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The Effect of a Single Exposure of Ultraviolet Rays on Performance in Selected Motor Parameters.

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THE EFFECT OF A SINGLE EXPOSURE OF ULTRAVIOLET RAYS ON PERFORMANCE IN SELECTED MOTOR PARAMETERS

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This study is dedicated

to my wife,

Christine

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ABSTRACT

The purposes of this study were to investigate the effect of a single erythemal intensity ultraviolet exposure on motor performance, and to determine if a difference exists between the effects of ultraviolet rays on physically active and relatively sedentary subjects. This study was conducted in 1974 during the months of January, February, and March, when normal solar radiation was relatively low.

Two experimental groups of trained and untrained subjects were formed from caucasian male students enrolled at East Carolina University, Greenville, North Carolina. The trained subjects were 20 wrestlers, swimmers, or basketball players who were training vigorously during the data collecting period. Untrained subjects were 20 volunteers from health classes who were not members of athletic teams or physical education classes.

Each subject was exposed to both an ultraviolet sunlamp and an incandescent lamp on a counter-balanced order. Ultraviolet treatment consisted of a 12-minute exposure from a General Electric RS 275 watt sunlamp on the abdomen and lower back. A placebo treatment was administered in the same manner with an outdoor floodlight (General Electric, model 150 PAR/FL). Subjects were not allowed to see the lamps, and were informed that ultraviolet rays of

different wavelengths were being used on the two treatment occasions. A waiting period of two weeks was observed between treatments.

Each subject was administered a motor performance test 24 hours after each treatment. The test battery consisted of a vertical power jump, a total body response test, elbow flexion strength, 30-yard sprint, and the Balke-Ware treadmill test of physical work capacity. A two x two factorial analysis of variance involving repeated measures was used to analyze performance changes under the two light conditions, and to determine interaction that might exist between groups and light.

Within the limitations of this study, the findings were:

1. Ultraviolet irradiation, as administered in this study, failed to affect performance in power, speed, or total body response.

2. Performance in elbow flexion strength was impaired at the .05 level of confidence after ultraviolet irradiation.

3. Ultraviolet irradiation impaired performance on the Balke-ware physical work capacity test at the .01 level of confidence.

4. There was no significant interaction between groups and light effects on performance in any of the parameters investigated.

Results of previous investigations concerning ultraviolet effects on man were discussed as plausible reasons for the decrement in physical work capacity observed in this study. Possible suggestions included: (1) a decreased reliance upon carbohydrates, necessitating an increased oxygen consumption, (2) ultraviolet induced destruction of erythrocytes, reducing the oxygen-transporting capacity of blood, and (3) an increase in cutaneous blood flow that may produce effects similar to the increased peripheral circulation that occurs during exercise in a hot environment, which is characterized by tachycardia induced by a reduced cardiac filling pressure and stroke volume.

Based on the findings, the following conclusions were formed:

1. A single ultraviolet exposure of erythemal intensity impaired performance in physical work capacity and muscular strength.

2. Motor parameters involving speed of muscular contraction were not affected by ultraviolet irradiation.

3. There was no difference with regard to the physical condition of the subjects and their response to an ultraviolet exposure.

4. A single ultraviolet exposure will not serve as an ergogenic aid to improve motor performance, and may even be considered ill advised.

Chapter 1

INTRODUCTION

Sunlight has long been considered important to health. Ancient Greek physicians prescribed sunbathing for increasing body weight, strengthening muscles, and restoring health in general.[1] Even today, the pale complexion of an untanned person is often interpreted as an anemic condition. In moderation, sun basking is considered capable of exerting a soothing effect that relieves tensions. Solar irradiation is also recognized for its antigermicidal effect and its antirachitic role. During World War II, German submarine personnel and troops stationed in Norway were exposed to artificial ultraviolet rays. Miners and factory workers deprived of adequate solar rays have also been administered artificial ultraviolet treatments.[2] Thus, solar exposure has been sought for its healthful effects, and artificial sources have been substituted when necessary.

Light ranges in wavelengths from 40 angstroms to 150,000 angstroms, but not all of these wavelengths may be

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[1]Sidney Licht, "History of Ultraviolet Therapy," Therapeutic Electricity and Ultraviolet Radiation, ed. S. Licht (2nd ed.; Baltimore: Waverly Press, 1967), p. 195.

[2]Lewis R. Koller, Ultraviolet Radiation (2nd ed.; New York: John Wiley and Sons, Inc., 1965), p. 226.

detected by the human eye. Visible light differs in wavelength for different individuals, and for each individual as he ages, but the visible light band as defined by the International Commission on Illumination ranges from 3800 to 7800 angstroms. Rays 7600 angstroms or longer are classified as infrared, and rays 3900 angstroms and shorter are considered to be ultraviolet.[3]

Within the ultraviolet spectrum, rays have been further classified as being in "Near, Far, or Extreme" regions according to their wavelengths. "Near" ultraviolet consists of wavelengths 3,000 to 4,000 angstroms in length; "Far" wavelengths range from 2,000 to 3,000 angstroms; and "Extreme" wavelengths are shorter than 2,000 angstroms.[4]

The advent of Christianity inhibited the development of knowledge concerning ultraviolet. Attributing curative powers to the sun was considered a pagan practice.[5] The scientific study of artificial irradiation is said to have originated as recently as 1899 with the discovery that the ultraviolet region of sunlight was the range of light that induced sunburn. N. R. Finsen, noted as a pioneer in the use of ultraviolet energy in therapeutic medicine, was awarded the Nobel Prize in 1903 for his contributions in this area.[6] Despite the frequent use of ultraviolet therapy in medicine today, considerable disagreement still exists

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[3]Koller, p. 3. [4]Koller, p. 5.

[5]Licht, p. 195. [6]Koller, p. 226.

regarding its effects and the physical basis for its action. The production of erythema, ultraviolet's antirachitic role, and the destruction of bacteria are the only areas of the biological field that are commonly accepted and supported by quantitative data.[7]

Outside of the realm of ultraviolet therapy and its contributions toward health in general, some investigators have claimed ultraviolet irradiation improves human work performance. While researching the effects of isometric exercise, Hettinger observed that the rate of strength gains from November through March were not as large as the gains made by subjects who trained during the summer months. Hettinger at first attributed this to dietary differences, or possibly differences in basic living patterns between the seasons. However, when these variables were controlled, the seasonal differences between muscular trainability still existed. Subjects were then exposed to weekly irradiations of artificial ultraviclet rays during the winter, and an increased rate of strength gains that paralleled those observed in the summer were noted. This increase, Hettinger concluded, was not due to an increase in vitamin D, because an increased consumption of vitamin D without ultraviolet had no effect on muscle trainability.[8]

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[7]Koller, p. 227.

[8]Theodor Hettinger, Physiology of Strength (Springfield, Illinois: Charles C. Thomas, Publishers, 1961), pp. 41-44.

Allen and Cureton conducted a study involving male physical education students at the University of Illinois who scored in the lower third of the freshmen class on a motor fitness test. Class members were exposed to the same physical activity for a period of ten weeks, but one group of experimental subjects received regular ultraviolet treatments tri-weekly, while the control group received no light treatment. The experimental group demonstrated improvement on the Schneider test of cardiovascular fitness, while the control group failed to improve. Various other physiological parameters investigated failed to show a significant change. However, the researchers reported that their observations, ". . . were all in the direction which suggests improved condition due to the ultraviolet irradiation."[9] Statistical comparisons were limited to initial and final scores for each group, and no comparisons were made between groups.

Some investigators have stated that improved motor performance occurs only when the ultraviolet dosage is of erythemal intensity. Minimal erythema is the level at which a reddening of the skin occurs following the treatment.[10]

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[9]Robert M. Allen and Thomas K. Cureton, "Effect of Ultraviolet Radiation on Physical Fitness," Archives of Physical Medicine and Rehabilitation, XXVI (October, 1945), 641.

[10]Bryan O. Scott, "Clinical Uses of Ultraviolet Radiation," Therapeutic Electricity and Ultraviolet Radiation, ed. Sidney Licht (2nd ed.; Baltimore: Waverly Press, 1967), p. 341.

An exposure of an intensity too low to produce an erythemal response is described as a suberythemal exposure. The minimal erythemal value for average untanned skin is 25,000 microwatt-seconds per square centimeter utilizing 2967 angstrom wavelengths, the most efficient wavelength for causing an erythemal response.[11] Erythema may be difficult to detect visibly. A latent period of several hours precedes an erythemal response, and a large variance exists between individuals in latency and degree of response. Erythema should not be confused with hyperemia, which is an immediate and temporary reddening caused by excessive peripheral blood flow.[12]

More recently, a series of studies have suggested that motor performance may be improved without erythemal intensity exposures or repeated treatments. Several studies originating from Texas Woman's University at Denton suggest that single suberythemic exposures incapable of producing an erythemal response may serve as an ergogenic aid that will temporarily improve performance. Cheatum investigated the influence of a single suberythemic exposure on speed in a 30-yard sprint. Female subjects were tested one hour after treatment under a General Electric RS 275 watt sunlamp or an incandescent lamp used for placebo effects. A beneficial effect was noted on each of the three sprints, but the last trial was the only trial that was significantly better under

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[11]Koller, p. 15. [12]Koller, p. 227.

ultraviolet conditions. Cheatum concluded that possibly a one-hour delay following treatment is not adequate to allow for the complete development of beneficial effects.[13]

A similar study was designed by Rosentswieg using the same treatment procedures as employed by Cheatum. The suberythemal treatments administered provided a dosage about one-half that suggested for an erythemal response. A bicycle ergometer was used to administer a physical work capacity test one hour after either an ultraviolet or placebo treatment. Subjects exercised until a heart rate of 170 was attained. The data revealed a positive trend for ultraviolet effects, but the difference was not significant until the scores of three trained subjects were removed from the data. Performance scores of the remaining five average subjects were significantly improved.[14]

Rosentswieg designed a third study to investigate the effects of ultraviolet on strength at one and five hours following exposure. Significant gains for the ultraviolet condition were not observed at either test hour. However, Rosentswieg concluded that the data collected on numerous

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[13]Billye A. Cheatum, "Effects of a Single Biodose of Ultraviolet Radiation Upon the Speed of College Women," The Research Quarterly, XXXIX (October, 1968), 482.

[14]Joel Rosentswieg, "The Effect of a Single Suberythemic Biodose of Ultraviolet Radiation Upon the Endurance of College Women," Journal of Sports Medicine and Physical Fitness, IX (June, 1969), 104.

muscle groups established a trend indicating ultraviolet may serve as an ergogenic aid to increase strength.[15]

The entire matter concerning beneficial effects from ultraviolet irradiation is subject to criticism, because the means by which ultraviolet could affect such changes is speculative. Beneficial claims are sometimes supported by observations rather than objective measurements of performance. Research has frequently involved case studies or small groups without statistical treatment of the collected data. Controls were lacking in some instances, or a placebo effect was not included. Contradictory results have been reported in some cases. Allen and Cureton detracted from the confidence that could be placed in their findings when they stated that the ultraviolet group showed greater interest and attended class more regularly.[16] This implied the possibility that factors other than ultraviolet influenced the gains of their experimental group.

STATEMENT OF THE PROBLEM

Based on suberythemic exposures, Rosentswieg and Cheatum suggested that a single ultraviolet treatment might serve as an ergogenic aid to improve motor performance.

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[15]Joel Rosentswieg, "The Effect of a Single Suberythemic Biodose of Ultraviolet Radiation Upon the Strength of College Women," Journal of the Association for Physical and Mental Rehabilitation, XXI (July/August, 1967), 131.

[16]Allen and Cureton, p. 644.

Does a single ultraviolet irradiation at an intensity recommended for minimal erythemal response affect motor performance, and if so, what particular motor parameters? Do trained subjects who are physically active respond to ultraviolet irradiation in the same manner as do untrained subjects whose daily customs are relatively sedentary?

PURPOSE OF THE STUDY

The purposes of this study were: (1) to determine if a single exposure of ultraviolet at an intensity suggested for minimal erythemal response influences motor performance in tests of power, total body response, strength, speed, and physical work capacity; and (2) to determine if active athletes respond differently from relatively sedentary subjects following a single treatment.

DELIMITATIONS OF THE STUDY

This investigation concerned the effects of ultraviolet rays on motor performance, with the following delimitations applicable to the findings. Ultraviolet irradiation was limited to the effects of wavelengths emitted by a General Electric RS 275 watt sunlamp, the only source of ultraviolet energy used in this study. No subject received a series of exposures; findings were limited to the effects of a single treatment suggested for a minimal erythemal response. The effects of different intensities was not considered a purpose of the study.

Motor performance, as investigated in this study, was limited to measures of power, total body response, strength, speed, and physical work capacity. Since all data were collected 24 hours after irradiation, conclusions concerning ultraviolet effects were limited to this particular time frame. No effort was made to observe changes that might occur at other time intervals.

Only male caucasian college students were used as subjects, and the findings may not apply to another race, sex, or age group.

LIMITATIONS OF THE STUDY

No attempt was made to determine the exact minimal erythemal threshold for each subject and to administer individual treatments accordingly. All subjects received a uniform treatment of the same intensity, and the erythemal and biological effects may have differed from one subject to another.

Although controls were adequate to standardize test procedures, no controls over subjects were possible beyond the confinements of the laboratory environment. Subjects were requested to continue their ordinary daily customs during the 24 hours before testing, but to refrain from smoking or eating one and three hours respectively before the tests. The investigator had to assume that the subjects adhered to these requests.

DEFINITION OF TERMS

For the purposes of this study, the following definitions are provided:

Ultraviolet treatment. An ultraviolet treatment was an exposure under a General Electric RS 275 watt sunlamp for twelve minutes on the anterior and posterior aspects of the upper torso, with the lamp positioned one yard from the subject. This dosage was selected to meet the 42 E-viton minutes per square centimeter standard adopted by the Council of Physical Therapy of the American Medical Association for a minimal erythemal response. Computation of the exposure time is presented in Appendix M.[17]

Placebo treatment. A placebo treatment is defined as an exposure under a General Electric incandescent outdoor floodlight (model 150 PAR/FL) on the anterior and posterior aspects of the upper torso, with the subject placed one yard from the lamp. Exposure times were twelve minutes on each side. Subjects were informed that an ultraviolet exposure was being administered during this treatment.

Suberythemic treatment. Suberythemic treatments were mentioned frequently in the literature review, but not used in this study. A suberythemic exposure is one inadequate in dosage to produce an erythemal response.

Trained group. Wrestlers, swimmers, and basketball players who were participating in vigorous daily exercise

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[17]Appendix M, page 93.

bouts as members of varsity athletic teams at East Carolina University served as trained subjects in this study.

Untrained group. The untrained group was comprised of volunteers from health classes who were not participating in regular exercise of a strenuous nature. These subjects were not enrolled in physical education classes nor members of athletic teams at East Carolina University.

Counter-balanced procedure. Light treatments were administered on a counter-balanced order, in which half of each group received ultraviolet irradiation on the initial treatment while the other half received a placebo exposure. Treatment conditions were reversed on the second exposure. The treatment format is presented in Appendix L.[18]

SIGNIFICANCE OF THE STUDY

Research is needed to clarify opposing claims relative to ultraviolet's effect on motor performance. Previous studies involving single exposures were all suberythemic, while several researchers using repeated treatments stressed the importance of erythemal irradiations for the promotion of beneficial effects. No studies were found concerning the effects of a single erythemal irradiation on performance. Previous investigators did not attempt to determine if ultraviolet and daily activity patterns interact to induce different responses.

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[18] Appendix L, page 92.

Chapter 2

REVIEW OF LITERATURE

Literature was reviewed concerning the biological effects of ultraviolet light and the effects of ultraviolet irradiation on physical performance.

BIOLOGICAL EFFECTS OF ULTRAVIOLET

Many influences govern the intensity of solar irradiation, including the time of day, the season, latitude, elevation above sea level, atmospheric turbidity, and the thickness of ozone layers.[1] The intensity of ultraviolet irradiation may be expressed in various ways and the amount of radiation required to produce erythema is often used as a convenient measure.[2] This is an inexact measure because erythema is relative and cannot be determined with exact accuracy. Individuals vary in sensitivity to light from time to time, and from one area of the body to another. The most sensitive areas of the body include the face, chest and abdomen, and the back and sacral region.[3] There is a latent

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[1] Lewis R. Koller, Ultraviolet Radiation (2nd ed.; New York: John Wiley and Sons, Inc., 1965), p. 107.

[2] Koller, p. 13.

[3] Arthur L. Watkins, A Manual of Electrotherapy (2nd ed.; Philadelphia: Lea and Febiger, 1962), p. 69.

period following exposure before erythema develops, and the determination of erythema depends to some extent on the time of observation. Despite these variables, Koller reported, ". . . the erythema unit based on the effect on the untanned human skin provides a useful method of rating and comparing various sources of ultraviolet radiation."[4]

Ultraviolet of different wavelengths have varying effects upon erythema. Bachem stated that erythemal efficiency is greatest around 2970 angstroms, decreases before increasing to a secondary peak at about 2540, and is least in the region of 3850 angstroms.[5] Koller wrote that 2967 angstroms is the most efficient wavelength for producing an erythemal response, and that practically all workers agree on the region between 2800 and 3200 angstroms.[6] As established by the American Medical Association, the spectral range of a sunlamp must be limited largely from 2900 to 3130 angstroms.[7] Koller also reported on specifications a sunlamp must meet concerning erythemal effectiveness. At a distance of two feet, no point within an 18-inch diameter circle shall receive less than one-third the value of ultraviolet energy that the lamp produces in the middle 0-5 degrees region.[8]

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[4]Koller, p. 15.

[5]Albert Bachem, "Ultraviolet Action Spectra," American Journal of Physical Medicine and Rehabilitation, XXXV (April, 1956), 177.

[6]Koller, p. 227. [7]Bachem, p. 186. [8]Koller, p. 41.

The amount of energy established for an erythemal response for average untanned skin is 25,000 microwatt-seconds per square centimeter using a wavelength of 2967 angstroms. Since solar energy and artificial lamps emit a variety of wavelengths, and all wavelengths are not equal in erythemal efficiency, the E-viton unit has been adopted by the International Council on Illumination as a means of weighing radiant energy of different wavelengths in equating erythemal effects. An E-viton is equal in erythemal effectiveness to ten microwatts of 2967 angstrom irradiation per square centimeter. Thus, 2500 E-viton seconds per square centimeter, or about 42 E-viton minutes per square centimeter, is considered a minimal erythemal dosage, regardless of the wavelengths used.[9]

Bachem reported on time factors in erythema. Middle wavelength ultraviolet (2900 to 3200 angstroms) induces erythema approximately two hours after exposure, the development of which usually peaks between one to two days later. The erythemic effect may persist as long as one to two weeks in extreme cases. Ascertaining erythema may be difficult because of the irregularity of the latent period and the difficulty in accurately distinguishing erythema from pigmentation that may be occurring simultaneously. Bachem observed wide variations in erythemal sensitivity and responses, both within and between individuals. Variations

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[9] Koller, p. 15.

in erythemal responses within time frames also fluctuated markedly with different energy dosages.[10]

All workers are not in agreement concerning the importance of erythemal irradiations to produce biological changes. Blum stated that the rate of development and fading differs from one person to another, and that minimal erythema, ". . . is not an exact index of the underlying photochemical process."[11] Watkins also felt that erythema is not the most important biological consequence of irradiation. He wrote that the erythemal unit's primary value is that it provides a means for gauging dosages to prevent sunburn. Watkins also felt that the erythemal unit provides a practical standard by which prospective lamp buyers can compare the efficiency of different sunlamps.[12]

Although many claims have been made concerning the effects of ultraviolet, the mode of action is not certain. Koller wrote that much research remains to be done before the modus operandi of ultraviolet is understood.[13] Fischer and Solomon also wrote that man's knowledge of ultraviolet mechanisms is limited primarily to single cell organisms, and that only plausible suggestions may be extended as to

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[10]Albert Bachem, "Time Factors of Erythema and Pigmentation Produced by Ultraviolet Rays of Different Wavelengths," The Journal of Investigative Dermatology, XXV (October, 1955), 215.

[11]Harold F. Blum, "The Physiological Effects of Sunlight on Man," Physiology Review, XXV (July, 1945), 493.

[12]Watkins, p. 48. [13]Koller, p. 226.

the rationale for ultraviolet therapy.[14] Laurens stated that the actions of ultraviolet rays must be considered both photochemical, involving the activation of numerous unnamed substances in the skin and blood for a short term effect, and biological, concerning metabolism and circulatory modifications of a longer duration.[15]

Since the penetrating depth of ultraviolet is only approximately one millimeter in human skin, the effect of ultraviolet is said to be through its indirect actions. Gordon wrote that only e[illegible]mal cells are directly affected and that the effects of ultraviolet must be due to ". . . protein molecules being affected by the absorption and disruption of cyclic amino acids, tryptophan, tyrosine and phynylalanine."[16]

Scott attributed ultraviolet with the production of an esophylactic effect by lowering the threshold of irritability of reticulo-endothelial cells in the skin.[17] This results in an increased production of antibodies and an

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[14]Ernest Fischer and Sidney Solomon, "Physiologic Effects of Ultraviolet Radiation," Therapeutic Electricity and Ultraviolet Radiation, ed. Sidney Licht (2nd ed.; Baltimore: Waverly Press, 1967), p. 247.

[15]H. Laurens, The Physiological Effects of Radiant Energy, (New York: The Chemical Catalog Co., 1933), p. 568.

[16]Edward E. Gordon, "The Biologic and Physiologic Effects of Ultraviolet Radiation," Archives of Physical Medicine and Rehabilitation, XXIX (January, 1948), 36.

[17]Pauline M. Scott, Clayton's Electrotherapy and Actinotherapy, (6th ed., London: Bailliere, Tindall and Cassell, 1969), p. 317.

increased resistance to colds and infections. However, Blum contended that research has failed to support ultraviolet as a cold preventive. Criteria for determining a common cold are too subjective, and much disagreement exists on this issue.[18]

Numerous studies indicate organic compounds are affected by ultraviolet irradiation, including ribonucleic acids and desoxyribonucleic acids.[19] Fischer and Solomon stated cellular damage, and possibly lethal effects, may occur as a consequence of ultraviolet irradiation. The exact cause of cellular destruction is unknown, but Fischer and Soloman hypothesized that the damage may result from an increased production of toxic materials stimulated by ultraviolet irradiation. Increased peroxide was suggested as a possible toxic substance that follows ultraviolet treatments.[20]

Painter stated that the exact means by which ultraviolet may destroy mammalian cells is unknown.[21] However, an unusual theory was proposed as to why mammalian cells

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[18] Blum, p. 520.

[19] Fischer and Solomon, pp. 252-254; see also Steven N. Buhl, R. B. Setlow and James D. Regan, "Recovery of the Ability to Synthesize DNA in Segments of Normal Size at Long Times After Ultraviolet Irradiation of Human Cells," Biophysical Journal, XIII (October-December, 1973), p. 1265.

[20] Fischer and Solomon, pp. 256-261.

[21] Robert B. Painter, "The Action of Ultraviolet Light on Mammalian Cells," Photophysiology, V (1970), p. 187.

have better resistance than unicellular organisms to the lethal effects of ultraviolet. All mammalian cells possess at least two genes of a similar role, and both would have to be inactivated for a lethal effect to occur. Painter wrote that no experimental proof exists to support this theory.[22]

Devyatka reported that gamma-globulin content in blood decreases during seasons of reduced ultraviolet irradiations.[23] Gamma-globulin is a protein that provides a resistance to infection. Devyatka believed gamma-globulin values could be used as an index of deficiencies of natural ultraviolet exposure.

Blum theorized that ultraviolet promoted increased thyroid activity, which caused a reduction in body weight of irradiated mice.[24] The increased thyroid activity was considered possibly induced by the release of histamines in the skin during irradiation.

Fischer and Solomon wrote that any effects observed in any organs other than the eye or skin must be attributed to indirect actions of ultraviolet.[25] These remote effects are probably caused by humoral transmission of substances

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[22]Painter, p. 172

[23]Docent D. G. Devyatka, "Serum Gamma-Globulins as Indicators of Deficiency in Natural Ultraviolet Radiation," Gigiena i Sanitariia, XXXI (June, 1966), 448.

[24]Harold G. Blum, "Physiological and Pathological Effects of Ultraviolet Radiation," Annual Review of Physiology, V (1943), 12.

[25]Fischer and Solomon, p. 289.

produced in the skin to other organs. The possibility exists that the nervous system is involved. Increased muscle tonus has been observed in areas exposed to ultraviolet, and in corresponding contralateral muscles. This indicates that the effects may involve a nerve phenomenon.

All workers do not agree that responses to ultraviolet are due to the release of histamines. Vascular injury in subepidermal and dermal capillaries and venules have been observed in animals following irradiation, and the investigators denied that histamine release produced this. Cotran and Pathak noted immediate vascular leakage following irradiation that decreased within a few hours after treatment, and then returned to a peak value 16 to 24 hours later. The mechanism for such actions is unknown, but the authors did not believe this leakage was induced by a release of histamines by the skin, since anti-histamines did not affect the reaction. Degenerative change following injury was stated as a possible cause.[26]

Hettinger theorized that ultraviolet may affect changes by increasing the production of male sex hormones.[27]

Laurens summarized many theories concerning the mode

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[26]Ramzi S. Cotran and Madhukar A. Pathak, "The Pattern of Vascular Leakage Induced by Monochromatic Ultraviolet Irradiation in Rats, Guinea Pigs and Hairless Mice," The Journal of Investigative Dermatology, LI (September, 1968), 155.

[27]Theodor Hettinger, Physiology of Strength, (Springfield, Illinois: Charles C. Thomas, Publishers, 1961), p. 44.

of action of ultraviolet. Following ultraviolet exposure, unknown substances are formed in the skin and transported to deep-seated organs through the circulatory system, stimulating intracellular oxidation. Ultraviolet may stimulate sensory nerve terminals in the skin, increasing skeletal muscle tonus. Possibly, ultraviolet produces tissue damage, which causes histamine-like vasodilator substances to be released in the skin and transported through the blood stream to deeper tissues and organs. Mineral and electrolyte changes may then occur that affect the hormonal and autonomic systems. Another similar theory is that cellular degeneration occurs with irradiation, which may cause the release of toxins that are circulated to various organs. The toxins stimulate defensive mechanisms within the body, resulting in beneficial adaptations. However, excessive tissue damage is believed to promote the release of too many toxins, resulting in negative rather than positive effects.[28]

Lehmann expressed a similar theory concerning ultraviolet and defensive mechanisms. He felt that the actions of ultraviolet could be explained through Selye's general stress syndrome, in which ultraviolet acts as the stressor agent.[29]

Horlick also believed that ultraviolet acted as a

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[28] Laurens, pp. 568-576.

[29] G. Lehmann, "Die Bedeutung einiger Wellenlangenbereiche fur die Leistungssteigernde Wirkung der UV-Bestrahlung," Strahlentherapie, XCV (1954), 452.

stress agent, resulting in adrenal hypertrophy and decreased serum cholesterol levels in irradiated rats.[30]

Literature frequently mentioned ultraviolet's tonic role that supposedly promotes a general well-being of the organism. Watkins wrote that sunbathing exerts a tonic effect, promoting mental and physical development.[31] Scott disagreed with this. There is much controversy among workers on this issue, and no definite evidence exists to support a general tonic effect from ultraviolet.[32]

Circulatory changes were discussed by Laurens as occurring in the realm of decreases in blood pressure, a reduction of angina pectoris, increased cardiac output and stroke volume, and variable changes in pulse rate. Factors mentioned as possible causes of these changes included hyperemia, blood viscosity changes, the release of depressor substances from the skin, sympathetic hypotonia, and a lowering of peripheral resistance to blood flow.[33]

Some workers have claimed beneficial effects occur within the blood. Mietkiewski observed an increase of 13 percent in the hematocrit of rabbits treated repeatedly during a period of four weeks. An increase in hematocrit values was observed after only one week of irradiation.

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[30]L. Horlick, "The Effect of Ultraviolet Irradiation on Sterol Metabolism in the Rat," Journal of Atherosclerosis Research, VI (March/April, 1966), 182.

[31]Watkins, p. 52. [32]Scott, p. 318.

[33]Laurens, pp. 168-187.

Hematocrit increases were attributed primarily to a 22 percent prolongation of the lifespan of erythrocytes.[34]

Mayerson and Laurens studied the effect of ultraviolet on dogs injected with an anemia producing drug, acetylphenylhydrazine. Irradiation was started at the time of injections, but ultraviolet failed to reduce the development of anemia. However, after the attainment of a peak anemia nine days later, irradiated dogs regenerated red blood cells and hemoglobin definitely better than did control animals. The authors could not account for this, and hypothesized that ultraviolet may promote a more efficient utilization of iron.[35]

Schwartz investigated the effects of exposing blood directly to ultraviolet. Patients representing 12 different diagnostic ailments were treated with an instrument that allowed blood to be reinfused after irradiation. Parameters investigated included counts of erythrocytes, leukocytes, reticulocytes, eosinophils, platelets, and coagulation time of blood. No evidence of a change in these values could be observed when the blood was exposed to ultraviolet rays.[36]

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[34] E. Mietkiewski, B. Kosmicki, and K. Naroznik, "Influence of Ultraviolet Rays on the Erythrocyte Count and Lifespan in Rabbits," Acta Physiologica Polonica, XIX (March /April, 1968), 171.

[35] H. S. Mayerson and Henry Laurens, "The Effects of Radiant Energy on Experimental Hemolytic Anemia," The Journal of Nutrition, IV (September, 1931), 351.

[36] Steven O. Schwartz and others, "Ultraviolet Irradiation of blood in Man," Journal of the American Medical Association, CXLIX (July, 1952), 1180.

Fischer and Solomon wrote that ultraviolet is capable of affecting numerous changes in circulation. The immediate response to ultraviolet exposure is a slight decrease in cutaneous blood flow, followed by a large increase several hours later.[37] Other circulatory changes include a temporary decrease in the blood sugar level, an increase in liver and muscle glycogen, and a decrease in blood lactic acid levels. There may be increases in red blood cells and hemoglobin, cardiac ouput, blood estrogen level, and blood flow to organs and muscles below the irradiated area. Reductions have been observed in blood pressure and heart rate, and hypercholesteremia and experimentally induced arteriosclerosis have reportedly been alleviated.[38]

Watkins, however, disagreed with findings that blood cells are affected by ultraviolet. Frequent reports of a large variety of blood changes have been published, which Watkins contended could not be substantiated and could not be assumed to be of therapeutic value.[39]

In vitro studies have shown ultraviolet impaired the capability of nerves to transmit action potentials. Eichenbaum and Cooper wrote that, following irradiation, nerves superfused with a Locke solution containing thiamine restored their action potential capabilities, while nerves

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[37]Fischer and Solomon, p. 306.

[38]Fischer and Solomon, pp. 290-295.

[39]Watkins, p. 50.

superfused in the same solution without thiamine failed to regenerate an action potential capability. The authors concluded that thiamine is destroyed by ultraviolet, and that thiamine is essential in the conduction process of nerves.[40]

Baran, Cerf and Josse investigated action potential capabilities in isolated frog muscle following irradiation. The authors theorized that ultraviolet decreased action potential capabilities by increasing the permeability of membranes to sodium. Another possibility discussed was a diminishing of the sodium removing mechanism that establishes polarity.[41]

EFFECTS OF ULTRAVIOLET IRRADIATION ON PHYSICAL PERFORMANCE

Lehmann advocated industrial use of ultraviolet as a means of improving the general health and productivity of workers. The German Krupp Industry employed a conveyor belt to transport seated workers past a series of ultraviolet lamps to administer a standard dosage to all subjects. An increased work production and decreased absenteeism caused

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[40] Joseph W. Eichenbaum and Jack R. Cooper, "Restoration by Thiamine of the Action Potential in Ultraviolet Irradiated Nerves," Brain Research, XXXII (1971), 258.

[41] T. Baran, J. Cerf, and Micheline Josse, "Influence Des Radiations Ultra-Violettes Sur Le Potentiel De Membrane, Etudie Sur Le Muscle Sartorius De Grenouille, Par La Methode Des Micro-Electrodes Intracellulaires," Revista Medico, XVI (July-September, 1972), 767.

by illness were observed within several months after the program was installed. Lehmann recommended that workers receive ultraviolet treatments at the end of the work shift in order that work production not be diminished by the initial fatiguing sensations experienced by many workers following irradiations.[42]

Spellerberg, a team physician at a sports college in Cologne, reported on the use of ultraviolet in athletics. The author's convictions of the benefits of ultraviolet were based on experiences of his rather than on scientific tests or an analysis of data collected. Subjects initially received a two-minute exposure that was gradually increased to ten minutes, and a total of 12 treatments were administered. Reductions of up to 50 percent were reported in injuries. Fewer early season muscular cramps and a reduction in sinus infections of swimmers were also reported for athletes receiving irradiations. The author contended that most athletes benefit from ultraviolet, with the exception of ping pong players, sprinters, and possibly ice hockey players. Spellerberg advised against administering ultraviolet rays within two days before a competitive event, when an athlete has overtrained or developed acute fatigue, and at the height of one's peak performance. Reasons were not given

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[42] G. Lehmann, "Ultraviolettbestrahlung als Mittel zur Erhaltung der Arbeitsfahigkeit und zur Gesunderhaltung des arbeitenden Menschen," Zentralblatt fur Arbeitsmedizin und Arbeitsschutz, I (January, 1951), 1.

for these suggestions. Spellerberg also believed that there are certain individual differences that cause some people to not respond to ultraviolet.[43]

Hettinger and Seidl reported on two different studies concerning the effect of repeated exposures on muscle trainability. Subjects were treated weekly at a distance of one meter from the lamp. The first exposure was a minimal erythemal dosage, which was increased 20-25 percent with each subsequent treatment. A bicycle ergometer test was given on the third and seventh days after each exposure, and the subjects also trained daily on elbow flexion and extension. Test procedures involved a foreperiod of six weeks of training and testing without rays, five weeks with rays, and two subjects who continued the procedures an additional four weeks without rays. The rate of strength gains almost doubled for six of seven subjects during the irradiation period of the study. An improvement was observed in the performance of five of the seven subjects on the bicycle test. The only subject who did not increase strength gains was one of the two subjects who failed to improve on bicycle performance.[44]

In a separate article, Seidl reported her results of

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[43]Bruno A. E. Spellerberg, "Sportliche Leistungssteigerung durch Systematische UV-Bestrahlung," Strahlentherapie, LXXXVIII (1952), 569.

[44]T. Hettinger and E. Seidl, "Ultraviolettbestrahlung und Trainierbarkeit der Muskulatur," Internationale Zeitschrift Fuer Angewandte Physiologie, XVI (1956), 177.

various studies with ultraviolet and stated that previous research had shown that the basal metabolic rate increased during the presence of erythema and decreased as erythema faded. During the decreased basal metabolism state following several erythemal treatments, ultraviolet irradiated subjects were able to perform a higher level of work for a given consumption of oxygen and increase performance in bicycle riding time. A study of the effects of different wavelengths indicated 2540 and 2970 angstroms wavelengths induced the largest improvements in work capacity. Performance of a 2800 angstroms group decreased during the eight weeks of treatment and then improved to exceed that of the other groups during the six weeks of post-treatment testing. Subjects receiving 3350 angstroms did not change in performance throughout the entire study. A complete reversal of physiological changes was often observed around the seventh or eighth week of treatment, which Seidl attributed to a possible thickening of the stratum corneum that limited light penetration and diminished irradiation effects.[45]

Seidl also investigated the effect of vitamin D on pulse rate, systolic and diastolic blood pressures, and bicycle ergometer endurance. Ultraviolet irradiation without vitamin D produced more favorable effects than vitamin D

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[45]Ellen Seidl, "The Influence of Ultraviolet Radiation on the Healthy Adult," The Biologic Effects of Ultraviolet Radiation, ed. Frederick Urbach (New York: Pergamon Press, 1969), pp. 447-458.

administered with ultraviolet treatments, while vitamin D alone resulted in little relative change.[46] Hettinger also reported that an increased consumption of vitamin D alone did not produce beneficial effects on muscle trainability, and when administered with ultraviolet, vitamin D tended to cancel the positive effects of light treatments.[47] The reason for these responses is unclear, but Seidl hypothesized that phosphate and glucose metabolisms were involved. Glucocorticoids, which are instrumental in glucose oxidation, are increased by vitamin D and reduced by ultraviolet irradiation. Carbohydrate utilization during rest and work were decreased during ultraviolet periods, as reflected by respiratory quotients.[48]

Seidl conducted a study of 13 subjects who trained four muscle groups isometrically for seven weeks without ultraviolet, seven weeks with treatments, and another six weeks without irradiations. During the ultraviolet period, an increased rate of strength gains was observed in 45 percent of the muscle groups, decreased gains in 22 percent, and no definite trends in 33 percent. Seidl concluded, in summary, that ultraviolet irradiation induces beneficial effects upon the circulatory system and energy metabolism, but investigations of the trainability of skeletal muscles

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[46]Seidl, p. 452.

[47]Theodor Hettinger, Physiology of Strength, p. 44.

[48]Seidl, p. 453.

involved too much individual variance and needed further research to provide definite conclusions.[49]

Lehmann studied the effects of several different wavelengths on resting heart rate, metabolism, and physical work capacity. His investigation agreed with Seidl's report that 2970 was the most productive wavelength when equal energy dosages were administered with each wavelength. However, Lehmann concluded that 2970 effects were similar to those of the full spectral field, and that there was no advantage in utilizing a monochromatic exposure. Lehmann stated an erythemal exposure was necessary to improve performance, and that the effects during the first few hours after irradiation, and in some instances even days later, may be opposite of the more permanent belated effects.[50]

Ronge irradiated 60 children between the ages of seven to twelve with a supplementary ultraviolet lighting system established in school classrooms, while 60 children in other classes acted as a control group. The study lasted 18 months, and Ronge observed that the control group decreased to a low point on a bicycle ergometer test in March during both winter seasons, while the ultraviolet group improved to a peak mean difference of 56 percent during the end of the winter season. Ronge varied this procedure the

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[49] Seidl, p. 455.

[50] G. Lehmann, "Die Bedeutung einiger Wellenlangenbereiche fur die leistungssteigernde Wirkung der UV-Bestrahlung," p. 447.

second year and gave either vitamin D or a placebo to the control group. On the endurance test given a month later, the vitamin D group improved on performance while the placebo group failed to improve. This finding that vitamin D improved work capacity is in opposition to the results of Seidl and Hettinger previously mentioned on page 28. Ronge advised against conclusions based on this single study, since it contradicted previously established findings.[51]

Klein conducted a twelve-week study involving 50 boys and 50 girls, ages twelve through fifteen, with a control group of equal composition. Ultraviolet treatments were given twice weekly at a distance of two meters from the subject. On the Schneider test of work capacity, no change in performance occurred for the control group. The ultraviolet group improved on the first three tests given during the irradiation period, and returned to pretreatment values on the last test, which was given six weeks after treatments had ceased. Girls improved slightly more than boys. The ultraviolet group gained 3.1 kilograms of weight as compared to 2.2 for the control group. Colds and absences were too infrequent to compare.[52]

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[51]Hans E. Ronge, "Korperliche Leistungssteigerung durch Systematische UV-Bestrahlung," Strahlentherapie, LXXXVIII (1952), 563.

[52]Ernst Klein, "Ergebnisse Statistischer Untersuchungen uber die Steigerung der Leistungsfahigkeit durch Ultraviolett-Bestrahlung von Schulkindern," Strahlentherapie XLV (1954), 454.

Zamkova studied sixth and seventh graders who were given a daily exposure of ultraviolet by means of a supplementary lighting system established in a school classroom. In comparison to a control group of equal composition, the ultraviolet group increased more in height and weight, made better grades, and demonstrated improved stability of clear vision and improved motor response time. Differences between the groups in vision and response time increased as tests were administered later in the day, which the authors interpreted to be an indication of greater fatigue among the control subjects at the end of the working day. The authors concluded, therefore, that ultraviolet increased working capacity by delaying fatigue.[53]

Although Zamkova and Krivitskaya reported improved response time, others were not in agreement on this issue. After making over 40,000 single measurements of reaction time, Seidl concluded that her data could show no probable influence of erythemic ultraviolet rays on reaction time.[54] Sigmund reported reaction time was improved for children and adults through ultraviolet irradiations. The improved mean was attributed to a reduction in the number of exceptionally

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[53]M. A. Zamkova and E. I. Krivitskaya, "Effect of Irradiation With Erythema Ultraviolet Lamps On the Working Capacity of Schoolchildren," Gigiena i Sanitariia, XXXI (April, 1966), 47.

[54]Ellen Seidl, "Zur Frage des Einflusses von Ultraviolettbestrahlung auf die Reaktionszeit," Internationale Zeitschrift Fuer Angewandte Physiologie, XVII (1958), 340.

slow reactions, and Singmund concluded that irradiation must have improved concentration and alertness.[55] Al'bitskaya and Gorkin, however, noted no significant effects of single or repeated minimal erythemal treatments on the length of the latent period for a motor reaction test involving button pressing.[56]

Allen and Cureton conducted one of the few studies published in America concerning ultraviolet effects on performance. The authors placed 22 students, who scored in the lower-third of the freshmen class on a muscular endurance test, into two groups equated on the basis of time in a mile run. Ultraviolet treatments were given to the experimental group tri-weekly. All subjects attended the same physical education class and participated in similar activities. The ultraviolet group improved 15.4 percent as compared to an 11.8 percent gain for the control group on a muscular endurance test, consisting of pull-ups, push-ups, sit-ups, squat jumps, and a mile run. On the Schneider test, the ultraviolet group's 19.2 percent gain was significant, while the control group's 1.5 percent increase was not. Statistical treatments were limited to comparisons between initial and

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[55] Rudolf Sigmund, "Die Wirkung ultravioletter Strahlen auf die Reaktionszeit des Menschen," <u>Strahlentherapie</u>, CI (1956), 623.

[56] E. F. Al'bitskaya and Z. D. Gorkin, "Effect of Ultraviolet Irradiation on the Functional State of the Basic Nerve Process in the Human Cerebral Cortex," <u>Gigiena i Sanitariia</u>, XXXI (June, 1966), 348.

final scores for each group. No statistical comparisons were made between groups.[57]

Several studies were unique because single ultraviolet exposures were used, the dosages were suberythemic, and the subjects were all females. Cheatum investigated speed in a 30-yard sprint one hour following irradiation for six minutes on the anterior and posterior aspects with a General Electric RS 275 watt sunlamp at a distance of one meter. At this distance, an RS sunlamp emits 3.14 E-vitons per square centimeter per minute for a total dosage of 18.8 E-vitons during a six-minute exposure. Subjects were tested under the influence of ultraviolet and a placebo treatment, and a significantly better score was attained under ultraviolet conditions on the third sprint.[58]

Rosentswieg applied these same treatment procedures to investigate physical work capacity. Bicycle ergometer riding time was measured until a heart rate of 170 beats per minute was attained. Results of the test were significantly improved times for five subjects following ultraviolet after the scores of three trained subjects were deleted.[59]

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[57]Robert M. Allen and Thomas K. Cureton, "Effect of Ultraviolet Radiation on Physical Fitness," _Archives of Physical Medicine and Rehabilitation_, XXVI (October, 1945), 641.

[58]Billye A. Cheatum, "Effects of a Single Biodose of Ultraviolet Radiation Upon the Speed of College Women," _The Research Quarterly_, XXXIX (October, 1968), 482.

[59]Joel Rosentswieg, "The Effect of a Single Suberythemic Biodose of Ultraviolet Radiation Upon the Endurance of College Women," _Journal of Sports Medicine and Physical Fitness_, IX (June, 1969), 104.

In another study, Rosentswieg duplicated these same treatment procedures to determine strength changes following ultraviolet exposures. However, this study was expanded to include three groups: (1) a group of caucasians tested one hour after exposure, (2) a group of negroes tested one hour after exposure, and (3) a group of caucasians tested five hours after exposure. Measurements were taken for right and left grip strength, back pull, leg lift, pushing, and pulling. Comparisons were made between ultraviolet and placebo for each event, and for a total strength score. Data were treated in a manner that allowed 15 different comparisons. No significant differences were found on any of the measures, but since mean strength scores were observed to be improved in 13 of the 15 comparisons following ultraviolet, Rosentswieg wrote that the results indicated ultraviolet may exert a beneficial effect on strength.[60]

SUMMARY OF LITERATURE

The review presented many theories concerning the mode of action for ultraviolet effects, and these usually emphasized biological reactions to substances released in the skin during irradiation. Ultraviolet has been shown to affect various aspects of circulation, but researchers are

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[60]Joel Rosentswieg, "The Effect of a Single Suberythemic Biodose of Ultraviolet Radiation Upon the Strength of College Women," Journal of The Association For Physical and Mental Rehabilitation, XXI (July/August, 1967), 131.

not in complete agreement on these changes or what causes them to occur. Investigators reported reductions in blood pressure, increased stroke volume, increased red blood cell count, reduced energy cost for a given work task, and a reduction in blood coagulation time. An increased red cell count was said to be due to an increased life span of erythrocytes. Cholesterol reductions and adrenal hypertrophy were reported in a study involving rats. Ultraviolet was found to hasten the regeneration of hemoglobin following clinically induced anemia. Circulatory changes occur as a response to ultraviolet effects on the skin, since one study reported direct irradiation of blood was not effective.

Evidence of damage to tissues was reported. Chromosomal damage has been established, and in vitro studies show action potential capabilities are impaired, and possibly completely destroyed, following irradiation.

Ultraviolet effects on various parameters of fitness were reported. Several studies supported improved work capacity based on the Schneider test or bicycle ergometer tests. Skeletal muscle trainability was also claimed to benefit from ultraviolet treatments. Most studies stated an erythemal dosage was necessary to improve performance, and two studies comparing different wavelengths reported 2970 angstrom length to be most effective when all wave lengths received the same energy dosage.

School children of different ages have improved in physical work capacity by means of artificial lighting systems located within the classrooms. A study of Russian children made claims of better grades, improved vision, and improved motor response time.

The production of vitamin D is not considered to be the mode by which ultraviolet induces physiological benefits, because vitamin D supplements did not induce changes in performance on physical work capacity tests.

Only four studies were conducted within the United States, and three of these involved single treatments. The single exposure studies all used female subjects and suberythemic treatments. Speed in a 30-yard dash and a bicycle ergometer work capacity test established qualified claims for ultraviolet. The other suberythemic study reported beneficial effects on strength that were not statistically significant.

Empirical observations or small group studies without statistical comparisons were reported frequently in the literature reviewed.

Chapter 3

DESCRIPTION OF PROCEDURE

OVERVIEW

Male caucasian students at East Carolina University, Greenville, North Carolina, were placed in either a group of 20 trained subjects or in a group of 20 untrained subjects. Each subject was tested for performance on leg power, total body response, elbow flexion strength, speed in running, and physical work capacity 24 hours after exposure to either an ultraviolet sunlamp or an incandescent light used for placebo effects. A counter-balanced technique was employed in administering light treatments.

Subsequent to the original exposure and performance tests, this procedure was repeated two weeks later with each subject receiving a light treatment opposite the one he originally received.

A two x two factorial design analysis of variance was employed to compare differences between the effects of the two treatment conditions on performance scores of each variable. This design provided a further comparison to determine interaction that might exist between treatment upon trained athletes as opposed to more sedentary subjects who were not participating in an exercise program.

SELECTION AND GROUPING OF SUBJECTS

An Untrained Group of 20 subjects were volunteers from health classes at East Carolina University. These subjects were not enrolled in physical education courses nor participating in exercise on a regular basis. An additional 20 male caucasian subjects were obtained from East Carolina University athletic teams that were actively training during the data collecting period. These subjects were either wrestlers, basketball players, or swimmers. The athletes were assigned to the Trained Group.

SAFETY OF THE SUBJECTS

Students who expressed a past history of adverse reactions or a tendency to blister quickly due to solar exposure were excluded from the study. Subjects who had taken any type of medication within the past month were not used. A past history of dermatitis was considered reason for exclusion from the study. Protective goggles were worn and a metal hood was placed over the subject's head for additional safety during irradiation. The genital area was covered with a folded towel.

LENGTH OF THE STUDY

This study was conducted during the months of January, February, and March, 1974. Normal solar radiation is relatively low during these months.

SELECTION AND TRAINING OF ASSISTANTS

Three graduate students of the Department of Health, Physical Education, Recreation and Safety at East Carolina University assisted with the study. All of the assistants were thoroughly informed of the purposes and procedures of the study, and trained regarding their specific assignments. Two of the assistants administered light treatments, while the third assisted in data collecting.

DESCRIPTION OF EQUIPMENT

Sunlamp - A General Electric RS 275 watt ultraviolet lamp (producing approximately 3.75 E-vitons per square centimeter at a distance of one yard) was employed to administer ultraviolet treatments.[1,2] Rays of all lamps lose intensity as they digress at an angle away from the center of focus of the bulb. Based on the angular distribution characteristics of the General Electric RS lamp, an exposure of twelve minutes was selected to produce an erythemal response of an area of 455 square centimeters.[3]

Incandescent Lamp - A General Electric outdoor floodlight (model 150 PAR/FL) was used for placebo treatments.

Vertical Jump Board - A strip of blackboard was marked in

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[1] General Electric Company, Cleveland, Ohio.

[2] Appendix M, page 93.

[3] Appendix M, page 93.

one-fourth inch increments and attached to the wall for data collecting in the power jump event.

Dekan Automatic Performance Analyzer[4] - A Dekan timer was used to collect data on the total body response event and the 30-yard sprint. The clock is calibrated in 1/100 of a second.

Cable Tensiometer[5] - A 200-pound capacity cable tensiometer (model T5 - 6007 - 114 - 00) was used for strength testing.

Goniometer[6] - A goniometer was used in establishing the elbow angle during strength testing.

Treadmill[7] - A Quinton treadmill (model 18-60) was used to administer the Balke-Ware test for physical work capacity. The unit has a speed control ranging from 1.5 to 15 miles per hour, and a grade control ranging from zero to forty percent.

Cardio Tachometer[8] - A Quinton cardio tachometer (model 609) was used to monitor heart rate during the Balke-Ware test. The average rate for the last 20 heart beats was displayed on a digital readout during the entire test procedure.

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[4]Dekan Timing Devices, Glen Ellyn, Illinois.

[5]Pacific Scientific Company, Anaheim, California.

[6]Orthopedic Equipment Company, Bourbon, Indiana.

[7]Quinton Instruments, Seattle, Washington.

[8]Quinton Instruments, Seattle, Washington.

PROCEDURE FOR TREATMENT

Each subject received both ultraviolet irradiation and an incandescent exposure for a placebo effect under a counter-balanced order. The actual purpose of the study was not revealed to the subjects. Each subject was told that ultraviolet rays have been claimed to improve physical performance, and that he was receiving ultraviolet irradiation from different sunlamps on the two treatment occasions in order to compare the effectiveness of the different wavelengths. Light treatments were conducted in a manner that prevented subjects from seeing either lamp. The order for treatments for all subjects is shown in Appendix L.[9]

The procedure for a treatment was as follows:

1. The subject was nude except for a metal hood and folded towl covering the face and genital areas respectively. Protective goggles were worn as an additional precaution against eye injury in the event the metal hood was accidentally displaced.
2. After the subject was positioned in a supine position for treatment, the proper lamp was inserted and positioned one yard from the subject, with the center of focus approximately two inches above the umbilicus.

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[9]Appendix L, page 92.

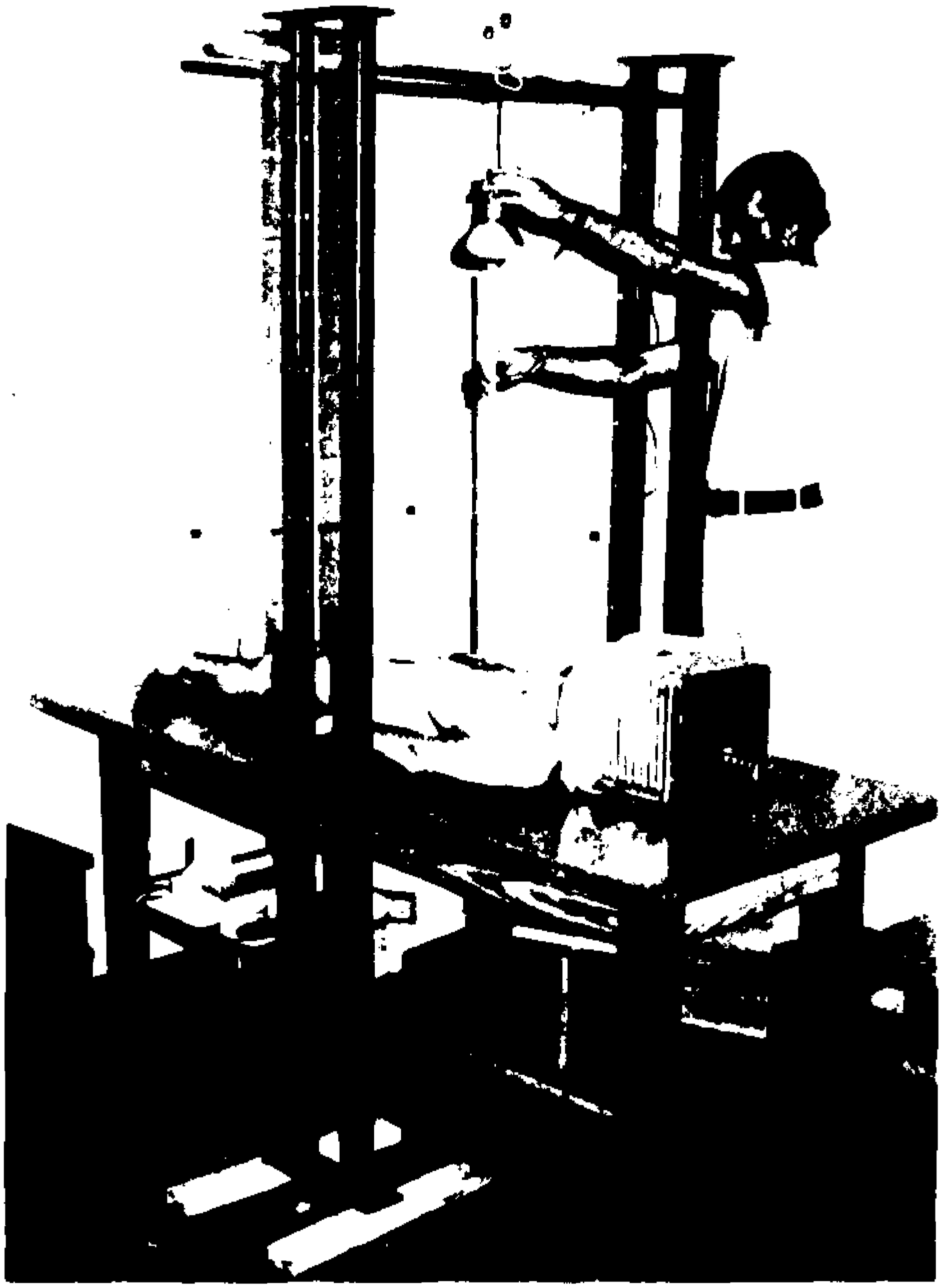

Figure 1

Administration of Ultraviolet Rays

3. A sheet was then pulled over the subject, and the lamp was turned on and allowed to "warm up" for five minutes, as recommended by the lamp manufacturers.[10]
4. The sheet was then removed to expose the subject for a 12-minute treatment.
5. After completing treatment on the thoracic and abdominal area, the subject then turned over for a 12-minute exposure on the posterior.

This procedure was repeated two weeks later when the subject returned at the same hour to receive an exposure under the lamp that was not used on the initial treatment.

PROCEDURE FOR TESTING

Subjects reported for testing approximately 24 hours following both treatments. This was selected because literature stated erythema often attains its peak intensity at this time.[11] The order and directions for testing were as follows:

Measurement of Body Weight

Body weight was recorded to the nearest one-fourth pound while the subject was dressed in the attire he wore

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[10]General Electric Company, Cleveland, Ohio.

[11]Albert Bachem, "Time Factors of Erythema and Pigmentation Produced by Ultraviolet Rays of Different Wavelengths," The Journal of Investigative Dermatology, XXV (October, 1955), 215.

during testing. This weight was used in computing his power jump score.

Vertical Power Jump

A slightly modified version of the vertical power jump as described by Johnson and Nelson was used in this event.[12] Reaching height was recorded to the nearest one-fourth inch while the subject stood with the dominant arm next to the wall and reached as high as possible with the fingers extended. The subject was then allowed two practice trials at a suggested three-fourths effort before jumping three times for score.

Jumping procedure. Each subject marked the fingers with powdered chalk and assumed a position with the dominant side to the wall. The hand used for marking was not lowered below the shoulder at any time during the jump, while the other hand was placed behind the back and tucked into the back of the shorts. Without taking a shuffle or stutter step of any type, the subject dipped as low as he desired and jumped to touch the board as high as possible.

Scoring. Differences between the height of each jump and standing reach were used to determine the vertical jump to the nearest one-fourth inch. Average distance of

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[12]Barry L. Johnson and Jack K. Nelson, Practical Measurements for Evaluation in Physical Education, (2nd ed.; Minneapolis, Minnesota: Burgess Publishing Company, 1974), p. 177.

Figure 2

Vertical Power Jump Testing

the three jumps was used to compute a vertical power jump in foot-pounds. $\frac{\text{Body Weight x Inches Jumped}}{12} = \text{VPJ}$

Total Body Response

Total body response was a measure of a subject's ability to respond to a complex stimulus and move either to his right or left a distance of seven feet. Reaction time and movement time were factors affecting performance on this event. A technique employed by Kendrick was used in this study.[13] Dekan timer pressure plates were located on each side of a two-foot square used as the starting area. The timer was started by the tester, and the subject stopped it by making contact with a pressure plate. A practice trial in each direction was given as a warm-up.

Response procedure. A visual hand signal for direction was given to the subject within one to two seconds after he had been alerted by a "ready" command, and the Dekan timer remote starter switch was activated simultaneously. The subject sprinted in the direction of the hand signal to step on the "stop pad," which automatically stopped the timer. A spacing of at least 10 seconds was allowed between the ten trials given for score. If a subject reacted in the wrong direction, the trial was voided and

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[13]Larry Lionel Kendrick, "Performance in Selected Gross Motor Skills Before and After Fatiguing Exercise," (unpublished Doctor's dissertation, Louisiana State University, Baton Rouge, Louisiana, 1967), p. 31.

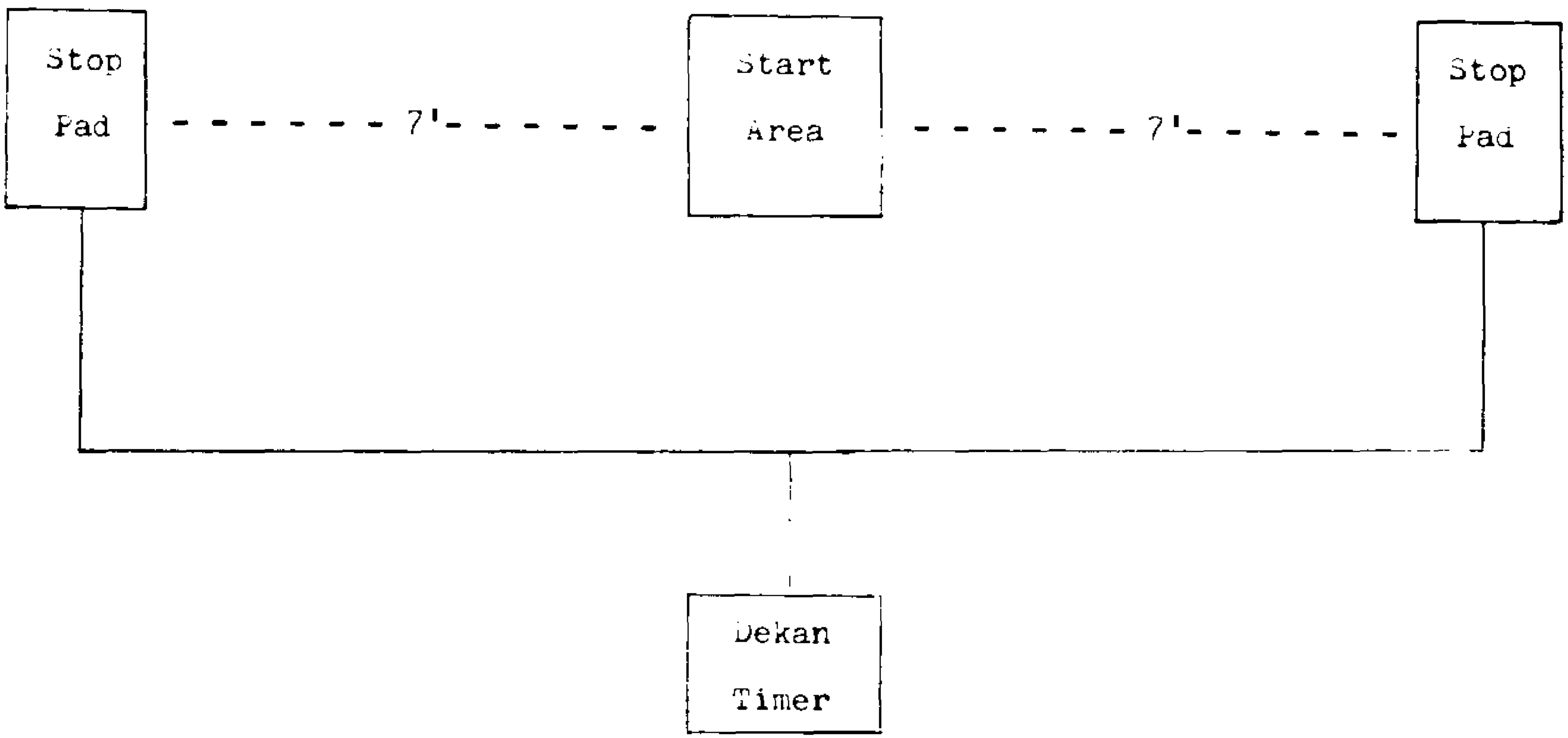

Figure 3

Diagram of Total Body Response Test Area readministered at the completion of the prescribed format. The format for the trials was:

Trial	Direction	Trial	Direction
1	Left	6	Right
2	Right	7	Right
3	Right	8	Right
4	Left	9	Left
5	Left	10	Left

The order for the format was reversed for alternate subjects and reversed for each subject on his two test days.

Scoring. The fastest and slowest times were discarded. Remaining trials were converted to velocity scores and averaged for a final score.

Strength Measurement

Static strength in elbow flexion of the dominant arm was used as the measurement of strength. A modification of the procedure described by Clarke was used with a strap placed immediately proximal to the head of the ulna instead of at a mid-point between the wrist and elbow.[14] Following two practice trials at a suggested three-fourths effort, the subject was given three trials for score. A 200-pound capacity cable tensiometer with 1/16 inch cable was used for data collecting.

Strength measurement procedure. The subject was placed in a supine position on a testing table. After a

[14]H. Harrison Clarke, Muscular Strength and Endurance in Man, (Englewood Cliffs, New Jersey: Prentice-Hall, 1966), p. 64.

Figure 4

Elbow Flexion Strength Testing

strap was positioned on the arm, a goniometer was used to establish the elbow at an angle of 115 degrees. The angle formed by the forearm and the testing cable was 90 degrees. On the command, "take up slack," the subject began steadily increasing tension and exerted a maximum contraction on the command, "pull." An explosive exertion or jerk was voided and the trial repeated. A 30-second interval was spaced between the three trials for score. During the testing procedure, the subject's elbow and shoulder were braced by a tester.

Scoring. Tension developed on the cable tensiometer was converted into pounds, and the three trials were averaged to determine the final score.

Thirty-Yard Sprint

A Dekan timer was used as the measuring instrument. The timer was connected with "start" and "stop" pads located 30 yards apart that allowed the subject to start and stop the timer. Thus, human error in timing and the subject's response to a visual or auditory stimulus were eliminated as factors in this event. Following two practice trials at a suggested three-fourths effort, the subject was given three trials for score. A rest interval of at least one minute was spaced between each sprint.

Sprint procedure. Each subject assumed a crouched standing position within five feet from the "start" pad. At his discretion, the subject started and activated the timer as he stepped on the "start" pad. When he touched the "stop" pad located 30 yards away, the timer stopped and displayed the time in 1/100 of a second.

Scoring. Recorded time was converted into a velocity score in feet per second, and the velocity scores were averaged for a final score.

Physical Work Capacity

The Balke-Ware progressive grade test was used to measure physical work capacity.[15] Based on his studies involving Air Force personnel, Balke wrote that this test provides an excellent indication of the level of oxygen consumption and capacity for sustained work that a subject is capable of maintaining for a prolonged period of time.

Work capacity testing procedure. Chest electrodes were attached as prescribed by Quinton Instruments.[16] An exercise cardio tachometer was used to monitor heart rate throughout the exercise bout. Average rate of the last 20 heart beats was displayed on the visual screen of the instrument panel.

The treadmill was started at a speed of 3.3 miles

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[15] Bruno Balke and Ray W. Ware, "An Experimental Study of 'Physical Fitness' of Air Force Personnel," United States Armed Forces Medical Journal, X (June, 1959), 675.

[16] Quinton Instruments Manual, Model 609, Seattle, Washington.

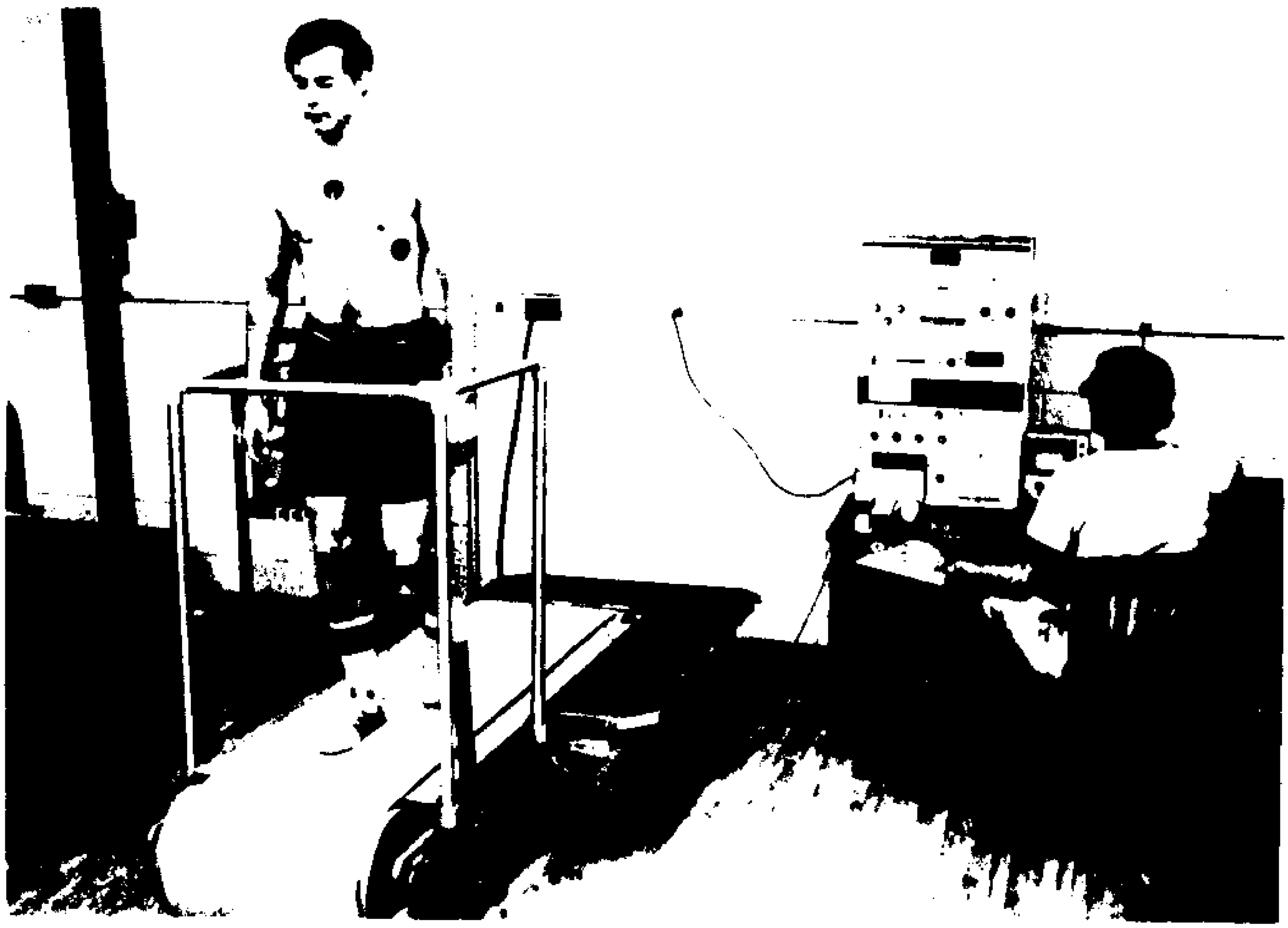


Figure 5

Balke-Ware Treadmill Test

per hour on a zero percent grade. As the subject lowered himself to the treadmill belt and released the handrail, a stop watch was started by the tester. At the end of each minute, the treadmill was increased one percent in grade, while the speed remained constant throughout the test.

Scoring. The test was terminated when a subject's heart rate attained 180 beats per minute on the digital readout. Exercise time was recorded to the nearest second and used as the final score.

STATISTICAL DESIGN

Reliability of the test procedures was determined by product-moment correlations of data collected on a test-retest basis. Computations of the correlations are presented in Appendixes G-K on pages 87 through 91. All of the test procedures had correlations that were significant at the .01 level of confidence as follows:

Vertical Power Jump	= .92
Total Body Response	= .85
Strength	= .84
Speed	= .95
Physical Work Capacity	= .96

A two x two factorial design analysis of variance was employed to compare differences between the effects of the two treatment conditions on performance scores of each variable. This design provided a further comparison to determine interaction that might exist between treatment effects upon trained athletes as opposed to more sedentary subjects who were not participating in an exercise program.

A predetermined .05 level of confidence was established for significance on all comparisons.

Chapter 4

PRESENTATION AND ANALYSIS OF DATA

This study was designed to investigate: (1) the effects of ultraviolet irradiation on motor performance, and (2) to determine if a difference exists between the effects of ultraviolet on physically active and sedentary subjects.

Members of athletic teams at East Carolina University who were training strenuously during the data collecting period comprised a group of 20 trained subjects, while 20 volunteers from health classes served as untrained subjects. Both groups were exposed to an ultraviolet sunlamp and an incandescent lamp for placebo effects. A counter-balanced treatment order was followed.

Each subject was tested on motor performance after each light treatment. The items investigated were the vertical power jump, total body response, 30-yard sprint speed, elbow flexion strength, and physical work capacity.

A separate analysis was made on each of the five test parameters. The statistical design was a two x two factorial analysis of variance featuring repeated measures. This design provided a comparison between groups, a comparison for light effects, and a comparison for interaction between groups and light.

ANALYSIS OF DATA FOR THE VERTICAL POWER JUMP

Mean vertical power jump scores following incandescent treatment were 230.40 foot-pounds for the untrained group and 234.74 for the trained group. After ultraviolet exposure, mean scores were 230.83 for the untrained subjects and 235.84 for the trained group. The combined mean for both groups was 232.59 following incandescent treatment, and 233.34 after ultraviolet irradiation. See Figure 6 on page 57.

A statistical analysis of the data presented in Table 1 indicates that none of the comparisons were significantly different. Vertical power jump performance was not affected by ultraviolet exposures.

Table 1

Analysis of Variance for the Vertical Power Jump After Incandescent and Ultraviolet Exposures

Source of Variance	Sum of Squares	df	Mean Square	F	P
A (Groups)	436.46	1	436.46	0.14	NS
Bet. Subj. Error	115,157.92	38	3030.47		
B (Light Effects)	11.77	1	11.77	0.19	NS
AB (Group x Light)	2.27	1	2.27	0.04	NS
Within Subj. Error	2,392.86	38	62.97		
Total	118,001.28	79			

$F_{.05} = 4.10$; $F_{.01} = 7.35$

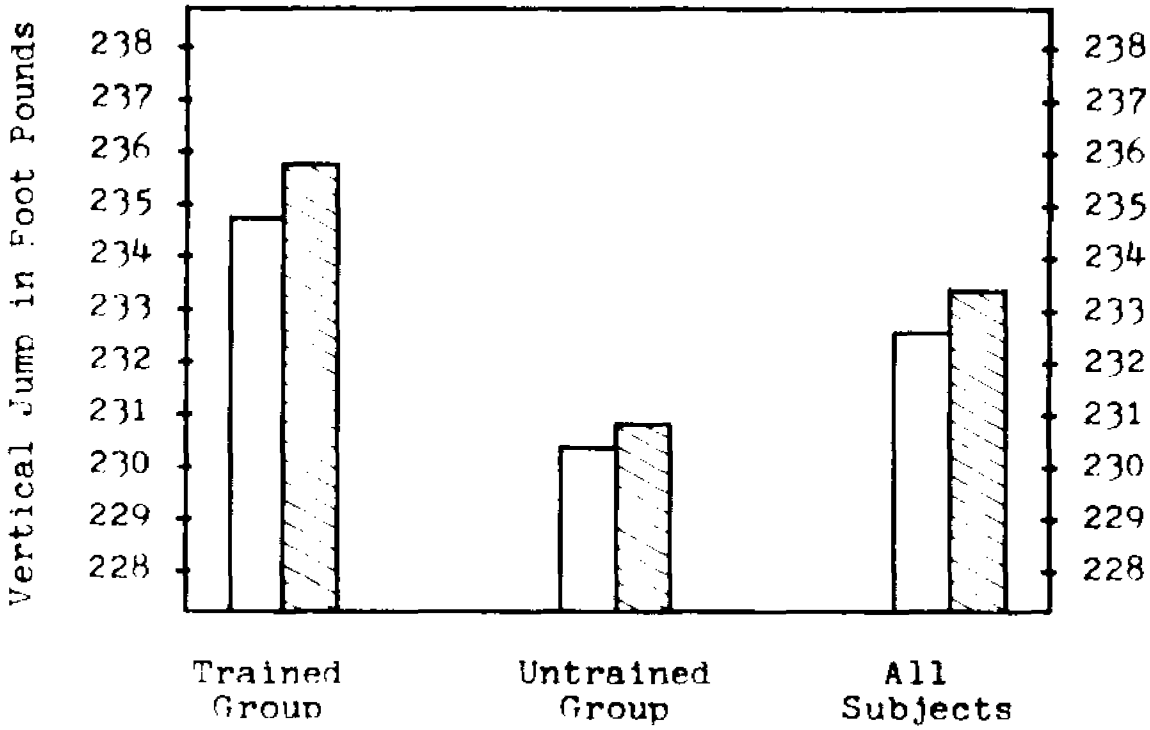
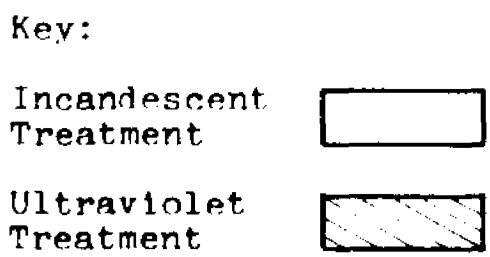


Figure 6

Vertical Power Jump Mean Scores Following Incandescent and Ultraviolet Treatments For Trained and Untrained Groups



ANALYSIS OF DATA FOR TOTAL BODY RESPONSE

Total body response times were converted to velocity scores and averaged. Mean scores following incandescent treatment were 6.201 and 6.326 feet per second for the untrained and trained subjects, respectively. Following ultraviolet irradiation, mean scores were 6.226 feet per second for the untrained subjects and 6.294 for the trained group. Combined mean performance scores were 6.264 after incandescent treatment and 6.260 feet per second following ultraviolet irradiation. See Figure 7 on page 59.

A statistical analysis of the data presented in Table 2 indicates that none of the comparisons were significantly different. Total body response performance was not affected by ultraviolet irradiation.

Table 2

Analysis of Variance for Total Body Response Velocity Following Incandescent and Ultraviolet Exposures

Source of Variance	Sum of Squares	df	Mean Square	F	P
A (Groups)	0.19	1	0.19	1.00	NS
Bet. Subj. Error	7.26	38	0.19		
B (Light Effects)	0.00	1	0.00	0.00	NS
AB (Group x Light)	0.02	1	0.02	0.49	NS
Within Subj. Error	1.26	38	0.03		
Total	8.73	79			

$F_{.05} = 4.10$; $F_{.01} = 7.35$

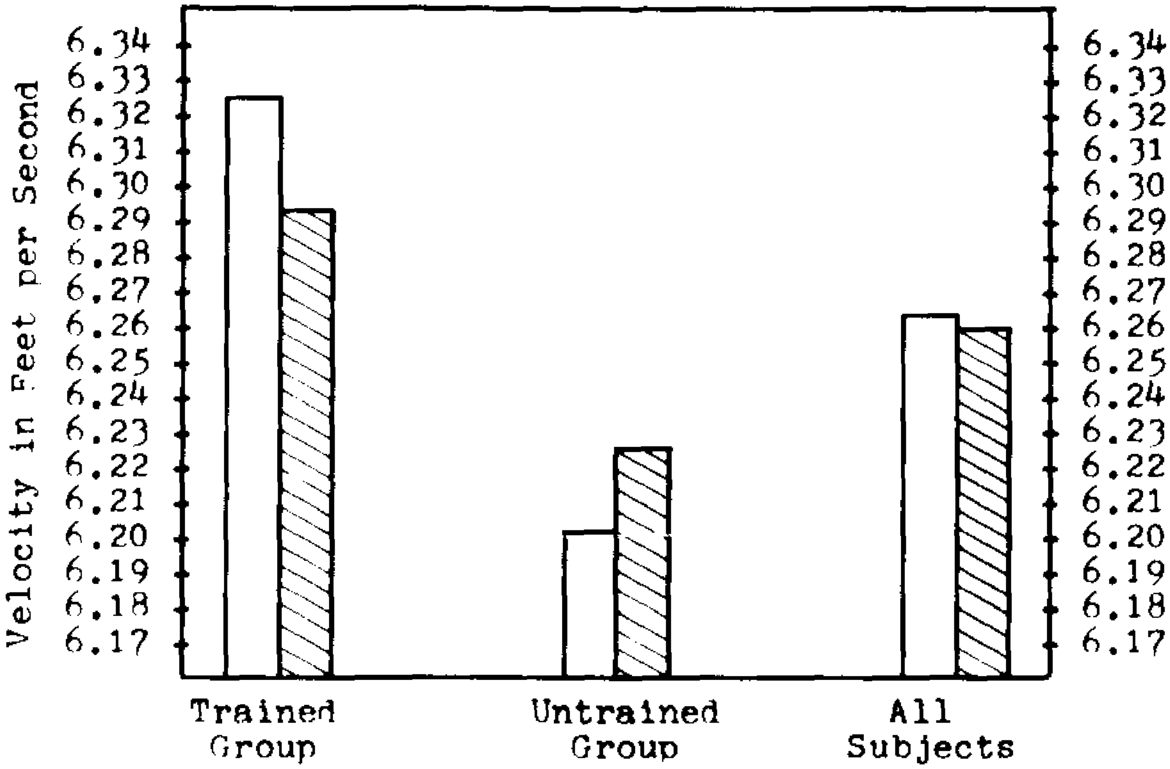


Figure 7

Total Body Response Mean Scores Following Incandescent and Ultraviolet Treatments For Trained and Untrained Groups

Key:

Incandescent Treatment

Ultraviolet Treatment

ANALYSIS OF DATA FOR ELBOW FLEXION STRENGTH

Mean elbow flexion strength scores noted following incandescent treatment were 72.02 pounds for the untrained group and 76.99 for the trained subjects. After ultraviolet irradiation, mean scores had decreased to 69.31 for the untrained group and 75.23 pounds for trained subjects. The combined mean was 74.50 pounds following incandescent treatment, and was 72.27 pounds after ultraviolet exposure. See Figure 8 on page 61.

A decrement occurred in elbow flexion strength after ultraviolet treatment, and the analysis presented in Table 3 indicates that the difference was significant at the .05 level of confidence. Other comparisons failed to meet the test for significance.

Table 3

Analysis of Variance for Elbow Flexion Strength After Incandescent and Ultraviolet Exposures

Source of Variance	Sum of Squares	df	Mean Square	F	P
A (Groups)	593.34	1	593.34	3.20	NS
Bet. Subj. Error	7,036.14	38	185.16		
B (Light Effects)	99.79	1	99.79	5.61	.05
AB (Group x Light)	4.50	1	4.50	0.25	NS
Within Subj. Error	676.23	38	17.80		
Total	8,410.00	79			

$F_{.05} = 4.10$; $F_{.01} = 7.35$

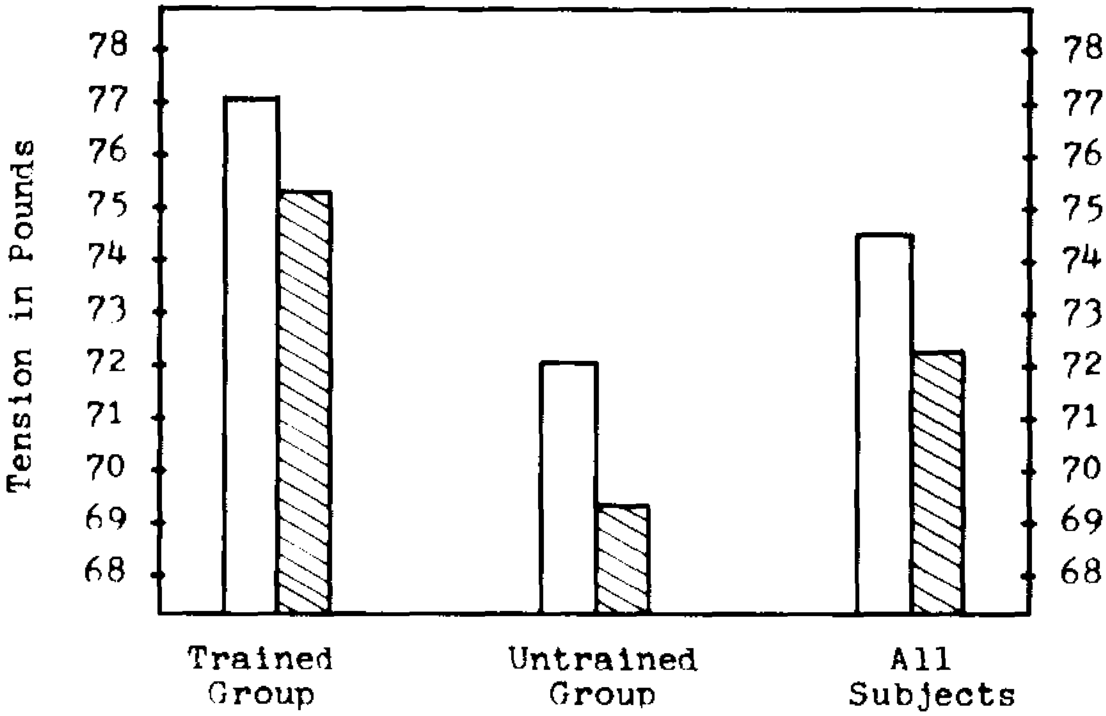
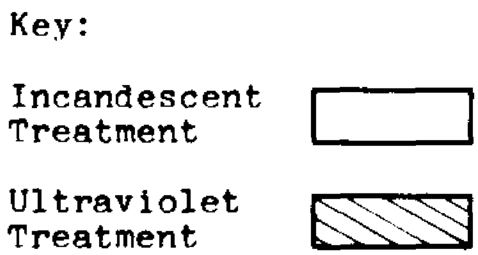


Figure 8

Elbow Flexion Strength Mean Scores Following Incandescent and Ultraviolet Treatments For Trained and Untrained Groups



ANALYSIS OF DATA FOR THE 30-YARD SPRINT

Mean performance scores on the 30-yard sprint after incandescent treatment were 22.33 feet per second for the untrained group and 22.60 for trained subjects. Following ultraviolet irradiation, mean scores were 22.37 feet per second for untrained subjects and 22.60 for the trained group. The combined means for both groups were 22.46 feet per second following incandescent treatment, and 22.48 after ultraviolet irradiation. See Figure 9 on page 63.

Table 4 indicates that none of the comparisons met the test for significance at the .05 level of confidence. This test failed to show that performance in the 30-yard sprint was affected by ultraviolet irradiation.

Table 4

Analysis of Variance for the 30-yard Sprint Following Incandescent and Ultraviolet Exposures

Source of Variance	Sum of Squares	df	Mean Square	F	P
A (Groups)	1.25	1	1.25	0.55	NS
Bet. Subj. Error	87.10	38	2.29		
B (Light Effects)	0.01	1	0.01	0.13	NS
AB (Group x Light)	0.01	1	0.01	0.13	NS
Within Subj. Error	3.16	38	0.08		
Total	91.53	79			

$F_{.05} = 4.10$; $F_{.01} = 7.35$

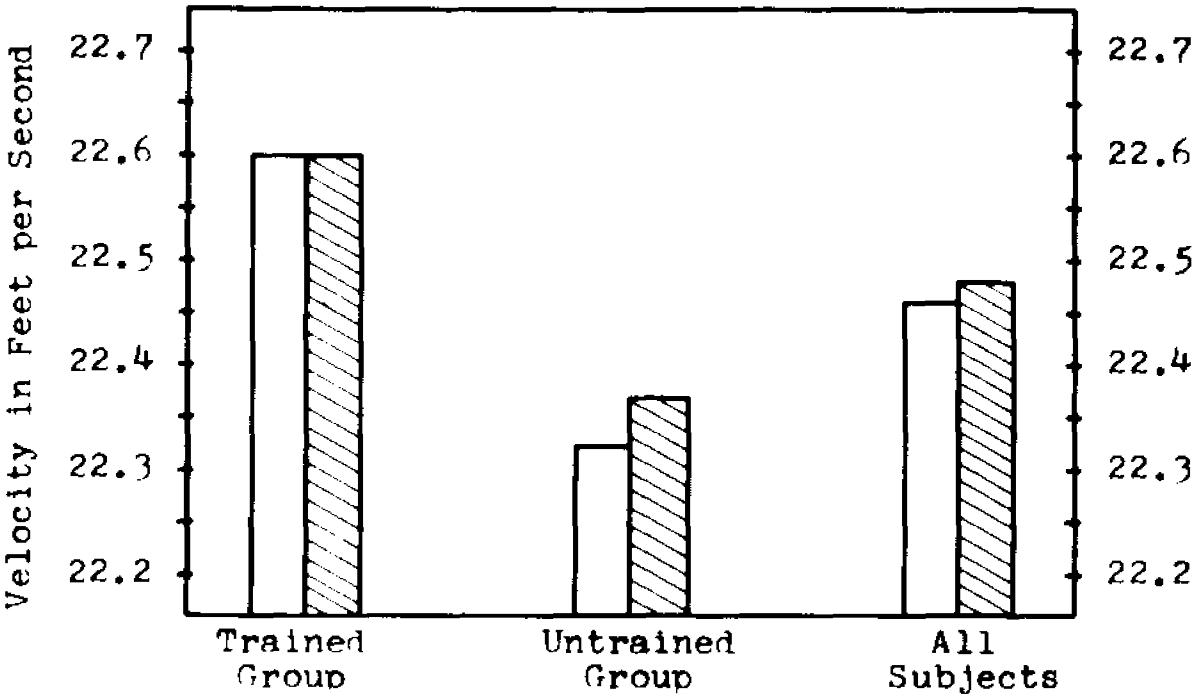
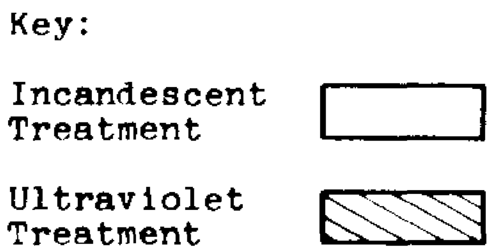


Figure 9

Thirty-Yard Sprint Mean Scores Following Incandescent and Ultraviolet Treatments For Trained and Untrained Groups



ANALYSIS OF DATA FOR THE BALKE-WARE TEST OF PHYSICAL WORK CAPACITY

Following incandescent treatment, mean performance scores for the untrained subjects were 17.91 minutes, and 24.64 for the trained group on the Balke-Ware test. Mean scores following ultraviolet irradiation were 17.32 minutes for the untrained group and 23.96 for trained subjects. For both groups combined, the mean score following incandescent exposure was 21.27 minutes, and 20.64 following ultraviolet treatment. See Figure 10 on page 65.

An analysis of the data presented in Table 5 shows the data met the test for significance, and the Null Hypothesis was rejected. Mean performance scores were impaired following ultraviolet irradiation. There was no significant interaction.

Table 5

Analysis of Variance for Physical Work Capacity After Incandescent and Ultraviolet Exposures

Source of Variance	Sum of Squares	df	Mean Square	F	P
A (Groups)	892.51	1	892.51	50.08	.01
Bet. Subj. Error	677.21	38	17.82		
B (Light Effects)	8.05	1	8.05	9.23	.01
AB (Group x Light)	0.04	1	0.04	0.05	NS
Within Subj. Error	33.14	38	0.87		
Total	1,610.95	79			

$F_{.05} = 4.10$; $F_{.01} = 7.35$

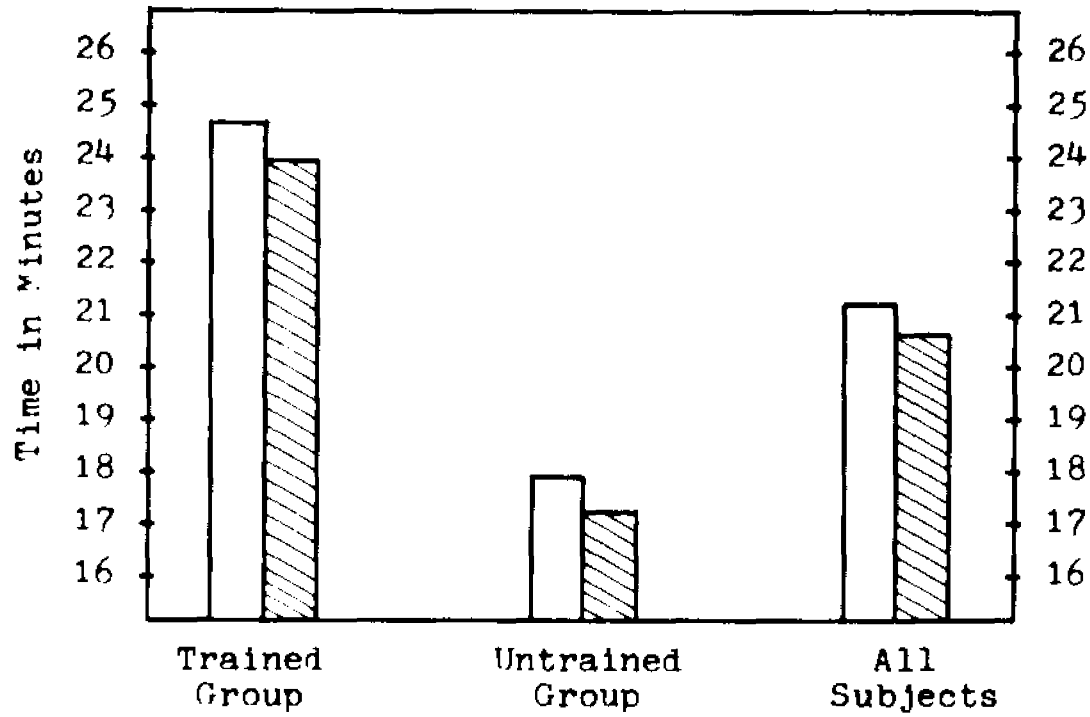
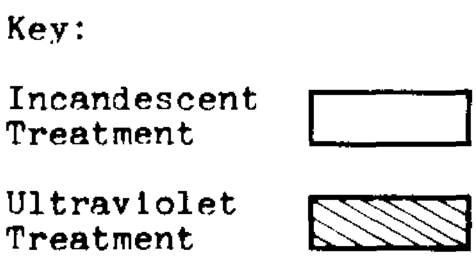


Figure 10

Balke-Ware Treadmill Test Mean Scores After Incandescent and Ultraviolet Treatments For Trained and Untrained Groups



Chapter 5

SUMMARY AND FINDINGS

This study was designed to determine the effects of a single exposure of erythemal intensity ultraviolet rays on motor performance, and to determine if a difference exists between the effects of ultraviolet rays on physically active and relatively sedentary subjects.

The study was conducted during the months of January through March, 1974, when solar radiation was relatively low. A group of 20 subjects were members of athletic teams at East Carolina University, Greenville, North Carolina. These subjects were wrestlers, swimmers, or basketball players, and were well trained during the data collecting period. A group of 20 untrained subjects were volunteers from health classes. These subjects were relatively sedentary and were not members of athletic teams or physical education classes. All subjects were male caucasian college students.

An ultraviolet treatment of 12 minutes duration with a General Electric RS 275 watt sunlamp was administered from a distance of one yard to the anterior and posterior aspects of the upper torso of each subject. For a placebo effect, each subject also received a similar exposure under an incandescent lamp. Light treatments were administered two weeks apart following a counter-balanced order.

Each subject was tested on motor performance after each light treatment. Parameters investigated included power (vertical jump), strength (elbow flexion), speed (30-yard sprint), total body response to a complex stimulus, and physical work capacity as measured by the Balke-Ware treadmill test. Performance tests were taken 24 hours after light treatments.

The statistical design used to analyze the data was a two x two factorial analysis of variance with repeated measures. This design provided a comparison for ultraviolet effects, and an analysis for interaction between groups and light effects.

The findings were:

1. Ultraviolet irradiation, as administered in this study, failed to affect performance in power, speed, or total body response.

2. Performance in elbow flexion strength was impaired at the .05 level of confidence following ultraviolet irradiation.

3. Ultraviolet irradiation impaired performance on the Balke-Ware physical work capacity test at the .01 level of confidence.

4. There was no significant interaction between groups and light effects on performance in any of the parameters investigated.

DISCUSSION OF FINDINGS

The results of this study show that a single exposure of ultraviolet rays did not produce significant changes in mean performance scores in power, total body response, or speed in running. Differences in mean scores were negligible in all three cases. Mean scores in the power jump were 232.59 foot-pounds following incandescent treatments and 233.34 after ultraviolet exposures. Total body response mean velocity scores were 6.264 feet per second after incandescent treatments as compared with 6.260 feet per second following ultraviolet irradiation. Mean velocity scores were 22.46 feet per second after incandescent treatments and 22.48 feet per second under ultraviolet effects.

Strength and physical work capacity were impaired following ultraviolet irradiation. Elbow flexion strength decreased from 74.50 to 72.27 pounds, and treadmill performance time decreased from 21.27 to 20.64 minutes.

Physical work capacity may have been affected by a summation of circulatory and metabolic parameters reportedly altered during the erythemal stage following ultraviolet irradiation.

The amount of oxygen required per caloric expenditure depends upon the source of energy involved in the oxidative process. Carbohydrates provide the most efficient source of energy during exercise, requiring less oxygen than fats or proteins per calorie provided. The proportion of energy sources involved in metabolism is indicated by the respiratory quotient, which increases with greater carbohydrate utilization and decreases with less involvement of carbohydrates.[1] Seidl reported that increased excretions of glucocorticoids important in the oxidation of glucose and lower respiratory quotients were observed in subjects during rest and work following ultraviolet exposures, placing a greater reliance on energy sources other than carbohydrates.[2] Fischer and Solomon stated that blood sugar levels decreased and metabolic rates and amino acid nitrogen levels in urine increased following ultraviolet exposures, indicating greater protein metabolism.[3] When utilizing energy sources other than carbohydrates, an increased consumption of oxygen is needed to accomplish a given work task, offering an explanation for decreased physical work capacity following the ultraviolet treatments.

Blood changes may have exerted a detrimental effect on physical work capacity. Although systematic treatments have been shown to increase erythrocyte counts, an increased

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[1]Peter V. Karpovich and Wayne E. Sinning, Physiology of Muscular Activity (7th ed.; Philadelphia: W. B. Saunders Company, 1971), pp. 80-82.

[2]Ellen Seidl, "The Influence of Ultraviolet Radiation on the Healthy Adult," The Biologic Effects of Ultraviolet Radiation, ed. Frederick Urbach (New York: Pergamon Press, 1969), p. 453.

[3]Ernest Fischer and Sidney Solomon, "Physiologic Effects of Ultraviolet Radiation," Therapeutic Electricity and Ultraviolet Radiation, ed. Sidney Licht (2nd ed.; Baltimore: Waverly Press, 1967), p. 292, p. 295.

destruction of red blood cells has been observed in blood and urine following irradiation.[4] Ricci stated that hemoglobin, which is contained in erythrocytes, determines the oxygen carrying capacity of blood.[5] Lower aerobic abilities of small children and females are partly due to lower hemoglobin concentrations in blood.[6] An increased destruction of erythrocytes induced by ultraviolet treatments may have adversely affected oxygen transporting capacity of the blood during the test of physical work capacity. However, blood analyses were not taken to confirm this occurrence.

Vascular changes altering the distribution of blood flow may have impaired physical work capacity. Increased cutaneous blood flow induced by exercise in a hot environment results in a reduced cardiac filling pressure and stroke volume, while an unchanged cardiac output is maintained by tachycardia.[7] Maximum heart rate is approached earlier during exercise in the heat because of an altered distribution of blood flow to the skin and visceral organs, and the ratio of cutaneous blood flow to cardiac output is

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[4]Fischer and Solomon, p. 293.

[5]Benjamin Ricci, Physiological Basis of Human Performance (Philadelphia: Lea and Febiger, 1967), p. 131.

[6]Per-Olof Astrand and Kaare Rodahl, Textbook of Work Physiology (New York: McGraw-Hill Book Company, 1970), p. 311, pp. 330-331.

[7]Loring B. Rowell, "Human Cardiovascular Responses to Exercise," Exercise and the Heart, ed. Robert L. Morse (Springfield, Illinois: Charles C. Thomas, Publishers, 1972), pp. 17-23.

suggested as an index of stress imposed during exercise in a hot environment.[8] A large increase also occurs in cutaneous blood flow during an erythemal response.[9] The effects of cutaneous circulation caused by ultraviolet irradiation may be similar to the stress imposed by increased peripheral circulation induced by a hot environment.

This study did not investigate the occurrence of any of the previously mentioned metabolic or circulatory changes. However, the combined effect of all or several of these as a result of ultraviolet irradiation may have exerted a detrimental effect on physical work capacity.

The reduction in strength observed in this study is difficult to explain, since strength is not as dependent as physical work capacity on circulation.[10] Watkins wrote that irradiation may promote a sense of "lassitude," and the subjects in this study may have developed a lethargic attitude toward a straining activity demanding a maximal exertion.[11]

No evidence can be offered to suggest why two parameters investigated in this study were impaired, while power,

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[8]Loring B. Rowell, "Effects of Strenuous Exercise and Heat Stress on Estimated Hepatic Blood Flow in Normal Men," Physical Activity and the Heart, eds. Martti J. Karvonen and Alan J. Barry (Springfield, Illinois: Charles C. Thomas, Publishers, 1967), pp. 75-76.

[9]Fischer and Solomon, p. 306.

[10]Astrand and Rodahl, p. 88.

[11]Arthur L. Watkins, A Manual of Electrotherapy (2nd ed.; Philadelphia: Lea and Febiger, 1962), p. 52.

speed, and total body response were unaffected. Contrary to strength and physical work capacity, performances in power, speed, and total body response were highly influenced by speed of muscular contractions. Perhaps these three unaffected parameters were more dependent upon skill and less reliant upon physical factors that might be affected by ultraviolet irradiation.

Performance scores between the Trained and Untrained Groups were significantly different in only one parameter investigated, physical work capacity. Appendix D on page 84 and Appendix F on page 86 reveal large ranges in performance that contributed to an increased between subject variance in the statistical treatment of data. This might be partly due to the fact that three different types of athletes (basketball players, wrestlers, and swimmers) were used in this study. Basketball players were capable of performing well in the vertical jump (as exemplified by subjects 34 and 35), but ectomorphic type players (subjects 33 and 34) were weak in elbow flexion strength. Lightweight class wrestlers (subjects 22, 23, 31, and 39) decreased the mean score for the Group in the vertical jump. Several swimmers (subjects 37, 38, and 40) were not adept in total body response, a task unrelated to proficiency in their particular sport. While basketball players and wrestlers usually performed well in total body response, some wrestlers (subjects 31 and 39) achieved low scores that decreased the Group's mean. In the 30-yard sprint, basketball players (exemplified by subjects 25, 32, and 33) were superior to some wrestlers (subjects 26, 31, and 39). A lightweight class wrestler (subject 23) performed below the mean of the Untrained Group in every test except total body response; however, this highly skilled wrestler was very adept in his particular sport. These results imply the principle of specificity of athletic ability endorsed by many physical educators.

CONCLUSIONS

Within the limitations of this study, the following conclusions were made:

1. A single ultraviolet exposure of erythemal intensity impaired performance in physical work capacity and muscular strength.

2. Motor parameters involving speed of muscular contraction were not affected by ultraviolet irradiation.

3. There was no difference with regard to the physical activity of the subjects and their response to an ultraviolet exposure.

4. A single ultraviolet exposure will not serve as an ergogenic aid to improve motor performance, and may be considered ill advised.

RECOMMENDATIONS

A need exists for additional knowledge concerning the effects of ultraviolet irradiation on performance in physical activities. Since past investigations have been predominantly conducted and published in Europe, many American physical educators and sports medicine professionals may be unaware of the possible effects of ultraviolet irradiation on motor performance. Problems worthy of further investigation include:

1. Does the accumulative effect of a series of ultraviolet treatments actually affect performance in competitive athletic events?

2. How is motor performance affected by a single ultraviolet exposure of a greater intensity than that used in this study? Would parameters that were unaffected in the present study be impaired if the subjects were exposed to ultraviolet rays capable of producing a second or third degree erythemal response?

3. What is the relationship between the initial and belated effects of ultraviolet treatments? Do subjects who display impaired performance to an initial exposure respond with favorable gains after receiving a series of treatments? Do subjects who are unaffected by initial treatments also fail to receive beneficial effects that many researchers claim occur as a result of systematic treatments?

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APPENDIX

APPENDIX A

TREATMENT RECORD SHEET

Group - Trained; Untrained

Name ______________________________ Number ______________

First Treatment ____________________

Date ________________ Hour ____________

Second Treatment ________________

Date ________________ Hour ____________

APPENDIX B

MOTOR PERFORMANCE RECORD SHEET

Group - Trained; Untrained

Treatment ______________________

Name ______________________ Weight ______________

Date ______________ Hour ______________

Test Events

Vertical Jump	1	2	3		
Jump Height	____	____	____		Average Foot/Lbs
Reach	____			Ave.	
Jump Distance	____	____	____	____	________

Total Body Response	1	2	3	4	5	
Time	____	____	____	____	____	
Velocity	____	____	____	____	____	
	6	7	8	9	10	Average Velocity
Time	____	____	____	____	____	
Velocity	____	____	____	____	____	________

Strength	1	2	3	Average in Pounds
Tension	____	____	____	
Pounds	____	____	____	________

30-Yard Sprint	1	2	3	Average Velocity
Time	____	____	____	
Velocity	____	____	____	________

	Minutes
Physical Work Capacity	________

APPENDIX C

UNTRAINED GROUP MEAN PERFORMANCE SCORES FOLLOWING INCANDESCENT TREATMENT

Subject	Vertical Power Jump (ft-lbs)	Total Body Response (ft/sec)	Elbow Flexion Strength (lbs)	Thirty Yard Sprint (ft/sec)	Physical Work Ca,acity (min)
1	254.94	6.275	79.92	22.84	18.75
2	247.49	6.600	64.83	23.30	16.50
3	217.84	6.145	67.50	20.77	13.00
4	249.01	6.539	83.33	23.42	22.48
5	299.67	6.756	74.83	23.66	21.70
6	145.83	5.983	75.50	23.19	21.05
7	206.83	6.496	74.33	23.22	14.08
8	229.91	5.955	81.00	21.21	15.08
9	213.60	6.233	70.17	21.98	16.87
10	235.81	6.709	65.83	22.56	20.93
11	200.00	5.861	61.33	21.95	12.98
12	169.27	5.550	62.50	21.55	15.73
13	256.26	6.113	58.00	20.74	19.05
14	232.73	6.319	89.75	21.92	16.68
15	239.58	5.418	61.33	20.58	18.77
16	239.35	6.083	80.83	23.26	21.52
17	254.60	6.065	75.50	21.78	20.22
18	228.93	6.655	67.83	23.18	18.43
19	274.69	6.224	65.00	22.34	14.38
20	211.68	6.046	81.00	23.06	20.03
Mean	230.40	6.201	72.02	22.33	17.91

APPENDIX D

TRAINED GROUP MEAN PERFORMANCE SCORES FOLLOWING INCANDESCENT TREATMENT

Subject	Vertical Power Jump (ft-lbs)	Total Body Response (ft/sec)	Elbow Flexion Strength (lbs)	Thirty Yard Sprint (ft/sec)	Physical Work Capacity (min)
21	250.72	6.719	79.25	23.24	27.65
22	200.28	6.341	71.83	23.26	24.53
23	170.81	6.661	67.67	21.61	17.48
24	221.06	6.393	71.17	23.24	21.53
25	259.60	6.146	91.83	23.50	28.13
26	241.18	6.048	96.75	21.10	30.58
27	203.44	5.901	78.83	23.34	26.07
28	200.81	6.739	96.08	23.16	23.05
29	253.13	6.341	79.25	23.54	22.43
30	218.51	6.063	72.67	22.39	26.05
31	199.74	5.801	65.33	20.12	27.42
32	273.49	7.156	75.33	24.13	22.62
33	259.38	6.889	66.67	23.89	25.87
34	283.40	6.326	61.67	22.13	24.65
35	343.47	6.240	86.67	22.08	26.78
36	229.18	6.509	75.50	23.18	24.63
37	256.90	6.070	63.17	23.94	20.60
38	227.31	6.075	63.67	23.24	21.03
39	179.01	5.923	79.25	20.51	28.08
40	218.29	6.188	97.17	20.30	23.58
Mean	234.74	6.326	76.99	22.60	24.64

APPENDIX E

UNTRAINED GROUP MEAN PERFORMANCE SCORES FOLLOWING ULTRAVIOLET TREATMENT

Subject	Vertical Power Jump (ft-lbs)	Total Body Response (ft/sec)	Elbow Flexion Strength (lbs)	Thirty Yard Sprint (ft/sec)	Physical Work Capacity (min)
1	271.96	6.246	81.67	23.04	18.45
2	254.53	6.301	65.67	22.71	16.77
3	205.10	6.245	76.83	20.95	12.55
4	247.25	6.550	73.50	23.83	22.05
5	274.67	6.859	80.25	23.79	17.97
6	146.81	6.003	73.83	23.02	18.48
7	203.84	6.289	66.50	23.28	14.40
8	238.38	6.096	80.50	21.20	14.58
9	200.69	6.263	65.33	21.84	18.93
10	251.24	6.933	71.83	23.52	21.27
11	201.27	6.126	58.50	22.00	11.07
12	166.03	5.828	63.33	21.55	14.57
13	247.63	5.918	55.17	20.90	19.48
14	237.96	6.385	86.50	21.82	17.05
15	258.56	5.545	58.33	20.49	17.20
16	243.57	6.015	67.75	23.96	20.12
17	249.75	5.899	68.33	21.79	20.63
18	239.34	6.725	56.83	23.16	16.78
19	268.25	6.096	63.50	22.26	14.37
20	209.79	6.199	72.00	22.28	19.75
Mean	230.83	6.226	69.31	22.37	17.32

APPENDIX F

TRAINED GROUP MEAN PERFORMANCE SCORES FOLLOWING ULTRAVIOLET TREATMENT

Subject	Vertical Power Jump (ft-lbs)	Total Body Response (ft/sec)	Elbow Flexion Strength (lbs)	Thirty Yard Sprint (ft/sec)	Physical Work Capacity (min)
21	242.31	5.970	84.83	22.39	25.17
22	199.00	6.481	67.50	23.08	25.12
23	155.56	6.660	66.67	22.12	15.67
24	227.33	6.468	66.67	23.26	20.93
25	273.07	6.318	89.00	23.38	28.42
26	251.56	6.084	90.00	21.71	27.83
27	213.19	6.514	82.67	23.87	24.07
28	198.49	6.409	93.50	23.44	22.17
29	251.56	6.094	72.17	22.86	25.28
30	210.00	6.514	71.33	22.62	24.08
31	197.08	5.969	68.33	20.52	25.98
32	271.14	6.486	67.33	24.13	23.55
33	259.61	6.908	71.50	23.58	25.35
34	293.49	6.204	58.50	22.10	24.08
35	360.64	6.173	92.75	22.08	26.70
36	233.94	6.398	66.50	23.04	24.30
37	275.91	6.001	75.33	23.20	21.15
38	219.26	6.245	62.83	23.10	18.87
39	193.58	6.124	70.33	20.51	27.35
40	190.07	5.865	86.83	21.01	23.08
Mean	235.84	6.294	75.23	22.60	23.96

APPENDIX G

PRODUCT-MOMENT CORRELATION COMPUTATION FOR RELIABILITY OF THE VERTICAL POWER JUMP

Sub	X	Y	x	y	x^2	y^2	xy
1	231.03	211.05	-45.43	-61.35	2063.88	3763.82	2787.13
2	250.79	245.62	-25.67	-26.78	658.95	717.17	687.44
3	307.20	283.73	30.74	11.33	944.95	128.37	348.28
4	240.02	241.86	-36.44	-30.54	1327.87	932.69	1112.88
5	264.42	257.46	-12.04	-14.94	144.96	223.20	179.88
6	224.93	232.29	-51.53	-40.11	2655.34	1608.81	2058.85
7	313.42	336.55	36.96	64.15	1366.04	4115.22	2370.98
8	242.98	243.54	-33.48	-28.86	1120.91	832.90	966.23
9	309.10	305.50	32.64	33.10	1065.37	1095.61	1080.38
10	307.52	275.33	31.06	2.93	964.73	8.58	91.01
11	277.31	276.75	.85	4.35	.72	18.92	3.70
12	235.81	224.84	-40.65	-47.56	1652.42	2261.95	1933.31
13	358.79	326.39	82.33	53.99	6778.23	2914.92	4445.00
14	258.96	248.64	-17.50	-23.76	306.25	564.54	415.80
15	282.92	288.00	6.46	15.60	41.73	243.36	100.78
16	314.17	311.46	37.71	39.06	1422.04	1525.68	1472.95
17	310.56	308.28	34.10	35.88	1162.80	1287.37	1223.51
18	301.10	333.00	24.64	60.60	607.13	3672.36	1493.18
19	221.67	225.25	-54.79	-47.15	3001.94	2223.12	2583.35
	5252.70	5175.54			27286.26	28138.59	25354.64

$\bar{X} = 276.46$

$\bar{Y} = 272.40$

$$r = \frac{xy}{\sqrt{x^2 \cdot y^2}} =$$

$$r = \frac{25354.64}{\sqrt{27286.26 \times 28138.59}} = \frac{25354.64}{\sqrt{767796882.7734}}$$

$$r = \frac{25354.64}{27709.15}$$

$$r = .92$$

APPENDIX H

PRODUCT-MOMENT CORRELATION COMPUTATION FOR RELIABILITY OF TOTAL BODY RESPONSE

Sub	X	Y	x	y	x^2	y^2	xy
1	5.72	5.91	-.62	-.42	.3844	.1764	.2604
2	6.81	6.68	.47	.35	.2209	.1225	.1645
3	6.31	6.39	-.03	.06	.0009	.0036	-.0018
4	6.79	6.85	.45	.52	.2025	.2704	.2340
5	6.12	6.29	-.22	-.04	.0484	.0016	.0088
6	6.25	6.11	-.09	-.22	.0081	.0484	.0198
7	6.67	6.92	.33	.59	.1089	.3481	.1947
8	6.68	6.55	.34	.22	.1156	.0484	.0748
9	6.25	6.04	-.09	-.29	.0081	.0841	.0261
10	6.18	5.98	-.16	-.35	.0256	.1225	.0560
11	6.00	6.27	-.34	-.06	.1156	.0036	.0204
12	6.60	6.52	.26	.19	.0676	.0361	.0494
13	6.08	5.97	-.26	-.36	.0676	.1296	.0936
14	6.27	6.12	-.07	-.21	.0049	.0441	.0147
15	6.45	6.38	.11	.05	.0121	.0025	.0055
16	6.23	6.09	-.11	-.24	.0121	.0576	.0264
17	6.30	6.40	-.04	.07	.0016	.0049	-.0028
18	6.43	6.45	.09	.12	.0081	.0144	.0108
19	6.31	6.39	-.03	.06	.0009	.0036	-.0018
	120.45	120.31			1.4139	1.5224	1.2535

$\bar{X} = 6.34$

$\bar{Y} = 6.33$

$$r = \frac{xy}{\sqrt{x^2 \cdot y^2}}$$

$$r = \frac{1.2535}{\sqrt{1.4139 \times 15224}} = \frac{1.2535}{\sqrt{2.1525213}}$$

$$r = \frac{1.2535}{1.4671}$$

$$r = .85$$

APPENDIX I

PRODUCT-MOMENT CORRELATION COMPUTATION FOR RELIABILITY OF ELBOW FLEXION STRENGTH

Sub	X	Y	x	y	x^2	y^2	xy
1	77.00	75.83	-1.14	-4.57	1.30	20.88	5.21
2	58.67	66.00	-19.47	-14.40	379.08	207.36	280.37
3	89.67	94.00	11.53	13.60	132.94	184.96	156.81
4	73.17	83.50	-4.97	3.10	27.70	9.61	-15.41
5	95.00	84.17	16.86	3.77	284.26	14.21	63.56
6	68.00	80.00	-10.14	-.40	102.82	.16	4.06
7	86.67	94.00	8.53	13.60	72.76	184.96	116.01
8	72.00	65.67	-6.14	-14.73	37.70	216.97	90.44
9	60.33	58.67	-17.81	-21.73	317.20	472.19	387.01
10	85.00	79.17	6.86	-1.23	47.06	1.51	-8.44
11	71.17	78.33	-6.97	-2.07	48.58	4.28	14.43
12	95.50	93.00	17.36	12.60	301.37	158.76	218.74
13	75.33	80.00	-2.81	-.40	7.90	.16	1.12
14	75.50	83.50	-2.64	3.10	6.97	9.61	-8.18
15	70.00	71.00	-8.14	-9.4	66.26	88.36	76.52
16	88.33	86.00	10.19	5.60	103.84	31.36	57.06
17	67.00	73.17	-11.14	-7.23	124.10	52.27	80.54
18	94.00	95.00	15.86	14.60	251.54	213.16	231.16
19	82.33	86.50	4.19	6.10	17.56	37.21	25.56
	1484.67	1527.51			2330.94	1907.98	1776.57

$\bar{X} = 78.14$

$\bar{Y} = 80.40$

$$r = \frac{xy}{\sqrt{x^2 \cdot y^2}}$$

$$r = \frac{1776.57}{\sqrt{2330.94 \times 1907.98}} = \frac{1776.57}{\sqrt{4447386.90}}$$

$$r = \frac{1776.57}{2108.88}$$

$r = .84$

APPENDIX J

PRODUCT-MOMENT CORRELATION COMPUTATION FOR RELIABILITY OF THE THIRTY-YARD SPRINT

Sub	X	Y	x	y	x^2	y^2	xy
1	22.17	22.32	.07	.65	.0049	.4225	.0455
2	22.32	22.39	.22	.72	.0484	.5184	.1584
3	22.61	21.50	.51	-.17	.2601	.0289	-.0867
4	21.79	21.23	-.31	-.44	.0961	.1936	.1364
5	22.73	21.72	.63	.05	.3969	.0025	.0315
6	21.79	21.41	-.31	-.26	.0961	.0676	.0806
7	22.90	22.98	.80	1.31	.6400	1.7161	1.0480
8	22.45	21.81	.35	.14	.1225	.0196	.0490
9	22.71	22.37	.61	.70	.3721	.4900	.4270
10	21.25	20.33	-.85	-1.34	.7225	1.7956	1.1390
11	18.11	17.66	-3.99	-4.01	15.9201	16.0801	15.9999
12	21.63	21.40	-.47	-.27	.2209	.0729	.1269
13	21.38	21.01	-.72	-.66	.5184	.4356	.4752
14	22.54	21.76	.44	.09	.1936	.0081	.0396
15	23.64	23.44	1.54	1.77	2.3716	3.1329	2.7258
16	22.24	21.97	.14	.30	.0196	.0900	.0420
17	22.20	21.11	.10	-.57	.0100	.3249	-.0570
	397.88	390.00			23.7562	29.1242	24.9287

$\bar{X} = 22.10$

$\bar{Y} = 21.67$

$$r = \frac{xy}{\sqrt{x^2 \cdot y^2}}$$

$$r = \frac{24.9287}{\sqrt{23.7562 \times 29.1242}} = \frac{24.9287}{\sqrt{691.8803}}$$

$$r = \frac{24.9287}{26.3036}$$

$$r = .95$$

APPENDIX K

PRODUCT-MOMENT CORRELATION COMPUTATION FOR RELIABILITY OF PHYSICAL WORK CAPACITY

Sub	X	Y	x	y	x^2	y^2	xy
1	18.75	18.45	-2.27	-2.06	5.15	4.24	4.68
2	27.65	25.17	6.63	4.66	43.96	21.72	30.90
3	13.00	12.55	-8.02	-7.96	64.32	63.36	63.84
4	17.48	15.67	-3.54	-4.84	12.53	23.43	17.13
5	21.70	17.97	.68	-2.54	.46	6.45	-1.73
6	28.13	28.42	7.11	7.91	50.55	62.57	56.24
7	14.08	14.40	-6.94	-6.11	48.16	37.33	42.40
8	26.07	24.07	5.05	3.56	25.50	12.67	17.98
9	16.87	18.93	-4.15	-1.58	17.22	2.50	6.56
10	22.43	25.28	1.41	4.77	1.99	22.75	6.73
11	12.98	11.07	-8.04	-9.44	64.64	89.11	75.90
12	27.42	25.98	6.40	5.47	40.96	29.92	35.01
13	19.05	19.48	-1.97	-1.03	3.88	1.06	2.03
14	25.87	25.35	4.85	4.84	23.52	23.43	23.47
15	18.77	17.20	-2.25	-3.31	5.06	10.96	7.45
16	26.78	26.70	5.76	6.19	33.18	38.32	35.65
17	20.22	20.63	-.80	.12	.64	.01	-.10
18	20.60	21.15	-.42	.64	.18	.41	-.27
19	14.38	14.37	-6.64	-6.14	44.09	37.70	40.77
20	28.08	27.35	7.06	6.84	49.84	46.79	48.29
	420.31	410.19			535.83	534.73	512.93

$\bar{X} = 21.02$

$\bar{Y} = 20.51$

$$r = \frac{xy}{\sqrt{x^2 \cdot y^2}}$$

$$r = \frac{512.93}{\sqrt{535.83 \times 534.73}} = \frac{512.93}{\sqrt{286524.37}}$$

$$r = \frac{512.93}{535.28}$$

$$r = .96$$

APPENDIX L

COUNTER-BALANCED SCHEDULE OF LIGHT TREATMENTS

Subject	First Treatment	Second Treatment
1	Incandescent	Ultraviolet
2	Ultraviolet	Incandescent
3	Incandescent	Ultraviolet
4	Ultraviolet	Incandescent
5	Incandescent	Ultraviolet
6	Ultraviolet	Incandescent
7	Incandescent	Ultraviolet
8	Ultraviolet	Incandescent
9	Incandescent	Ultraviolet
10	Ultraviolet	Incandescent
11	Incandescent	Ultraviolet
12	Ultraviolet	Incandescent
13	Incandescent	Ultraviolet
14	Ultraviolet	Incandescent
15	Incandescent	Ultraviolet
16	Ultraviolet	Incandescent
17	Incandescent	Ultraviolet
18	Ultraviolet	Incandescent
19	Incandescent	Ultraviolet
20	Ultraviolet	Incandescent
21	Incandescent	Ultraviolet
22	Ultraviolet	Incandescent
23	Incandescent	Ultraviolet
24	Ultraviolet	Incandescent
25	Incandescent	Ultraviolet
26	Ultraviolet	Incandescent
27	Incandescent	Ultraviolet
28	Ultraviolet	Incandescent
29	Incandescent	Ultraviolet
30	Ultraviolet	Incandescent
31	Incandescent	Ultraviolet
32	Ultraviolet	Incandescent
33	Incandescent	Ultraviolet
34	Ultraviolet	Incandescent
35	Incandescent	Ultraviolet
36	Ultraviolet	Incandescent
37	Incandescent	Ultraviolet
38	Ultraviolet	Incandescent
39	Incandescent	Ultraviolet
40	Ultraviolet	Incandescent

APPENDIX M

COMPUTATION OF ULTRAVIOLET EXPOSURE TIME

Basic Considerations

1. An erythemal dosage is approximately 42 E-viton minutes (2500 E-viton seconds per square centimeter divided by 60 seconds = 41.67 E-viton minutes).[1]

2. The intensity of sunlamps ". . . varies inversely as the square of the distance from the lamp."[2]

3. Intensity decreases as the rays digress from the center of focus. At 7.5 degrees, rays of the RS 275 sunlamp are approximately 92.5 percent of the intensity emitted at the center of focus.[3]

4. The General Electric RS 275 watt sunlamp emits 5.4 E-vitons per square centimeter at a distance of 30 inches.[4]

Computation of Exposure Time

$$\text{Intensity } (36") = \frac{\text{Intensity } (30") \times (30")^2}{(36")^2}$$

$$\text{Intensity } (36") = \frac{5.4 \text{ E-vitons} \times 900}{1296} = 3.75 \text{ E-vitons per cm}^2.$$

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[1] Lewis R. Koller, Ultraviolet Radiation (2nd ed.; New York: John Wiley and Sons, Inc., 1965), pp. 15-19.

[2] Koller, p. 49. [3] Koller, p. 48. [4] Koller, p. 49.

APPENDIX M (continued)

Intensity at 7.5 degrees from center of focus = 92.5 percent of 3.75 E-vitons = 3.47 E-vitons.

Dosage for 12 minutes exposure at the center of focus = 3.75 E-vitons x 12 = 45 E-vitons per square centimeter.

Dosage for 12 minutes exposure at 7.5 degrees from the center of focus = 3.47 E-vitons x 12 = 41.64 E-vitons per square centimeter.

Area Exposed Within 7.5 Degrees From The Center of Focus

Radius = 36 inches x .1317 (tangent of 7.5 degrees)

Radius = 4.74 inches = 12.04 centimeters

Area = Pi x Radius^2 = 3.14 x $(12.04)^2$

Area = 455.17 square centimeters

VITA

Robert Baxter Gantt was born in Albemarle, North Carolina, on April 25, 1930. He completed his public school education in the Albemarle City Schools in 1948.

In 1952 he received the Bachelor of Arts degree, with a major in Physical Education, from the University of North Carolina in Chapel Hill. After serving three years in the United States Marine Corps, the author was employed as a teacher and coach at Albemarle High School. The following year, he returned to the University of North Carolina as a graduate student and received the M.Ed. degree in Physical Education in 1957.

From 1957 through 1962, the author taught physical education and coached various sports (football, wrestling, track, and tennis) at Albemarle Senior High School.

In 1962, he was employed by East Carolina University, Greenville, North Carolina. While teaching in the Department of Health, Physical Education and Recreation, the author served as head wrestling coach for five years and assistant football coach for eight years.

He enrolled at Louisiana State University in 1970 to pursue work toward the Doctor of Philosophy degree in Physical Education. The author is presently an assistant professor of physical education at East Carolina University.

EXAMINATION AND THESIS REPORT

Candidate: Robert Baxter Gantt

Major Field: Health, Physical & Recreation Education

Title of Thesis: The Effect of a Single Exposure of Ultraviolet Rays on Performance in Selected Motor Parameters

Approved:

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

Date of Examination:

April 24, 1975