HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND
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TECHNICAL REPORT

EP-75

AMERICAN NEGRO-WHITE DIFFERENCES IN HEAT TOLERANCE

QUARTERMASTER RESEARCH & ENGINEERING CENTER
ENVIRONMENTAL PROTECTION RESEARCH DIVISION

JUNE 1958

NATICK, MASSACHUSETTS

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HEADQUARTERS
QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
OFFICE OF THE COMMANDING GENERAL
NATICK, MASSACHUSETTS

Major General Andrew T. McNamara
The Quartermaster General
Washington 25, D. C.

Dear General McNamara:

This report, "American Negro-White Differences in Heat Tolerance," is a study of certain body measurements (internal temperature, pulse rate, and sweat loss) which indicate the level of strain experienced by American Negro and White soldiers who were exposed to hot-wet and hot-dry temperature conditions.

Present military concepts indicate the need for maximum utilization of the individual soldier's ability. The material contained in this report may be used in developing a list of simple body characteristics which will indicate the relative individual and group's ability to withstand or minimize the effect of the heat stress accompanying military operations in a hot environment. With the development of such a list men can be pre-selected for the duty which most closely fits their ability to perform under heat stress, thereby improving our utilization of manpower and equipment.

Sincerely yours,

C. G. Calloway

C. G. CALLOWAY
Major General, USA
Commanding

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HEADQUARTERS QUARTERMASTER RESEARCH & ENGINEERING COMMAND, US ARMY
Quartermaster Research & Engineering Center
Natick, Massachusetts

ENVIRONMENTAL PROTECTION RESEARCH DIVISION

Technical Report

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AMERICAN NEGRO-WHITE DIFFERENCES IN HEAT TOLERANCE

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FOREWORD

It has long been recognized that there exists a large variation in individual ability to tolerate severe climatic conditions. If the individuals with high and low tolerance to a given climatic stress could be easily distinguished, it would open new avenues for improving soldier performance under stress conditions. Men could be selected for special duty, and clothing and equipment design could be adjusted to individual needs. At present, no simple method exists to distinguish individual or sub-group ability. The experiments reported in this study indicate some of the morphological characteristics inherent in racial differences which may be used to distinguish high and low tolerance of heat.

AUSTIN HENSCHEL, Ph.D.
Chief
Environmental Protection Research Division

Approved:

WILBUR M. SKIDMORE, Colonel, QMC
Commanding Officer
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ABSTRACT

The physiological responses of American White and Negro soldiers were studied under hot-wet and hot-dry conditions.

Under hot-wet conditions 40 pairs of men matched for body fat, weight, and stature were walked around a course at 3-1/2 mph for one hour.

Under hot-dry conditions 8 pairs of men also matched for body fat, weight, and stature were studied under 8 different conditions which included combinations of clothing, sun, shade, walking, and sitting.

The results of this series of experiments indicated:

1) Under hot-wet conditions with both Negroes and Whites clothed and walking, the Negroes had a higher physiological tolerance.

2) Under hot-dry conditions with both groups clothed, walking, or sitting they had about equal tolerance.

3) Under hot-dry conditions with both groups nude and exposed to the sun, sun-tanned Whites had the higher tolerance.

These results further suggested that the differences found were not a function of transient environmental effects and are mostly genetic in origin.

AMERICAN NEGRO-WHITE DIFFERENCES IN HEAT TOLERANCE

Introduction

The science of genetics has emphasized the importance of natural selection in the formation of taxonomic races. This in turn indicates the desirability of re-evaluation of human races in terms of the possible sources of selective forces. Such a re-evaluation may be based on ecological inferences from the distribution of modern races; or a specific hypothesis may be tested by experimental means.

It is the purpose of this study, using the experimental approach, to compare the heat stress resistance (heat tolerance) of Negroes and Whites. The development of this type of knowledge will eventually permit us to define some of the role of climate in the selection of certain morphological characteristics.

The American Negro as a racial group constitutes a mixed genetic population, (Herskovits, 1928, 1930; Meier, 1949; Glass and Li, 1953). For this reason it should not be assumed that the heat stress resistance of the American Negro is identical to that of any other group. Comparison between American Whites and American Negroes has value primarily as an estimate of the variation in heat resistance which is related to genetic factors. The American Negroes as a group have a genetic inheritance drawn from a tropical population, while American Whites for many generations have lived almost exclusively in temperate climates. If there is a genetically-controlled difference in the heat stress resistance of these groups, it would strongly indicate the presence of a genetic difference in heat tolerance between temperate and tropical populations; however, the extent of the potential genetic difference cannot be ascertained by studying these groups alone.

Past studies on racial differences in heat tolerance are inadequate in the light of our present knowledge of acclimatization and human temperature regulation. Most of the work used for comparison was performed under different environmental conditions. Caplan and Lindsay (1946) studied mine workers in India under saturated hot-wet conditions and compared their results to those of Mackworth (1945) on Whites in England. Wyndham studied South African and Tanganyikan Negroes under hot-wet conditions (Wyndham et al, 1952 and 1953) and compared his results with those obtained elsewhere on Whites (Eichna(1945), McArdle et al (1947), and others).

He also compared his African results with those of Robinson on Mississippi sharecroppers (1941) discussed below. In both studies a difference between racial groups was claimed. Rectal temperatures and pulse rates were slightly lower in the non-White groups; sweat loss was much lower in the non-Whites.

Two aspects of these studies qualify interpretation of the results. First, the experiments were not designed for direct racial comparisons. Neither the level of acclimatization nor the climatic exposure conditions were the same for the White and non-White groups. Thus, the comparisons are subject to possible variations in responses caused by the level of acclimatization, small differences in heat stress levels, climatic conditions during non-test periods, and even differences in diet.

Second, in both studies the average body weight of the non-Whites was much lower than that of the Whites with whom they were compared. From the data of Adolph (1947) relating body weight to sweat loss, it may be assumed that most of the sweat loss difference between groups in the above studies was a function of the differences in body weight. Of course, even if the group differences in sweat loss are a function of body weight, they can be considered a genetically-determined racial difference, since weight is partially under genetic control.

The racial comparison study of Robinson et al (1941) remains the most complete study so far, despite the limitations of some of the conclusions reported. His study was made before heat acclimatization was a well-known phenomenon, and his effort to acclimatize the men brought from the North before comparing them to the Southern Whites was not adequate to insure an equal degree of acclimatization. However, for a racial comparison, Southern Negro and Southern White sharecroppers were studied. Since the environmental backgrounds of the groups were similar, differences in cultural and acclimatization factors were reduced. Fortunately, body weights for the two groups were also quite similar. The most important difference noted was in post-stress rectal temperatures. Under identical workloads the Negroes had a mean rectal temperature of 100.9°F. as compared to 101.6°F. for the Whites. Robinson concluded that the racial differences in heat stress resistance could probably be attributed 1) to racial differences in the surface-area-over-weight index and 2) to mechanical efficiency. He based these conclusions on an assumed racial difference in oxygen consumption per unit of surface area. It has been demonstrated that surface area is not the best reference for oxygen consumption (Wedgwood et al, 1953); and it is quite possible that the presumed extra mechanical efficiency of the Negro sharecroppers is attributable to a racial difference in body composition.

In summarizing the published evidence, although some experimental deficiencies may exist in all the studies, it cannot be said in any instance that the total results can be dismissed because of inadequate experimental or environmental controls. Instead, the published material, particularly Robinson's work, strongly supports the conclusion that there is a genetically-determined racial difference in resistance to hot-wet heat stress.

Experiments in Heat Tolerance

Because of the differences between hot-wet and hot-dry climates, two separate experiments were performed; one under moderate hot-wet conditions in Virginia and the other under hot-dry conditions in the Yuma Desert. The experiments were designed to test whether American White and Negro soldiers showed any difference in their ability to withstand heat stress.

Part I - Hot-Wet Conditions

1. Procedure and methods

Potential strain differences due to racial differences in body size and composition were controlled by selection. One hundred American Negro and one hundred American White soldiers were measured at Fort Lee, Virginia. From these 200 men, 40 pairs of volunteers were matched as closely as possible for percent of fat in the body, fat-free weight and stature.

TABLE I. A COMPARISON OF BODY COMPOSITION MEASUREMENTS ON MATCHED AMERICAN NEGROES AND WHITES
(40 Negroes, 40 Whites)
(Hot-wet climate, Fort Lee, Virginia)

Measurement	White		Negro		Mean Difference
	Mean	S.D.	Mean	S.D.	
Percent of Fat in the Body*	5.3	3.2	5.2	3.4	.1
Fat-free Weight (kg)*	66.1	6.3	66.1	6.0	0
Stature (cm)	175.1	6.5	172.9	5.7	2.2

*Percent fat and fat-free weight were estimated using the QMC caliper described by Newman (1952).

These 40 pairs were then subdivided into four groups of matched pairs, each of which contained 10 Negro and 10 White soldiers matched for body size and composition. Each group followed the experimental procedure twice and an average of the strain measurements for both days was used for the analysis. Each matched pair, therefore, was exposed to equal heat stress. The strain measurements were: sweat loss, rectal temperature, and pulse rate per minute. In detail, each group reported to a walking course at 12:45 P.M. They stripped and weighed nude on a gram scale accurate to ± 10 g. They then inserted rectal catheters which contained thermocouples for reading rectal temperatures. All men wore the same style and quantity of clothing, which consisted of Army fatigue uniforms, caps and boots.

After each pair had weighed and dressed, rectal temperature was recorded on a potentiometer. These temperatures have a reproducibility of ± .10°F. The men were dispatched in pairs at 5-minute intervals. They walked around a half-mile course at a rate of 3-1/2 miles per hour. To insure that a constant pace was held by all men, two timekeepers were posted, one at the starting point and one at the halfway mark. At the end of one hour the men stopped at the observation tent, where pulse was immediately counted. Rectal temperatures were again read from the potentiometer. Each pair then undressed, wiped off all sweat, and were weighed. Identical procedure was followed for all groups on all days.

Sweat loss was calculated in the following manner: sweat loss equalled initial weight minus final weight. Water intake and urine output were prevented, so that no corrections were required. It was considered unnecessary to correct for respiratory loss of weight, since this constitutes a negligible source of error under these conditions (Kleeman et al, 1953).

2. Results

Field work always has one uncontrollable variable: weather. In this study the weather was cool for Virginia in August. Within the test hours the temperature averaged 84.3°F. and the relative humidity averaged 44 percent. This low stress level was reflected in low strain levels. Because of the activity level these climate are considered to exert only mild hot-wet heat stress on the subjects. (See Table VIII, Appendix)

Negro-White differences in heat stress responses are shown in Table II. As measured by a paired T-test, there was a statistical significant difference at the .05 level or better between the pre-walk rectal temperatures of the Negroes and Whites. The significa

was increased by the exercise to .01. There was no significant difference at the .05 level for pulse rate or sweat loss.

TABLE II. A COMPARISON OF AMERICAN NEGRO AND WHITE HEAT STRESS RESPONSES
(40 Negroes, 40 Whites)
(Hot-wet climate, Fort Lee, Virginia)

Measurement	White Mean	White S. D.	Negro Mean	Negro S. D.	Mean Difference	Significance of Difference
Pre-Test Rectal Temp. (°F)	99.6	.38	99.4	.42	0.2	$>.05$
Post-Test Rectal Temp. (°F)	100.4	.45	100.0	.45	0.4	$>.01$
Pulse Rate (Beats per/min.)	122.4	12.9	119.4	14.6	3.0	$<.05$
Sweat Loss (Grams per/hr.)	912	139	873	137	39	$<.05$

3. Potential source of difference

Eighteen Whites, but only 4 Negroes in this study, came from Northern States. There was, therefore, a possibility that the difference in rectal temperatures was a function of the Northern origin of the Whites. Accordingly, 18 Southern Whites were selected who had been studied on the same days as the 18 Northern Whites and who had comparable body compositions. The strain measurements of these 18 Southern Whites were compared to the same strain measurements for the 18 Northern Whites (Table IX Appendix). The slight differences that were found indicated that Southern Whites were lower in heat tolerance. However, these differences were in no case statistically significant. This comparison seemed to indicate that the locale from which the subjects were drawn did not influence their heat tolerance.

There still remain several possible non-genetic explanations for the difference between the racial groups. Probably some differences exist in the childhood nutritional patterns of the two groups.

However, body composition (fat, weight, stature) was controlled by the matched pair technique, and differences in responses cannot be attributed to the Negro's lower body fat or greater linearity $\left(\frac{\text{stature}}{\text{weight}}\right)$.

Differences in physical conditioning might also affect resistance (Bass et al, 1953). For this reason an effort was made to obtain racial groups in the same state of physical training. The men participating in this study came from the same Army units, and as the Army no longer segregates the races, these men had, for at least the previous 6 months, performed similar duties.

There may be other potential sources of difference which have not been considered, but the data strongly suggest that under similar mild hot-wet stress loads American Negroes have lower rectal temperatures than American Whites and that this difference is probably not attributable to post-conception environment. The data do not indicate the mechanism of the genetic difference. That is, it cannot be determined whether the lower rectal temperatures in the Negroes are related to greater peripheral blood flow, greater mechanical efficiency, or more effective performance in other temperature regulatory mechanisms such as sweat distribution.

4. Extrapolation to representative groups

Because the Negroes and Whites in this study were selected for similar gross morphologies, neither group is representative of its respective population in terms of body composition. From studies of Army populations, it is known that U. S. Army Negroes (Newman, 1956) are lower in body fat and have slightly more fat-free weight.

If representative samples had been chosen, the results might have reflected greater racial differences in heat strain measurements. On the basis of work in previous experiments on White soldiers (Baker, 1955) a fatter White group would have had higher rectal temperatures, pulse rates, and sweat losses. Thus, in representative population samples not matched for body composition, the Negro-White differences in strain responses might have been greater (Whites higher, Negroes lower).

The varying daily weather conditions made it necessary to analyze each daily subsample of Negroes and Whites separately. The multiple subdivision of the group left a uniform sample size of 10, which was small for correlation analyses. Rectal temperatures were significantly correlated with fat in only one of the subsamples. This is to be expected because of the low ambient temperature. As shown in Table III, there was consistent and significant correlation between sweat loss and fat-free weight for both Negroes and Whites.

TABLE III. CORRELATION COEFFICIENTS FOR SWEAT LOSS AND FAT-FREE WEIGHT
(10 Negroes, 10 Whites)
(Hot-wet climate, Fort Lee, Virginia)

Sample Group	Whites	Negroes
August 4 and 5	.64	.51
August 6 and 9	.94	.60
August 10 and 11	.58	.86
August 12 and 13	.66	.71

The regression equations of sweat loss on fat-free weight indicated a considerable between-group variation in regression slopes (Figure 1). Most of this variation is attributable to the small sample sizes, but some part of it may be related to the between-group differences in heat stress levels.

No significant differences were found between the regressions of sweat loss on weight for Negroes and Whites. These results make it more probable that the regressions of fat-free weight on sweat loss found for Whites may be validly applied to American Negroes.

Assuming that there is no difference in the regressions, in representative racial samples, there would not only be a significant difference (Negroes lower) in rectal temperature which may under heat stress be genetically determined, but also a significant difference (Negroes higher) in sweat loss, determined by racial differences in body composition.

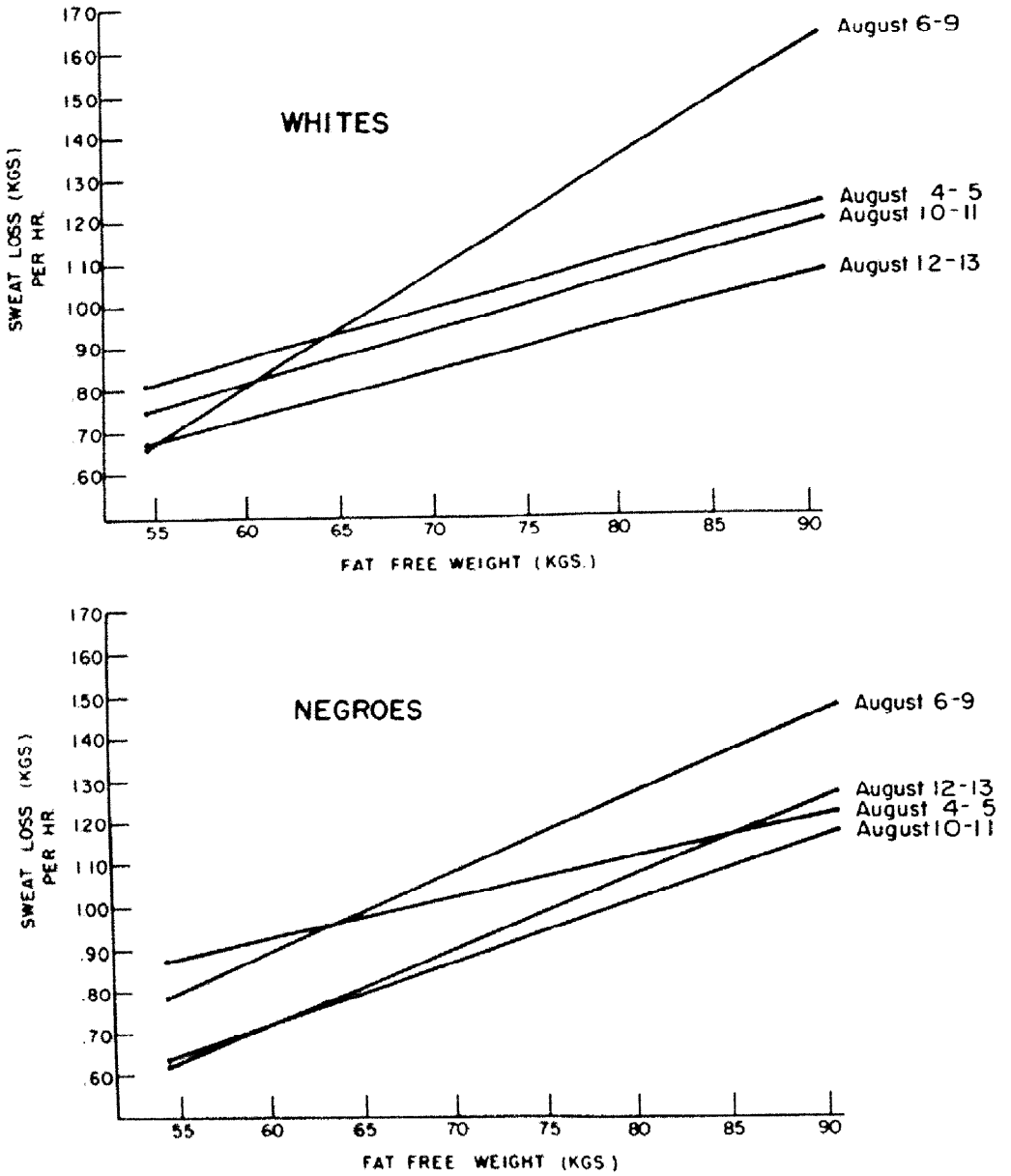

Figure 1. Regressions of sweat loss to fat free weight

Part II - Hot-Dry Conditions

1. Procedure and methods

For the study under desert conditions a sample of 8 White and 8 Negro subjects was chosen from a group of approximately 50 men. These two samples were matched for body composition and proportions, as the group for hot-wet conditions had been matched.

Measurements were also made of skin color reflectance on both White and Negro groups. A Photovolt reflectometer was used to make the measurements. The readings with an amber tristimulus filter were made weekly at five sites: the cheek, the chest over the nipple, the inner arm, the outer arm, and the back over the inferior angle of the scapula. The measurements were repeated three times at each site, and an average was calculated.

After the men were thoroughly heat-acclimatized in the desert, a Latin square experimental design was implemented so that each man was studied under 8 different desert conditions for 2 hours. Negroes and Whites were paired so that in each day's study there were 8 pairs, one under each condition. Each man repeated each condition 4 times for a total of 32 exposures. The conditions were combinations of: sun, shade, nude, clothed, walking, and resting.

"Shade" was obtained from a large assembly tent. "Walking" was around a small rectangular course at the rate of 3 mph, and "rest" was sitting inactive on a foot locker. A more complete description of the experimental design and conditions will be published (Hanson).

The physiological measurements made were: rectal temperature (initial and final) - by means of a clinical thermometer; total sweat loss - by weight change corrected for water intake; evaporated sweat loss - by total sweat loss minus sweat retained in the clothing; pulse rate - counted for 20 seconds at the wrist.

2. Results

Analysis of the effects of the experimental variables showed that most conditions had significantly different effects on the men.

The Negroes and Whites showed significant differences (by variance analysis) in their initial and final rectal temperatures but not in total sweat loss, evaporated sweat loss, or pulse rates. In all 8 of the conditions Whites had lower absolute values. Table IV shows the absolute values and the difference in rectal temperature between Negroes and Whites.

TABLE IV. RECTAL TEMPERATURE FOR 8 NEGROES AND 8 WHITES UNDER VARIOUS CONDITIONS (°F)
(Hot-dry climate: Yuma, Arizona)

	Conditions							
	Shade Clothed Rest	Shade Nude Rest	Sun Clothed Rest	Sun Nude Rest	Shade Clothed Walk	Shade Nude Walk	Sun Clothed Walk	Sun Nude Walk
	Initial rectal temperature							
Negroes	99.19	99.21	99.21	99.21	99.27	99.20	99.23	99.22
Whites	99.00	99.02	99.01	99.00	99.02	98.99	98.96	99.08
Difference	-.19	-.19	-.20	-.21	-.25	-.21	-.27	-.13
	Final rectal temperature							
Negroes	99.19	99.26	99.32	99.54	100.15	100.17	100.31	100.40
Whites	99.11	99.18	99.30	99.30	99.92	99.98	100.07	100.02
Difference	-.08	-.08	-.02	-.24	-.23	-.19	-.24	-.38

- indicates temperature of Negroes higher

a. Rectal temperature

The Negro-White difference in initial rectal temperature is in no way affected by the condition to which they were later exposed, but is important in calculating the total heat storage during the experimental condition. Prior to the experiment, the men rested on cots for one hour in a tent in the desert. The racial difference found in the initial rectal temperatures must, therefore, be attributed to this pre-exercise condition, as there is no difference under neutral climatic conditions (unpublished data on file at Environmental Protection Research Division, QM R&E Center, Natick, Massachusetts).

The final rectal temperature differences seem to show a very definite pattern related to the specific condition to which the men were exposed. When the men were in the shade or protected from the direct sun by clothing, the Negroes had a slightly higher rectal temperature than the Whites. When the nude skin was exposed to the sun both Negro and White rectal temperatures rose, but the Negroes experienced greater rise. When walking nude in the sun, with a maximum of skin exposed, the racial

difference in rectal temperatures amounted to almost .40°F. This pattern is shown even more clearly when the rectal temperature rise from initial to final is examined (see Table V). When the Negroes were protected from the sun, their rise in rectal temperature was the same or even lower than that of the Whites. Only when the two groups were walking nude in the sun did the Negro rectal temperature rise substantially more than the White.

TABLE V. RECTAL TEMPERATURE RISE FOR 8 NEGROES AND 8 WHITES FROM INITIAL TO FINAL READINGS (°F)
(Hot-dry climate, Yuma, Arizona)

	Shade Clothed Rest	Shade Nude Rest	Sun Clothed Rest	Sun Nude Rest	Shade Clothed Walk	Shade Nude Walk	Sun Clothed Walk	Sun Nude Walk
Negroes	.00	.05	.11	.33	.88	.97	1.09	1.20
Whites	.11	.16	.29	.30	.90	.99	1.11	.94
Difference	+.11	+.11	+.18	-.03	+.02	+.02	+.02	-.26

\+ indicates temperature of Whites higher
\- indicates temperature of Negroes higher

b. Sweat loss

Although the sweat losses were not significantly different between the two groups at the 5% level, the differences approximate what was found in rectal temperatures (i.e., Negroes were higher). See Table VI. Again the major difference is found when the two groups are exposed nude to the sun, resting or walking, although a large difference also appears when the two groups are walking clothed in the shade.*

* Data derived from a similar experiment performed since the preparation of this paper showed substantially the same pattern analyzed here. Since sweat loss differences for clothed Negroes and Whites walking in the shade were approximately half of the value reported in this study, the present value may be non-significant variation (Hanson manuscript, QM R&E Command).

TABLE VI. TOTAL SWEAT LOSSES FOR 8 NEGROES AND 8 WHITES, UNDER VARIOUS CONDITIONS (grams)
(Hot-dry climate, Yuma, Arizona)

	Shade Clothed Rest	Shade Nude Rest	Sun Clothed Rest	Sun Nude Rest	Shade Clothed Walk	Shade Nude Walk	Sun Clothed Walk	Sun Nude Walk
Negroes	963	1255	1393	2010	2143	2221	2582	2796
Whites	961	1219	1407	1857	1997	2166	2502	2656
Difference	-2	-36	+14	-153	-146	-55	-80	-140

\+ indicates sweat loss of Whites higher
\- indicates sweat loss of Negroes higher

c. Calculation of heat absorption

The effect of the nude exposure to the sun in establishing racial difference in responses strongly suggests that greater heat absorption by the Negro skin may be the major factor determining the observed differences. By utilizing the skin reflectance reading, an estimate was made of the difference between the two groups. The amber tristimulus filter used to measure skin color transmits light in the approximate wave length of 600 millimicrons, which falls near the middle of the visible sunlight spectrum; thus skin reflectance reading with this filter offers a rough estimate of the heat absorption from the sun. From the four areas exposed to the sun (cheek, chest, arm, and back) an average reflectance during the study was derived. It was found that the Negroes absorbed approximately 84.6% of the light received while the Whites absorbed approximately 69.7%.

The average radiation of the sun was measured with a pyrheliometer in a horizontal position. For the total experimental period the radiation averaged 846.5 kilogram calories per square meter per hour (Kg. cal/m^2/hr). If this is corrected for the normal incidence then the radiation intensity was 977.5 Kg. cal/m^2/hr. Woodcock (manuscri has shown that at the angle of the sun encountered under these experimental conditions, the seated and walking man has about 20% of his surface area exposed to the sun. The Negroes and Whites had identical surface areas of 1.90 square meters as calculated by the DuBois formula from height and weight (DuBois, 1936). This means they both had about .38 square meters of skin exposed to the sun. From these figures was

calculated the approximate heat absorbed from the sun by the two groups by means of the following formula:

> Kg. cal. of heat absorption = (2-hr. radiation in Kg. cal./m^2) multiplied by (Surface area exposed in m^2) multiplied by (Skin absorption).

It was found that the Negroes absorbed 628 Kg.cal. during the average 2-hour exposure while the Whites absorbed only 518 Kg. cal., or 110 Kg. cal. less.

Although rectal temperatures were significantly different for the two racial groups, the total heat storage difference as calculated from rectal temperature difference was very small. This means that there should have been a fairly large difference in evaporated sweat loss to account for a large difference in solar radiant energy absorption. Assuming water evaporation to have an equivalent of .58 Kg. cal./g, the Negro theoretically should have evaporated 190 more grams of sweat than the White. As shown in Table VII the difference was of this general magnitude.

TABLE VII. EVAPORATED SWEAT LOSS FOR 8 NEGROES AND 8 WHITES UNDER VARIOUS CONDITIONS
(grams)
(Hot-dry climate, Yuma, Arizona)

	Shade Clothed Rest	Shade Nude Rest	Sun Clothed Rest	Sun Nude Rest	Shade Clothed Walk	Shade Nude Walk	Sun Clothed Walk	Sun Nude Walk
Negroes	922	1229	1326	1982	1953	2181	2350	2780
Whites	923	1195	1344	1823	1822	2121	2286	2608
Difference	+1	-34	+18	-159	-131	-60	-64	-172

\+ indicates sweat loss of Whites higher
\- indicates sweat loss of Negroes higher

Discussion and conclusions

Until recently the human species was taxonomically divided into races based on what were assumed to be adaptively "neutral" characteristics. At first these were body measurements and attributes, later blood factors such as the ABO antigens. In turn each of these characteristics was proven to have selective or adaptive aspects so that they could no longer be considered "neutral." This has led the modern geneticist and physical anthropologist to postulate a system of races which is based on geographical population isolates which conform more closely to genetic units (Boyd, 1953 and Garn and Coon, 1955). Classification of this nature certainly is genetically sound since it fulfills most of the requirements for the group to be considered a breeding isolate. The most important criticism which can be leveled against the geographical concept of race is that it is only a functional system without time depth or proof of genetic affinity. This is not so much a criticism of the system as it is a comment on the present state of our knowledge about the genetic and adaptive aspects of human morphology. Even though the geographical system appears to be the best that can be formulated at this time, we should not be satisfied with it. Instead, as pointed out by Garn (1957), we must seek to define the adaptive nature of morphological characteristics.

Until the mass population shifts of the late eighteenth and early nineteenth centuries, African and European populations were restricted to separate climatic zones. Evolutionary theory suggests that some of the morphological differences that separate these groups may be based on the selective survival of genes which were adaptive to these differing environments. However, climatic zones vary in many ways and surveys of the native populations do not tell us which environmental isolates may have exerted selective pressure on the morphological characteristics. One of the best documented factors in the environment is climate; given this single factor, it has been possible to apply an experimental approach and thus investigate the relative tolerance of two racial groups to a given environmental stress.

In the present studies the experimental approach has been applied to investigate the possible role of climate in explaining the differences in American Negroes and Whites. The results of these experiments fit the spatial distribution of present day populations, since the Negroes of the world do not predominate in desert areas but are found in hot-wet areas. Distinctive groups such as Nilotics, Bushmen, and Australian aborigines are the only Negro-like men found in the desert. These groups have been variously described as race mixtures, hybrids, and even separate races. While any of these descriptions is a possibility, the experimental evidence indicates that the morphologically typical Negro would be

selected against by the climatic conditions, and the alternative possibility, therefore, remains that these groups came from the same ancestral genetic pool as the hot-wet area Negro, but were modified by climatic selection.

Once quantitative relationships have been established between environmental elements, (e.g., air temperature, solar radiation) and racial characteristics, it should be possible to apply these relationships to data on previous climates. In this way critical attention could be focused on those areas and times at which climate was exerting strong adaptive pressure. This would permit us to construct a racial classification with time depth as well as inferred genetic unity.

Acknowledgements

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APPENDIX: SUPPLEMENTARY TABLES

TABLE VIII. WEATHER CONDITIONS, FORT LEE, VIRGINIA
(1200 to 1500 Hours)

Date	Temperature (°F)	Relative Humidity (%)	Windspeed (MPH)	Radiation (Langley Units)*
August 4	85	57	1.8	42.4
5	86	60	0.3	33.1
6	81	39	1.5	60.1
9	88	51	7.5	66.0
10	87	46	1.8	42.9
11	85	34	4.8	57.4
12	80	27	3.0	51.9
13	82	38	3.0	70.6

*from 45°South; gram cal/cm^2/hr.

TABLE IX. A COMPARISON OF THE STRAIN LEVEL OF NORTHERN AND SOUTHERN WHITES

Measurement	Mean Northern	Mean Southern	Difference	Significance
Rectal Temp.(°F) Pre-walk	99.6	99.6	0	none
Post-walk	100.3	100.6	0.3	none
Pulse rate (beats per min.)	124.7	126.8	2.1	none
Sweat rate (gm.per hr.)	904	978	74	none
Stature (cm.)	173.5	176.3	2.8	none
Fat-free weight (kg.)	66.8	68.8	2.0	none
Percent body fat	6.7	5.5	1.2	none

TABLE X. A COMPARISON OF BODY COMPOSITION MEASUREMENTS ON 8 EACH MATCHED AMERICAN NEGROES AND WHITES (Hot-dry climate, Yuma, Arizona)

Measurement	Mean		Difference	Significance
	White	Negro		
Percent fat in the body	7.4	6.0	1.4	none
Fat-free weight (kg.)	70.1	71.2	1.1	none
Stature (cm.)	175.5	175.0	.5	none

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The physiological responses of American White and Negro soldiers were studied under hot-wet and hot-dry conditions.

Under hot-wet conditions 40 pairs of men matched for body fat, weight, and stature were walked around a course at 3-1/2 mph for one hour. Under hot-dry conditions 8 pairs of men also matched for body fat, weight, and stature were studied under 8 different conditions which included combinations of clothing, sun, shade, walking and sitting.

The results of this series of experiments indicated:

1) Under hot-wet conditions with both Negroes and Whites clothed and walking, the Negroes had a higher physiological tolerance. 2) Under hot-dry conditions with both groups clothed, walking, or sitting they had about equal tolerance. 3) Under hot-dry conditions with both groups nude and exposed to the sun, sun-tanned Whites had the higher tolerance.

These results further suggested that the differences found were not a function of transient environmental effects and are mostly genetic in origin.

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