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열감지지수를 활용한 신체온도의 예측

Prediction of a rectal temperature utilizing a thermal perception index

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요 약 이 논문은 신체온도를 직접 측정하지 않고서 신체온도를 예상하는 모델을 연구한 것이다. 열감지지수 (TPI)를 개발하여 환경으로부터 느끼는 체감온도와 몸의 내부온도인 직장온도 (Trec)와 몸의 외부온도인 피부온도 (Tskin)를 예측하도록 하였다. Kwon과 Ramsey의 개발모델을 Goldman의 모델과 비교해본 결과 정확도에 통계적으로 유의한 차이가 없었다.

회귀분석과 경험을 토대로 만든 체감온도를 예측할 수 있는 손쉬운 Kwon의 열감지지수 (KTPI)도 제시하였다.

대부분의 사람들이 쉽게 예측할 수 있도록 측정 또는 사용가능한 몇 개의 환경변수로부터 쉽게 몸의 예상 내부온도와 외부온도를 계산할 수 있게 단순화하였다.

1. Introduction

Despite the fact that environmental thermal stresses may have a significant effect on a safe working capability, their contribution has seldom been considered.

Predicting a body temperature without a direct measuring has a useful application for busy working environment. Without disturbing the workers, a relatively accurate body temperature can be predicted using a thermal perception index. With this predicted body temperature, it can be used as a guideline for diagnosing the hazardous working environment.

Soule et al. (1978) observed that the worker output (march rate) was slightly reduced under hot-humid conditions (40C and 75% RH), but remained the same under hot-dry conditions although increased physiological strain was present.

A thermal perception index is an environmental predicting index, but it can be used as predicting deep body temperature, that is, a rectal temperature. Rectal temperature is not rapidly changeable even though environmental temperature is greatly changed. Therefore, one or two degree change in a rectal temperature can be dangerous or vital for a human life.

Over 39C in a deep body temperature for several hours, human cannot think properly and cannot behave normally. Over 40C, he (or she) may lose his (or her) life if he (or she) did not have a proper medical treatment.

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2. Prediction of a rectal temperature using a thermal perception index

A rectal temperature prediction equation was developed using a computer simulation and a regression analysis. Since thermal perception index (TPI) has an ability to calculate a body temperature, simplified prediction models were developed to predict a body temperature.

Once thermal perception index (TPI) was calculated from following equations, body temperature (rectal and skin temperature) can be predicted.

KTPI is Kwon's thermal perception index, which is based on a simulation and an experience using an empirical equation. This is very simple to calculate like a discomfort index. When Ta is less than -20C, then V becomes 2V and for -20C < Ta < 0, -V becomes 1.5V.

When Ta is greater than 30C, then V becomes +0.5V and for 0C < Ta < 20, -V is not changing.

In addition, a general prediction model and WBGT also developed for easy understanding for most people.-

Trec = 35.89 + 0.05TPI
Trec = 35.04 + 0.07Ta + 0.01RH
Tskin = 27.95 + 0.15TPI
Tskin = 25.42 + .2Ta + 0.03RH

where
TPI = -9.18 + 1.14Ta + 3.38Pa (R2=.95)
(where Pa is in kPa.)
= -4.38 + 1.22Ta 0.27V (R2=.95)
(where V is m/sec.)
= -16.886 + 1.359Ta + 0.189RH 0.5V (R2=.85)
(where Ta is in C.)
= 3.074 + 0.965Ta 1.017V + 0.026Ta*V + 0.15RH (R2=.90)

KTPI = 0.85Ta + 0.15RH V
(for 0 Ta < 30, when Ta 30C, -V becomes +0.5V)

WBGT = 0.76TPI 3.73
(or TPI = 4.91 + 1.32WBGT)
WBGT = -7.767 + 1.10Ta 0.091RH + 0.38V
(R2 = .84)

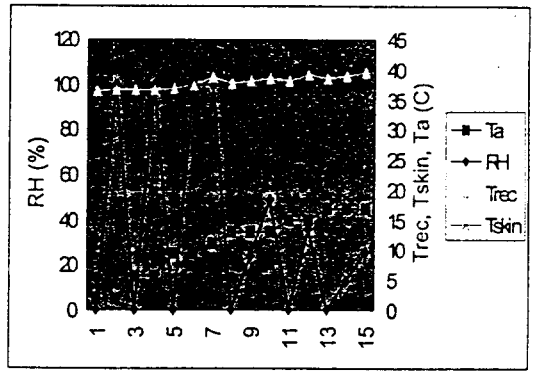

Figure 1. Trend of predicted rectal temperature (Trec) and predicted skin temperature (Tskin) by an air temperature (Ta) and relative humidity (RH)

Therefore, using a WBGT or an air temperature as an input variable, a rectal temperature can be predicted using following equations:

Trec = 36.14 + 0.066WBGT
Trec = 35.54 + 0.06Ta
Trec = 35.05 + 0.07Ta + 0.01RH
Trec = 35.05 + 0.07Ta + 0.01RH 0.3V

Tskin = 28.74 + 0.14WBGT
Tskin = 27.46 + 0.13Ta
Tskin = 25.42 + 0.2Ta + 0.03RH
Tskin = 25.42 + 0.2Ta + 0.03RH 0.08V

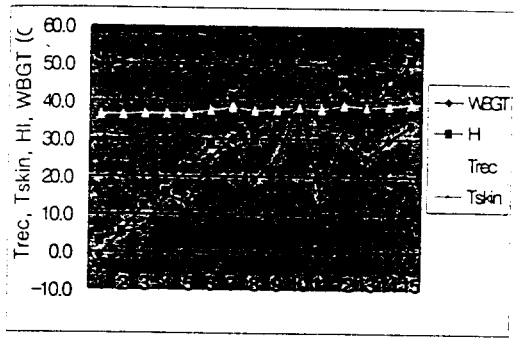

Figure 2. Relationship among predicted rectal temperature (Trec), predicted skin temperature (Tskin), WBGT, thermal perception index (TPI)

There is a relationship between a rectal temperature (Trec) and skin temperature (Tskin).

$$Trec = 22.687 + 0.468Tskin$$
$$(R2 = .99,\ CV = .26)$$

3. Validation of an rectal temperature prediction model

In the arena of a rectal temperature model, Goldman's predicted rectal temperature was accepted as a relatively accurate prediction model. Therefore, Kwon and Ramsey's predicted equation was compared with a Goldman's prediction model.

Table 1 shows a validation for predicted rectal temperature with an actual rectal temperature (RT) and Goldman's predicted rectal temperature (Tgold) through actual rectal temperature data from a literature. Last row in table 1 indicated that a predicted rectal temperature (Trec) using a thermal perception index provides a good prediction for a rectal temperature.

Table 1. Validation of a rectal temperature for Kwon and Ramsey model and Goldman's prediction model with a literature data

Authors Of Study	Relative Difference RT - Trec	Relative Difference RT - Tgold	Absolute Difference RT - Trec	Absolute Difference RT - Tgold
Belding	-0.200.19	0.250.16	0.230.16	0.250.16
Burse	0.180.16	0.400.21	0.180.16	0.400.21
Doherty	0.080.19	-0.010.17	0.180.10	0.120.12
Gonzalez	-0.060.18	0.190.15	0.160.09	0.150.15
Robinson	0.070.26	0.330.27	0.210.16	0.380.19
Shapiro	0.050.40	0.100.36	0.300.24	0.360.10
Winslow	0.000.18	-0.170.22	0.170.08	0.230.16
Wyndham	0.250.13	0.370.10	0.250.13	0.370.10
Combined	0.040.24	0.140.24	0.210.14	0.280.15

4. Discussion

A rectal temperature is a good indicator of a deciding rule for a health care in the working environments. Therefore, a simple predicted rectal temperature was developed and this will have a useful application without disturbing busy workers. Skin temperature prediction

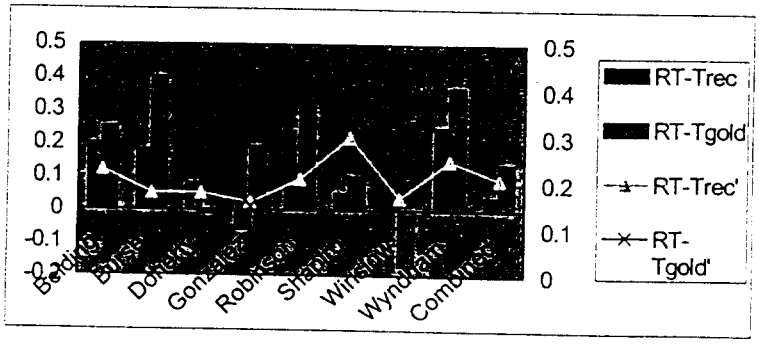

Figure 3. Relative difference (bar) and absolute difference (line) among actual rectal temperature (RT) and thermal perception index (TPI)'s predicted rectal temperature (Trec) or Goldman's predicted rectal temperature (Tgold)

equation was provided as a reference for a decision making.

The easy calculable prediction equations for human body temperatures are provided when following climatic variables are available

Trec = 35.54 + 0.06Ta
Tskin = 27.46 + 0.13Ta
Trec = 35.04 + 0.07Ta + 0.01RH
Tskin = 25.42 + .2Ta + 0.03RH
Trec = 35.04 + 0.07Ta + 0.01RH - 0.3V
Tskin = 25.42 + .2Ta + 0.03RH 0.8V

Other simple rectal temperature prediction equations using WBGT or thermal perception index (TPI) will be a useful guideline for busy working workers in real world.

Trec = 36.14 + 0.07WBGT
Tskin = 28.74 + 0.14WBGT

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Abstract Currently, heat index was developed by Dr. Steadman and have used in US weather bureau and military.

Generally, a prediction equation for heat index was not easy to calculate, so a simple prediction equation was needed for most people.

This paper shows simple prediction equations for heat index to calculate human-feel like temperature using a few environmental parameters. This predicted equation is called a thermal perception index (TPI) or a simple heat index (SHI).

Newly developed most simple equation is that SHI = TPI = -7.07 + 1.22Ta. An empirical thermal heat index was also developed (THI = 0.85Ta + 0.15RH - V). Most complete and versatile simple thermal perception index was finally developed (THI = -3.074 + 0.965Ta - 1.017V + 0.026Ta*V + 0.15RH).

The simulation result of an extensive range of environmental conditions indicated that there is not a significant difference in most cases. Therefore, simplified TPI is useful indicator of environmental changes and easy to use for most people.