HEAT TOLERANCE OF ELDERLY PERSONS LIVING IN A SUB-TROPICAL CLIMATE

by

A. Henschel, M. Coles, O. Lyczkowskyj,
T. Doyle and L. Margolies

Department of Health, Education, and Welfare
Bureau of Disease Prevention and Environmental Control
National Center for Urban and Industrial Health
Occupational Health Program

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ABSTRACT

The capacity of elderly persons to tolerate a standardized heat-work load was measured under rigidly controlled conditions on a group of 32 females, average age 69 years, and a group of 68 males, average age 72 years, who lived in the St. Petersburg area; age range was 60-93 years. The standard test consisted of five minute seated rest followed by four five-minute work periods on a bicycle ergometer. Each work period was followed by a ten minute rest period while seated on the ergometer. The four work periods were at progressively increasing levels of severity with average O_2 consumptions of 10, 13, 16 and 19 cc/kg per minute at 92°F dry-bulb and 82°F wet-bulb temperatures. Pulse rates, ventilation rates, O_2 consumption and oral temperatures were measured during the last minute of each work period. Twelve lead EKG were taken and blood cholesterols were measured. Each subject completed the test on two occasions, once in the spring and again in the fall after a summer of exposure to a natural hot humid environment. Resting EKG's were normal in 40 per cent; about 90 per cent considered their health to be good. Blood cholesterol levels averaged 235 mg per cent in the males and 250 mg per cent in the females. Those with abnormal EKG's did not have higher cholesterol levels. Ability to tolerate the

ABSTRACT (cont)

heat-work load was surprisingly good. Under conditions of heat and work at a level of work that required an O_2 consumption four times resting values pulse rates were 119 for the females and 105 for the males. The pulse rates for the females were 10-15 beats per minute lower than those observed in a group of young and middle aged women performing the same rate of work at "comfort temperatures." For the males the work pulse rates were only slightly (2-6 beats per minute) lower than those observed in a large group of young and middle aged coal miners. It would appear that elderly persons who are free from active disease processes can tolerate a moderate heat-work load without difficulty.

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INTRODUCTION

The predictive schema which was developed by the Division of Occupational Health,* USPHS, for the Office of Civil Defense,[1,2] permits one to estimate the probable effect of any combination of temperature, humidity, radiant heat load, air movement, physical activity and clothing upon a specified "standard man." This predictive schema also permits one to estimate the probable difference in responses brought about by certain non-standard states of the individual involved, including the effects of acclimatization, disease processes and aging. In the preparation of the schema, numerous inconsistencies and inadequacies were evident in the published data. Some of the most outstanding deficiencies concerned alterations in performance capabilities and adaptive capacities that accompany the processes of aging.

Aging may affect an individual's reactions and tolerance to heat stress by its physiological concomitants alone or through the disease states that tend to be more prevalent in later life. In

* Now the: Bureau of Disease Prevention and Environmental Control
National Center for Urban and Industrial Health
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either case, the effect may be an alteration in the ability to adjust to a heat load or an unwillingness to "tolerate" a degree of partial failure or severe discomfort. Knowledge of the relative incidence of these two processes in elderly people is required since under shelter conditions some individuals may be treated by reassurance, or by minor assistance through temporary difficulties, while others may require special provisions. This study was undertaken to provide data necessary for strengthening the predictive schema by measuring the effects of aging and associated conditions on the physiological responses to a standardized environmental heat and work stress at different seasons of the year in a sub-tropical climate. The study design and the criteria used for estimating physiological strain and heat tolerance capacity were based on the concepts set forth by Lee and Henschel [1,2] in order that the observed responses could be directly compared to the predicted responses.

SUBJECT GROUP

The subjects for this heat tolerance study who were tested at the end of both a winter and a summer season were 68 males and 32 females over 60 years of age who were selected from a group of

158 volunteers. The demographic data on the group are presented in Table I. The age range was 60-93 years with a mean of 69 for the females and 72 for the males.

The subjects were a highly motivated self-selected group of individuals. In several respects, they differed from those of a cross-sectional survey of 2544 persons 65 years of age or older assembled by the Florida State Health Department using adequate statistical sampling techniques from citizens of the same general area [(3)]. As seen in Tables II and III, the subjects of the heat tolerance study utilized the services of physicians and medications much less than did the Health Department survey subjects. Over 90 per cent of the heat tolerance study group considered their health to be very good or good. Only 5 in the entire group had blood cholesterol levels above 280 mgm. per 100 cc, which is considered to be the upper end of the normal range.

The 12 lead electrocardiograms were within normal limits in 56 per cent of the males and 63 per cent of the females. In a group of patients of similar age admitted to the local Veterans Administration Hospital for non-cardiac disorders, abnormal electrocardiograms were observed in 70 per cent. Obviously the individuals who comprised the subject group for this heat tolerance study enjoyed better health than would be expected of a group of similar age and background.

The smoking history of the subjects in this study also showed an interesting trend. About 40 per cent of the males and 20 per cent of the females had never smoked. Of those who had been habitual cigarette smokers nearly 75 per cent had stopped smoking within the past 10 to 15 years. It is unusual to find such a high percentage of success in breaking the cigarette smoking habit among any age group.

METHODS

Each volunteer, before being selected as a participant in the study was given a medical examination including a 12 lead resting EKG, and was questioned regarding health status, occupational experiences and areas of past residence. The individuals whose EKG, medical examination or the medical history revealed no signs or symptoms of serious disabilities, were scheduled to report for the standard work-in-heat test.

The standard work-in-heat test consisted of a 70-minute exposure in a controlled environment chamber at 92°F dry-bulb temperature, 82°F wet-bulb temperature, minimum wind speed of less than 100 feet per minute and wall temperatures equal to air temperature. This combination of dry-bulb and wet-bulb temperatures resulted in an effective temperature of 85°F and a Relative Strain

Index of 0.5[1,2]. An environment equal to a RSI of 0.5 or an ET of 85°F would be expected to produce serious physiological and psychological strain in heat unacclimatized elderly persons[1].

During the exposure period, the subject went through the following sequence of activities in the chamber: rest for 10 minutes seated on a Lanooy bicycle ergometer; work 5 minutes on the bicycle set at a resistance requiring 10 watts of external work; rest 10 minutes; work 5 minutes at 20 watts; rest 10 minutes; work 5 minutes at 30 watts; rest 10 minutes; work 5 minutes at 40 watts; rest 10 minutes. Working on the bicycle set at 10, 20, 30 and 40 watts required work energy expenditures one, two, three and four times greater, respectively, than the resting level. The Lanooy bicycle ergometer has the advantage that the work level is constant for any resistance setting within a wide range of pedaling speeds. In our tests pedaling speed was maintained at approximately 50 revolutions per minute. During the ninth minute of the first rest period and during the fifth minute of each work period, heart rate (from lead 2 of EKG), ventilation rate and volume (Edwards mask and a dry gas meter), and oxygen consumption (Beckman paramagnetic O_2 analyzer) were recorded. Body weights (clothed in standard cotton twill work ensemble) were measured before and at the completion of the standard work-in-heat test.

HEAT TOLERANCE AND AGING

The standard work-in-heat test with all measurements was completed by all of the 100 subjects on two occasions: at the end of a summer session after several weeks or months of exposure to a natural hot-wet environment, and at the end of the winter season after the outside temperature had been mild to cool for several weeks.

RESULTS AND DISCUSSION

The data on the physiological responses to the various levels of work during the standard work-in-heat test are presented in Table IV for the tests conducted during a winter season and during the summer season.

The seated rest pulse rates at the beginning of the test averaged about 80 beats per minute for both the female and male groups. This, in addition to the relatively low ventilation volumes and oxygen consumption, is evidence that the subjects were quite at ease and not apprehensive about the test procedure or about any ill effects that might be induced by the test.

With each increase in work level a corresponding increase in pulse rate, ventilation and oxygen consumption occurred. The increases progressed in regular steps corresponding to the increasing levels of physical work. At the 30 and 40 watt levels of work the pulse rates and oxygen consumption per kilogram of body weight were consistently higher in the female than in the male group. Higher energy cost per unit of body weight for smaller individuals than for larger individuals has been shown for other groups of people(4).

No differences were found between the rest pulse rates and oxygen consumption values summer and winter. Several differences did occur, however, for each of the four levels of physical work. The pulse rates in both the women and men were about 5 beats per minute higher during the winter season than during the summer season. Ventilation rate, total oxygen consumption and even oxygen consumption per kilogram of body weight were consistently lower in the summer. These differences presumably indicate that the subjects were more active out-of-doors in the heat in the summer and were therefore in better physical condition and, also, more highly acclimatized to heat. These data would suggest that these elderly people were capable of developing heat acclimatization and physical conditioning and were, in fact quite responsive to moderate changes in their environment and level of activity.

HEAT TOLERANCE AND AGING

The work-in-heat test as presented to these subjects did not seriously tax their capacities to meet the challenge. Based on criteria used by Lee & Henschel[1,2] more physiological and psychological strain had been anticipated. The consequences to otherwise healthy elderly persons of exposure to a hot-humid environment are, therefore, overestimated by this Relative Strain Index. However, had the environmental conditions been much more severe or had the work periods been longer with a corresponding decrease in the rest time, a combination would have been reached wherein the subjects could not maintain physiological balance. At low levels of metabolic activity, physiological balance no doubt could be maintained and no special physiological problems should be encountered under shelter conditions comparable to those used in this test. Lofstedt has shown that for a 4-hour exposure at rest (110-130°F DB) in hot conditions tolerance was lower in older men (over 40 years), in women regardless of age and in children, as compared to healthy young adult males. For lower levels of heat exposure, responses to heat did not differ between the groups[7].

Our subject groups, however, were not entirely representative of all elderly persons. As already noted (Table I), they enjoyed better health, were physically active and were capable of being self-sufficient. Many persons of similar age do not enjoy a comparable level of good health. This poses the question of whether the elderly people comprising this study are physiologically equal to or inferior to younger people. Data are available on younger age groups who composed the sample of women and men studied during the USPHS survey of the incidence of chest disease in a population of coal miners and their wives. In both the chest disease and heat tolerance studies the subjects worked on the bicycle at 40 watts of external resistance. The air temperature was 75-80°F in the laboratory in which the chest disease study was made while it was considerably hotter (92°F) in the heat tolerance test room. The pertinent data are presented in Table V for comparison.

Ventilation rate and oxygen consumption, both total and cc/kg body weight, were higher in the elderly heat tolerance subjects during the 40 watt level of work but were not higher during the rest period before the work started. The work and rest pulse rates were, however, lower in the older people even though the work was performed in much hotter conditions. The higher ventilation by the elderly group in the hot conditions is consistent with observations we have made in other heat tolerance studies in our laboratories where it was observed that for any level of physical work, ventilation volume increased with increasing ambient temperature. In these studies oxygen consumption decreased slightly with increasing ambient temperature.[8] A similar lower oxygen consumption was not observed in the elderly group. In comparing the ventilation volume and oxygen consumption during work as a function of age, a consistent increase was observed going from age group 32 years through 45 and 55 years to the 69-72 year groups.

The lower pulse rates during work in the heat tolerance study group as compared to the miners and their wives, which was most striking in the elderly women, might indicate a higher level of physical fitness. But this might be questioned because the coal miners' wives were an active group who performed normal household duties besides caring for their children - this is hardly a sedentary occupation. The elderly women had fewer duties around the home but probably had more time to participate in activities outside the home. In any event both the elderly women and the men could perform work at a level requiring about one liter of oxygen consumption a minute without evidence of serious physiological strain. This is consistent with the observations reported by Dill and others[5,6] that for moderate levels of physical and environmental stresses age per se does not severely restrict adaptive capacity.

HEAT TOLERANCE AND AGING

CONCLUSIONS

Under mainly sedentary conditions and a range of dry-bulb and wet-bulb temperatures likely to be encountered in civil defense shelters, elderly individuals who are otherwise relatively free of acute or chronic diseases should present no unusual problems. Extreme heat or demands for more than light physical activity could exceed their tolerance capacities and could present special problems in shelter care and regimen. However, because the incidence of serious acute and chronic disorders increases with age, it must be assumed that, in a random cross-section group of elderly individuals which might be included in a population occupying a shelter, the incidence of heat intolerance would be substantially higher in older people.

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TABLE I

Personal and Cholesterol Data for the Males and Females
of the St. Petersburg Study

	FEMALES		MALES	
	Mean	S.D.	Mean	S.D.
Number	38	--	62	--
Age, Years	69	4	72	7
Height, Centimeters	159	5	171	11
Weight, Kilograms	63.7	10	74.5	10
Cholesterol Mg%-Normal EKG	254	--	232	--
Cholesterol Mg%-Abnormal EKG	253	--	238	--

TABLE II

Percentage of Persons Who Used Medicines and Drugs

Heat Tolerance Subjects for Last 5 Yr. Period Compared With Health Department Group for Last 2 Yr. Period

	Health Department Group	Heat Tolerance Group	Significance
Male	70.0	38.5	$p < .001$
Female	82.1	57.3	$p < .001$

TABLE III

Percentage of Respondents who Utilized M. D. Services During the Last 2 Year Period for Health Department Group Compared with Heat Tolerance Group During Last 5 Year Period.

	Health Department Group		Heat Tolerance Group		
	Male	Female	Male	Female	Significance
Used M.D.	75.8	78.8	59.3	32.2	$p < .001$
No M.D.	24.2	21.2	40.7	67.7	$p < .001$
TOTAL	100	100	100	100	

TABLE IV

Pulse rate, ventilation volume and oxygen consumption data for the men and women on the standard graded work and heat test. Test was repeated on the same subjects at the end of the winter and the summer seasons.

Pulse rate in beats per minute, ventilation in liters per minute, oxygen consumption in liters per minute and cc per kilogram of body weight per minute for rest and for work at 10, 20, 30, and 40 watts.

	Women				Men			
	Winter		Summer		Winter		Summer	
Variable	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Rest, pulse	80	13	81	12	80	12	78	11
" ventilation	10.2	2.5	10.3	2.8	13.2	5.0	12.2	2.9
" O_2, liters	0.32	0.06	0.32	0.07	0.41	0.08	0.40	0.06
" O_2/cc/kg.	5.1	0.9	5.1	1.0	5.5	1.1	5.4	1.0
10 Watts, pulse	96	16	90	12	91	14	85	11
" ventilation	16.8	4.1	14.5	3.0	18.6	3.9	17.6	2.6
" O_2, liters	0.66	0.17	0.56	0.11	0.78	0.17	0.65	0.12
" O_2/cc/kg. min.	10.3	2.1	9.0	1.5	10.6	2.4	9.3	1.6
20 Watts, pulse	103	14	95	12	94	15	88	11
" ventilation	19.3	4.1	17.2	3.0	21.4	5.9	20.0	2.6
" O_2, liters	0.87	0.16	0.72	0.12	0.96	0.21	0.85	0.11
" O_2/cc/kg.	13.2	2.4	11.5	1.7	12.9	3.1	11.7	1.9
30 Watts, pulse	110	16	105	12	99	15	93	11
" ventilation	22.3	4.6	20.5	3.3	24.0	6.3	23.0	3.2
" O_2, liters	0.98	0.20	0.89	0.14	1.11	0.20	1.03	0.11
" O_2/cc/kg.	15.5	2.8	14.2	2.0	14.9	2.4	14.0	1.2
40 Watts, pulse	119	16	115	13	105	17	99	13
" ventilation	26.2	5.1	24.6	3.5	27.1	6.8	26.4	3.7
" O_2, liters	1.19	0.11	1.10	0.13	1.28	0.23	1.22	0.13
" O_2/cc/kg.	18.9	3.1	17.5	2.3	17.2	2.8	16.6	2.4

TABLE V

Pulse rates, ventilation volume and oxygen consumption during standard graded work tests for the elderly males and females in St. Petersburg and for younger age groups of women living in Richwood, West Virginia and for coal miners from the Appalachian region.

	Females				Males			
Subject Source	St. Pete	Richwood			St. Pete	Coal Miners		
Age, Years	69	32	45	55	72	33	45	56
Height, Centimeters	169	164	164	113	171	176	176	174
Weight, Kilograms	63.7	62.5	65.7	67.0	74.5	76.7	80.2	77.7
Rest, Pulse Rate	80	95	91	88	80	91	89	86
" , Vent. L.	10.2	9.2	9.3	9.1	12.2	8.9	9.2	9.7
" , O_2 cc/min.	320	340	350	330	410	440	440	440
" , O_2 cc/kg. min.	5.1	5.5	5.4	5.0	5.5	5.9	5.9	5.8
40 Watts, Pulse Rate	119	132	131	137	105	111	109	106
" , Vent. L/min.	26.2	23.5	24.0	25.4	27.1	22.7	23.8	24.8
" , O_2 Liters/min.	1.19	1.02	1.06	1.17	1.28	1.21	1.04	1.06
O_2, cc/kg./min.	18.9	16.9	16.6	17.2	17.2	13.5	13.6	14.1