PHYSIOLOGICAL RECOVERY FROM WORKING IN COLD STORAGE

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The purpose of this study is to compare the recovery time of core temperature and skin temperature at finger, hand, shin, neck, scapula and toe of workers working in cold storage by using forced warm air and not using forced warm air.

The quasi - experimental research design was conducted with thirteen male workers from the Canned Food Industry as the subjects. Each subject was asked to work in cold storage for 45 minutes then leave cold storage to rest in a rest area. Warm air supply was provided for the experimental group until the temperature recovered. In each group, the subjects had to work in the same cold storage and then leave the cold storage to rest. One group had to warm their hands with forced warm air; whereas, the other group did not.

The result of this study showed that the core temperature and skin temperature at hand, finger, shin, neck, scapula and toe in the forced warm air group could recover more quickly than the that of the group without using forced warm air. The recovery time for both group was less than 15 minutes (rest period.) Moreover, the results revealed significant differences in heart rate between the group with forced warm air and group without forced warm air.

The heat exchange rates between the air and hands of worker were 582.78 kcal/m^{2}hr with the forced warm air group, and 33.71 kcal/m^{2}hr with the group not using forced warm air. Forced warm air at the temperature of 45 degrees celcius should be used while the workers turn both hands up and down alternatively. Workers should be allowed to remove their hands if the heat be comes unbearable, but then they should try again. This method can reduce the side effects of chapped skin or burning.

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การวิจัยนี้มีวัตถุประสงค์เพื่อทำการศึกษาเปรียบเทียบการปรับตัวคืนสู่สภาพเดิมของอุณหภูมิภายในร่างกาย อุณหภูมิผิวหนัง (นิ้วมือ, มือ, คอ, ไหล่, แข้ง, นิ้วเท้า) หลังจากทำงานในห้องเย็นโดยใช้เครื่องเป่าอากาศอบอุ่นและไม่ใช้เครื่องเป่าอากาศอบอุ่น

วิธีการวิจัยในการศึกษานี้เป็นการศึกษากึ่งทดลอง (Quasi - Experimental Research Design) กลุ่มทดลองเป็นคนงานเพศชาย 13 คน จากโรงงานอาหารกระป๋อง โดยทดลองให้คนงานทำงานในห้องเย็นเป็นเวลา 45 นาที และออกจากห้องเย็นมานั่งพักโดยให้เป่ามือด้วยเครื่องเป่าอากาศ อบอุ่นจนกว่าอุณหภูมิปรับสภาพเดิม ในอีกกลุ่มหนึ่งให้ทำงานในห้องเย็นเช่นเดียวกันแต่เมื่อออกจากห้องเย็นให้นั่งพักโดยไม่ใช้เครื่องเป่าอากาศอบอุ่น

ผลการศึกษาพบว่ากลุ่มคนงานที่ใช้อากาศอบอุ่น อุณหภูมิภายในร่างกาย อุณหภูมิผิวหนัง (นิ้วมือ, มือ, คอ, ไหล่, แข้ง, นิ้วเท้า)ปรับตัวสู่สภาพเดิมเร็วกว่ากลุ่มซึ่งไม่ได้เป่ามือด้วยอากาศอบอุ่นและเร็วกว่า 15 นาทีซึ่งเป็นเวลาพักระหว่างชั่วโมงทำงาน และจากการทดลองยังพบอีกว่าการเป่ามือด้วยอากาศอบอุ่นไม่มีผลกระทบต่อการปรับตัวสู่สภาพเดิมของอัตราการเต้นหัวใจ

อัตราการแลกเปลี่ยนความร้อนระหว่างอากาศและมือของกลุ่มใช้อากาศอบอุ่นเท่ากับ582.7 kcal/m^{2}hr. และกลุ่มไม่ใช้อากาศอบอุ่นเท่ากับ 33.71 kcal/m^{2}hr. ซึ่งการเป่ามือด้วยอากาศอบอุ่น 45 องศาเซลเซียส จะให้คนงานพลิกคว่ำ – หงายมือทั้งสองด้านสลับกัน หรือถ้าทนร้อนไม่ไหวก็ให้ชักมือออกแล้วเป่าใหม่ ซึ่งจะช่วยลดอาการแห้งแตกหรือร้อนมากเกินไปได้

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CHAPTER I

INTRODUCTION

1.1 Statement of problem

Nowadays in Thailand, agriculture fisherly and industry have been developed. There are a lot of industrial products modify from agriculture and fisherly products. Preservation and modification processes are used for keeping raw materials (e.g. prawns, fish and meat) and they were always kept in low temperature storage because of the bacterial reduction activity. The temperature needed for cold storage is about -18 to -40 °C . (1) Present, there are 237 cold storage - industry factories, 5,498 million baht for investment and 23,967 workers . (2) Workers have to work in cold storage for a long time. Working in cold storage may cause a lot of illness e.g. hypothermia, muscle weakness and blood circulate reduction that make them got finger and toe pain. (4) Nevertheless, it causes chronic disease e.g. gastrointestenal tract disease, back and joint pain, bronchial disease and the white disease in workers. (11) Department of Occupational and Safety, (5) study worker who worked in cold storage were observed. The result indicated that skin temperature after working 45 minutes was too low and after rest period about 15 minutes, skin temperature still lower than normal human temperature especially at fingers. As low temperature, tissue will be damaged because of low blood circulation, evaculation and oxygen supply so organs will be damaged too. If the lower the temperature of hand and fingers is, the less response of the nerve of hand and fingers becomes, causing loose grip and less sense of touch which easily brings about the accident from performing work. So it is not enough if workers just only have a rest time after working in cold storage without using warm system. They should be rewarmed by using system such as forced warm air, warm water or hot – steel plate to increase their body temperature espectially, hand and finger skin temperature.

For that reasons, the researcher interested in the procedure of how to keep warm of the workers' hands by using forced warm air at 45 °C to increase temperature to hand to be recovered more quickly and take less than 15 minutes. The result from this study will have benefit to health promotion and prevention from working in cold storage. Additional, the workers will work more effectively.

1.2 Objective

1.2.1 General objective :

To study the physiological recovery form working in cold storage.

1.2.2 Specific objectives.

1. To examine the recovery times of core temperature and skin temperature at hand, finger, shin, neck, scapula, and toe from working in cold storage.
2. To compare the recovery periods of core temperature and skin temperature at hand, shin, neck, scapula, finger and toe from working in cold storage between with and without forced warm air.

3. To examine the effect of recovery time of heart rate after recovery by forced warm air.

1.3 Hypotheses

1.3.1 Recovery times of core temperature of the workers with and without forced warm air are different.

1.3.2 Recovery times of skin temperature at hand , finger and toe of the workers with and without forced warm air are different.

1.3.3 Recovery times of skin temperature at hand, finger and toe of the workers that recovered by forced warm air are more quickly than 15 minutes.

1.4 Variables

1.4.1 Independent Variable

- with and without forced warm air

1.4.2 Dependent Variables

- Recovery time of core temperature
- Recovery time of skin temperature at hand, finger, shin, neck, scapula and toe

1.4.3 Control Variables

- Sex
- The environmental condition in cold storage ; temperature, wind, humidity.

1.5 Operational Definition

1.6.1 Cold storage is the storage room at -16 °C which contains the fishes at Canned Food Industry.

1.6.2 Workers are persons who carried containers pass to another divisions of

1.6.3 Physiological parameters are core temperature skin temperature (finger, hand, shin, neck, scapula, toe) and heart rate.

1.6.4 The physiological recovery is the condition that core temperature skin temperature (finger, hand, shin, neck, scapula, toe) and heart rate recover to normal level after working in cold storage, by assumption that normal level of core temperature skin temperature (finger, shin, neck, scapula, hand, toe) and heart rate are the same values that measured before starting to work each day which different in each person.

1.6.5 The recovery time is the time that was used to recovery since out of the cold storage until regular and constant.

1.6.6 Forced warm air is air wihich blowing by Rapid Hand Dryer (Model HTE – 4, STIBEL ELTRON) having rate of flow 205m^2/hr. and average heat temperature 45 degree celsius.

CHAPTER II

Literature Review

1. Body temperature

The body can be considered conceptually in two parts, a 'core' and a 'shell' (inner and outer).[4] [7] It is core temperature (t_{cr}) which the thermoregulatory system attempts to maintain (around 37 °C) and as part of thermoregulation the shell temperature (t_{sh}) varies. Mean body temperature (t_b) is the average temperature over the whole body (shell and core) and is often taken as a weighted average of shell and core temperature. In practice, there is no such thing as core or shell temperature. They provide only a conceptual convenience. It has been suggested that they be defined as sites on the body. For example, core temperature could be defined as hypothalamus temperature of rectal temperature. Shell temperature could be defined as the average temperature over the skin (mean skin temperature, t_{sk}). This however misses the point. 'core' and 'shell' temperatures provide convenient concepts. In practice, temperatures vary over the should of the body. If one is considering a particular area of the body then one should refer to that (e.g. rectal temperature). Experience has shown however how particular temperatures (rectal, mean skin, oral, aural, etc.) relate to human responses (heat stress, cold stress, comfort) and how one can view the temperature in the conceptual framework of body core and shell.

1.1 Core temperature

Core temperature has no definition as core tissues are not defined. However it is generally considered as inner body temperature or the temperature of the vital organs including the brain. These core tissues are maintained within a narrow range of temperatures by thermoregulation. If core temperature rises or falls, then there are practical consequences for the body in terms of health, comfort and performar. An 'estimate' of 'core' temperature is therefore useful and this is obtained by a number of methods. Each method has its own characteristics and method of useful interpretation associated with it. For example, aural (external auditory meatus) temperature can give information about brain temperature and responds rapidly to changes. It may therefore be useful for investigation thermoregulation and transient conditions; its sensors, however, can be affected by the external environment. Rectal temperature provides a method little influenced by external environment, and it provides a good average value of internal body temperature; however, it is slow to respond to changes and is affected by leg muscle temperature.

1.2 Shell temperature

The temperature of the shell (outer tissues of the body) varies with external environmental conditions and the thermoregulatory state of the body (vasodilated, sweating, etc.). Shell temperature is often taken as the mean skin temperature (t_{sk}) over the body. Local skin temperature can, however, vary from the mean. In the cold for example, feet and hands can have much lower skin temperatures than the trunk or forehead. Local skin temperatures can be important (to health or performance, for example), and should be measured individually (e.g. on hands and feet). Mean skin temperature is commonly calculated by taking a weighted average (according to body mass/area) of temperature taken from a number of body sites. The number of sites required to provide a representative average increases as the body becomes cold and skin temperatures vary across the body.

1.3 Mean body temperature

Mean body temperature (t_b) is the average temperature of the body. It is usually estimated from a weighted average of shell and core temperatures.

$$t_b = \alpha t_{sk} + (1 - \alpha)t_{cr} \quad \text{..................} \quad (1)$$

where α is a weighting factor that depends upon skin blood flow. Estimates of α vary from 0.1 to 0.3 for vasodilated and vasoconstricted skin respectively.

2. Physiological responses to cold [6] [8] [9]

When the body becomes cold, vasoconstriction reduces blood flow to the skin and hence heat loss. Where there is a tendency for body temperature to fall, non-shivering thermogenesis (muscle tensing, feeling of stiffness and enhanced metabolism) will increase heat production. As the body temperature falls (skin, skin with core, or both) and thermoregulates, shivering begins; there may also be some ‘reaction’ type shivering (at higher body temperatures) due to psychological response and rate of fall in skin temperature due to sudden exposure. Initially, there is asynchronous firing of muscle fibres to produce heat but no work. After further cooling the muscle discharges synchronize to produce the 10 - 12 Hz oscilation associated with shivering and hence producing heat. Heat production can be increased by up to six times the resting levels over short periods and around double for longer durations. During exercise shivering is inhibited. There are large individual variations in response.

Shivering is an effective method of increasing heat production. In the limbs some heat is lost to the skin but some will be transferred to maintain body temperature. The neck muscles in animals (including man) are the first to shiver. This will help maintain brain temperature. Shivering is inhibited in some illnesses and by some drugs, e.g. insulin. It is also affected by levels of O_2/CO_2 and is inhibited by any form of anaesthesia. In surgical operations for example, falls in deep body temperature can be marked if the operating theatre is not kept warm.

The effectiveness of human thermoregulation in the cold is such that an environment which produces any fall in deep body temperature below about 36 °C can be regarded as severe and a fall below 35 °C (hypothermia) potentially dangerous. In 'controlled' hypothermia (e.g. for operations), powerful techniques (e.g. ice cooling or the use of lytic drugs) in anaesthetized patients must be used. These are very specialized conditions however, and under normal conditions environments must be extreme. There are also great individual differences in response. Violent shivering occurs in an attempt to maintain body temperature. If temperature begins to fall muscles become stiff and blood viscosity increases so movements become clumsy. There may be a clouding of consciousness (e.g. confusion and sometimes apathy), a loss of sensory information (e.g. blurring of vision) and unconsciousness. There is a large individual variation but almost all persons will be unconscious at an internal body temperature of 30 - 31 °C, and at these levels and below there will be major risk of death due to ventricular fibrillation (asynchronous behaviour of cardiac muscle -

probable due to the direct of low temperature on the pacemaker). The effects of reduced internal body (core) temperature are summarized in Table 2.1

Low body temperatures can lead to death; however, survival will depend upon the individual. The brain will survive for longer with reduced blood flow at low temperatures as metabolic rate is reduced. Open heart surgery can be successfully completed at heart temperatures of 18 - 20 °C. At 15 °C the heart will cease to function but even at body temperatures as low as 10 °C for short periods rewarming may be successful. Individual cases and highly controlled conditions however should ant confuse the overall picture which is that it takes extreme conditions to reduce body temperature below 36 °C and any temperature below 35 °C can be dangerous.

In cold conditions where vasoconstriction reduces blood flow and hence heat loss. There is an apparently anomalous reaction where at around 12 °C (or below depending upon rate of cooling, muscle and skin temperatures) vasodilation occurs. This is called cold induced vasodilation (CIVD). The response is shown in figure 2.1

Core temperature		
(°C)	(°F)	Clinical signs
37.6	99.6	'Normal' rectal temperature
37.0	98.6	'Normal' oral temperature
36.0	96.8	Metabolic rate increases in an attempt to compensate for heat loss
35.0	95.0	Maximum shivering
34.0	93.2	Victim conscious and responsive, with normal blood pressure
33.0	91.4	Severe hypothermia below this temperature
32.0	89.6	Consciousness clouded; blood pressure becomes difficult to obtain;
31.0	87.8	pupils dilated but react to light; shivering ceases
31.0	86.0	Progressive loss of consciousness; muscular rigidity increases;
29.0	84.2	pulse and blood pressure difficult to obtain; respiratory rate decreases
28.0	82.4	Ventricular fibrillation possible with myocardial irritability
27.0	80.6	Voluntary motion ceases; pupils nonreactive to light; deep tendon and superficial reflexes absent
26.0	78.8	Victim seldom conscious
25.0	77.0	Ventricular fibrillation may occur spontaneously
24.0	75.2	Pulmonary oedema
22.0	71.6	Maximum risk of ventricular
21.0	69.8	Fibrillation
20.0	68.0	Cardiac standstill
18.0	64.4	Lowest accidental hypothermia victim to recover
17.0	62.6	Isoelectric electroencephalogram
9.0	48.2	Lowest artificially cooled hyperthermia patient to recover

Table 2.1 *Progressive clinical presention of hypothermia.*

The so-called 'hunting phenomenon' is due to vasoconstriction followed by vasodilation as vasoconstriction cannot be effected at low temperatures. As temperature rises with blood blow, so vasoconstriction is applied again and skin temperature falls. Hence, there is a cyclic change in skin temperature. This can easily be demonstrated by immersing the hand in cold water, or is commonly experienced when 'playing' in snow for example.

There is some debate over exact physiological mechanisms or 'biological' advantages which CIVD offers. Hands become warm and can perform as increased blood flow supplies the hands and limbs. However, there is a net increased heat loss - leading rapidly to death in cold water for example at a time when the body is attempting to preserve heat for survival.

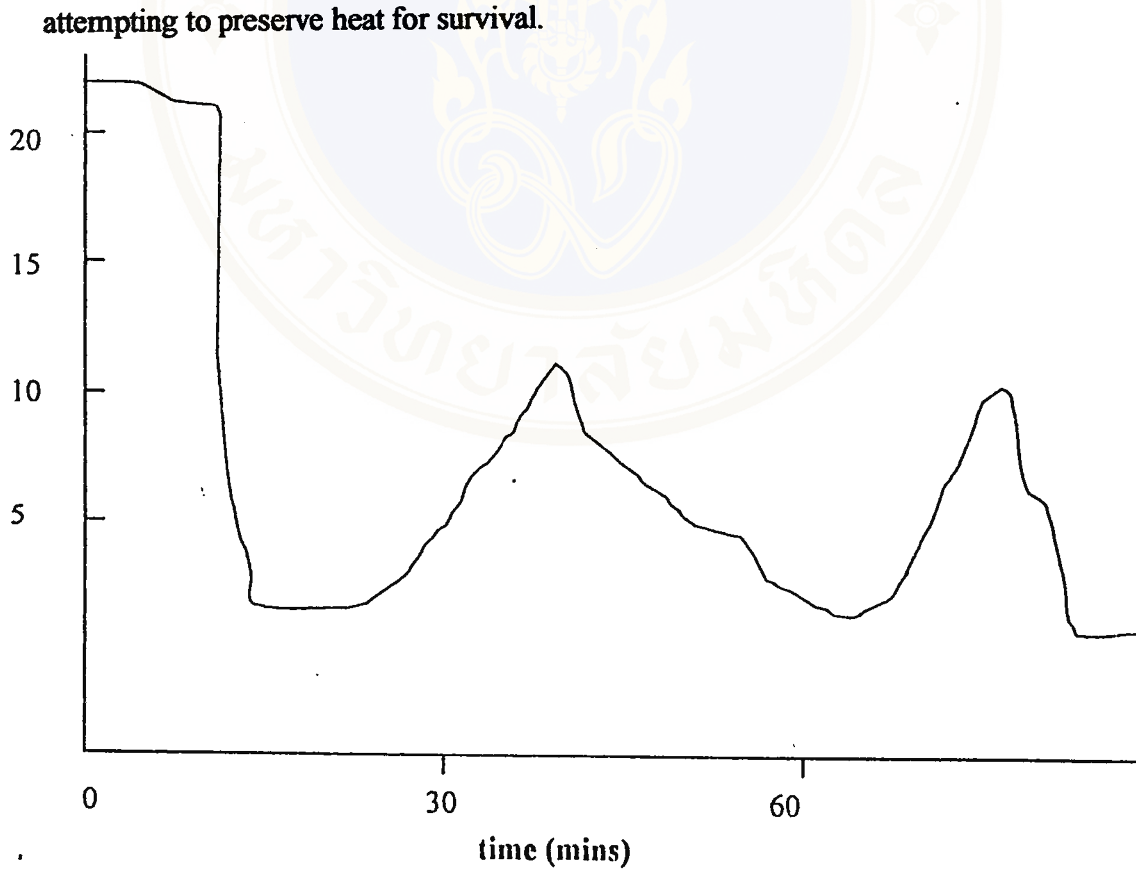


Figure 2.1 *The effects of cold-induced vasodilation (CIVD) on finger skin temperature. Measured with a thermocouple under adhesive tape.*

or apathy generated by low body 'core' temperatures for example.

The industrial contexts, offices or schools, cold can produce discomfort which can behaviour in terms of absenteeism from workplaces, desks or even from work call. Distraction and discomfort not only affects absenteeism but can lead to a in attention and a breakdown of discipline.

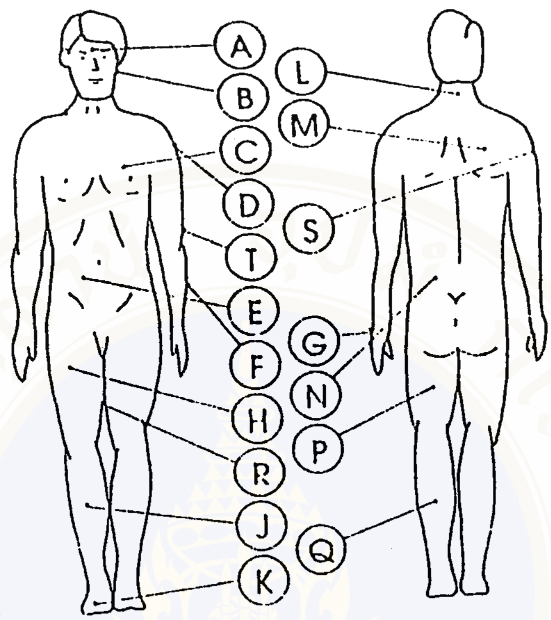
3. Measurement of physiological response [6] [10]

3.1 Skin temperature

Skin temperature can be measured by placing sensors on the skin (thermocouples, thermistors, etc.) or by measuring thermal radiation which has the advantage or non-contact.Contact techniques must overcome the problem of interference, for example due to insulation and pressure and also must account for the heat transfer between sensor and the environment - air, radiation, etc. Skin temperature devices include harnesses, which expose the sensor to the skin with good contact but do not insulate it, so called air and vapour permeable tape, which covers the sensor and metal-based tape allowing conduction between skin and sensor. All methods have errors and corrections to readings may be necessary.

Mean skin temperature (t_{sk}) is the mean value of the skin over the whole body and can be measured with an infra-red scanning radiometer. More traditional methods estimate t_{sk} from weighted average measurements of temperature at specific points on the skin. The weighting used is usually related to body surface area (e.g. trunk has a high weighting, hand a low one, etc.), but other methods could consider distribution of thermoreceptors or sweat glands over the body. Many different methods have been proposed and used. The general principle derives from statistical sampling methods. The greater the variation in temperature, the more points needed to have a representative sample. For the human body therefore, fewer points are required for assessment in the heat where skin temperature is homogeneous (due to vasodilation) and more points are required in the cold where skin temperature is heterogeneous (due to vasoconstriction). A summary of methods is provided in Figure2.2 and Table 2.2

A number of studies have compared the use of fewer points (which is more convenient) to results obtained using a large number of points, in an attempt to compare methods. The results however will depend upon conditions and differ between studies. A practical consideration is the time required to prepare a person for measurement and the interference caused by the associated wires and equipment. For this reason telemetry systems are sometimes used. In general, mean and local skin temperature can be related to thermal discomfort, and local skin temperatures (e.g. fingers, toes) can be used as 'safety limits' for exposure to cold environments, and hand skin temperature related to manual performance in cold environments.



A	forehead	J	right shin
B	left side of face	K	right instep
C	left upper chest	L	neck
D	left front shoulder	M	right scapula
E	right abdomen	N	left paravertebral
F	left outer mid lover arm	P	left posterior thigh
G	left hand	Q	left calf
H	right anterior thigh	R	right mid inner thigh

Figure 2.2 *Measurement sites used, over a number of methods, in the estimate of mean skin temperature over body, from a weighted average of skin temperatures at the individual skin sites. (See also Table 2.2)*

sites	Weighting coefficients										
	1	2	3	4	5	6	7	8	9	10	11
A	0.07	0.07								0.07	1/14
B			0.10	0.149	0.14						
C		0.0875	0.125	0.186	0.19	0.30	0.50			0.175	1/14
D			0.07	0.107		0.30					
E	0.35	0.0875									1/14
F	0.14	0.14	0.07		0.11		0.14				
G	0.05	0.05	0.06		0.05				0.16	0.05	1/14
H	0.19	0.095	0.125	0.186	0.32	0.20				0.19	1/14
J	0.13	0.065	0.15			0.20	0.36		0.28		1/14
K	0.07	0.07	0.05								1/14
L									0.28		1/14
M		0.0875							0.28	0.175	1/14
N		0.0875	0.125	0.186	0.19						1/14
P		0.095									1/14
Q		0.065								0.20	1/14
R			0.125	0.186				1.00			
S										0.07	1/14
T										0.07	1/14

1= Hardy/DuBois, 7pt; 2=Hardy/DuBois 12pt; 3=AREC, 10pt; 4=Teichner, 6pt; 5=Palmes/Park, 6pt; 6=Ramanathan, 4pt; 7=Burton, 3pt; 8=medial thigh, 1pt; 9=ISO, 4pt; 10=ISO, 8pt; 11=ISO, 14pt

Table 2.2 *Weighting coefficients used in formulae for calculating estimates of mean skin temperature from skin temperatures at individual sites*

involoving heat flow for example. Instruments used generally involve mercury-in-glass thermometers, thermistors and thermocouples, but other equipment such as radio pills, heat-flow meters and infra-red thermometers are also used. It is important to note that all of these measurements will differ in temperature and each will have its own characteristics and method of interpretation. In addition, some will be more convenient to measure, some more acceptable to the subject, and all will have practical considerations in measurement and require experience in their use. These are discussed below (from top to tail).

3.2 Measurement of internal body temperature [6]

There are numerous methods for measuring internal body (core) temperature. These include measurements in all accessible places (oriphae) and other derived methods

3.3 Tympanic temperature

A small sensor touching the tympanum will reflect the temperature of blood in the internal carotid artery which also supplies the hypothalamus, the main centre for thermoregulation. After careful inspection of the meatus (ear canal), contact is made between the sensor and the tympanum. This can prove very painful (and cause fainting) to the subject and great care must be taken. This method is not generally found acceptable to subjects either in laboratory or field investigation. If contact is maintained and the sensor is insulated from outside conditions, then tympanic temperature provides a reliable estimate of changes in brain temperature with time. Use of infra-red (non-contact) sensors make the measurement of tympanic temperature acceptable. An infra-red thermometer for measuring tympanic temperature is now available and may become widely accepted.

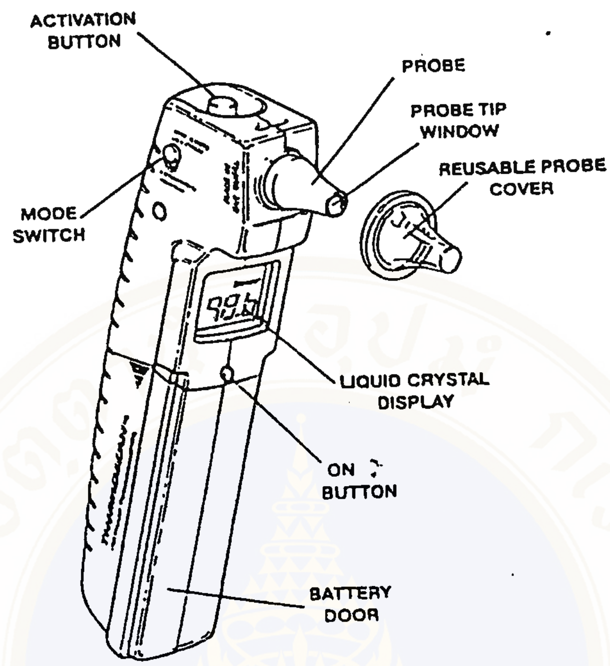


Figure 2.3 Infra-red thermometer to measure tympanic temperature.

3.4 Aural temperature

Based on a similar principle, but a more acceptable and widely used method, to tympanic temperature, this is measured in the external auditory meatus (ear canal). The small sensor is placed close to the tympanum. Greater precaution is required to insulate the sensor from the external environment to avoid conduction of heat down wires and penetration of external environmental conditions. Insulation can be provided by 'fitted' plastic ear plugs, foam ear plugs (which roll up, are placed in the ear canal and expand to take its shape) and additional tape and ear muffs or other harness devices can provide good insulation (and help keep the sensor in position). Adequate insulation is difficult to achieve in cold conditions. One active method involves a 'zero-gradient' thermometer which consists of ear muffs containing a heated element which maintain a zero-gradient with a sensor inside the ear canal. This method works very effectively but requires an additional power supply. Experience with the use of aural temperature indicates that it can provide a useful estimate of the change in brain temperature with time. Acceptability will depend upon fitting and sensors can cause discomfort over long periods of time. For any measure of ear canal temperature, especially when isolation is involved, there will be an interference with acoustic performance which may be unacceptable for some investigations.

3.5 Forehead temperature

The measurement of skin temperature on the forehead can give an estimate of 'brain' temperature, particularly when the person is hot (in fever for example). Thermistors and thermocouples will provide measures; however an often used method of measurement on babies is to stretch some calibrated thermosensitive material across the baby's forehead and numbers on the material will change colour according to temperature. This method will be affected by external conditions, in some applications, because vasoconstriction in the forehead is limited, but it will provide a useful and acceptable first approximation.

3.6 Oral temperature

This method is widely used in medical applications. The sensor (mercury-in-glass maximum thermometer, thermistor or thermocouple) is placed under the tongue, hence near the lingual artery. It is convenient that, with guidance, subjects place a mercury-in-glass thermometer under the tongue themselves. External conditions may have great influence and the mouth should be held closed for a few minutes (i.e. > 4), the thermometer removed and the reading taken. In very hot (high air and/ or radiant temperatures) conditions, it may be necessary to take the reading with the sensor still in the mouth, or take other precaution } use of beaker of water example (to prevent the mercury rising up the stem when exposed to the hot environment). Continuous recording can be mand using a detal mount holding a thermometer under the tongue. Breathing and saliva will influence the measure which causes difficulties during physical activity , eating, talking, etc. Oral temperature is sometimes underestimated in its usefulness; it can be acceptable and used effectively if careful attention is given to the measurement method.

3.7 Oesophageal temperature

A sensor placed in the oesophagus at the level of the heart will reflect internal blood temperature, for example of the aorta going to the brain and the rest of the body. A small sensor (coated with analgesic gel to reduce discomfort) is introduced through the nose and inserted to the required position (25% of a person's height gives a rough guide on catheter length). This method is used in laboratory investigation; however it may not be accepted by subjects, or experimenter - it is uncomfortable and can be painful and even dangerous. Once positioned, however, there are few problems and a reliable measure is taken, although swallowed drink, food and saliva will influence the readings.

3.8 Rectal temperature

A temperature sensor is inserted (> 100 mm) by the subject into the rectum and provides a measure representative of the temperature of a large mass of deep body tissue, independent of ambient conditions. Once located the sensor is found comfortable and generally acceptable. A 'swelling' in the cable inserted just inside the anus, and tape, will hold the sensor in position during exercise. In some subjects there is general dislike for this measure (mainly the concept) and particularly with connotations regarding the spread of viral diseases. This measure gives a value of 'average' internal body temperature; however, it may not be representative of brain temperature and particularly changes in temperature. It will also be affected by 'cold' blood or 'hot' blood from the legs during vasoconstriction or exercise respectively.

3.9 Measurement of thermal effects on heart rate [6]

Heart rate, measured for example in beats per minute (bpm), provides a general index to stress on the body (or anticipated exertion, pleasure, etc.) which can be caused by activity, static exertion, thermal strain, psychological responses. The electrical activity of the heart, was represented by an electrocardiogram (ECG), describes the rhythmic cycle of contractions etc. of components of the heart, making up the beat (auricle, ventricles, etc.) and can also be affected by stress on the body. For example, in hypothermia or with abnormal heart function, non-typical ECG patterns can be seen. Electrocardiograms require more sophisticated equipment than simple measurements of heart rate.

To determine the thermal effects on hart rate one can divide overall heart rate into a number of (non-independent) components.

$$HR = Hr_o + \Delta HR_m + \Delta HR_s + \Delta HR_t + \Delta HR_n + \Delta HR_c \quad \ldots\ldots\ldots \quad (2)$$

where

HR = overall heart rate

HR_o = heart rate at rest

ΔHR_m = component due to activity

ΔHR_s = component due to static exertion

ΔHR_t = component due to thermal strain

ΔHR_n = component due to psychological reactions

ΔHR_c = residual component - circadian rhythm, breathing etc.

If HR_o is measured and other components can be assumed to be negligible ΔHR_t can be estimated from

$$\Delta HR_t = HR_r - Hr_o \quad \ldots\ldots\ldots\ldots\ldots \quad (3)$$

where HR_r is the heart rate after recovery from activity in the heat but still containing the thermal component. This recovery time up to the break is on average four minutes' but it may be longer, for high activity levels. The 'recovery' curve should be measured to identify this point . The ΔHR_t component provides a measure of thermal strain and can be related to deep body temperature. A similar principle can be used to determine ΔHR_m from HR and hence estimate metabolic heat production.

Heart rate can be measured using a simple pulse detected with the hand placed on the wrist or neck. Electrocardiogram measures give heart rate but are over-elaborate if this is the only parameter of interest. Infra-red techniques, electrical sensors and temperature sensors relating to changing blood flow in the finger or ear lobe for example can also be used.

As well as portable pulse reading devices attached by wires to sensors and carried on belts, there are now a number of simple reading devices available. One such device comprises electrodes strapped around the chest which send radio signals to a watch worn on the wrist. These devices are reliable, and data can be stored for later analysis, allowing recording at a pre-programmed rate, of heart rate over 24-hour periods if required.

If a number of devices are used, careful consideration should be given to range of reception (approx 1 m) and interference between devices. Methods of determining heart rate should be considered and ideally compared with ECG traces over a number of conditions.

3.10 Measurement of body mass loss [6]

Body mass loss is related to thermal strain, mainly due to sweat loss. It is also affected by evaporative loss due to breathing and differences in mass between expired CO_2 and inspired O_2.

A simple method of measurement is to weigh a subject nude before exposure (N_B), clothed before exposure (C_B), clothed after exposure (C_A) and nude after exposure (N_A). The following can then be determined (assuming all mass loss is sweat).

$N_A - N_B$	Total mass (sweat) loss from the body
$C_B - N_B$	Dry weight of clothing
$C_A - N_A$	Wet weight of clothing
$(C_A - N_A) - (C_B - N_B)$	Sweat trapped in clothing
$(N_A - N_B) - [(C_A - N_A) - (C_B - N_B)]$	Sweat evaporated

Dripping of sweat can also be important and in a laboratory can be measured by collecting it in a pan of oil placed beneath the subject. Naturally, all inputs (food, drink, etc.) and outputs (urine, stools, etc.) should be accounted for. Scales used should ideally have an accuracy at around 5 g and not less than 50 g although it depends upon application. Caution should be taken with some scales with digital readings which falsely imply great accuracy. Simple devices such as the use of small sheets of absorbent paper inside clothing have been use, e.g. to assess comfort of seating and total sweat loss estimated.

Continuous measurement of mass loss can be made with highly sensitive balances, although these are used mainly in the laboratory. Vapour pressure sensors on the skin (within clothing) will also provide continuous estimate of mass loss with time.

4. Cold Stress [6]

Cold stress is a fundamentally different kind of problem than heat stress. Whereas adaptive mechanisms such as sweating and acclimation are crucial during heat stress exposures, the physiological adaptations to cold stress have less dramatic effects. The first physiological response to cold stress is to conserve body heat by reducing blood circulation through the skin. This effectively makes the skin an insulating layer. A second physiological response is shivering, which increases the rate of metabolism. Shivering is a good sign that cold stress is significant and that hypothermia may be present. These responses, however, are relatively weak as a protection mechanism. Behavior is the primary human response to preventing excessive exposure to cold stress. Behaviors include increasing clothing insulation, increasing activity, and seeking warm locations.

Insulation is a critical characteristic of clothing worn during cold stress exposures. Clothing materials used for their insulating characteristics include cotton, wool, silk, nylon, down, and polyester. Generally, better insulation is achieved by layering clothes rather than having one garment. The further advantage of layers is that a person can add or remove layers to adjust for differing insulation needs during the work period.

The insulating value of clothing is greatly diminished by moisture. Sources of water are the work environment and sweat. Water vapor permeability is also important. If sweat is allowed to evaporate through the clothing, it does not accumulate in the clothing. Once clothing becomes wet, it is important to replace it immediately.

Like layering, clothing ventilation is a valuable means to adjust the heat transfer properties of the ensemble. During low levels of work, insulation demands are high; as the work rate increases, insulation must decrease to maintain thermal equilibrium. In addition to removing layers, the effective insulation of an ensemble can be reduced by increasing air movement under the clothing by increasing clothing ventilation.

Hazards associated with cold stress are manifested in two distinct fashions: systemic (hypothermia) and local (localized tissue damage). The disorders related to cold stress exposures are described in Table 2.3

As hypothermia progresses, depression of the central nervous system becomes more severe. This accounts for the progression of signs and symptoms from sluggishness through slurred speech and unsafe behaviors to disorientation and unconsciousness. The ability to sustain metabolic rate and reduced skin blood flow is diminished by fatigue. Thus fatigue increases the risk of severe hypothermia through decreasing metabolic heat and increased heat loss from the skin. Because blood flow through the skin is reduced to conserve heat, the skin and underlying tissues are more susceptible to local cold injury.

Disorder	***Symptoms***	***Signs***	***Causes***	***First Aid***
Hypothermia	Chills Pain in extremities Fatigue or drowsiness	Euphoria Slow, weak pulse Slurred speech Collapse Shivering Unconsciousness Body temperature <95 F (35° C)	Excessive exposure Exhaustion or dehydration Subnormal tolerance (genetic or acquired) Drug/alcohol abuse	Move to warm area and remove wet clothing Modest external warming (external heat packs, blankets, etc.) Drink warm, sweet fluids if conscious Transport to hospital
Frostbite	Burning sensation at first Coldness, numbness, tingling	Skin color white or Grayish yellow to Reddish violet to black Blisters Response to touch Depends on depth of Freezing	Exposure to cold Vascular disease	Move to warm area and remove wet clothing External warming (e.g., warm water) Drink warm, sweet fluids if conscious
Frostnip	Possible itching or pain	Skin turns white	Exposure to cold (above freezing)	Similar to frostbite
Trench Foot	Severe pain Tingling, itching	Edema Blisters Response to touch Depends on depth of Freezing	Exposure to cold (above freezing) and dampness	Similar to frostbite
Chilblain	Recurrent, localized itching Painful inflammation	Swelling Severe spasms	Inadequate clothing Exposure to cold and dampness Vascular disease	Remove to warm area Consult physician
Raynaud's disorder	Fingers tingle Intermittent blanching and reddening	Fingers blanch with cold exposure	Exposure to cold and vibration Vascular disease	Remove to warm area Consult physician

Table 2.3 *Cold-Related Disorders Including the Symptoms, Signs, Causes, and Steps for First Aid*

Note: Hypothermia is related to systemic cold stress, and the other disorders are related to local tissue cooling.

4.1 Model of Thermal Balance

Systemic cold stress can be quantified in terms of heat exchange and how much heat in the body can be stored (S):

$$S = M + (R + C) + K + E \quad \text{..............} \quad (4)$$

M is metabolic rate and represents a source of internal heat gain. $(R + C)$ is the combination of heat loss due to cooler air and surroundings. K is conduction to a solid surface in contact with the body. E is evaporative cooling by sweat evaporation; it has a negative value.

Because the flow of heat is away from the body. Thermal equilibrium is established when $S = 0$.

M can be increased as a behavioral response to cold stress, and significant contributions to thermal balance can be made by reducing $(R + C)$ and K with behavioral adaptations like clothing and avoidance of clod environments. For a given level of clothing, the greater the work demands (greater metabolic rate), the greater the level of cold stress that can be tolerated.

The objective of systemic cold stress control is to avoid hypothermia by limiting the minimum core temperature to 96.8 F (36 C) for prolonged exposures and to 95 F (35 C) for occasional exposures of short duration

4.2 Measurement of Cold Stress

Two climatic factors in the environment influence the rate of heat exchange between a person and the environment. These factors are air temperature and air speed. As the difference between skin and ambient temperatures increases and/or the air speed increases, the rate of heat loss from exposed skin increases. The rate of heat loss is approximated by Equation

$$H = (7 \times 10^5)(10\ V_{air}^{0.5} + 10.45 - V_{air})(33 - T_{db})(W / m^2) \text{ .... } (5)$$

Where H = The rate of heat loss W / m^2

V_a = Air velocity m/s

T_d = Dry buld temperature °C

The equivalent chill temperature (ECT) (also known as the windchill index) was developed by the U.S. Army to account for both factors, the air temperature and the air speed. Table 2.4 show the ECT for different combinations air temperature and speed. The table was generated by determining the heat loss under conditions of each combination of air temperature and speed, and then computing an equivalent air temperature with no air motion with which the same rate of heat loss occurs.

Air speed M/s	Air temperature (°c)										
	10	4	-7	-12	-18	-23	-29	-34	-40	-46	-51
0.00	10	4	-7	-12	-18	-23	-29	-34	-40	-46	-51
2.2	9	3	-9	-14	-21	-26	-32	-38	-44	-49	-56
4.5	4	-2	-16	-23	-31	-36	-43	-50	-57	-64	-71
6.7	2	-6	-21	-28	-36	-43	-50	-58	-65	-73	-80
8.9	0	-8	-23	-32	-39	-47	-55	-63	-71	-79	-85
11	-1	-9	-26	-34	-42	-51	-59	-67	-76	-83	-92
13	-2	-11	-28	-36	-4[illegible]	-53	-62	-70	-78	-87	-96
16	-3	-12	-29	-37	-46	-55	-63	-72	-81	-89	-98
>16	-3	-12	-29	-38	-47	-56	-65	-73	-82	-91	-100
Little Danger If exposures with dry skin and less than 60 min. Caution: Avoid false sense of security				Increasing Danger Exposed flesh may freeze with 1 min.			Great Danger Flesh may freeze within 30 s.				

Table 2.4 *Equivalent Chill Temperature (ECT) in Degrees C for Different Combinations of Air Temperature and Air Speed (also known as the windchill index)*

4.3 Recognition of Cold Stress

Subjective responses of workers provide a good tool for recognition of cold stress in the workplace. If the workplace is generally described as cold, then cold stress may be present. Worker behaviors to cold stress exposures are generally those of seeking warm locations, adding layers of clothing, or increasing the work rate. Other behaviors are loss of manual dexterity, shivering, accidents, and unsafe behaviors.

Using the first-aid logs and other records, determine whether there is a pattern of signs and symptoms that might be attributed to hypothermia. A physiological marker is reduced core temperature below 96.8 F (36 C).

If there is a noticeable drop in manual dexterity reported by workers or supervision, local cold stress is possible. In addition, if there is a pattern of cold-related disorders reported in the first-aid logs, injury and illness logs, and workers compensation records, the work conditions should be evaluated.

4.4 Evaluation of Cold Stress

4.4.1 Workplace monitoring

When temperatures fall below 61 °F (16 °C), workplace monitoring should be performed conducted. Below 30 °F (-1 °C), the dry bulb temperature and air speed should be measured and recorded at least every 4 hours. When air speed is greater than 5 miles per hour (2 m/s), the ECT should be determined from Table 2.4 When the ECT falls below 19 °F (-7 °C), it should also be recorded.

4.4.2 Systemic cold stress.

Hypothermia can occur with air temperatures up to 50 °F (10 °C). The ACGIH recommends that employers require protective measures when air temperature is less than 41 °F (5 °C). Equation 6. can be used to estimate the amount of clothing insulation (I_{clo} in clo units, where 1 clo = 0.156 m^2 °C/W) required for a specific task in a given air temperature (T_{db} in degrees °C) and metabolic rate (M in watts). Figure 2.4 illustrates the relationships among temperature, work rate, and clothing necessary to maintain thermal equilibrium based on Equation.

$$I_{clo} = 11.5\,(33 - T_d)\,/\,M \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (6)$$

Where I_{clo} = the amount of clothing insulation in Clo unit (1 Clo = 0.155 m^2 . °C/W) reqired for a specific task in a give air temperature and metabolic rate

T_d = air temperature in degree °C

M = Metabolic rate in Watt

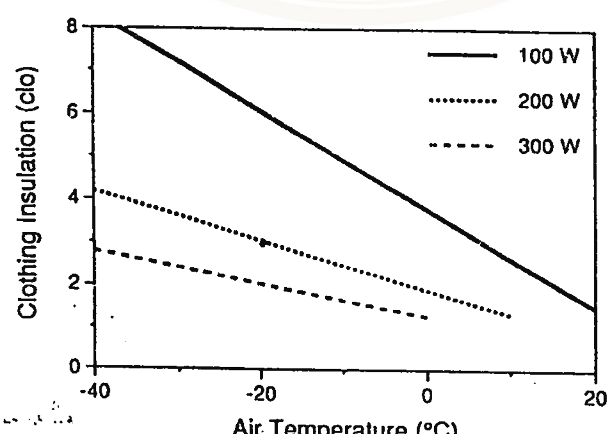


Figure 2.4 *illustrates the relationships among temperature, work rate, and clothing necessary to maintain thermal equilibrium based on equation.*

It should be reconized that the clothing must be kept dry and that I_{clo} will vary with different tasks and environments.

4.4.3 Local cold stress.

Skin cannot be freezed until the air temperature is less than 30 F (-1 °C), and there is the risk of local cold injury associated with ECTs greater than -22 F (-30 °C) (or heat loss rates less than 1,750 w/m^2). The temperature limit for surfaces with which exposed skin makes incidental contact is 19 F (-7 °C). If the contact is prolonged (for example, for tools), the limit is 30 F (-1 °C).

Manual dexterity drops when there is uninterrupted work for 10-20 minutes at temperatures below 61 °F (16 °C).

5. Working practices for cold environments [6] [11]

Workers may become uncomfortable in the cold and loss in manual dexterity and distraction effects for example can contribute to accidents. Correct working practices should prevent hypothermia, cold injury, illness and death from cold. The American Conference of Government and Industrial Hygienists provide threshold limit values (TLVs) for exposure to cold based on the wind chill index (WCI). There are limits within which nearly all workers can be repeatedly exposed without adverse health effects. suggest that protection must be provided to workers in terms of:

1. adequate insulating clothing - to maintain core temperature above 36 °C; and

2. special precautions for older workers or workers with circulatory problems - providing extra clothing insulation or a reduction in the exposed period, and taking the advice of a medical officer.

Guidance for evaluation and control

General

1. For exposed skin, cutaneous exposure should not be permitted at equivalent chill temperature of -32 °C or less.
2. At air temperatures below 2 °C, workers who become wet should be given a change of clothing and treated for hypothermia.

Manual Dexterity

1. Special protection for the hands is required to maintain manual dexterity for the prevention of accidents, e.g. warm air jets, radiant heaters, warm plates, and thermal inslation on tool handles.
2. If air temperature is below 16 °C , 4 °C , or - 7 °C for sedentay, light or moderate work , respectively , and fine manual dexterity is not required, then gloves should be used.

Contact Injury

1. When cold surfaces are < - 7 °C and within reach a warning sould be given to prevent inadvernt contact by bare skin.
2. If air temperature is < -17.5 °C wear mittens and design maching control, etc. accordingly.

Protective Clothing and Protective Practive

1. Wind : protect from velocity by using wind shields or wind break garments.
2. Wet clothing : in light work use water impermeable outer garment, in heavy

work outwear should be changed as it becomes wetted. Design for easy ventilation. If sweating has occurred change into dry clothing before entering cold area. Change socks while work day was required.

3. Extremities : if handwear, footwear and facemasks cannot prevent excessive cold, then supply in auxiliary heated versions.
4. Limited clothing insulation : if available clothing is inadequate then redesign work to reduce exposure or wait until conditions are less cold.
5. Working with liquids : special care taken if evaporative liquids (e.g. alcohol, gasoline_ may spill on the hands in cold temperatures.
6. Work-warming regimen : use heated warming shelters (tents, cabins, rest rooms, etc.) and loosen clothing in shelter or change to warm clothing including shoes. Provide warm sweet drinks. Limit intake of coffee due to diuretic and circulation effects.
7. Very cold environments < -12 °C equivalent chill temperature : worker kept under constant observation. Use buddy system. Avoid sweating. Avoid periods of rest or low work level. Instruct workers on current practices and first aid.

Workplace Recommendations

1. Air velocity : keep below 1 m s^{-1} in refrigerated rooms. Provide wind protection clothing. Use safety goggles out of doors especially in sleet and snow.
2. Monitoring : monitor air temperature, air velocity and equivalent chill temperature.

3. workers : exclude workers suffering from diseases or taking medication which interferes with normal body temperature regulation or reduces tolerance to cold. For very cold conditions medical certification is required.

The above paragraph provide guidelines for developing working practices for cold exposure and are based on a summary of those presented in ACGIH (1992). Specific working practices will depend upon the practical application and context and should be developed within any industry. It should also be awared that all problems of people working in the cold are not fully quantified or understood.

A full analysis of task requirements and the working practices can be used in job design or redesign for improving working condition. Any comprehensive analysis including organizational aspects and available technology may lead to a great reduction or loss altogether of the necessity for people to be exposed at all.

6. Acclimatization to cold [10] [12] [13]

Acclimatization to cold is much less pronounced; in fact, there is doubt that true physiological adjustment to moderate cold takes place when appropriate clothing is worn. The first reaction of the body exposed to cold temperature is shivering – the generation of metabolic heat loss. Also, some changes in local blood flow are apparent. There are so – called " local " acclimatizations, particularly in blood flow in the hands and face. However, normally the adjustment to cold conditions is more one of proper clothing and work behavior than of pronounced changes in physiological and regulatory function. Thus, the body has little or no need to change its rate of heat production or, relatedly, of food intake, in " normally cold " temperature.

There are no great differences between females and males with respect to their ability to adapt to either hot or cold climates, with women possibly at a slightly hight risk for heat exhaustion and collapse and for cold injuries to extremities. However, these slight statistical tendencies can be easily counterated by ergonomic means and may not be obvious at all when observing only a few persons of either gender.

There is doubt that people learn to behave in cold climates such that they can survive and keep warm. In terms of human thermal environments therefore the body is generally exposed to a 'warm' micro-climate even when environmental temperatures are very low. The question of whether there is physiological acclimatization is therefore difficult to show and evidence is inconclusive.

Rivolier et al. categorize the possible adaptation of the body (of peoples who live permanently in cold climates) into three types along a continuum. (14)

1. Hypothermic - 'allowing' body temperature to fall hence reducing heat loss.
2. Insulative - enhanced insulation hence preventing cooling.
3. Metabolic - increased heat production (e.g. non-shivering thermogenesis)

There is some evidence of these types of adaptation; however results are inconclusive. Aborigines live in hot daytime climates and sleep in cold night-time climates. At night they are said to suppress shivering and allow body temperature to fall. In these conditions people from temperate climates fail to sleep. There are numerous examples of such adaptations but also other possible explanations. For example, Aborigines may have adapted their behaviour to receive radiant heat form nearby fires during the night. This has also been suggested as an explanation for the ability of the (now extinct) indians of the Tierra del Fiego to maintain heat balance while lightly clothed and in cold climates. There are numerous studies of adaptation of those who live and work in cold environments and of comparisons and possible physiological acclimatization in those exposed after being in temperate regions. The results have been generally inconclusive. An interesting adaptation is reported concerning Tibetan monks in the Himalayas. By imagining heat production wihtin the body (in this case to melt imagined ice in the brain), it is said that internal heat production can be greatly increased. This effect however was not repeated in the laboratory. The example provides some evidence that cultural (and religious) practices could be adopted to have further practical utility in the avoidance of cold stress for example or in controlled loss of body weight.

Rivolier et al. (1988) [14] review the problem and describe an experiment where twelve men were studied before, during and after return from a six-month Antarctic expedition. They were interested in whether it was possible to induce acclimation (i.e. in a laboratory) by immersion in cold baths, whether this had any advantage while living in the cold, whether a short stay in the Antarctic induces acclimatization and whether acclimation or acclimatization are similar. After the extensive 'experiment' there was no clear evidence of acclimation or acclimatization to cold. It can be concluded that if there is acclimatization of the whole body to the cold, evidence for it is not outstanding and for practical purposes it can be assumed that any advantages will be gained from behavioural changes and learning to live in the cold. It may be expected that any acclimatization would lead to lower preferred temperatures. This is not necessarily the case. There is some evidence that people adapted to living in extremes, heat or cold prefer lower and high temperatures, respectively. It may be flat acclimatization involves an early reaction, anticipation and compensation mechanism.

There is evidence of local acclimatization to cold of the fingers and hands. It is often cited that people whose hands are regularly exposed to cold exhibit less vasoconstriction and more prolonged cold induced vasodilation (CIVD). This has the advantage of maintaining manual performance. Other studies cite fishermen. Eskimos and pearl divers who are all exposed to cold water but maintain hand temperature. Whether this response is local acclimatization or whether hands have become damaged and restrict the ability ot vasoconstrict has yet to be established.

7. Cold Injuries [9] [15] [16]

Cold injuries can be classified as being either local or systemic. Local cold injuries result when the shell temperature, that of the skin and the peripheral tissues, is exposed to freezing temperatures but the core body temperature is maintained. If however, the cold induces a drop not only in the peripheral temperature but also in the core temperature, then more systemic manifestations such as hypothermia can be produced. In this section the local cold injuries-frostnip, chilblains, and frostbite foot-will be discussed along with the systemic injury of hypothermia.

7.1 *Frostnip*

Frostnip is a slow-developing condition that results in blanching or whiteness of the skin. This is usually associated with reversible ice crystal formation on the skin's surface. Frostnip usually will develop slowly and painlessly and usually affects the tips of the ears, nose, cheeks, chin, fingertips, and toes. Unfortunately, this condition is not first recognized by the victim but rather by a companion. Frostnip often is confused with frostbite. It is frequently seen in conditions of high wind, extreme cold, or both.

Most commonly no permanent tissue damage will be obtained from frostnip. It is important to treat this condition in an appropriate fashion to prevent tissue damage. The treatment that is recommended for frostnip is to provide warming of the effected tissue by the firm steady contact of a warm hand, by blowing hot breath on the effected tissue, or by holding the injured body part in either the axilla or the groin area. It is extremely important not to rub the skin with snow. This old folklore treatment can actually result in more damage to the tissue. As the tissue gradually warms and thaws out, the color returns and the victim may experience tingling in that body part. Indeed, several days after the tissue has warmed, the skin may continue to be red, and there may even be some flaking of the skin. As in all types of cold injuries, it is best to try to prevent their onset. There is no guaranteed prevention for frostnip, except to allow for adequate protection of exposed body parts and to recognize the environmental risk conditions.

7.2 *Chilblains*

Chilblains are commonly grouped with trench foot or immersion foot. The underlying etiology of this condition results from repeated exposure of bare skin to cold water or from wet dooling of an extremity for prolonged periods of time, usually at a temperature around freezing. Trench foot usually affects the lower extremity, and chilblains are found on the hands and feet. Initially, this condition damages the capillaries of the skin. With further progression of the injury, one can see necrosis or gangrene of the skin, underlying muscles, nerves, and other associated soft tissue. This injury initially results in red, swollen, hot, and tender skin. It can then progress to mottled skin with a pale or grayish blue tint. The usual initial symptoms are that of tingling, and/or burning. The extremity also may feel cold and numb.

Upon rewarming of the effected body part, there is a typical sequence of events. The skin may again become red, swollen, and hot. Areas of increased itchy sensations may develop. These areas may blister and/or develop localized gangrene. Interestingly enough, recurrence of this injury tends to happen in the same area of the body. This is probably related to some degree of permanent injury to the peripheral vascular system in that body part. The treatment of this particular entity depends of the cause. If the injury has developed secondary to exposure to a wet, cold environment, then the limb must be cleaned, dried, and carefully rewarmed. The rewarming of the limb should take place in an appropriate environment. If this environment is not available, then the limb is at risk for reexposure to increased cold. Unfortunately, there is no specific treatment for this entity once skin injury has been established. Therefore, all treatment should be geared to prevent recurrence and to protect the area that is injured from further exposure to cold.

7.3 *Frostbite*

Frostbite represents one of the worst local cold-related injuries. It is caused by the actual freezing of the soft tissue. The danger of frostbite must be considered very strongly whenever there is exposure to extreme cold. It is important to be aware of the effects of wind-chill, direct contact with frozen objects, and hypoxia from high altitudes as well. It is also believed that the abuse of internasal cocaine can increase the risk of nasal frostbite. The areas of the body that are commonly involved in frostbite injury are the fingertips, earlobes, tip of the nose, toes, and any exposed areas of skin. Frostbite can be classified into various stages based on the degree of injury. First-degree frostbite is usually associated with local pain or discomfort. There also is usually a numbness, redness, or swelling of the affected area. Second-degree frostbite displays all of the previously mentioned symptoms along with the development of a serous superficial blistering. Third-degree frostbite brings on the development of deep blistering, which is of a hemoserous nature. Fourth-degree frostbite involves the deep soft tissues. This includes bone and could result in possible mummification of the tissues, leading to the need for amputation.

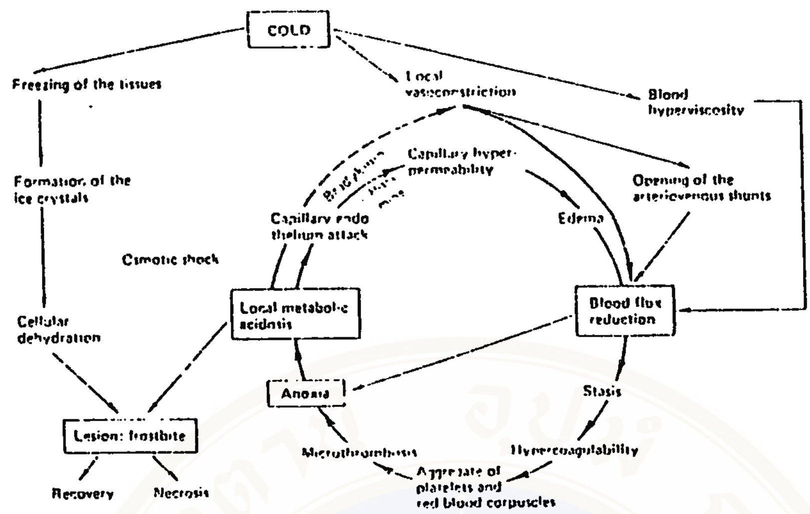
Initially, the victim experiencing frostbite will develop swelling and redness of the effected body part. This is often preceded by itching or prickling sensations. After this initial appearance, the skin on the frostbitten area may appear white, often with a yellowish to bluish tint that gives it the appearance of wax.

The treatment of frostbite should be directed toward the prevention of any further injury to the tissue and to being able to prevent the necrosis of any damaged tissue. While it may appear to be a justifiable treatment, rubbing or massaging frostbitten tissues is strongly contraindicated. The accepted therapy for frostbite is rapid rewarming. In this regard, a whirlpool type of device is ideal. It is recommended that the water temperature be 40 to 42 °C (104 to 108 °F). The utilization of dry heat such as from a camp fire, car exhaust, or radiator is contraindicated. This type of rewarming is slow and the heat is often not equally distributed. In addition, because of numbness, there is a chance for the skin to become burned from this type of heat. If out in the field with a victim who is experiencing frostbite, it is strongly recommended not to thaw out the frostbitten part unless there is a mechanism available to keep it thawed. If the frostbitten part is thawed and then allowed to refreeze, there is a greater risk of more extensive damage. Depending on the extent of the frostbite and the penetration into the deeper tissues, the time of thawing can take from 30 to 45 min. It is important to note that upon rewarming of the frostbitten body part, the victim will experience pain. The degree of pain will be related to the degree of frostbite injury. The victim may need an analgesic to help him or her deal with the pain. It is extremely important to educate the victim that this pain on rewarming is not a dangerous sign, but rather part of the natural process of rewarming.

After the body part has been rewarmed and blood flow returns to the area, the injured tissue may appear mottled, blue, or purple. There may be swelling, resulting in large blisters or gangrenous areas several days after treatment. as well These blisters may eventually form blackened necrotic areas of tissue. The area of necrotic tissue can easily be separated from the normal skin. The new skin is usually of a poorer quality than the original and appears to be very sensitive to cold.

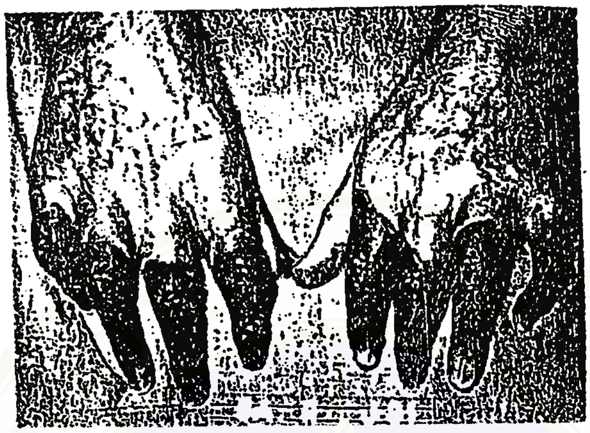
The initial management of the frostbite injury after thawing should be of a protective nature. It should include the use of an antibiotic type of ointment to the skin. The skin also should be protected with soft sterile bandages. Whenever possible, blisters should be left intact, but they may require further debridement after arrival at a health-care facility. The involved skin should be protected from extreme contact. This can be done by either elevating the limb or designing a protective cradle around the limb to prevent any pressure. Anyone who has experienced a frostbite injury should be examined in a medical facility. It is generally recommended that all frostbite injuries greater than first-degree be observed in a hospital. It is often difficult to access viability accurately from the gross appearance of the damaged part. Therefore, it is necessary to observe such injuries over time. This is especially important when considering the possibility of amputation. Amputation should be delayed as long as possible to allow the tissues truly to demonstrated what is necrotic and what is salvageable.

Ultimately, the best way to treat frostbite is to prevent frostbite. There are many ways to prevent frostbite, and most important is to prepare for the environment. This requires the individual to be aware of not only the actual temperature but the emperature as affected by windchill factors. Prevention includes adequate and properly fitted clothing as well as protection of exposed body parts, e.g., hands, feet, nose, and ears. It is extremely important to keep clothing dry and prevent subsequent chilling from the moist clothing next to the body. If a body part feels as though it were getting cold, the individual should move it continually and be careful not to keep it in one position for a long time. This is especially true with the toes and the hands. However, if the face begin to feel cold, it is important to use the facial muscles to help generate some heat in that area. Remember that when out in a harsh environment, it is imperative to observe the other people's faces and any other exposed skin for possible signs of frostbite injury.



Figures2.5 *Physiopathological mechanisms of frosbite*

Figures2.6 *Third degree frosbite of the two feet*



Figures2.7 *Third degree frosbite of the fingers*

8. Review of research study

Giesbrecht, Schroederm and Briston. [17] have studied the treatment of mild immersion hypothermia by forced-air warming. Forced-air warming is used for prevention or reversal of hypothermia in surgical patients. In the present study, the efficacy of this system for treatment of immersion hypothermia was evaluated. Six men and two women were twice immersed in 8 °C water until hypothermic. They were then rewarmed by either : 1) shivering-only inside a sleeping bag; or 2) forced-air warming. Esophageal and skin temperature, cutaneous heat flux and metabolism were measured. Afterdrop (± SD) during forced-air warming (0.43 ± 0.26 °C) was ~30% less than during shivering (0.61 ± 0.26 °C) ($p < 0.001$). Rewarming rate during forced-air warming (3.26 ± 1.8 °C h^{-1}) was not significantly different from shivering (3.02 ± 1.2 °C h^{-1}). Skin temperature was higher during forced-air warming by 3.7 °C early and

4.5 °C after 35 min of warming. Heat production increased by 77 W over the initial 20 min of shivering, and subsequently declined, compared to an immediate decrease with forced-air warming. During shivering heat flux ranged from 30 W early in rewarming, to 50 W after 35 min, compared to -237 W and -163 W respectively, for forced-air warming. Forced-air warming attenuated afterdrop and the metabolic stress of shivering while maintaining an average rate of rewarming comparable to shivering. Forced-air warming is a safe, simple, noninvasive treatment and could be used effectively in an emergency medical facility, and possibly in some rescue/emergency vehicles or marine vessels.

Romet and Hoskin. [18] Studied the temperature and metabolic responses to inhalation and bath rewarming protocols. Rewarming of mildly hypothermic subjects was compared using three different techniques that have been suggested for use in field situations. Eight subjects were cooled for up to 1 h, on four occasions, in a filled whole-body water calorimeter controlled at 22 °C. Following cooling, rewarming was initiated by one of four procedures : inhalation of warmed and humidified air at 40 °C or 45 °C, immersion in 40 °C water, or spontaneously by shivering. Deep body temperature was recorded simultaneously at three different sites : rectal, esophageal, and auditory canal. Skin temperatures were recorded from four sites : chest, forearm, thigh, and calf. Results showed that rapid external rewarming in 40 °C water produced the quickest rate of rewarming and smallest magnitude and duration of afterdrop. Regardless of which rewarming protocol was followed, the esophageal site always showed the smallest afterdrop. Although there were no differences in the rewarming rates calculated for each of the three core temperature sites during inhalation and spontaneous rewarming, both auditory canal and esophageal sites rose significantly quicker than rectal during the rapid rewarming in 40 °C water. Inhalation rewarming led to a depressed metabolic rate, compared to spontaneous rewarming, which was not compensated by heat provided through the respiratory tract. It was concluded that for mildly hypothermic subjects, rapid rewarming in 40 °C water was the most efficient procedure and that esophageal temperature-the closest approximation of aortic blood or cardiac temperature is the most sensitive to change during rewarming by any procedure. Inhalation rewarming may be suitable as a passive rewarming technique by eliminating respiratory heat loss, allowing rewarming to occur and while preserving metabolic stores.

Romon et al. [19] An investigation of skin surface temperature variations under actual work conditions for four locations on the hand studied the utility of hot water immersion sinks for restoring heat to the hands during exposure to moderately cold temperatures in a food processing plant. Hand skin temperature was recorded for 15 subjects in 2 jobs with an ambient temperature of 13.3 °C (56 °F) and 1 jobs with an ambient temperature of 23.9 °C (75 °F). Averaged over all jobs, the mean temperature for the dorsal and palmar third finger was 17.7 °C (63.9 °F), which was significantly ($p < 0.01$) cooler than the mean dorsal and palmar hand temperature of 28.9 °C (84.0 °F). There was no significant difference between dorsal and palmar temperatures for either the finger or the hand ($p > 0.05$). In the warm environment there were no significant differences in skin temperature for any of the four hand locations ($p > 0.05$). An exponential model of digital warming and cooling was empirically derived using 12 subjects for predicting finger skin temperature when periodically rewarming the hands using a hot water immersion sink. The dorsal and palmar finger had a mean time constant of 151 sec for warming during immersion, 640 sec for initial cooling after a 15 - to 30-min rest break at room temperature, and 198 sec for cooling after rewarming in the hot sink. The sink did not appreciably raise minimum finger skin temperature after subjects rewarmed the hands for as long as 2 min and then worked for more than 10 min without a rewarming session.

Giesbrect et al. [20] Studied a second postcooling afterdrop : more evidence for a convective mechanism. An attempt was made to demonstrate the importance of increased perfusion of cold tissue in core temperature afterdrop. Five male subjects were cooled twice in water (8 °C) for 53-80 min. They were then rewarmed by one of two methods (shivering thermogenesis or treadmill exercise) for another 40-65 min, after which they entered a warm bath (40 °C). Esophageal temperature (T_{es}) as well as thigh and calf muscle temperatures at three depths (1.5, 3.0, and 4.5 cm) were measured. Cold water immersion was terminated at T_{es} varying between 33.0 and 34.5 °C. For each subject this temperature was similar in both trials. The initial core temperature afterdrop was 58% greater during exercise (mean ± SE, 0.65 ± 0.10 °C) than shivering (0.41 ± 0.06 °C) ($P < 0.005$). Within the first 5 min after subjects entered the warm bath the initial rate of rewarming (previously established during shivering or exercise, ~0.07 °C/min) decreased. The attenuation was 0.088 ± 0.03 °C/min ($P < 0.025$) after shivering and 0.062 ± 0.022 °C/min ($P < 0.025$) after exercise. In 4 of 10 trails (2 after shivering and 2 after exercise) a second afterdrop occurred during this period. They suggested that increased perfusion of cold tissue is one probable mechanism responsible for attenuation or reversal of the initial rewariming rate. These results have important implications for treatment of hypothermia victims, even when treatment commences long after removal from cold water.

Tochihara, et al. [22] Subjects were 10 workers (Group R) working in two cold storages (air temperature was between -20 °C and -23.2 °C), and eight workers (Group C) working in a general storehouse (air temperature was between 12 °C and 15.2 °C). They were all male workers operating forklift-trucks. Average (SE) age for Group R was 41.4(1.3) years and for Group C was 47.3(1.6) years. Hand tremor, handgrip strength, pinch strength, counting task, flicker value, peak flow rate and blood pressure were measured five times (before work, at 10 a.m., before lunch, at 3 p.m. and after work) per day. Blood samples were collected before lunch. Free fatty acid (FFA) of Group R was significantly higher than that of Group C. There were no significant differences in handgrip strength, pinch strength, counting task, flicker value and peak flow rate between Group R and Group C. However, changes in hand tremor and diastolic blood pressure for Group R were significantly greater than those for Group C. Only for Group R, there was a significant relationship between FFA and the hand tremor values measured the second time. Work loads of Group R would be increased by not only the extreme coldness but also large temperature difference between the inside and the outside of the cold storages. The actual forklift work in these cold storages did not cause a distinct reduction in manual performance, but caused an increase in stress which would be expressed as an increase in catecholamine excretion.

Griefahn, et al. [4] Studied the working in moderate cold : a possible risk to health. The present report concerns a cross-sectional study, in which 1,213 workers in cold environments, mainly from distributors, meat productions, and from breweries completed an extended questionnaire where personal variables and a large spectrum of working conditions, of acute and chronic symptoms, complaints and diseases were ascertained. High prevalences were found for non-specific symptoms, gastrointestinal complaints, pains in the back and in the joints, rheumatic and bronchitic complaints, colds, hearing problems, and the symptoms of he white finger disease. Some of them were significantly associated with the climate at the workplace, particularly with cold, changes in temperature, and drafts. The results support the hypothesis that moderate cold at the workplace constitutes a health risk and form the basis for further, more directed analytical studies.

Giesbrecht and Briatow. [22] Studied the influence of body composition on rewarming from immersion hypothermia. This study was conducted to determine if the differences between efficacies of three treatments for immersion hypothermia are affected by body composition. Twelve subjects were divided into equally sized low (LF) and high (HF) fat groups. On three occasions subjects were each immersed in cold water until esophageal temperatures (T_{es}) decreased to ~33.2 °C (LF) and ~35.8 °C (HF). They were then rewarmed by : 1) shivering; 2) appolication of external heat; or 3) treadmill exercise in a balanced design. For HF, the afterdrop during exercise (1.04 ± 0.2 °C) was greater than during shivering (0.35 ± 0.3 °C) and external heat (0.36 ± 0.1 °C) ($p < 0.01$). In LF, however, the exercise afterdrop (0.75 ± 0.2 °C) was greater than only external heat (0.35 ± 0.2 °C) ($p < 0.05$) but not shivering (0.58 ± 0.4

°C). There was a positive relationship between % fat and afterdrop for the exercise condition with a slope (95% C.I.) of 0.03 (0.01 to 0.05) °C % fat $^{-1}$ ($r^2 = 0.37$, $p < 0.05$). The exercise rewarming rate (3.48 ± 1.1 °C h^{-1}) was greater ($p < 0.01$) than during both shivering (1.80 ± 0.7 °C h^{-1}) and external heat (2.22 ± 0.7 °C h^{-1}) in HF while no difference was seen between the three treatments. (5.28 ± 0.4, 4.86 ± 1.1 and 5.16 ± 0.7 °C h^{-1}, respectively) in LF. There were inverse relationships between % fat and rewarming rate in the exercise -0.12 (-0.23 to -0.01) °C h^{-1} % fat $^{-1}$, (r^2 = 0.38), shivering -0.27 (-0.38 to -0.16) °C h^{-1} % fat $^{-1}$, (r^2 = 0.76) and external heat -0.26 (-0.35 to -0.17) °C h^{-1} % fat $^{-1}$, (r^2 = 0.83) conditions ($p < 0.05$). The inter-treatment differences between these techniques are accentuated in the HF, and attenuated (afterdrop) or even eliminated (rewarming rate) in the LF subgroup.

Daanen and Van De Linde. [23] Compared four noninvasive rewarming methods for mild hypothermia. Four noninvasive rewarming techniques for mildly hypothermic subjects were compared. Seven subjects were cooled in a water bath of 15 °C for 2 h to an average esophageal temperature (T_{es}) of 36 °C. Thereafter, the subjects were rewarmed by immersion of the body in a water bath of 42 °C (Method 1), the body but not the extremities in water of 42 °C (Method 2), only the extremities in water of 42 °C (Method 3), or spontaneous rewarming in blankets (Method 4). Method 1 showed the highest rewarming rate in T_{es} (10.1 °C/h) and an afterdrop in T_{es} of 0.18 °C. Method 2 showed the same afterdrop, but a lower rewarming rate (7.5 °C/h). In Method 3, the heat uptake of the extremities was too low to rewarm the subjects effectively. The afterdrop and rewarming rate were 0.38 °C and 0.8 °C/h, respectively. Method 4 had the lowest rewarming rate (0.2 °C/h), and an afterdrop

(0.14 °C) which was not significantly lower than that of Method 1 or 2. Therefore, Method 1 is recommended for rewarming mild hypothermic subjects because of its high rewarming rate and small afterdrop.

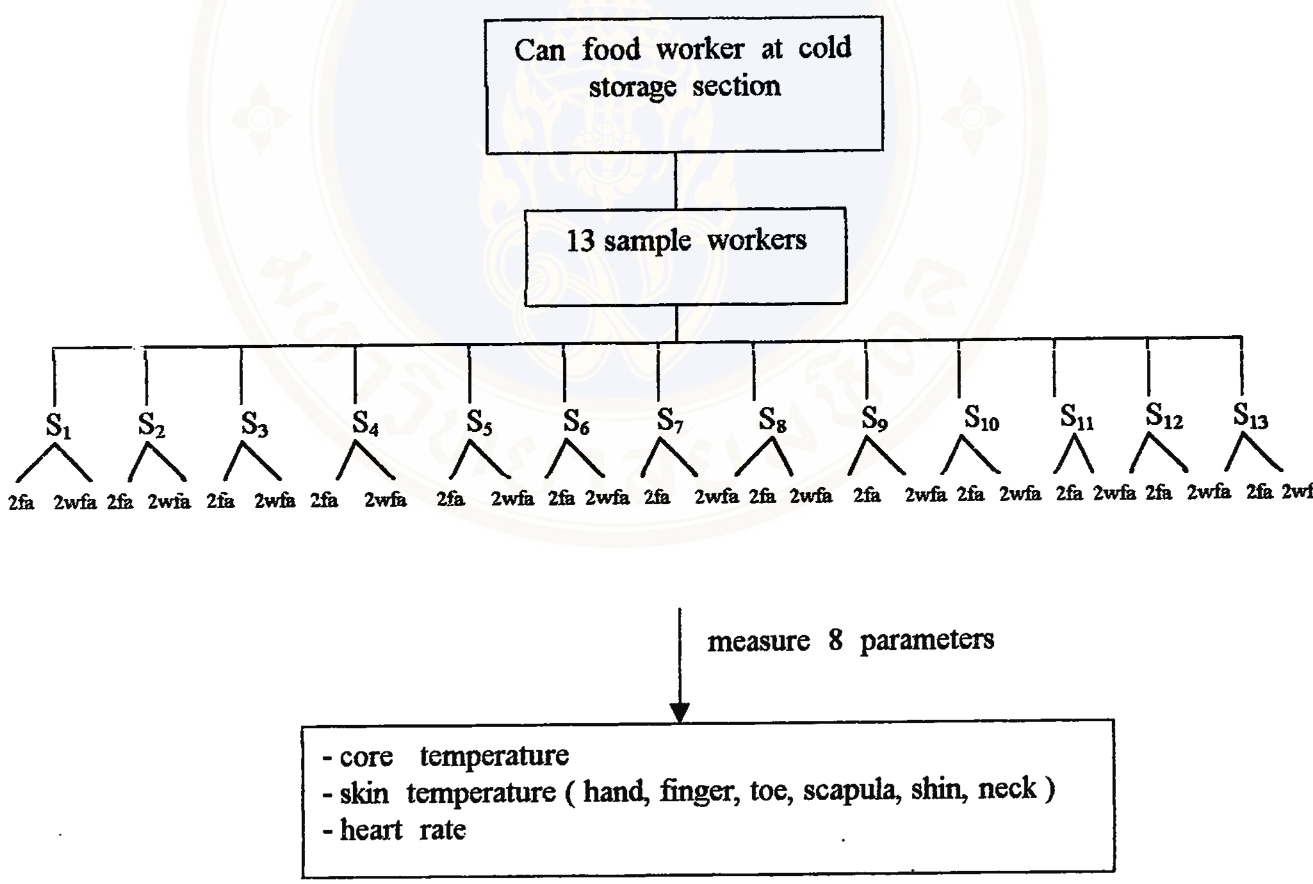
Tochihara, et al. [24] This study was conducted to investigate the effect of different exposure rates on thermal responses with the total cold exposure time the same under each of the conditions. After resting in a warm room (25 °C) for 10 minutes, six male students wearing standard cold protective clothing entered an adjoining cold room (-25 °C). Each 5-, 10- and 20- minute cold exposure was repeated 12, 6 and 3 times, respectively. Each cold exposure was followed by a similar duration of rest at 25 °C. Total cold exposure time was the same under the three conditions. Rectal temperature, skin temperatures, blood pressure. 17 hydroxycoyticoids (OHCS), counting task and subjective responses were measured. At the end of the cold exposure skin temperatures in the shorter exposures were higher than those in the other conditions, except on the foot. Discomfort due to cold was less in the shorter exposures and manifestation of discomfort was delayed. However, there were no differences among the three conditions in the fall of rectal temperature and urinary excretion of 17 OHCS, which are good indices of cold stress. Moreover, increase in blood pressure and decrease in counting task due to cold were not different among the three conditions, liven though the cold exposure time for each stay was short, when cold exposures were repeated frequently, cold stress of the whole body and decrease in manual task performance were the same as in the longer cold exposure.

CHAPTER III

MATERIALS AND METHODS

3.1 Study Design

The study design was a quasi experiment. The design of this study can be represented as the following:



S_1 - S_2 = subject no1 to no13

fa = forced warm air

wfa = without forced warm air

3.2 Population and sample

3.2.1 Population

The male workers who work at a Canned Food Industry with the following characteristics were the population of this study

1. work in cold storage section
2. Aged between 20 - 45 years.
3. Work during 7.00 am. to 4.00 pm.
4. Work experience in cold environmental workplace ≥ 1 years.
5. Sleeping hours ≥ 6 hrs / day
6. No history of heart – lung disease, hypertension and no fever or take medication during experimental period.
7. The subjects should come to participate in this experiment with pleasure.

3.2.2 Sample

Thirteen male workers, who worked in a cold storage section were includes in the study. Sample size in this study was calculated from the following formula.

$$n = \frac{2(Z_{\alpha} + Z_{\beta})^2 \sigma^2}{(\mu_c - \mu_t)}$$

Where, n = the desired sample size of the workers in each study group

μ_c = true mean of the outcome measure(recovery time of core temperature) for control group (with out forced warm air)

μ_t = true mean of the outcome measure for test group (forced warm air)

σ^2 = variance of the outcome measure for a single individual (assumed to be the same for all subjects in both groups)

$Z\alpha = Z_{0.05} = 1.645$

$Z\beta = Z_{0.05} = 1.645$

α = type I error

β = type II error

$\beta = 1 - \alpha = 1 - .05 = .95$

$$n = \frac{2\,(1.645 + 1.645)^2\,(1.33)^2}{(7.38 - 6.04)^2}$$

$= 21.26$

3.3 Experimental procedure

3.3.1 Recruitment of studied subjects.

Thirteen subjects with the mentioned population characteristics were recruited as the subjects of the study. They were informed about the study perpose, the study procedure. They were requested to follow the following requested to the following requirement during the study.

- They could not drink water until almost finish the experiments.
- They must dress clothes, caps, shoes and groves in the same type and model.
- They must work in the cold storage for 45 minute.
- The study involved the workers who carried 50 trays containing fish of 22 kgs in weight from the plant's floor onto the pallets within 10 minutes.

3.3.2 The researcher attached the skin temperature sensors on the subjects (hand, finger, shin, neck, scapula and toes). Then the personal heat stress monitor was attached. The subjects wore clothes, caps, shoes and gloves respectively.

3.3.3 The researcher record the subjects's heart rate, core temperature, skin temperature at hand, finger, shin, neck, scapula and toes.

3.3.4 The subjects entered to the cold storage one person per time. Each subject caried the frozen fishes - tray from factory floor on pallet for 45 minutes. The air velocity, air temperature and humidity were recorded by the researcher. After they finished their work period and went outside the cold storage, the researcher recorded their core temperature, heart rate, skin temperature at hand finger, shin, neck, scapula and toes, then let they sat down on the chair in the resting room. They blow their hands with warm air until core temperature, skin temperature and heart rate recoveryed to normal level, the researcher recorded recovery time, finisned the procedure.

For without forced warm air group :

The workers worked as the same with forced warm air group but while They were sitting for a rest, they did not blow their hands with forced warm air.

3.4 Instrumentation.

3.4.1 Physiological studies

1. Core temperature and heart rate : Personal heat stress monitor hs 3800 (Metrosonics Ltd, USA) EKG. Type electrodes belts configuration rate 40 to 200 beats/minuts,resolution 1 beat/minute. Core temperature rang 33 to 40 °C accuracy ± 1 °C

2. Forced warm air : Rapid hand dryer (Model HTE - 4,Stiebel Eltron) having rate of flow warm air 205 m^3 / hr and average heat temperature 45 calsius.

3.5 Methods of measurement

3.5.1 Skin temperature

For measurement of the skin temperture (hand, finger, shin, neck, scapula and toe) were measured.

3.5.2 Core temperature and heart rate measured by fastened with body to check the changeable of body temperature by aerial sensor : inspected before experiment all the time in cold storage and every resting time in 1 minute.

3.6 Statistical analysis

The analytical data would be separated into 2 sections include :

1. Descriptive statistics (mean, Standard deviation and percentages) to describe and present about distribution of personal characteristics, core temperature, skin temperature and heart rate.

2. Inferential statistics is to analysis the experiment at t – test and Mann Whitney U test

All comparison were performed .05 significant difference.

CHAPTER IV

Results

The results of this study were devided into three parts as follows :

4.1 General characteristics of samples.

4.2 Results of physiological parameter

4.3 Statistical analysis of physiological recovery

4.1 General characteristics of samples

Thirteen male workers volunteered as subjects. Their mean (SD) age (years), weight (kgs), height (cm.) and work experience (years) were 34.54 (±8.81), 62.15 (±6.31), 168.38 (±6.89) and 3.08 (± 1.71) respectively. Most of them lived in Northeastern of Thailand. All subjects had primary school education. 9 samples reported drinking and 11 reported smoking . The results were shown in table 4.1

Table 4.1 *General characteristics of samples*

Characteristics	Number
Sample subjects	13
Age (years)	
- Min – max	20 – 45
- Mean ± SD	35.54 ± 8.81
Weight (kgs)	
- Min – max	53 – 75
- mean ± SD	62.15 ± 6.31
Height (kgs)	
- min – max	158 – 180
- mean ± SD	168.38 ± 6.89
Warking Experience (years)	
- min – max	1 – 7
- mean ± SD	3.08 ± 1.71
Domicile	
- Central	2
- Northern	3
- Northeastern	8
Education	
- Primary school	13
Drinking	
- Yes	9
- No	4
Smoking	
- Yes	11
- No	2

4.2 Result of physiological parameter

Table 4.2 *Core temperature, skin temperature and heart rate before and after working in cold storage.*

Physiological Parameters	Before		After	
	Range	$\bar{X} \pm SD$	Range	$\bar{X} \pm SD$
Skin temperature				
Hand (°C)	33.65-35.85	34.57±0.58	11-19	15.05±1.85
Shin (°C)	33.85-36.3	35.06±0.59	28.95-34.25	31.76±1.50
Neck (°C)	34.25-37.15	35.38±.052	31.45-35.9	33.85±0.84
Scapula (°C)	33.15-36.55	35.14±0.64	31.45-35.85	33.82±0.81
Finger (°C)	32.2-35.85	33.73±.0.74	10.85-18.55	14.19±2.13
Toe (°C)	33.45-35.65	34.58±0.67	24.6-32.55	29.62±1.89
Core temperature(°C)	35.65-37.2	36.56±0.38	34.5-36.9	35.76±0.60
Heart Rate(beat/min)	61-82	70.54±4.92	74-96	85.44±5.41

4.3 Statistical analysis of physiological recovery

The mean value of recovery time of skin temperature (shin,neck, scapula) were 9.77±1.88, 13.42±1.50,13.31± 1.64, and 16.73±2.41,16.88±2.38,16.77±.95, for with and without forced warm air, respectively. The significance difference of the two groups was determined by t – test and found that there was significant difference between the two group.

The median of recovery time of skin temperature (hand, finger, toe) and core temperature were 7.0,9.0,10.50,6.0 and 26.0,26.0,19.50,7.0 for with and without force warm air, respectively. The significance difference of the two groups was determined by Mann Whitney U test.

The recovery time of forced warm air are more quickly than 15 minutes which less than the period of resting time of working. The mean value of recovery time of heat rate were 15.77 minutes and 16.04 minutes for without and with forced warm air, respectively. The significance difference of the two group was determined by t – test and found that there was no significant difference between the two groups. The results were shown in table 4.3

Table 4.3 Comparison of recovery time of *Core temperature, skin temperature and heart rate between forced warm air and with out forced warm air.*

Physiological	Forced warm air		Without forced warm air		P – value
Parameters	Median	$\bar{X} \pm SD$	Median	$\bar{X} \pm SD$	
Hand	7.00	6.92±1.32	26.00	25.85±2.63	.000**
Shin	9.00	9.77±1.88	18.50	18.73±2.41	.000*
Neck	13.00	13.42±1.50	17.00	16.88±2.38	.000*
Scapula	13.00	13.31± 1.64	17.00	16.77±1.95	.000*
Finger	9.00	9.23± 1.53	26.00	25.65±2.77	.000**
Toe	10.50	10.65± 1.41	19.50	19.73±2.24	.000**
Core	6.00	6.04± 0.96	7.00	7.38±1.33	.000**
Heart Rate	16.50	16.04± 1.53	16.00	15.77±2.33	.615*

* p – value of t - test

** p – value of Mann Whitney U test

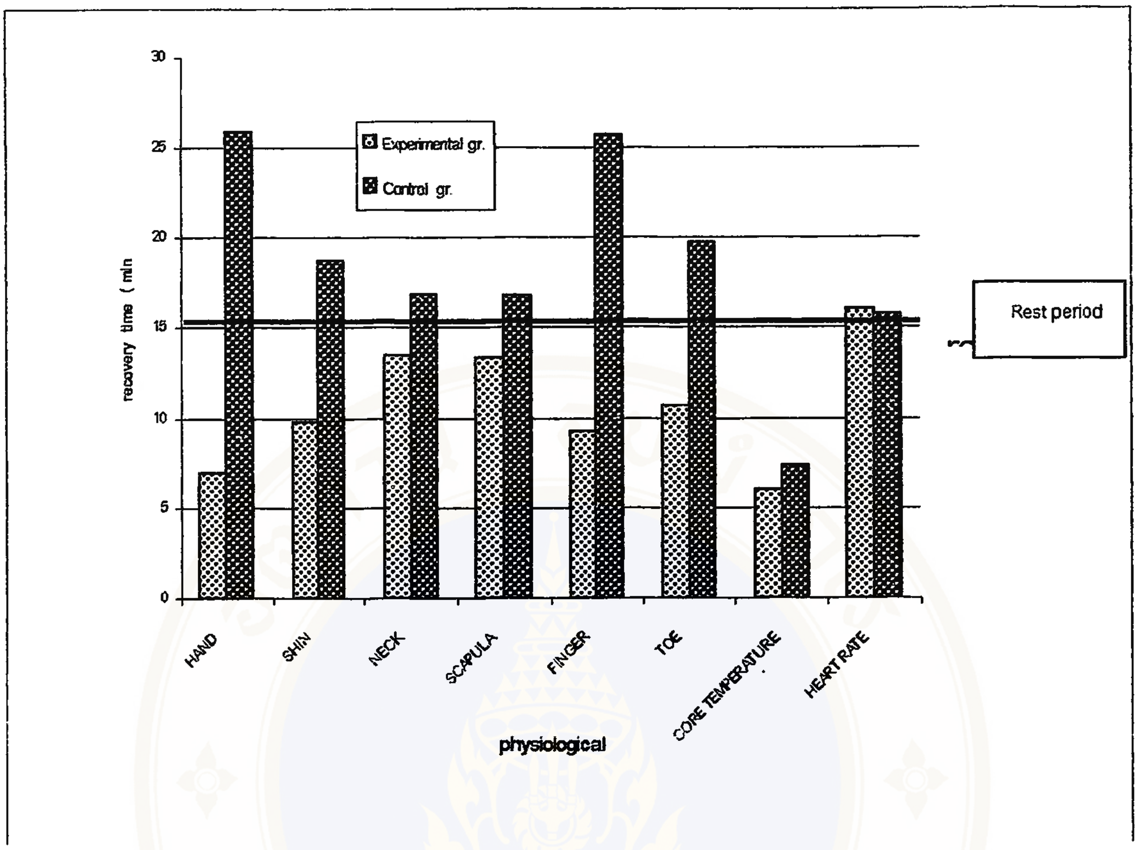
CHAPTER V

Discussions

Forced warm air is used for prevention or reversal of hypothermia, and recommended to prevent the accident from working in cold environment and to maintain manual dexterity. The purpose of this study is to compare the recovery time of core temperature and skin temperature at finger, hand, shin, neck, scapula, and toe after working in cold storage by using forced warm air and without forced warm air.

The Quasi - Experimental Research Design was conducted in this study. Thirteen male workers in the canned food industry were selected as the subjects. Each subject in with forced warm air group worked in cold storage for 45 minutes and left out cold storage for resting in the rest room. They had to blow their hands with warm air until the temperature could be recovered. In without forced warm air group, the working schedule in the same cold storage will be performed, but after left out cold storage for resting, the workers did not blow their hand with warm air.

The result of this study showed that core temperature, skin temperature at hand finger, shin, neck, scapula and toe in with forced warm air group could be recovered more quickly than without forced warm air group. The recovery time took less than 15 minutes (rest period) Moreover, we found no significant different of heart rate between two groups.



After applying forced warm air, the temperature of the hand and finger skin restore to normal level before the working interval break time is over. It could gain benefit to workers as follows.

1. Preventing worker from disease and injury due to the coldness, e.g. white finger, frostbite, pain in hands and fingers.
2. Increasing ability to work with hands, which automatically increasing the work capacity of the workers and reducing accident from performing work because the lower the temperature of hand and fingers is, the less response of the nerve of hand and fingers becomes, causing loose grip and less sense of touch which easily brings about the accident from performing work.

3. Applying forced warm air keep hand dry, thus reducing the loss of heat from hands and fingers.

It was found that recovery of body temperature after applying forced warm air is at the rate of 7.3 °C / hour (at room temperature of 28 - 32 °C). This is different from Gierh's studies, whose test is emerging the test group in cold water of 8 °C, until becoming hypothermia before giving forced warm air. The recovery rate found from this test is 32 °C/ hour (at room temperature of 22 °C). The difference of the test results is probably due to method of measuring body temperature, temperature in the testing room, and anatomical difference of the test groups.

The utilization of warm water and hot steel plate were recommended to cope with cold stress. Each of them have both advantageous and disadvantageous points of view. For instance, introducing warm water can increasc the body temperature quite quickly, because water contains higher heat conduction than air, but wetting hands should be considered. The workers have to wipe off their hand after warm water application. The another research is hot steel plat. The applying of hot steel plate can increase temperature only in area it is touched.

From this study, using forced warm air could be introduced among cold storage factories.

CHAPTER VI

Conclusion and Recommendation

6.1 Conclusion

Blowing forced warm air at the wind speed of 379.6 m/min and temperature of 45 degree celcius at the workers' hand after they left the cold storage room caused the heat exchange between the air and hands via conduction. Calculate from the equation:

Surface area :

$$S = 0.007184 \quad W^{0.425} \; H^{0.725}$$

S = surface area (M^2)

W = weight (Kg.)

H = height (cm)

surface	Area (%)
Hand	5
Trunk	36.02
Arm	13.41
Leg	31.72
Feet	6.82
Head	7

The rate of the exchange via conduction

$$C = 0.55V^{0.6} (Ta - Ts)$$

C = the rate of the heat exchange via conduction (kcal/m^2.hr.)

V = the air speed (m / min)

Ta = temperature of the air (celcius)

Ts = temperature of the skin (celcius)

The heat exchang rate of the workers' hands (with forced warm air group)

$$C = 0.55 (379.6)^{0.6} (45 - 14.97) = 582.78 \text{ kcal/m}^2 \text{hr.}$$

The heat exchang rate of the workers' (without forced warm air group)

$$C = 0.55 (15)^{0.6} (32 - 15.14) = 33.71 \text{ kcal/m}^2 \text{hr.}$$

Comparing with the values received from the calculations, the study finds that the heat exchange rate of the with forced warm air group was quicker than that of the without forced warm air group . As a result, the temperature of the workers' hands in the with forced warm air group turned to the original plight more quickly than that in the with out forced warm air group.

Recommendation

Suitable for the work in cold storages and in which low - temperature work pieces or utensils are grabbed by hands, forced warm air appliances can increase the hands' and water's temperature, dry sweats and water on hands, and reduce hazards from diseases as well as work injuries. The forced warm air devices can be used as follows.

1. Each apparatus in use should be able to turn itself on or automatically, to save power and prevent electric shocks. It must turn on when hands are put inside the air channel and stop when hands are taken out.

2. A grill should be put in between the air duct and hands so that they are 7 - 10 centrimetres far from the air duct. Hands might be burnt if getting too close to the air duct.

3. Hands and fingers temperature should be estimated throughout the initial use - period to estimate the workers' heat recovery time. Such time will be used to control the utilization duration to ward off dangers. During the assessment, the workers should sit down, not be allowed to drink water, not be assessed in regard to the temperature of their hands and fingers as well as heart rate.

4. While the forced warm air device used, gloves should be taken off to quicken the heating process.

5. Palms should be turned up and down periodically when the air is blown. If feeling too hot, take the hands out and then put them back to get the blow again.

6. To reduce the workers' tiredness and allow relaxation, the forced warm air appliance should be installed at the level the workers can use when sitting.

Reference

1. ภาควิชาวิทยาศาสตร์และเทคโนโลยีการอาหาร. มหาวิทยาลัยเกษตรศาสตร์. วิทยาศาสตร์และเทคโนโลยีการอาหาร , 2538 .

2. กรมโรงงาน กระทรวงอุตสาหหรรม. รายงานทำเนียบโรงงาน ประจำปี 2539.

3. วรมนต์ ศรีพรหม. อุณหภูมิร่างกาย. สัญญาณชีพ มหาวิทยาลัยเชียงใหม่ , 2537.

4. Barbara Griefahn, Perter Mchnert, Perter Brode, and Alfons Forsthoff. Working in Moderate Cold : A Possible Risk to Health. Journal of Occupational Health . 39 : 36 - 44; 1997.

5. ภาควิชาอาชีวอนามัย แลความปลอดภัย คณะสาธารณสุขศาสตร์ มหาวิทยาลัยมหิดล. ศึกษาผลกระทบจากการทำงานในห้องเย็น, 2540.

6. K. C. Persons . Human thermal Environments. University of technology United kingdom, 1992.

7. สุภาพ สุจริต อุณหภูมิร่างกาย สรีรวิทยา คณะวิทยาศาสตร์ มหาวิทยาลัยมหิดล, 2538.

8. TEOFILO L. Comprensive Therapy 21 (12); 697 - 704.

9. Daniel D. Arnheim, Modern Principles of Athletic Training. Times Mirror/ Moshy College Publishing. 1989.

10. ISO. Evaluation of Thermal Strain by Physiological Measurements (ISO 9886) 1992.

11. Barbara A.Alog , Jill Niland , Patricia J. Quinlan. Cold Stress. Fundamentals of Indestrial Hygiene 4 th Edition., 1996.

12. สุรวรรณา หัวสหฤกษ์. สรีรวิทยา 1. พิมพ์ครั้งที่ 4. ภาควิชาสรีรวิทยา คณะแพทย์ศาสตร์ ศิริราชพยาบาล มหาวิทยาลัยมหิดล, 2535.

13. Kart Kraemer , Henrike kroemer , Katrin kroemer - Elbert How the Body interacts with the Environment. Egonomic:How to Design for Ease and Efficiency Prentice Hall Englewood Clitts NJ, 1994.

14. Rivolier,J.,Goldsmith,R.,Logg,D.J. and Taylar,A.J.W.,Man in the Antarctic, Toy &Francis,London 1988.

15. Wayne K. Gersoff and H.Andrew Motz. Sports Injuries

16. Willie Hammer.Heart and Temperture. Occupational Safety management and Enginoring. Forth Edition Prentice Hall, Englewood Clitts. New Jersy , 1989.

17. Gordon G.Giesbrecht . Treatment of mild Immersion hypothermia by fored air warming.Aviation Cpace & Environmental Medicine 65; 803-808 : 1994

18. Tiit T. Romet and Robert W. Haskin . Temperature and Metabolic Responses to Inhalation and Bath Rewarming Protocols. Aviation, Space and Environmental Medicin . 59 ; 630 -634 : 1989.

19. Ramon J. Geron and et. al. Hand Skin Temperature Variations for warker in Moderately Cold Environments and the Effectiveness of Periodic Recovery. AM. IND. HYG ASSOC J. 56: 538 -567 ; 1995

20. Gordon G. Geiesbrecht & Gerald K. Brislow. J.Appl Physiol . 63 (6) ; 2375 - 2379 : 1987.

21. Yutaka Tochihara and Tadakasu Ohnaka. Effect of repeated exposures to sevely cold environment on thermal responses of humans. Ergonomic.1995,Vol 38, No.5.987-995.

22. Gordon G. Giesbreeh. Influence of Body Composition on Rewarming from Immersion Hypothemia. . Aviation,Space, and Environmental Medicinc. 66 (12) : 1144 – 1150.

23. H.A.M. Daanen and F.J.G. Van DE Linde. Comparison of Four Noninvasive Rewarming Methods for Mild Hypothermia. Aviation,Space and Environmental Medicine 63; 1070 – 1076 : 1992

24. Yutaka Tochihara, Chiyoji Ohkubo, Iwao chiyama and Hiromi Komine. Physiological Reaction and Manual performance during Work in Cold Storage. Journal of Physiological Anthropology 14(2) : 73 - 77

Questionnaire

Number................

1. General Charateristice

Name.......................................Surname...

Age..................Year Body Weight ....kgs.

Height............cms.

Domicile...

Drink Habit ( ) not ( ) drink

Smoke Habit ( ) not ( ) smoke

2. Physiological data

Before working in cold Storage

Heart rate .... beat/minute

Skin Temperature

Hand ....°C

Shin ....°C

Neck ....°C

Scapular............°C

Fingers ....°C

Toes ....°C

Core Temperature ....°C

After working in cold Storage 45 minute

Heart rate .... beat/minute

Skin Temperature

Hand ....°C

Shin ....°C

Neck ....°C

Scapular............°C

Fingers ....°C

Toes ....°C

Core Temperature ....°C

Recovery time

Heart rate .... minute

Skin Temperature

Hand .... minute

Shin .... minute

Neck .... minute

Scapular............ minute

Fingers .... minute

Toes .... minute

Core Temperature .... minute

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