From paper to (i)pad: The Development of the Thermal Risk App.

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Abstract

It has long been recognised that a key control in the management of heat stress is the education of the worker in relation to the impact of the many variables in a hot environment. For too many years the use of one parameter, the air temperature, has been the focal point of the general workforce as the measure of heat stress. Whilst there have been many tools and training materials available, most have relied on a formal training program or complicated assessments. The Basic Thermal Risk Assessment (BTRA) was introduced via the AIOH heat stress standard in 2003 as a first level assessment and was originally developed as a training tool. However over the years it has evolved in a different direction. The review and modification of this tool in the latest AIOH Heat Stress Guide began its journey back to its original intent. In early 2014 a question was posed on a Heat Stress forum discussion:

"If you had a Heat Stress App for your workers, what would you want it to tell them?"

This triggered a chain of events that led to the development of the Thermal Risk App.
This is its story.

Introduction

During the summer months the Australian climate poses a unique challenge to professionals working in the health and safety field. Heat stress issues are common place as the northern regions are regularly subjugated to temperatures reaching above 50 degrees centigrade and humidity levels ranging from dry to extremely humid. Despite these conditions, workers are still required to perform tasks at all hours of the day and so it is important that there is an assessment tool that allows them to determine whether or not a particular condition is hazardous to their wellbeing and understand how to reduce their risk.

Too often site health and safety advisers are confronted with employees waving thermometers and asking *"at what temperature do we stop work?"* Despite what some sources may say, there is no one set temperature at which this decision can be made. Moreover, there are usually a number of control measures that can reduce worker's risk of suffering heat related illness but these are often ignored in the focus to determine a "risk rating" or "stop work" temperature. A key aspect of all training in the management of heat stress is imparting the knowledge of the numerous variables associated with heat exposure and how they impact on individuals. Such was the genesis of the basic thermal risk assessment (BTRA) on which the phone app was based.

Background

The concept of a basic thermal risk assessment was not unique and work along similar lines was also being carried out by researchers elsewhere around the world at that time (Biomed 1998, Bethea & Parsons 2002, ISO 10551 - 2002).

After discussion with a number of potential workforce frontline users it was determined that what was required was a simple tool that:

1. Assesses a number of factors that impact on the individuals' heat stress.
2. Is easily understood and employs non-technical terminology
3. Does not require too much writing/typing (i.e. tick boxes wherever possible)
4. Provides some form of simple measure

The original format (Table 1) consisted of a simple table of areas of impact that required the user to tick the appropriate box in the first section, add up the values and then combine these with the number obtained from the metabolic work rate. Some examples of metabolic work rates taken from the ISO 7243 standard were included as a guide rather than the more extensive ISO 8996, again keeping in line with the overall concept of simplicity.

Light work: Sitting or standing to control machines; hand and arm work assembly or sorting of light materials.

Moderate work: Sustained hand and arm work such as hammering, handling of moderately heavy materials.

Heavy work: Pick and shovel work, continuous axe work, carrying loads up stairs.

Figure 1 - The Basic Thermal risk assessment as it appeared in the 2003 AIOH Standard.

HAZARD TYPE	**Assessment Point Value**		
	1	2	3
Hot Surfaces	Contact Neutral ❑	Hot on Contact ❑	Burn on Contact ❑
Exposure Period	< 30 min❑	30 min - 2 hours ❑	> 2 hrs ❑
Confined Space	No ❑		Yes ❑
Task Complexity	Simple ❑	Moderate ❑	Complex ❑
Climbing, ascending, descending	None ❑	Moderate ❑	Significant ❑
Distance from cool rest area	<50 Metres ❑	50-100 Metres ❑	>100 Metres ❑
Distance from drinking water	<30 Metres ❑	30-50 Metres ❑	>50 Metres ❑
Clothing (permeable)	Single layer (light) ❑	Single layer (mod) ❑	Multiple Layer ❑
Respiratory Protection (negative pressure.)	None ❑	Half Face ❑	Full Face ❑
Acclimatisation	Acclimatised ❑		Unacclimatised ❑
SUB-TOTAL A			

	2	**4**	**6**
Metabolic work rate	Low ❑	Medium ❑	High ❑
SUB-TOTAL B			

This was then to be used in conjunction with an air temperature measure.

Whilst this method of risk assessment was an improvement on just measuring the air temperature on its own, it was seen as too limiting as it didn't include other aspects of the environment. There also needed to be more guidance as to what impact the temperature had on the overall strain. This was overcome by including the wet bulb globe temperature (WBGT) as an additional parameter in the overall assessment.

	1	**2**	**3**	**4**
Wet Bulb Globe Temperature	< 24°C ❑	>24°C ≤ 27°C ❑	>27°C ≤ 30°C ❑	> 30°C ❑
SUB-TOTAL C				

A new simple equation was added to the process such that:

*Basic Thermal Risk = (A+B)*C*

Where:

A is the sub-total of the hazard types

B is a value assigned to the metabolic work rate, and

C is a value allocated to the WBGT result.

The weighting of each of the parameters were arbitrarily determined from the author's judgement of the perceived indicative effect of the relative parameters on the individual, to be used only as a qualitative measure.

If a number is generated there is the expectation that there must be some form of scale to measure it against. Hence a scale was developed in which the resultant value could be then compared against a measure of potential risk. This was:

- *If the total is less than 28 then the risk due to thermal conditions are low to moderate.*
- *If the total is 28 to 60 there is a potential of heat-induced illnesses occurring if the conditions are not addressed. Further analysis of heat stress risk is required.*
- *If the total exceeds 60 then the onset of a heat-induced illness is very likely and action should be taken as soon as possible to implement controls.*

It was in this form that the basic thermal risk assessment later appeared in the Australian Institute of Occupational Hygienists standard (Di Corleto et al 2003) and remained until the revision in 2013.

In this ten year period the BTRA appeared in many forms and variations and in some instances, whether rightly or wrongly began to be used as a quantitative assessment, a use which was never intended. This may have inadvertently been encouraged by the inclusion of the WBGT measure. It was meant to be a conservative first level tool to inform users of areas of risk that could be targeted by potential control options and start the process of assessment, not be the decision maker itself. Controlling or reducing the overall risk to workers often took a backseat to getting the "right" risk rating so that work could proceed, even though OH&S law requires businesses to reduce the risks to as low as reasonably practicable.

In 2013 during the re-write of the AIOH heat stress standard it was acknowledged that the BTRA was in need of a review. Throughout the years users had recommended potential improvements and modifications to better characterise the heat exposure as well as pointing out a number of anomalies.

"Why does the assessment add 1 to the equation for not wearing respiratory protection and likewise for not working in a confined space?" or "Why isn't sun exposure considered?"

It was also a chance to take the assessment back to basics. The inclusion of the WBGT measure added a level of rigor to the process but it also made it more complicated for the original intended audience, the worker. Their access to a WBGT monitor on a construction site or out in the field was just not practical but going back to just the air temperature was not going to be acceptable. After reviewing a number of indices the final choice was the Apparent Temperature in its original form (Steadman 1979). What may have been lost by not including the additional parameters was made up for in its simplicity and subsequent more frequent use. Air temperature and relative humidity are readily available either by using a sling psychrometer or accessing a weather website. Providing a basic table from which to determine the apparent temperature by aligning two measures seemed to be the way to go. It was in this new form (see figure 2) that the BTRA appeared in the 2013 AIOH heat stress guide (Di Corleto et al 2013).

Figure 2 - The Basic Thermal risk assessment as it appeared in the 2013 AIOH Heat Stress guide.

HAZARD TYPE	**Assessment Point Value**			
	0	1	2	3
Sun Exposure	Indoors ❑	Full Shade ❑	Part Shade ❑	No Shade ❑
Hot surfaces	Neutral ❑	Warm on Contact ❑	Hot on contact ❑	Burn on contact ❑
Exposure period	< 30 min ❑	30 min – 1hour ❑	1 hour - 2 hours ❑	> 2 hours ❑
Confined space	No ❑			Yes ❑
Task complexity		Simple ❑	Moderate ❑	Complex ❑
Climbing, up/down stairs or ladders	None ❑	One Level ❑	Two Levels ❑	>Two Levels ❑
Distance from cool rest area	<10 Metres ❑	10 - 50 Metres ❑	50-100 Metres ❑	>100 Metres ❑
Distance from drinking water	<10 Metres ❑	10 - 30 Metres ❑	30-50 Metres ❑	>50 Metres ❑
Clothing (permeable)		Single layer (light) ❑	Single layer (mod) ❑	Multiple layer ❑
Understanding of heat strain risk	Training given ❑			No training given ❑
Air movement	Strong Wind ❑	Moderate Wind ❑	Light Wind ❑	No Wind ❑
Resp. protection (-ve pressure)	None ❑	Disposable Half Face ❑	Rubber Half Face ❑	Full Face ❑
Acclimatisation	Acclimatised ❑			Unacclimatised ❑
SUB-TOTAL A				

		2	4	6
Metabolic work rate*		Light ❑	Moderate ❑	Heavy ❑
SUB-TOTAL B				

		1	2	3	4
Apparent Temperature		< 27°C ❑	>27°C ≤ 33°C ❑	>33°C ≤ 41°C ❑	> 41°C ❑
SUB-TOTAL C					

TOTAL = A plus B Multiplied by C =

Then in early 2014 someone asked a question on a heat stress forum:

"If you had a Heat Stress App for your workers, what would you want it to tell them?"

So began the modernisation of the BTRA.

Design and Build

With advances in mobile technology and the abundance of smart phones it seemed reasonable that the BTRA would be a useful digital tool to have and use at a moment's notice through a smart phone app. The advantages of having the BTRA as an app include:

- Convenient to use by both workers and employees and even the general public
- Removes the need to use a paper checklist and do manual calculations
- Removes the need to carry a laptop to use a spreadsheet for the checklist and calculation
- Can be used as a training and education tool for workers

Smart phones use different operating systems (OS) based on their make and model. The top three mobile operating systems used on smart phones are Apple's iOS, Android OS and Windows Phone OS. The different operating systems used on smart phones meant that the app would have to be designed and built for each operating system to ensure maximum availability of the app to end users. In addition, the three operating systems each use different programming languages including *objective-C, C++, C#* and *Java*. Thus began the arduous task of learning new languages.

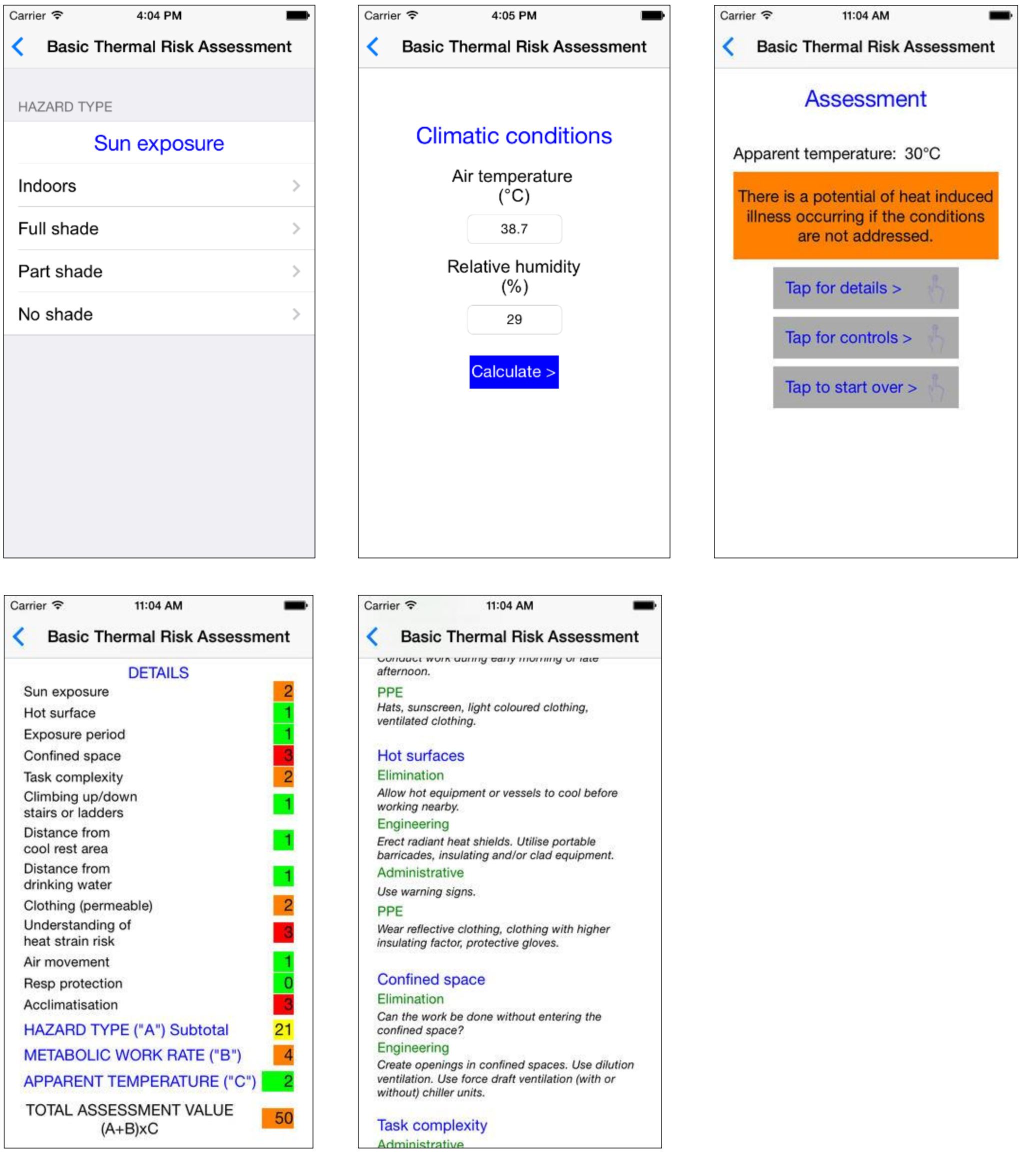
Development initially started with the Windows Phone 8 OS as this was the smart phone being used by one of the authors and programmer (1) which meant that the app could be tested on an actual smart phone device. The programming language used by Windows Phone is *C#*. Using the spreadsheet for the BTRA, the first step to development of the app was to take the information in the spreadsheet and conceptualise how this would look like in an app. This included designing the user interface and the output page. After a month of learning *C#* programming and writing the app, the first app for the Windows Phone was developed and made available on the Windows Phone store. This app was released for testing purposes. Feedback to further improve the app and correct any bugs was sought from users. However feedback was slow to come due to the limitation of the small percentage of Windows Phone users.

Recognising this limitation quickly, development on the Apple iOS and Android OS versions of the app began simultaneously. With the user interface and design concept already mapped out, it was simply a matter of quickly learning the *Objective-C* programming language used by Apple iOS and *C++* and *Java* programming languages used by Android OS. After a couple of weeks of numerous emails back and forth between the authors, testing, re-testing and modifying the app, the BTRA app for the Apple iOS and Android OS were in a format deemed to be suitable and made available to end-users free of charge. Feedback came through quickly and included several themes such as format and appearance, some terms were too technical and needed simpler alternatives, provision of examples and descriptions of the choices available for hazard types, the use of a traffic light colour concept and how to better refine and present controls based on user selection of hazard types among others. These are discussed in more detail below.

Format and appearance

The user interface and output screen of the Apple iOS and Android OS are very similar when compared to the Windows Phone OS. This relates to the different tools available for each OS. Even so the information provided in each OS is exactly the same as is the output. Each risk factor, metabolic work rate and apparent temperature is inputted in a separate screen and a final assessment screen showing the risk of heat induced illness with options to view more details and suggested controls.

Figure 3 - App Screenshots



Technical terms, provision of examples and description of choices with traffic light colour concept

Some terms were too technical for the lay worker and required simpler alternatives e.g. changing "permeable" to "waterproof" and "impermeable" to "non-waterproof". Some of the choices for hazard types were considered vague and non-descriptive and users requested provision of examples as a guide to better understand the selection being made e.g.

Single layer (Light) clothing: 145 - 155 grams per square meter of fabric (e.g. light loose fitting ventilated shirts)
Single layer (Moderate) clothing: 190 - 210 grams per square meter of fabric (e.g. unventilated standard cotton drill shirts)
Multiple layers: More than one layer of clothing. Can be a combination of light and moderate.

The above example would then use the traffic light colour concept, which has been utilised throughout the app. The first option would be *green* in colour the second option *amber* and the third option *red.* This would enable users to instantly know if an option is a low, medium or high risk.

Building a stronger control focus

It has already been stated that the previous version of the BTRA was not always being used to identify potential control options. In addition, feedback from frontline workers indicated that although the BTRA was helpful in identifying risk factors relevant to their task and worksites, typical frontline workers may not be aware of different ways to reduce the severity of these factors that could be applied to their worksites. As a result, a list of example control measures was developed and incorporated into the app accessible from the Assessment summary page. The controls are organised according to each BTRA risk factor (e.g. "sun exposure" or "distance from cool rest area") and are presented according to where they sit in the "hierarchy of control" which is referenced by most OH&S legislation and guidance. As a result, users of the app are able to view a list of control options relevant for the risk factors identified as being significant for their worksite and select these according to the hierarchy of controls. The list is by no means exhaustive and it is likely that frontline workers will often be able to come up with simple and innovative control measures that OH&S "experts" cannot see. The point is that the BTRA app must ultimately be focused on controlling heat stress risks (by reducing the severity of risk factors) and it would seem this is a helpful way of achieving this.

Future improvements

In the future, the app could be improved to further strengthen the control focus. Rather than displaying the entire list of controls, they could be displayed to be tailored towards risk factors that are elevated i.e. those highlighted in red or amber. This would focus users' attention on the higher hazards (more critical risk factors) and hence the control options that will have the most impact on reducing the overall heat stress risk. In the current format the app lists all controls and consequently the current list of controls is by no means as extensive as it could be. Limiting the report to present only controls for risk factors that meet the red or amber criterion would enable the inclusion of a more extensive list of controls to be stored in the app. Another improvement to the app could involve an automatic feedback mechanism so that if users select a control measure or a selection of measures that reduce the severity of a risk factor or several factors, users could see the reduction in the overall risk score. For example, by erecting shade barriers this would reduce the "Sun Exposure" risk factor to a score of 1 which would then reduce the overall risk score and may lower the risk guidance. This would require some more complex programming and may not be practicable at present.

Additional user suggestions have been:

- use of the GPS to pull information about air temperature and humidity from weather stations or websites
- The ability to save individual risk assessments on the phone and/or email the completed risk assessment so that it can be printed out
- The ability to move backwards to correct previous risk factor selections

Going forward: Potential future refinement

The current app has been targeted at the frontline worker and hence is informative but simplistic in nature. Going forward there is also an opportunity to develop a more technical app for the health and safety professional. This could be based around heat stress analysis tools such as the rational indices (i.e. ISO 7933 predicted heat strain and/or the thermal work limit) which utilise numerous equations and algorithms. The goal here would be to similarly focus the attention of the technician towards the parameters within the heat balance equation that are having the greatest impact (i.e.

such as radiation, evaporation, metabolic load etc.) to enable a more effective selection of controls to reduce the impact of the environment and task. There may also be potential to develop an app for the area of physiological monitoring. This would however require significant additional work to develop an algorithm that would successfully integrate all the relevant pieces of information for the required usable output.

Conclusion

What started as a simple question during a discussion between a group of individuals with a common interest in heat stress has evolved and grown. This application has been designed as a basic first level tool to fill a perceived gap in the heat stress management and training process. Its success has shown that there is an appetite for the use of this form of approach in the occupational health and safety area. The original goal was a risk assessment tool for the hot environment. It needed to:

- Provide an indication of the risk to a heat stress illness or injury,
- Focus the user's attention on potential control measures and provide example measures
- Be written in simple terms and easy to interpret
- Be useable as a training tool,

From the perspective of the development team it appears that these criterion have been met however the true measure of its success will be determined in the uptake and use of the app. Ultimately it will be the worker at the frontline that will determine whether it is a useful tool or not.

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