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The Work Fatigue of the Several Workloads with the Impermeable Clothing

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ABSTRACT

산업장에서 발생하는 작업피로는 작업부하(작업의 강도, 속도, 그리고 시간 등) 작업조건(특수복, 방수복, 마스크 등의 착용)의 복합효과로 일어나는 것으로 볼 수 있을 것이다. 본 연구에서는 여러 산업장에서 보호복으로 착용하는 방수복의 효과를 작업부하시간, 생리학적인 관점(심박수)과 열압박의 조건에서 비교하여, 각 경우의 작업피로 정도를 분석해 보고자 한다.

This paper reports the results of four related studies concerning the combined effects of impermeable clothing and alternating levels of workload. The negative consequences of impaired evaporation due to impermeable clothing are compared for different schedules, workloads, preheating, and high heat conditions.

1. INTRODUCTION

An ever increasing number of jobs and work tasks require the use of impermeable clothing. Workers involved in solid waste management, asbestos removal, nuclear power plant operations, exposure to high radiant heat, and to a wide array of toxic chemical hazards must wear protective clothing which possesses some level of impermeability[1]. This paper investigates the combined effects of impermeable clothing and alternating (high and moderate) workload levels. Four related preliminary studies are reported: these include analysis of impermeable clothing and,

a. Alternating workload(per time schedule)
b. Alternating workload(per heart rate limits)
c. Pre-work heat exposure
d. High heat load.

The impermeable clothing(IC) used in these studies was a loose fitting vinyl garment consisting of a long sleeved top and long trousers with elastic closure at all openings of the neck, waist, arms, and legs. Physiological stress and the long duration time requirement supported the utilization of the same subject over the entire period, rather than the use of different subjects for different sub-studies.

Alternating levels of high and modrate workload were generated, according to prescribed schedules, by means of running and working, respectively. High workloads in all instances were

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at or above the 90% maximum heart rate level. The maximum heart rate was estimate as: 220-age in years[2].

2. ALTERNATING WORKLOAD(PER TIME SCHEDULE)

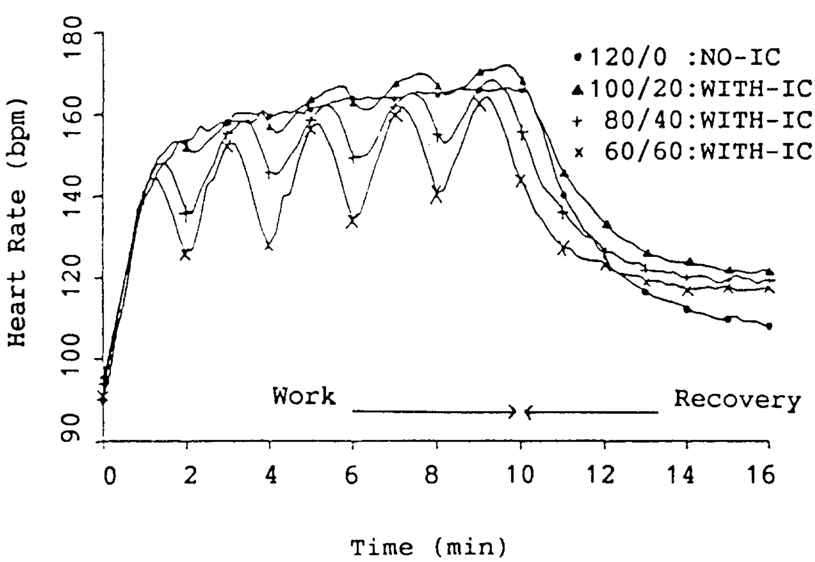
In the first study, a continuous high workload without impermeable clothing(no-IC) was compared with tree other combinations of alternating high/moderate workload(with-IC). The alternating conditions for each level were based on a 120 sec schedule which was repeated consecutively throughout a ten min work period. This was followed by a six min recovery period. The high workload was obtained during running, and the moderate workload during working obtain these four conditions:

1. 120/0 (120 sec continues high workload, no-IC)
2. 100/20 (100 sec high and 20 sec moderate, with-IC)
3. 80/40 (80 sec high and 40 sec moderate, with-IC)
4. 60/60 (60 sec high and 60 sec moderate, with-IC)

Each of these four conditions were replicated three times. Clothing for the no-IC condition consisted of a cotton warm-up suit with long sleeved top and long trousers which were snugly fitted at all openings. This clothing was also worn over the previously described impermeable clothing during the with-IC conditions. These data were collected indoors in a reasonably constant temperature of 72/62 F(22/17C) dry bulb/wet bulb.

Figure 1 depicts heart rate response to the experimental conditions during both work and recovery. The continuous work(120/0, no-IC) shows a gradual increase in heart rate until the end of the work and a rapid reduction of heart rate during the recovery. The influence of the impermeable clothing is seen in the other with-IC schedules, which tend to show a more rapid

Figure 1. Impermeable Clothing(IC) and Alternating Workload(120 sec Schedule: HIGH/, MODERATE)



heart rate increase during work, and also very strong interference with the reduction of heart rate during recovery. The schedule of 100/20 generates heart rates that the higher than those during the continuous work: this show the heart rate to be more dominantly affected by the impermeable clothing than by the 20 sec intervals of reduced workload during each 120 sec work bout.

Cardiac cost as indicated by average heart rate is another useful way to evaluated the relative impact of the IC and different alternating work schedules. Table 1 shows the average cardiac cost (bpm) during the entire work and recovery period (16 min), and during these periods separately. Duncan's Multiple Range test of the data shows cardiac cost during all periods to be significantly higher for schedule 2(100/20) than for schedule 1 (120/0). For the total 16 min period, schedule 1(120/0) and schedule 3(80/40) do not show significantly different cardiac cost. However, during the 10 min period, 1>3 and during the 6min recovery period this is reversed and 3>1. This suggests recovery periods, the cardiac cost for the schedule of 80/40, with-IC is basically equivalent to the continuous work where impermeable clothing is not present.

Table 1 : Impermeable Clothing and Cardiac Cost During Work Recovery. Condition 1 is 120/0: NO IC, 2 is 100/20: WITH-IC, 3 is 80/40: WITH-IC, 4 is 60/60: WITH_IC. (Duncan's Multiple Range Test, Conditions With Same Group Letter Are Not Statistically Different at 5% Level.)

	16 minutes		10 minutes		6 min(recovery)	
Group	Condition	Mean	Condition	Mean	Condition	Mean
A	2	74.093	2	83.394	2	59.009
B	3	70.041	1	81.878	3	55.270
B	1	69.763				
C	4	61.670	3	79.150	1	50.117
D			4	69.672	4	48.694

3. ALTERNATING WORKLOAD (PER HEART RATE LIMITS)

This study utilized the same impermeable clothing and instrumentation previously mentioned, but the schedule for alternating workload was based upon reaching target heart rate levels. Two experimental conditions were observed: with-IC and no-IC. The experimental protocol called for an initial bout of high workload (running) to be continued until the subject's heart rate reached the high level which was 90% of maximum heart rate. Maximum heart rate was 90% of maximum heart rate. Maximum heart rate was estimated as 220 minus age. The time required to reach the high heart rate would then be recorded, and a moderate workload(working) would be initiated. At that time when the heart rate reached the 80% of maximum level, the time would again be recorded, and a high workload would again be initiated. This procedure was repeated to generate an alternating work schedule of time required to reach the 90%(151 bpm) and 80%(134 bpm) maximum heart rate workload levels. The with-IC combinations were replicated three times each in an outdoors environment where the mean temperatures were 78/63 F(25/17C) dry bulb/wet bulb.

Figure 2 shows the time intervals associated with these high (90%%) and moderate (80%) heart rate levels during nine consecutive cycles totalling approximately 20 min. The time at high workload is similar for both the with-IC and no-IC conditions during the early cycles. Towards the end of the 20 min period, the with-IC condition approaches 40 sec worktime compared to 60 sec for the no-IC condition. The effect of IC on the time it takes to return to the moderate 80% heart rate. The presence of the IC, however, more than doubles the amount time required to rech this lower heart rate level.

Figure 2. Impermeable Clothing (IC) and Alternating Workload (Heart Rate Limits: HIGH-90% Max, MOD-80% Max)

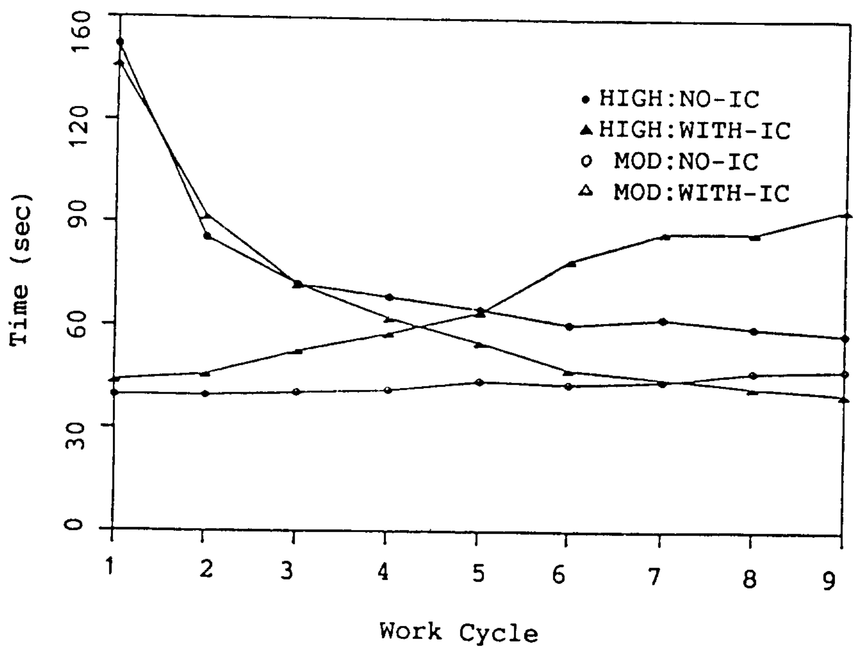


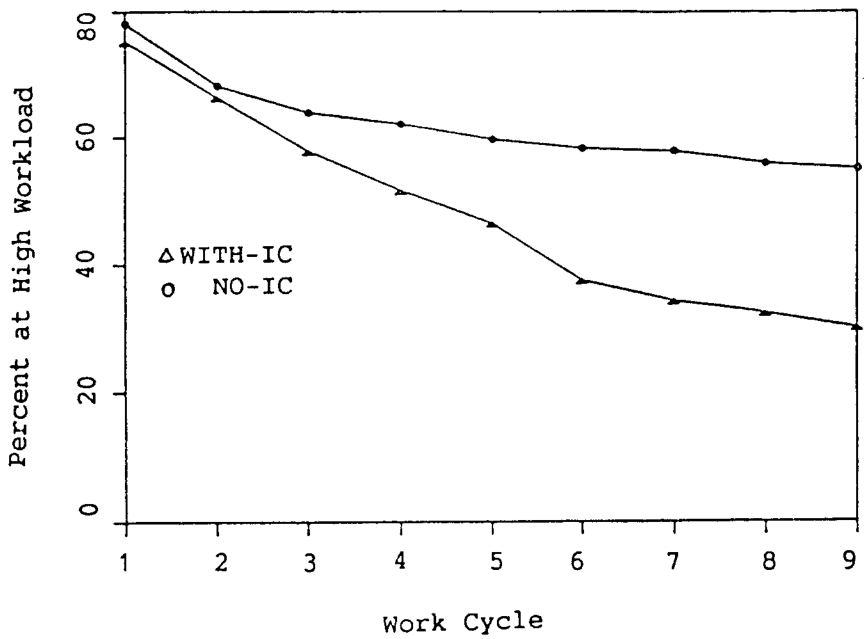
Figure 3 shows the percent of time spent at high workload, as another way of comparing tfects of impermeable clothing. After 20 min of work the no-IC condition allowed high workload to be maintained 60% of the time, whereas the with-IC condition limited the high workload only 30% of the time.

4. PRE-WORK HEAT EXPOSURE

This study also compares the heart rate response to high intensity workload both with and without impermeable clothing, but adds the dimension of a pre-work heat exposure. Since the heat retention characteristics of the IC are very strong, this study provides a look at the initial and residual effects in the cardiovascular system of providing an environmental heat load prior to actual work and metabolic heat production.

The clothing and heart rate monitoring instrumentation of this study have been previously described. The high level workload was obtained by running on an indoor track in a ressonably constant temperature of 74/62 F(23/17C) dry bulb/wet bulb.

Figure 3. Impermeable Clothing (IC) and Alternating Workload (Percentage of Time Spent in HIgh Workload)



The pre-heat exposure was generated by placing the subject for minutes in a sauna which maintained at an air temperature of 203F (95C) and a relative humidity of 4%. Four experimental conditions were tested:

1. Impermeable clothing and pre-heating (IC & pre-heat)
2. Impermeable clothing (IC)
3. No-impermeable clothing and pre-heating (no-IC & pre-heat)
4. No-impermeable clothing (no-IC)

Each of these four conditions were replicated three in a completely randomized sequence.

Figure 4 displays the heart rate response during a 32 minute period which included 12 minutes of exercise and 20 minutes of recovery. The condition of IC & pre-heat, which intuitively would represent the most stressful condition, yields significantly higher work and recovery heart rate responses. Conversely, the no-IC condition has lowest work and recovery heart rate responses.

The effect of pre-heating is noticeable in the heart response of the first few work minutes, but tends not to be dominant as metabolic heat continues to build during the work session. During work the three conditions, other than IC & pre-heat, each present a heart rate response which is not significantly different from one another. During recovery, however, this difference is very noticeable. The requirement for the cardiovascular system to be involved in heat dissipation creates a residual load during recovery which is reflected in the different and deduced levels of heart rate response for each condition: and no-IC (which is lowest).

Figure 4. Impermeable Clothing (IC) and Pre-Work Heat Exposure

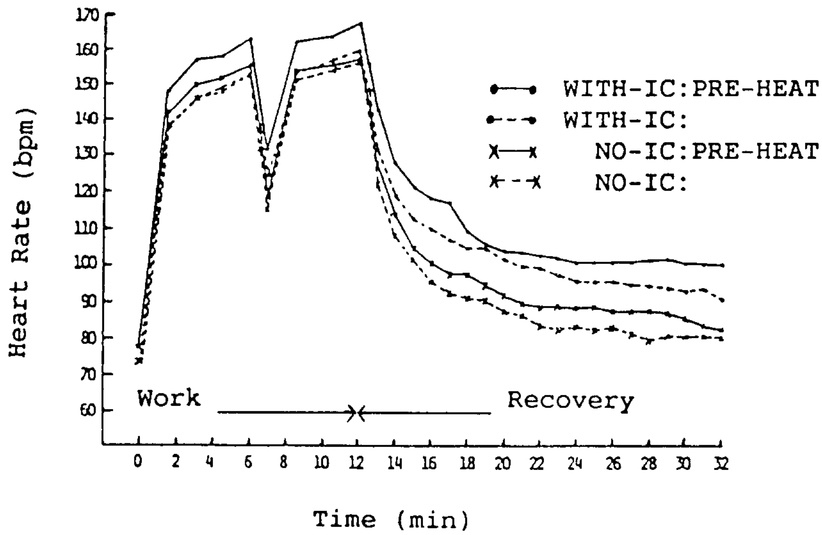
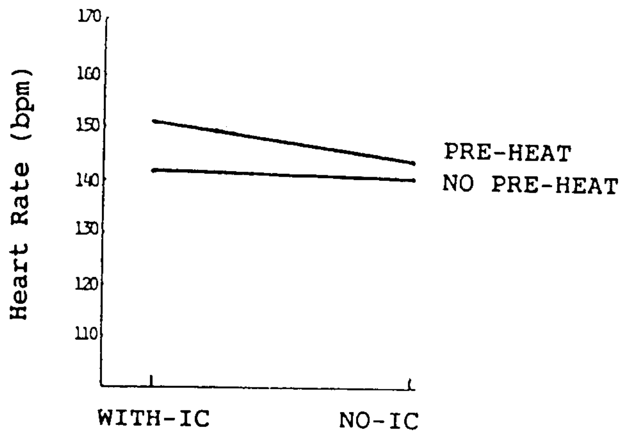


Figure 5 presents a closer analysis of the heart rate for the IC & pre-heat interaction. This interaction clearly shows the pre-het condition to yield statistically higher values than for no pre-heating. The combination of IC & pre-heat, however, yields a higher heart rate than the no-IC & pre-heat combination. For no-preheating conditions, the ence of the IC was not noticeable in the heart rate values. This study is reported more completely in Ramsey(3).

Figure 5. Impermeable Clothing (IC) and Pre-Work Heat Exposure Interaction



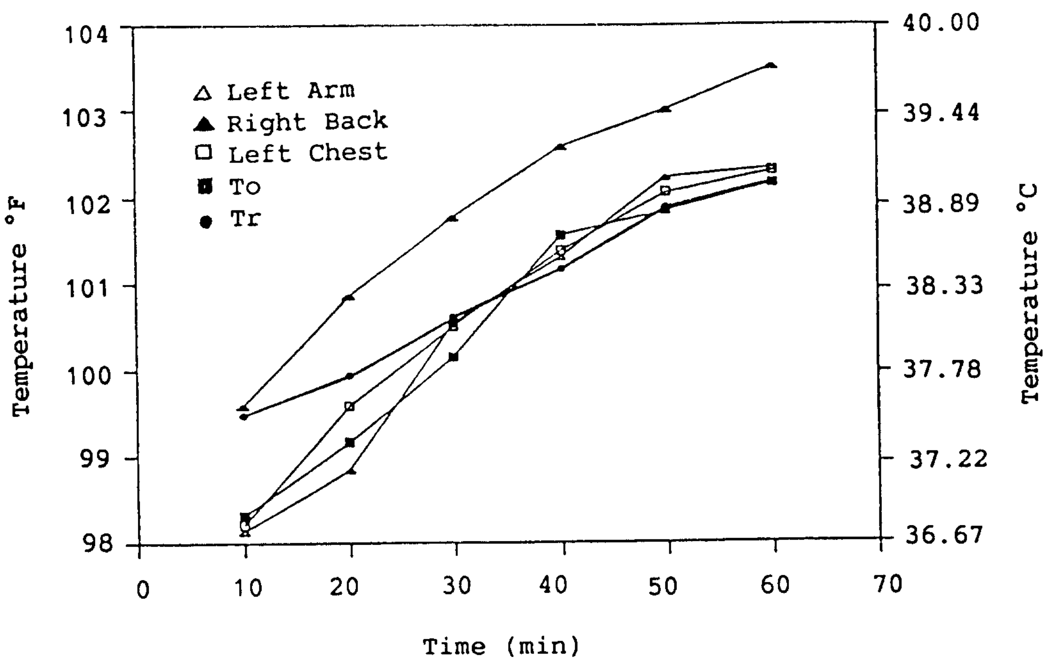
5. HIGH HEAT LOAD

This study exposed the subject in IC to both a high environmental temperature and moderately heavy metabolic heat load. The data were collected in an outdoors environment having a mean WBGT of 89 F (32C). Workload was generated with procedure of alternating running and walking which maintained the heart rate at an average of 80% of maximum(134bpm) with variations between 75% and 85% of maximum(126 to 143bpm). These data were replicated four times. The subject, impermeable garment and heart rate monitoring instruments have been previously three surface thermistors for measurement of skin temperature. Three additional body temperature and environmental measurements were taken for a total of six measurements as follows:

1. Left arm.	Under the armpit in the harness.
2. Right back.	located above the latissimus dorsi on the harness.
3. Left chest.	Beneath the pectoralis, center chest in the harness.
4. Oral.	Under the tongue, close mouth.
5. Rectal.	Inserted 15cm beyond the sphincter.
6. WBGT.	Measured at worksite using WBGT meter (RSS-211, Reuter-Stokes, Ltd.)

Thermistors numbered 1 through 5 above were connected to a Telethermometer(Yellow Springs Instruments, Inc.) which was carried in the subject's hand during the work periods. The workload was adjusted in an alternating scheme according to the heart rate display which was monitored continuously. At approximately 10 min intervals during the session, the subject would stop for about 2 min while temperature data were collected.

Figure 6. Impermeable Clothing (IC) and Body temperature



Summary results of this study are shown in Figure 6. Rectal temperature (Tr) shows a regular increase of approximately 0.5 F during each 10 min. Oral temperature (To) starts lower, but after about 35 min reaches Tr and continues to track it closely. Thermistors 1 and 3 located in the left arm and left chest, respectively, operate similarly to To and Tr after about 35 minutes. It would be expected that these skin temperatures would cross over and and tcontinne above Tr, his appears to be the case, although these differences are not statistically significant.

Therimistor 2 on the right back is consistently and significantly higher, but this was determined to result from the data collection procedure rather than from the thermistor location. The orientation of the data collection station, with the outdoor sun striking the right back of the subject, caused a disproportionate amount of time to be spent in this position. The running and walking pathway provided equivalent exposure to the entire body, but during data collection the radiant heat exposure was undirectional. The directional heat effects of the outdoor sun were very noticeable to the subject's skin; radiant heat transferred conductively to the subject, generated a hot and uncomfortable condition.

6. SUMMARY

In summary, it is suggested that during the first minutes of exposure even at high work and high heat conditions in impermeable clothing, the heart rate responses do not differ widely from those without impermeable clothing. However, as exposure continues the consequences of impaired evaporation become more noticeable. A major differential effect was notes in all conditions during the recovery after work, due again to impermeable clothing's restraint on the ability to transfer heat to the environment. Significantly negative effects in physiological strain were also encountered when the level of workload was increased or when the condition of preheating was added.

It also appears that a schedule of alternating workload in impermeable clothing can be used to maintain cardiovascular strain at an equivalent level to that of continuous work without impermeable clothing. After 20 minutes of alternating workload, the presence of the impermeable clothing more than doubled the amount the time require to reach the lower workload heart rate and it also limited the high workload condition to only 30% of the time.

It appears that harness mounted skin thermistors may provide useful correlate information concerning deep body necessary to adequately shield and insulate the thermistors from these directional effects.

REFERENCES

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