration is mounting.[4,17–19] Hence, chronic cyclic heat stress and dehydration from strenuous work in hot environments remains a key focus of the aetiology for the epidemic.

Other still unknown factors have been suggested to play a role in the MeN epidemic,[1,20,21] in particular, pesticides.[22–26] However, the overall evidence for pesticides is scant,[5,27] just as it is for other suggested risk factors including nephrotoxic medications, alcohol, arsenic, cadmium, silica and infectious agents.[1,20,21,28] Nonetheless, interaction of heat stress and demanding work could impact uptake of toxins if exposure to these is documented.[29]

The Worker Health and Efficiency Program Working Group is conducting a multiphase intervention study during cane cutting in El Salvador with the primary objectives to prevent heat stress and dehydration without decreasing productivity. This intervention broadly follows OSHA's Water.Rest.Shade (WRS) programme for people working in hot temperatures.[8] Efficiency improvements use expertise from the Australian sugarcane industry. A secondary objective is to determine whether this intervention will result in reduced health consequences from heat stress and dehydration, with or without evidence of preserved kidney function over the day and over the harvest.

Here we report the overall methods and lessons learned from Phase 1 of the intervention, which assessed (1) the feasibility of providing a WRS programme while improving cutting techniques and work processes, (2) evidence that the intervention reduced worker heat stress and (3) feasibility of extensive data collection for Phase 2 evaluation of the intervention in addressing the broader health issues.

MATERIALS AND METHODS

Context and preintervention work conditions

The El Salvador sugarcane industry employs approximately 11 000 cane cutters during the November to April harvest period. In the remaining months of the year, the cutters work various other jobs, mostly in farming.

The present study was conducted at one of the largest sugar mills, Ingenio El Ángel (henceforth: the mill), whose operations provide work to approximately 4000 cane cutters via a variety of subcontracting arrangements. The leadership of the study mill has been in the vanguard of the issues of occupational health, child labour and workers' rights. The workers are organised in 'frentes de roza' (cutting fronts) consisting of 40–70 workers led by a 'caporal' (supervisor). The caporales report to a subcontractor, cooperative or landowner who sells the cane to the mill. Workers are paid piecework wages, based on tons[30] or area cut.[18] The workers live in nearby communities and are transported to sugarcane fields at dawn in the caporal's truck or bus.

Cane fields are burned the night before cutting to remove vegetation, concentrate sugar crystals in the cane, and eliminate rats, snakes and other infectious or poisonous vectors. Workers use mill-provided machetes, shirts, hats, gloves and shin guards. The cutting process begins by cutting the stalk a few centimetres above ground level by swinging a machete to shoulder level while bending at the knees and/or waist. Workers either top each stalk as it is cut, or stack them and top the cut stalks lying on the ground. After cutting enough stalks, the cane is gathered by hand, moved to a pile to be 'grabbed' by a tractor's crane attachment[7] and loaded on a truck for transport to the mill. A 'checker' records each 'grab' (colloquially 'garrada', ~½ ton) as the basis for worker wages.

A worker's daily cutting section is generally six rows across, 25–50 m long. Workers bring water to the field, usually in gallon-sized plastic containers, meant to last for the full day. The container is left at the beginning of the cutting area or carried by the worker as he travels across the assigned area, variably walking back to drink from the container. All work is done under direct sunlight.

Environmental measurements

Wet bulb globe temperature (WBGT) was measured in the cane fields from 1 December 2014 until the end of the harvest. A QUESTemp 34 (3 M) recorded dry bulb, wet bulb, globe temperature and relative humidity at 15 min intervals. The device was placed at waist level in the open field and monitored by a trained assistant over the entire workday. The device automatically calculates and records WBGT as:

$$\mathrm{WBGT} = 0.7 \times \text{wet bulb} + 0.2 \times \text{globe temperature} + 0.1 \times \text{dry bulb}$$

Two-weekly measurements by WeatherHawk 232 Direct Connect Weather Station were highly correlated, so only WBGT is reported.

The intervention

Two groups of cane cutters were invited to the study. The Inland group (the ~70 workers in one front) lived between the towns of Suchitoto and San José Guayabal in central El Salvador, at ~450 m altitude. The Coastland group (~60 workers from a larger front) near San Luis Talpa, a sea-level south-central region. The two groups represented two distinct environments, but otherwise similar in cane cutting.

Both groups participated in a preharvest baseline examination, and an end-of-harvest follow-up; the Inland group participated in two intermediate examinations as well. Table 1 describes participation over the harvest period. The WRS intervention[8] and efficiency training were provided to the Inland group starting in January 2015, 2 months into the 5-month harvest season. The original plan was to initiate the same intervention in the Coastland group but poor participation along with security concerns led to delaying their intervention to the next harvest.

Water.Rest.Shade

A rest programme was designed with all rest occurring in the shade of a portable canopy (figure 1) that moved progressively alongside the cane cutting teams throughout each workday. Early morning is cooler, with temperature rising steeply at around 09:30. Consequently, the schedule began with a 1.5–2 h working interval at the start of the day followed by hour-long work periods thereafter, broken by 10–15 min rest breaks and a 45 min lunch break.

Each worker was supplied with a 3 L backpack mounted water bladder with connected flexible tube and mouthpiece (CamelBak) for continuous hydration. The model used was created for US Special Forces engaged in desert warfare. The insulated, antimicrobial bladders are designed for minimal

Table 1 Pattern and type of data collection for two study groups

	Baseline	Biweekly Nov/Dec	Preintervention	Biweekly Jan/Feb	Mid-term	Biweekly Mar/Apr	End of harvest
Number of field visits	1	2	1	2	1	3	1
Participants							
Inland	56	37	42	41	41	41	41
Coastland	60	21	13				41
Questionnaire	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Physical exam	Yes		Yes		Yes		Yes
Biomonitoring							
Haemogram*	Yes		Yes		Yes		Yes
Serum†	Yes		Yes		Yes		Yes
Basic urine‡	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Extended urine§	Yes		Yes		Yes		Yes
WBGT	Daily in both groups						
Water refills				Daily self-report (Inland group)			
Difficulty of work				Weekly assessment (Inland group)			

*Haemogram at Laboratorio CECIAM Escalón, San Salvador.
†Serum chemistry at Lund University.
‡Urine assessments in field only (dipstick, osmolality and microscopic sediment evaluation).
§Urine chemistry at Lund University.
WBGT,wet bulb globe temperature.

movement during activity in extreme heat and need only annual cleaning.

The CamelBaks were refilled at rest breaks with water maintained in 40 L coolers placed under each shade canopy. The coolers were filled daily with fresh water from a water truck brought to the field by the mill. At the end of each day individuals reported number of CamelBak refills.

Efficiency training

Two Australian cane cutting experts, one a world champion manual cane cutter,[31] made the following recommendations for improved efficiency:

1. A redesigned machete for improved ergonomics. The Australian designed machete introduced was lighter with an ergonomic handle design and an angled curve in the middle of the blade. Whereas the flat end of the blade was used for cutting with the original machete, the curve in the new machete resulted in less bending.
2. A reduced number of rows cut (from six to four or five), and improved stacking method in order to reduce lateral carrying distance and workload.

The Australian experts visited the fields, demonstrated the new methods to mill engineers and workers, and trained workers on how to use the machete during a 3-week period.

Figure 1 Workers in the cane field taking a break in the shade provided by the mobile canopies (note the wheels on the frame and the CamelBaks).

The mill"s daily records (tons/individual) were used for evaluation of productivity.

Questionnaires and measures of health outcomes

All participants had a baseline examination 1 week before the start of the harvest. The examination took place in each of the two communities where the workers lived. Workers arrived early in the morning at the same time that fieldwork usually begins.

After signing an informed consent, participants were weighed, had their height measured on a combined digital weighing scale with a mechanical height rod (SECA electronic AD 769, Seca, Birmingham, UK), and body mass index was calculated. Blood pressure and heart rate were measured once after the participant had been seated for a minimum of five minutes using a digital system (Omron HEM 7220, Omron Healthcare Inc, Bannockburn, Illinois, USA). Venous blood and urine samples were collected.

A standardised 45 min interview included questions regarding sociodemographic data; past and present work history including exposure to occupational and environmental hazards focusing on heat, cane-burning and pesticides; use of tobacco, alcohol and recreational drugs; general health including history of hypertension and diabetes; current bodily pains; medication used for reported conditions as well as use of other known nephrotoxic substances; family history of CKD; and past and present heat stress and dehydration symptoms.

During biweekly (every 2 weeks) field visits to the Inland (intervention) group (table 1), a shortened 10 min questionnaire was administered asking about the difficulty of assigned work, hydration, current occupational hazards, medication use, heat stress symptoms and bodily pain.

Additionally, research assistants used a survey form to collect information on Camelbak refills from each worker (daily), use of the new machete (weekly) and difficulty of cane being cut (weekly).

In the Inland group, the sampling consisted of preshift and postshift blood and urine samples collected at three occasions during the harvest; the second week of January (right before the intervention), in March (mid-intervention) and mid-April (final week of the harvest). Additional urine samples were collected preshift and postshift every second week throughout the harvest. In the Coastland group, only baseline and end-of-harvest samples were obtained for the majority of workers (table 1).

Qualitative evaluation

A qualitative evaluation of Phase 1 was conducted near the end of the harvest by researchers external to the implementation of the intervention. Five focus groups (45–60 min) were organised with 5–11 participants, two for cane cutters (younger and older, in the field), and one each for family members (in a home), company employees in charge of the intervention (in a meeting room) and research assistants (in a restaurant). An emergent design was used permitting flexibility in posing questions and obtaining complementary indepth information through individual interviews. The topics addressed were water, rest and shade, the new machete, the data collection, and the participation of the various actors in the programme.

Analysis

WBGT values were summarised as hourly averages by day and grouped into categories to determine proportion of work-time spent with respect to OSHA work-limit guidelines (≥26, <28°C=25% rest; ≥28, <30°C=50% rest; ≥30°C=75% rest).[8] Intervention impact was assessed comparing mean individual production (tons/person/day), water intake (L) and symptom occurrence (per cent preintervention and postintervention) in the Inland group. Mean individual production and average individual change in production for the Inland group were compared with the five most productive (of 27 total) cutting fronts of the mill. Focus groups and interview data were transcribed and organised by group type then assessed for risk and illness perceptions before and after the intervention.

RESULTS

Study population

Over the course of the harvest, approximately 70 workers in the Inland group worked at least briefly. Fifty-six appeared for baseline testing, and of these, 14 discontinued working early and did not return for subsequent testing. In the Coastland group, the caporal supervised a cutting front of 300 workers divided into five subfronts. Sixty workers from different subfronts appeared at baseline, and of these 15 never started working or discontinued work early. Out of the remaining 45 workers, all but 13 ceased participation during the harvest. This happened mainly because we dealt with the caporal only and not with the subgroup leaders, which made communication routes less effective. Owing to this markedly reduced participation, and added to the gang-related security issues that emerged in the coastlands, we chose not to initiate the intervention in the Coastland group during Phase 1. However, an end-of-harvest examination was possible to perform in both groups (table 1). Workers received US$8 for each of the four sampling days in which they participated.

Both groups were predominantly male, with 2% and 12% of female workers (none pregnant) in the Inland and Coastland groups, respectively. Ages ranged from 18 to 63, with only 12 out of 116 >50 years old. Women and men performed the same cane-cutting tasks. There were a few differences in occupational histories between the groups (table 2). There were no migrant workers in either study group.

Heat exposure

Early morning (06:00–07:00) WBGT measures were cooler inland than coastland (17.8°C±2.3°C vs 21.5°C±2.0°C). For the Inland group, WBGT remained, on average, <26°C until after 09:00, thereafter steadily increasing until midday. In the Coastland group, WBGT increased more rapidly, with WBGT <26°C only until 08:00. Across the harvest, this pattern was replicated with the average maximum hourly WBGT inland 29.3°C±1.7°C, and coastland 31.0°C±1.5°C typically reached 13:00–13:30 in the inland, and 11:30–12:30 at the coastland (figure 2).

The working conditions for the two groups differed with respect to length of workday and to level of heat stress exposure. The Inland group worked 8–10 h, including a lunch break, with meals provided by the mill (starting typically at 06:00, finishing around 15:00), while the Coastland group finished their workday before lunch, usually after 4–5 h of work (starting similarly at 06:00, finishing around 11:15). With scheduled breaks, the Inland group rested 25% of the workday, but still worked outside OSHA-recommended work/rest periods 42% of the time. The Coastland group worked only 60% of the Inland group's total harvest hours. However, without any scheduled breaks they spent 74% of their hours outside OSHA guidelines, and half of those hours were at levels (>30°C WBGT) where OSHA recommends 75% rest. Even had the Coastland group also rested 25% of the time, it would have exceeded the recommended work limits 59% of the time.

Table 2 Basic sociodemographic data and exam findings by study group

	Inland	Coastland
	n=56	n=60
	n (%)	**n (%)**
Male	55 (98%)	46 (77%)
Female	1 (2%)	14 (23%)
Work history in		
Cotton	1 (2%)	18 (30%)
Other agriculture	49 (88%)	42 (70%)
Construction	23 (41%)	28 (47%)
Mining	0 (0%)	1 (2%)
Current smokers		
Males	18 (33%)	11 (24%)
Females	0 (0%)	0 (0%)
Alcohol consumption		
Males (sometimes)	21 (38%)	18 (39%)
Males (often/every day)	1 (2%)	1 (2%)
Females (sometimes)	0 (0%)	3 (21%)
Females (often/every day)	0 (0%)	0 (0%)
Mother or father with CKD	4 (7%)	6 (10%)
Systolic ABP >140	11 (20%)	8 (13%)
Glucosuria	1 (2%)	0 (0%)
	Mean (SD)	**Mean (SD)**
Age (years)	34 (12)	33 (11)
Education (years)	5.9 (3,6)	4.9 (3,6)
Harvests worked (number of seasons)	7.1 (7)	7.6 (6,7)
BMI (kg/m^2)	24.1 (3,9)	23.8 (4,5)
Systolic ABP (mm Hg)	129 (12)	123 (14)
Diastolic ABP (mm Hg)	75 (11)	71 (8)

ABP, arterial blood pressure; BMI, body mass index; CKD, chronic kidney disease.

Intervention impact

Water consumption

Using all available biweekly data, self-reported water consumption in the Inland group increased postintervention on average from 5.1 to 6.3 L daily, a difference of 1.2 L (95% CI 0.8 to 1.6).

Production change

Individual daily average production in the Inland group increased over the course of the harvest improving from 5.1 tons/person/day at the intervention start to 7.3 tons/person/day in the penultimate period. There was an expected drop in total production in almost all groups during the last weeks, when generally smaller fields are cleared.

When production in the intervention group was compared with the five most productive cutting fronts, the proportionate increase in individual average daily production, preintervention and postintervention, was significantly better for the intervention group compared with each of the other groups ($p<0.05$ in all cases).

Symptoms of heat stress

Preliminary analysis of symptoms related to heat stress and dehydration before and after the intervention showed a general reduction in these symptoms (figure 3). Most symptoms of heat exhaustion decreased substantially, especially for feeling feverish, exhaustion, nausea and cramps. Some symptoms of dehydration (the occurrence of very dry mouth and very little urine) decreased substantially postintervention, but reports of dark urine and dysuria did not change. These latter findings are being further explored. Few workers reported fainting and vomiting at any time during the harvest.

Qualitative findings on impact of the intervention

Overall, the focus groups revealed a positive perception of the new machete. The workers attributed less musculoskeletal pains to the lighter tool. Workers also reported they cut more cane even with the rest periods. The lighter blade, however, wore down somewhat more rapidly.

Most workers reported they adapted well to the CamelBak, and had more access to water of higher quality (cool and clean). Workers welcomed the rest periods, which they used for refilling the CamelBaks, drinking more water, sharpening their machete, and even communicating with their families. The access to shade during the scheduled rest was especially commented upon positively.

Both groups of workers as well as family members and the health personnel assisting in the data collection perceived an

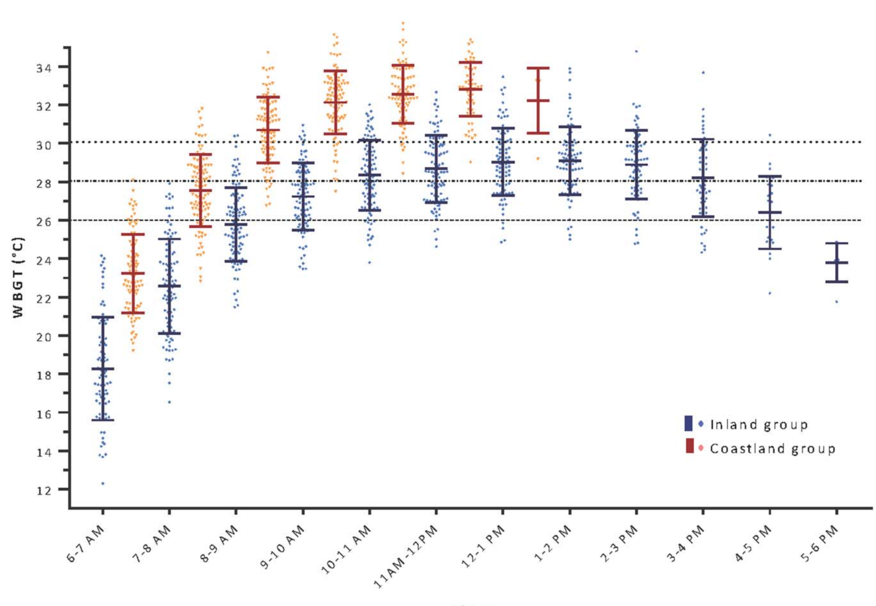

Figure 2 Daily distribution of hourly wet bulb globe temperature (WBGT) averages for Inland (blue) and Coastland (red) groups across the harvest. Individual days (dots) plus, hourly averages and SDs across the harvest are represented. Dashed lines indicate the Occupational Safety and Health Administration permissible heat exposure limit values.[8]

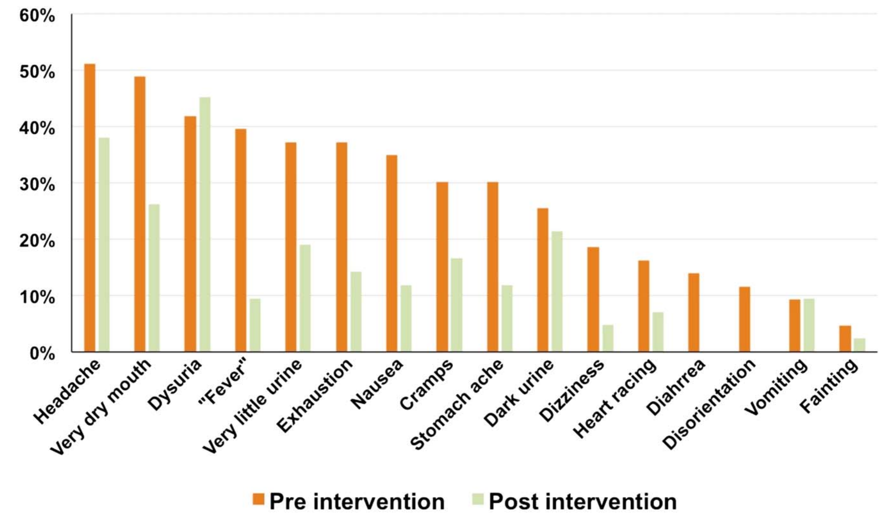

Figure 3 Percentage of Inland workers reporting symptoms of heat stress and dehydration preintervention (January 2015) and postintervention (at the end of harvest, April 2015).

improved health status of the workers, for example less fatigue, and, as noted by the caporal, no more cases of heat exhaustion needing medical attention. Research assistants reported workers bringing in lighter colour postshift urine samples.

Some negative feelings about select aspects of the intervention were also expressed. Older workers mentioned not always following the instructions to take rests. The staff professionals needed extra effort to overcome scepticism about managing the WRS intervention which will be addressed with improved communication in Phase 2.

DISCUSSION

Sugarcane workers (including those from other places who seasonally migrate for cane-cutting jobs) are long-term residents of Mesoamerica. Hence the workforce in general, and the workforce studied, could be considered naturally acclimatised to the background heat and humidity of El Salvador. The relevant aspect of sugarcane agriculture as practiced in this region is the physically demanding nature of the work that is added to the hot background environment. Work in other agricultural settings (cocoa, coffee, bananas, corn, etc), as well as industrial settings (mining, construction, etc), is hard work, but the evidence suggests work in sugarcane harvesting is the most physically demanding of all.

The decision about sample size for Phase 1 was made for the primary objective of testing feasibility and acceptance. However, a sufficient number of study participants were included to permit identifying a large positive or negative effect on health and efficiency. Total number of workers tested in Phase 1 was smaller than planned since we had to postpone the intervention in the Coastland group to next year (see above). Continued discussions with the Coastland group eventually resolved confusions about the study so that, by the end of harvest, 41 of the 45 asked to continue in the study. CamelBaks were distributed to all these participants and we collected final samples on these while continuing to build a relationship for the Phase 2 expanded intervention.

The Water.Rest.Shade intervention

Rest

The continuous monitoring of WBGT throughout the harvest documented well the extreme nature of the working conditions. The intervention rest schedule designed for this study provided daily rest for approximately 25% of the workday. Still, over 40% of the work hours during the harvest were spent at WBGT levels where a minimum of 50% rest time is recommended. Notably, the Inland fields reached an average maximum WBGT of 29.3°C and included at least 10% of hours worked at a level where OSHA recommends work be limited to 25% of the time.[8] Similar findings have been reported from a study of Costa Rican sugarcane workers.[7]

Water

The CamelBaks were almost immediately adopted by most workers resulting in a self-reported 25% increase in mean water consumption. Furthermore, respondents in the focus groups reported that by observing their urine being analysed, they learned that the colour and amount of urine could indicate dehydration, and help them know they needed to drink more water.

Shade

The qualitative assessment indicated that the cutters found particular benefit from the shade component. They noted that, prior to the intervention they had always brought some water with them, and knew they could rest if they wanted to, but rest breaks were often possible only under direct sunlight. Almost everyone used the shaded area for their rest periods and seemed to enjoy both the comfort and the camaraderie the shaded area offered (figure 1).

Symptoms of heat stress

The integrated measurement of the impact of the WRS intervention was characterised best by the change in heat-related symptoms that the workers reported (see figure 3). Also in the qualitative study, workers specifically mentioned less or no symptoms postintervention, fewer medications needed for symptoms (also noted by the caporal) and overall being in a better mood.

The efficiency intervention

The new machete

The new machete proved effective in not reducing work efficiency during the intervention. Initially, workers did not have faith in the thinner, less rigid machete, but the first cutters using it convinced the others that it made the work easier. For the most part, the new machete lasted although it did appear it would have to be replaced the next year.

Fewer rows and more efficient stacking

One demonstration of the impact of fewer rows cut and more efficient stacking was the mill staff response. When they observed the improved efficiency, they introduced the change in number of rows cut for all other cutting fronts despite not having the WRS programme for those teams.

The result of the two changes was a notable increase in work efficiency especially in light of the added rest time over the workday. The intervention group's average preintervention production was lower than in the other five most productive groups (significantly so for three) while average postintervention production was significantly higher than in all but one of the other groups. Some portion of the improvement seen in the other major groups might be explained by adoption of the change in number of rows cut for all cutting fronts after the early success in the Inland group. Whether this difference might be attributed to the new machete, the WRS protocol, or both, cannot be determined.

Perceptions of change

The qualitative analysis offered important insights about how the intervention was received. For the most part, workers and worker families responded positively to the intervention. The caporal and the workers reported that working conditions had changed. They had believed that the poor working conditions were inevitable, but during the intervention came to realise that conditions could be modified so that, even with the harsh weather circumstances, the work could be improved.

Mill leadership was enthusiastic and supportive of the programme from the onset. By contrast, mill personnel operating closer to the fieldwork initially were concerned about the rather difficult changes and extra work the intervention imposed. It took time and effort from researchers and mill leadership to understand the technical needs of the cane-cutting process, the scientific needs of the intervention and to achieve effective communication. As the intervention became more established and initial difficulties were resolved, the benefits for the workers became evident and the mill personnel were increasingly positive.

Lessons learned

An intervention, especially on a larger scale, is costly, time consuming and induces a great deal of uncertainty. To achieve the necessary long-term commitment to the change, a notion of ownership by all actors and a willingness to assume responsibility for the different components of the intervention is key. Some of our plans would have been better implemented had we understood the different nature of leadership in the two study groups. Although we did not succeed entirely during Phase 1, several important lessons were learned. We have to be as clear as possible with workers and with mill staff about the intended intervention, the objectives we have in mind, and the need to fit these into the existing work practices and work environment. We emphasise flexibility and openness to different routes to achieve this. One example is that the plan to reduce six-row to four-row cutting had to be modified. The demands on the worker were least with four rows, but the loading equipment used to collect the cut cane could not fit in the narrow spaces created by cutting only four rows.

Overall assessment

This study is the first formal evaluation of a W.R.S intervention in the sugarcane industry. There were several essential components of the intervention programme, each critical to the initial success demonstrated. First, there was the identification and enthusiastic participation of a willing and collaborative mill owner. Second, there was engaged professional staff at the mill that designed and constructed the shade tents to accommodate circumstances in the field, and the need to move them constantly, and that organised effective delivery of water to the fields on a daily basis. The staff also worked closely with the Australian consultants to implement the efficiency intervention in the process, becoming early converts to the advantages of the new, lighter machete. Third, there was a research staff that willingly and reliably attended to the numerous individual requirements essential to field collection of biological materials and survey administration. Each time the staff went to the field they had to leave their homes before 03:00 and spend the long days in the fields working closely with the cane cutters to collect all necessary data with efficiency and proper care of all sample materials. Biological samples had to be carefully stored and maintained at constant cold temperatures. Good working relationship with workers and staff was crucial. Fourth, the attention and care of the security forces (police and sometimes military escorts) assigned to us by the mill was invaluable. Finally, and at the core of the study, were the members of the sugarcane-cutting workforce and their leader. They understood the reasons for the study and had a high level of commitment to participation. Without this, the study could never have been attempted.

We concluded that it is possible to implement a focused WRS programme for manual sugarcane cutters in conjunction with an efficiency training programme. Although economic analysis is needed to draw cost–benefit conclusions, we found increased productivity and improved work satisfaction that benefits workers and the mill. It was possible to accomplish a repeated and extensive monitoring of work and environmental conditions and biological sampling in the field. By involving key stakeholders and necessary expertise, this study suggests that a scaleup of such an intervention is feasible and could be beneficial to the workforce and to the mill.

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Contributors JG conceived and CW prepared the first protocol draft. The final protocol was produced with essential input from all authors. TB, EJ, IW, RG-T collected the field data. DHW was the principal investigator and supervised the project, together with RG-T as local PI. TB was responsible for data management and statistical analyses. RAIL analysed the weather data. All authors contributed to interpretation of the results. TB prepared the first draft, DHW was responsible for all subsequent drafts with input from all authors, and submitted the manuscript. All authors contributed critically to revised drafts with text and intellectual content. Non-author members of the WE Program Working Group either collected different types of data or were responsible for laboratory analyses. All authors of this article have read and approved the final version submitted.

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Patient consent Obtained.

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