APPENDIX 3
Modifications to an interactive model
of the human body during exercise:
With special emphasis on thermoregulation

by

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## NOMENCLATURE

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE</td>
<td>Age of the athlete, years</td>
</tr>
<tr>
<td>GAIN1</td>
<td>Gain constant based on level of training</td>
</tr>
<tr>
<td>GAIN2</td>
<td>Gain constant based on level of dehydration</td>
</tr>
<tr>
<td>HT</td>
<td>Height of the athlete, cm</td>
</tr>
<tr>
<td>MKG</td>
<td>Mass of the athlete, kg</td>
</tr>
<tr>
<td>Ts</td>
<td>Mean skin temperature</td>
</tr>
<tr>
<td>T_head</td>
<td>Temperature of the head</td>
</tr>
<tr>
<td>T_arm</td>
<td>Temperature of the arms</td>
</tr>
<tr>
<td>T_hand</td>
<td>Temperature of the hands</td>
</tr>
<tr>
<td>T_ft</td>
<td>Temperature of the feet</td>
</tr>
<tr>
<td>T_leg</td>
<td>Temperature of the legs</td>
</tr>
<tr>
<td>T_th</td>
<td>Temperature of the thighs</td>
</tr>
<tr>
<td>T_tr</td>
<td>Temperature of the trunk</td>
</tr>
<tr>
<td>VO_2max</td>
<td>Maximum oxygen uptake</td>
</tr>
</tbody>
</table>
INTRODUCTION

Since 1988 an interactive computer model of the human body during exercise has been under development by a number of undergraduate students in the Department of Chemical Engineering at Iowa State University. The program, written under the direction of Dr. Richard C. Seagrave, uses physical characteristics of the user, environmental conditions and activity information to predict the onset of hypothermia, hyperthermia, dehydration, or exhaustion for various levels and durations of a specified exercise. The program, however, was severely limited in predicting the onset of dehydration due to the lack of sophistication with which the program predicted sweat rate and its relationship to sensible water loss, degree of acclimatization, and level of physical training. Additionally, it was not known whether sweat rate also depended on age and gender. For these reasons, the goal of this creative component was to modify the program in the above mentioned areas by applying known information and empirical relationships from literature. Furthermore, a secondary goal was to improve the consistency with which the program was written by modifying user input statements and improving the efficiency and logic of the program calculations.

Principle Mechanisms of Heat Transfer During Exercise

The human body exchanges heat with the environment by four basic mechanisms; radiation, conduction, convection, and evaporation. These mechanisms are the same whether heat is imposed to the body metabolically, as in exercise, or environmentally. Radiative heat transfer occurs by the
transmission of electromagnetic heat waves between objects without the involvement of molecular contact. Heat transfer by radiation may result in either heat loss or gain depending on conditions in the environment. For example, when a person is cooler than the surroundings, he/she will absorb radiant heat energy. Conversely, when a person is warmer than the surroundings, he/she will lose heat to the environment.

Conductive heat transfer occurs when heat energy is transferred between objects by direct physical contact. Approximately three percent of a person’s total heat loss at rest in a room temperature environment occurs via this mechanism (Brooks et al., 1987). Therefore, during exercise, heat loss by means of conduction is considered negligible. Conduction also occurs within the body itself as heat is conducted from the inner core to the skin or vice versa depending on the temperature gradient.

Convective heat transfer, a form of conduction of heat to a fluid, occurs via the circulation of air molecules adjacent to the skin. As air molecules are warmed, they become less dense, rise away from the body, and are displaced by cooler molecules. During exercise in air, heat loss due to convection is influenced by both the velocity of the athlete and the wind.

Finally, evaporative heat transfer occurs by way of the change of liquid water on the surface of the skin to gaseous water vapor in the environment. Evaporative heat transfer is the most important mechanism of heat transfer during exercise. In evaporation, heat is transferred from the body to water on the surface of the skin. When the water has gained sufficient energy, approximately 0.58 kilocalories per gram of water depending on the skin temperature, it vaporizes and heat is removed from the skin. It is important to note that unlike
radiation, conduction, and convection which occur because of temperature gradients, evaporation is driven by a gradient in the vapor pressure. During exercise, this fact is especially salient in an environment where the ambient temperature and relative humidity are high. In this situation, the body gains heat by convection and radiation, and evaporation becomes the only mechanism by which the body can lose heat. However, when the relative humidity is high, temperature regulation becomes more difficult because the vapor pressure of the air is close to that of moist skin. Therefore, the rate of evaporation is greatly reduced. Sweating in these environments results in sensible water loss that can lead to dehydration without a cooling effect to the skin (McArdle, 1986).

In addition to the four basic mechanisms of heat transfer, heat loss via respiration (a combined mechanism) must also be considered during exercise. Respiratory energy losses occur via the evaporation of water in the lungs and respiratory tract as well as by the convective cooling effect of breathing.

**Physiological Control of Heat Transfer During Exercise**

There are two principle mechanisms by which the body can control the balance between heat production and heat loss during exercise. First, the body can change its surface temperature by altering blood flow to the skin. When blood vessels to the skin dilate (vasodilation), warm blood from the core of the body is brought to the surface where heat is lost via radiation and convection. Conversely, when these blood vessels constrict (vasoconstriction), heat is conserved in the inner core and less heat is lost to the surroundings. Second, the body can regulate the rate of sweating.
These physiological mechanisms are governed by the thermoregulatory center located in the hypothalamus. The hypothalamus functions as the body's thermostat by maintaining the body core temperature within a narrow range around its set-point of 37 degrees Celsius. When the core temperature increases above or decreases below this set-point, the hypothalamus initiates a response to increase or decrease heat production or facilitate heat loss.

The anterior hypothalamus reacts to increases in body heat, while the posterior hypothalamus is responsible for regulating reactions to a cold environment (Åstrand, 1986). Therefore, when the anterior hypothalamus senses an increase in core temperature above the set-point, it stimulates the sweat glands resulting in increased evaporative cooling. In addition, normal vasoconstriction is inhibited and blood flow to the skin is promoted. Conversely, when the posterior hypothalamus senses a decrease in core temperature below the set-point, the vasomotor center causes the peripheral blood vessels to constrict and, if the core temperature drops significantly, shivering commences.

LITERATURE REVIEW

Numerous reviews on the subject of exercise thermoregulation have been written in the past two and a half decades. For additional information on this subject, the reader is referred to two of the more recent reviews, Gisolfi et al. (1984) and Buskirk (1977).
Before specifically addressing the areas of interest of this work, it is necessary to provide background information regarding the relationships of physiological variables such as skin and core temperature to effector responses.

Since body tissue temperatures differ based on local rates of heat production and heat exchange as well as heat transfer between locations in the body, definitions are necessary to specify these variations. This paper will only consider the differences between core and skin temperatures.

Deep-body, or core temperature, is usually measured at one of three locations; rectum, esophagus or the tympanic membrane. These estimates of core temperature are not wholly equivalent to each other, but have been shown to vary in parallel and are thus effective measures of relative changes (Åstrand, 1986).

Skin temperature can be determined by assigning weights to specific skin temperature measurements at various locations on the body in proportion to the fraction of the body’s total surface area represented by that location. The most commonly used formula which was developed by Hardy and Dubois follows (Åstrand, 1986):

\[ T_s = 0.07 \, T_{\text{head}} + 0.14 \, T_{\text{arm}} + 0.05 \, T_{\text{hand}} + 0.07 \, T_{\text{ft}} + 0.13 \, T_{\text{leg}} + 0.19 \, T_{\text{th}} + 0.35 \, T_{\text{tr}} \]

It is generally accepted that skin temperature is dependent on the environmental temperature surrounding the skin and is relatively independent of exercise load. Conversely, the core temperature is independent of the ambient temperature and is largely dependent on the relative exercise load, as expressed as a percentage of maximum oxygen uptake, \( VO_2 \, \text{max} \) (Åstrand, 1986). For example, if two people perform the same absolute work load but have different
maximum oxygen uptakes, the person with the lower VO$_2$ max will experience a greater rise in core temperature. However, if the same two people exercise at the same percentage VO$_2$ max, their core temperatures should increase by approximately the same amount.

In contrast, sweat rate is more closely related to the absolute work load than to relative work load (Buskirk, 1977). Furthermore, body core temperature can be as much as ten times more influential on sweat rate than skin temperature (Wyndham, 1965). Wyss et al. (1974) supported this finding by concluding that sweat rate was virtually independent of steady state skin temperature and that body core temperature was the dominant factor in skin blood flow, heart rate and sweat rate determination. Additionally, Davis et al. (1976) concluded that skin temperature was independent of evaporative sweat loss and relative exercise load.

**Effects of Heat Acclimatization and Physical Training**

Adaptations to sweating are typically caused by both an exercise and a heat effect (Nadel et al., 1974). However, it has been shown that these adaptations occur via two different mechanisms. Physical training results in enhanced sweating at a given level of central drive. The increased metabolic rate during training increases thermoregulatory demand and induces an increased peripheral sensitivity of the sweat glands (Nadel et al., 1974). In other words, physical training increases the slope of the sweat rate versus core temperature relationship. Nadel et al. (1974) noted an increase of 67 percent in this slope as a result of ten consecutive days of one hour exercise at a relative exercise intensity of 70 to 80 percent VO$_2$ max.
In contrast to physical training, heat acclimatization lowers the threshold core temperature at which sweating starts, increases sweating capacity, decreases skin temperature, and reduces the heart rate (Nadel et al., 1974; Fortney and Senay, 1979; Frye and Kamon, 1981; Horstman and Christensen, 1982). Nadel et al. (1974) noted a 0.3 degree Celsius decrease in the threshold core temperature, while Brooks et al. (1987) noted a three fold increase in sweating capacity from 1.5 to 4 kilograms per hour as a result of heat acclimatization.

According to Bass (1963), the acclimatization process begins on the first day of exposure and is well developed in 4 - 7 days. It can be induced by short intermittent periods of work or exercise in the heat, and is retained during periods of no exposure for about two weeks. Additionally, persons in good physical condition tend to acclimatize more rapidly than unfit subjects. However, physical training cannot replace heat acclimatization (Strydom et al., 1966; Gisolfi and Cohen, 1979). Training results in partial acclimatization that may improve heat tolerance by up to 50 percent (Gisolfi and Cohen, 1979), but training alone cannot substitute for exercise in the heat.

Figure 1 of Appendix A illustrates schematically the effects on sweat rate of both heat acclimatization and physical training discussed above.

**Effect of Dehydration**

As noted previously, athletes who exercise for prolonged periods can lose up to four liters of body fluids in the form of sweat and can experience a total weight loss of seven to eight percent of body weight during an endurance event such as a marathon (Lamb, 1984). Since the body contains only 40 liters of fluid, of which 5 liters are blood, loss of a large portion of this fluid results in a decrease
in blood volume, cardiac output, and blood pressure. A loss of two to three liters of body fluids during exercise causes a reduction in sweating which results in an increase in core temperature (Nadel, 1979). The data of Greenleaf and Castle (1971) show that at a level of dehydration equivalent to loss of fluid equal to about five percent body weight, core temperature increases significantly due to inadequate sweating. Nadel (1979) further postulates that dehydration causes a reduction in the sensitivity of the sweat rate. In other words, dehydration decreases the slope of the sweat rate versus core temperature relationship. Please refer to Figure 2 in Appendix A for a schematic illustration of this effect.

**Effects of Age and Gender**

Although the experimental data are limited, the evidence in literature suggests that there are few differences in the thermoregulatory responses which can be ascribed to age and gender (Davies, 1979). Studies by Drinkwater et al. (1982) show that the functional capacity of the sweating mechanism in healthy older women does not decrease with age. Additionally, no differences were reported between the sexes with respect to sweat rate or efficiency in dry heat, but women maintained a higher sweating efficiency in humid heat (Frye and Kamon, 1983). This increased efficiency allows women to conserve body water while maintaining a similar core temperature to that of men. In other words, for the same degree of evaporative cooling, women secrete less wasteful sweat. When men and women of similar fitness levels are compared, the previously reported gender differences with respect to heat exposure disappear (Avellini et al., 1980). Furthermore, Horstman and Christensen (1982) concluded that active
men and women compared at the same level of relative exercise intensity performed exercise equally well in dry heat.

PROGRAM MODIFICATIONS

As many individuals had modified various parts of the program over the past four years, the program contained inconsistencies. Therefore, to improve the program two types of modifications were made; organizational changes and functional changes. Organizational changes involve modifications that changed the order in which the program performed specific operations. Functional changes are modifications that improved specific functions of the program, i.e. the consistency of wording in the user input statements, or changes to specific calculations.

In addition to the organizational and functional changes, specific modifications were made to the program as a result of information found in the literature. Modifications were made to account for the following effects; physical training, acclimatization to heat, and dehydration. Additionally, a modification was made to correct the program for its premature prediction of the onset of dehydration. Please refer to the program listing in Appendix C for an updated version of the program.

Organizational Changes

Modifications which improve the flow and efficiency of the program are described below. Please refer to the flow diagram in Figure 3 of Appendix A for more detailed information regarding the general organization of the program.
(1) The main program was divided into four sections: (a) user input, (b) calculation of constants and initial values, (c) calculation of material and energy balances, (d) calls for subroutines to calculate fuel usage, print summary information, and plot data.

(2) The section which prints summary information was rewritten as a subroutine (PRINTAB).

(3) The order of the user input statement was improved. The program now asks the user to input information in the following order; personal physical characteristics, environmental conditions and activity information.

(4) All format statements were moved to the end of the program or subroutine to which they apply.

Functional Changes

In order to improve the consistency of the program and the manner in which certain calculations are performed, the following modifications were made:

(1) The number of variables and constants defined within the program was increased.

(2) The language of the variable and constant definitions was improved to maintain consistent use of language throughout the list. Units of the variable or constant were also included in the definition.

(3) Additional tests were added in the user input section to ensure valid information is entered.

(4) Screen stops were added for all output printed to the screen.

(5) The consistency of the language in the user input section was improved.

(6) All FORTRAN ‘print’ statements were changed to ‘write’ statements to facilitate future modifications to input/output formats.
(7) A question regarding the user's gender was added to the input section.

(8) A subroutine PLOTDATA was added to plot program results versus time. These results include: core temperature, heat loss, body weight, and skin temperature.

(9) Revised expressions were added to calculate basal metabolic rate (Olson, 1992). The expressions follow:

Female: \( \text{BASAL (kcal/day)} = 655.1 + 9.563 \text{ MKG} + 1.850 \text{ HT} - 4.676 \text{ AGE} \)

Male: \( \text{BASAL (kcal/day)} = 66.5 + 13.75 \text{ MKG} + 5.003 \text{ HT} - 6.775 \text{ AGE} \)

**Correction for Premature Prediction of Dehydration**

Several simulations of the program at various levels and durations of exercise indicated that the program prematurely predicted the onset of dehydration. This occurred because the sweat rate equations estimate a high amount of sensible water loss as run-off. It is postulated by Seagrave that high quantities of run-off are estimated because Nielsen's (1969) sweat rate measurements were taken after steady state temperatures had been achieved. However, the program uses these sweat rate estimations in an unsteady state capacity. According to Kerslake (1963), loss of sweat by dripping does not begin until the sweat rate has reached one-third of the maximum evaporative capacity. Therefore, to improve the program, it is necessary to determine the point at which sweat run-off commences.

The program was modified by adding a statement to calculate one-third maximum evaporative capacity, the point at which sweating begins. If the sweat rate has not reached this point, the program uses the rate of evaporative mass transfer as an estimation of the water loss. However, if the sweat rate has
reached one-third maximum evaporative capacity, the program uses the water loss calculated by the WATERLOSS subroutine.

Effect of Heat Acclimatization

Before any modifications could be made to the program, the existing sweat rate equations in the WATERLOSS subroutine had to be modified. These equations had been extrapolated by Woodard from data given in Nielson (1969). These relationships expressed sweat rate as a function of skin temperature at given metabolic rates and skin temperatures. These relationships were modified to express sweat rate as function of body core temperature, rather than skin temperature. To make this modification, core temperature, skin temperature and sweat rate data were generated using the program. Subsequently, linear regressions were performed on the data to generate equations which expressed sweat rate as a function of body core temperature for given skin temperatures and metabolic rates. Please see Table 1 in Appendix B for the revised sweat rate equations.

To account for heat acclimatization, two modifications were made. First, if the athlete is both acclimatized to heat and physically trained, the maximum sweat rate (MAXSR) is set to 4.0 kilograms per hour and the set-point of the body core temperature is lowered by 0.3 degrees Celsius to 36.7 degrees. However, if the athlete is not acclimated to heat, the maximum sweat rate is set to 1.5 kilograms per hour and the body core temperature is set to the standard set-point of 37 degrees Celsius.
**Effect of Physical Training**

To modify the program for the effect of physical training on sweat rate, statements were added to section 2 of the main program to change the slope of the sweat rate equations that appear in subroutine WATERLOSS. If an athlete is trained, GAIN1 is set to 1.65, or the slope of the sweat rate equation is increased by 65%. However, if the athlete is not trained, there is no change to the slope of the sweat rate equation and GAIN1 is set equal to 1.0.

**Effect of Dehydration**

To account for the effect of dehydration, statements were added to adjust the slope of the sweat rate equations in the WATERLOSS subroutine as dehydration progresses. The gain constants were chosen somewhat arbitrarily due to the lack of specific numerical information provided in the literature. However, statements were added in section 3 of the main program to adjust the slope of the sweat rate equations in the following manner; when the body is less than one percent dehydrated, no change is made to the slope of the sweat rate equation or GAIN2 is set to 1.0. When total dehydration is between one and two percent, the slope of the sweat rate equation is decreased by five percent or GAIN2 is set to 0.95. For increasing percentages of dehydration, the slope is decreased in ten percent increments to a maximum level of dehydration of five percent of the total body weight. At this level of dehydration, the slope of the sweat rate equation has been decreased a total of 35 percent.
RECOMMENDATIONS FOR FUTURE WORK

In order to improve the program the following recommendations are provided as areas of future work:

(1) Modify the program to account for partial acclimatization to heat.

(2) Modify the program to account for the fact that women are less wasteful sweaters.

(3) Add sweat rate equations for metabolic rates greater than 1700 kilocalories per hour.

(4) Further quantify the effect of dehydration on sweat rate.

(5) Determine the effect of cold acclimatization on exercise thermoregulation.

(6) Quantify the effect of transverse wind velocity on the total velocity.

(7) Quantify maximum glucose usage for all exercises included in the program.
LITERATURE CITED


Olson, C. E., 1992. Integration of human material and energy balance in life support system descriptions, AeroE 499 Project, Iowa State University, Ames, IA.

Woodard, L. K., 1988. Model of the human body during exercise, ChE 490 Project, Iowa State University, Ames, IA.


ACKNOWLEDGMENTS

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Additionally, I would like to thank the NASA Advanced Life Support Division and Honeywell Foundation for the financial support provided throughout the duration of my graduate study at Iowa State University.
Figure 1: Chest sweating rate as a function of esophageal temperature prior to acclimatization, following 10 days of physical training and following 10 day of heat acclimatization. (Taken from Nadel, 1974)

Figure 2: A schematic representation of one possible effect of dehydration on the sweating rate as a function of internal temperature. (Taken from Nadel, 1979)
Figure 3: Flow Diagram of a Model of the Human Body During Exercise
APPENDIX B:
### Table 1: Revised Sweat Rate Equations

<table>
<thead>
<tr>
<th>Metabolic Rate (kcal/hour)</th>
<th>TSC Constraint(s) (Deg. C)</th>
<th>Regression Equation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 300</td>
<td>None</td>
<td>DSWEAT = 0.046122 TBC - 1.16399</td>
</tr>
<tr>
<td>301 - 500</td>
<td>&lt;= 33.0</td>
<td>DSWEAT = 0.063091 TBC - 1.53415</td>
</tr>
<tr>
<td></td>
<td>&gt; 33.0</td>
<td>DSWEAT = 0.295611 TBC - 9.53531</td>
</tr>
<tr>
<td>501 - 700</td>
<td>&lt;= 33.4</td>
<td>DSWEAT = 0.091916 TBC - 2.21063</td>
</tr>
<tr>
<td></td>
<td>&gt; 33.4</td>
<td>DSWEAT = 0.512109 TBC - 16.9846</td>
</tr>
<tr>
<td>701 - 900</td>
<td>&lt;= 32.0</td>
<td>DSWEAT = 0.223172 TBC - 6.03852</td>
</tr>
<tr>
<td></td>
<td>&gt; 32.0</td>
<td>DSWEAT = 0.390976 TBC - 11.8576</td>
</tr>
<tr>
<td>901 - 1100</td>
<td>None</td>
<td>DSWEAT = 0.256577 TBC - 5.75055</td>
</tr>
<tr>
<td>1101 - 1300</td>
<td>&lt;= 29.0</td>
<td>DSWEAT = 0.439115 TBC - 12.3871</td>
</tr>
<tr>
<td></td>
<td>&gt; 29.0</td>
<td>DSWEAT = 0.314289 TBC - 8.09200</td>
</tr>
<tr>
<td>1301 - 1500</td>
<td>&lt;= 28.6</td>
<td>DSWEAT = 0.699080 TBC - 21.2381</td>
</tr>
<tr>
<td></td>
<td>&gt; 28.6</td>
<td>DSWEAT = 0.227225 TBC - 4.99327</td>
</tr>
<tr>
<td>1501 - 1700</td>
<td>None</td>
<td>DSWEAT = 0.053090 TBC + 1.639657</td>
</tr>
</tbody>
</table>
APPENDIX C: PROGRAM LISTING
MODEL OF THE HUMAN BODY AND EXERCISE

REAL Y,N,WTLBS, MKG, TIC, WMPH, WMETPS, BASAL, GAIN1, GAIN2
REAL RHUM, MDOT, VMPH, VMETPS, VELTOT, TBC, HV, PA, YA, AIRMOL
REAL VAIRL, VOMAX, MILE, IPVO, PVO, SGLU, TSC, DSWEAT, PS, SWEAT, DTB
REAL TSWEAT, DGLU, GLU, QRES, QEVAP, QCONV, QRAD, QTOT, CB, AC, HC, CA
REAL KG, AV, AR, HR, TIF, VOL, LRA, CLO, K, YARRAY(40), WATERLOSS
REAL CHFRAC, LFRAC, CHEQ, LIPEQ, TOTCAL, CHCAL, LIPCAL, CALEQ
REAL LIPUSED, CHUSED, BCM, BCMB, QUAD, HAM, BICEP, TRICEP, CALF
REAL HTVAP, DRAIN, DRIP, MAXSR, TS

CHARACTER ANS*4, C*1, WW*3, GENDER*1, ICASE*1
CHARACTER NAME*50, EXDESC*50, CLOTHES*50, BOXANS*15, FRAME*15

INTEGER I*, F, NUMDAT, ICLO, CHOICE, I, XARRAY(40)
INTEGER AGE, FT, IN, MIN, SEC, TMAX, ACTLEV, ACCLEV

COMMON NAME, FF, IN, WTLBS, AGE, CLOTHES, MIN, SEC, ACTLEV, EXDESC
COMMON MDOT, VOL, VMPH, TIF, RHUM, WMPH, TS, CBW, CBT, FTSC, TOTCAL
COMMON CHCAL, LIPCAL, CHUSED, LIPUSED, TIME

write(*,2) 'This program is designed to inform well trained'
write(*,*) 'and novice athletes how long they may exercise at'
write(*,*) 'a certain level before one of the following'
write(*,*) 'conditions occur:
write(*,1)
write(*,3) 'a) hyperthermia: estimated core temperature'
write(*,3) 'surpasses 40 Deg. C (104 Deg. F)'
write(*,3) 'b) dehydration: loss of body water exceeds 5%'
write(*,3) 'of body weight'
write(*,3) 'c) estimated muscle glycogen supply exceeded'
write(*,3) 'd) hypothermia: estimated core temperature'
write(*,3) 'drops below 34 Deg. C (92 Deg. F)'
write(*,1)

PROGRAM VARIABLES/CONSTANTS

VARIABLE/CONSTANT DESCRIPTION

AC Body area available for convection (94% total body area, m^2)
ACCLEV Level of acclimatization of user (heat, cold, unacclimatized)
ACTLEV Activity level of user (trained/untrained)
AGE Age of the athlete (years)
<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIRMOL</td>
<td>Air intake conversion (mol/hr)</td>
</tr>
<tr>
<td>ANS</td>
<td>Answer to question (yes/no)</td>
</tr>
<tr>
<td>AR</td>
<td>Body area available for radiation (78% total body area, m^2)</td>
</tr>
<tr>
<td>AV</td>
<td>Body area available for evaporation (15% total body area, m^2)</td>
</tr>
<tr>
<td>BASAL</td>
<td>Basal metabolic rate (kcal/min)</td>
</tr>
<tr>
<td>BCM</td>
<td>Volume of body (m^3)</td>
</tr>
<tr>
<td>BCMB</td>
<td>Volume of body taking into account body build (m^3)</td>
</tr>
<tr>
<td>HAM</td>
<td>Glycogen content in hamstrings (mmol)</td>
</tr>
<tr>
<td>BICEP</td>
<td>Glycogen content in bicep (mmol)</td>
</tr>
<tr>
<td>BSA</td>
<td>Surface area of body as a function of athlete height and mass (m^2)</td>
</tr>
<tr>
<td>CA</td>
<td>Heat capacity of air (kcal/gmole*Deg. C)</td>
</tr>
<tr>
<td>CALF</td>
<td>Glycogen content in calf (mmol)</td>
</tr>
<tr>
<td>CB</td>
<td>Heat capacity of the body (kcal/kg*Deg. C)</td>
</tr>
<tr>
<td>CBT</td>
<td>Current body temperature (Deg. F)</td>
</tr>
<tr>
<td>CBW</td>
<td>Current body weight (lbs)</td>
</tr>
<tr>
<td>CLO</td>
<td>Clothing correction factor</td>
</tr>
<tr>
<td>CU</td>
<td>Carbohydrates used by muscle (grams)</td>
</tr>
<tr>
<td>DGLU</td>
<td>Glucose used initially (grams)</td>
</tr>
<tr>
<td>DRIP</td>
<td>One-third maximum evaporative capacity (kcal/min)</td>
</tr>
<tr>
<td>DSWEAT</td>
<td>Sweat rate as a function of skin temperature (kg/hr)</td>
</tr>
<tr>
<td>DTB</td>
<td>Body temperature change (Deg. C/6 sec)</td>
</tr>
<tr>
<td>EMAX</td>
<td>Maximum evaporative capacity (kcal/6 sec)</td>
</tr>
<tr>
<td>EXDESC</td>
<td>Type of exercise</td>
</tr>
<tr>
<td>FRAME</td>
<td>Body frame size of user (small/medium/large)</td>
</tr>
<tr>
<td>FT</td>
<td>Height of user (inches)</td>
</tr>
<tr>
<td>FTSC</td>
<td>Skin temperature (Deg. F)</td>
</tr>
<tr>
<td>GAIN1</td>
<td>Gain constant used in modifying sweat rate based on level of training</td>
</tr>
<tr>
<td>GAIN2</td>
<td>Gain constant used in modifying sweat rate based on level of dehydration</td>
</tr>
<tr>
<td>GENDER</td>
<td>Gender of the user (male/female)</td>
</tr>
<tr>
<td>GLU</td>
<td>Glucose used (grams/6 sec)</td>
</tr>
<tr>
<td>HC</td>
<td>Convective heat transfer coef. (kcal/(m^2<em>hr</em>C))</td>
</tr>
<tr>
<td>HR</td>
<td>Radiative heat transfer coef. (kcal/(m^2<em>hr</em>C))</td>
</tr>
<tr>
<td>HD</td>
<td>Difference between heat generated and heat lost</td>
</tr>
<tr>
<td>HT</td>
<td>Height of user (cm)</td>
</tr>
<tr>
<td>HV</td>
<td>Heat transfer coefficient for vaporization (kcal/(m^2<em>hr</em>mmHg))</td>
</tr>
<tr>
<td>HVAP</td>
<td>Heat of vaporization of water @ 37 Deg. C (kcal/mol)</td>
</tr>
<tr>
<td>ICLO</td>
<td>Input indication of user clothing factor</td>
</tr>
<tr>
<td>IOPTION</td>
<td>Program calculation option</td>
</tr>
<tr>
<td>KG</td>
<td>Mass transfer coefficient for evaporation of water (kg/(hr<em>mmHg</em>m^2))</td>
</tr>
<tr>
<td>MAXSR</td>
<td>Maximum sweat rate depending on level of acclimatization (kg/hr)</td>
</tr>
<tr>
<td>MDOT</td>
<td>Metabolic energy rate (kcal/hr)</td>
</tr>
<tr>
<td>MILE</td>
<td>Time of mile (min)</td>
</tr>
<tr>
<td>MIN</td>
<td>Time of mile (min)</td>
</tr>
<tr>
<td>Variable</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>MKG</td>
<td>Athlete's mass (kg)</td>
</tr>
<tr>
<td>N</td>
<td>No, answer to question</td>
</tr>
<tr>
<td>NAME</td>
<td>Name of program user</td>
</tr>
<tr>
<td>NUMDAT</td>
<td>Counter used to determine number of data points sent to output file</td>
</tr>
<tr>
<td>PA</td>
<td>Vapor pressure of water at ambient temperature using the Antoine equation (mmHg)</td>
</tr>
<tr>
<td>PS</td>
<td>Vapor pressure of water at skin temperature using the Antoine equation (mmHg)</td>
</tr>
<tr>
<td>PVO</td>
<td>Percent maximum oxygen capacity required for a certain level of exercise (%)</td>
</tr>
<tr>
<td>QCONV</td>
<td>Heat transfer by convection (kcal/min)</td>
</tr>
<tr>
<td>QEVAP</td>
<td>Heat transfer by evaporation (kcal/min)</td>
</tr>
<tr>
<td>QRAD</td>
<td>Heat transfer by radiation (kcal/min)</td>
</tr>
<tr>
<td>QRES</td>
<td>Energy lost in respiration (kcal/min)</td>
</tr>
<tr>
<td>QTOT</td>
<td>Total heat transfer (kcal/min)</td>
</tr>
<tr>
<td>QUAD</td>
<td>Glycogen content in quad (mmol)</td>
</tr>
<tr>
<td>RHUM</td>
<td>Relative humidity</td>
</tr>
<tr>
<td>SEC</td>
<td>Time of mile (s)</td>
</tr>
<tr>
<td>SGLU</td>
<td>Rate of glucose consumption at a certain level of exercise (mmol/kg*min)</td>
</tr>
<tr>
<td>SKO</td>
<td>Thermal conductivity of skin at given body core temperature (kcal/(m<em>min</em>Deg. C))</td>
</tr>
<tr>
<td>SWEAT</td>
<td>DSWEAT conversion (kg/6 sec)</td>
</tr>
<tr>
<td>TBC</td>
<td>Body core temperature (Deg. C)</td>
</tr>
<tr>
<td>TIC</td>
<td>Initial ambient temperature (Deg. C)</td>
</tr>
<tr>
<td>TRICEP</td>
<td>Glycogen content in tricep (mmol)</td>
</tr>
<tr>
<td>TSC</td>
<td>Relation for body skin temperature</td>
</tr>
<tr>
<td>TSWEAT</td>
<td>Added water loss (kg)</td>
</tr>
<tr>
<td>TT</td>
<td>Time counter (min)</td>
</tr>
<tr>
<td>VAIRL</td>
<td>Rate of air intake for a particular exercise wrt MDOT (l/min)</td>
</tr>
<tr>
<td>VMETPS</td>
<td>Velocity created by the athlete (m/s)</td>
</tr>
<tr>
<td>VMPH</td>
<td>Velocity created by the athlete (miles/hr)</td>
</tr>
<tr>
<td>VELTOT</td>
<td>Total net velocity of the wind (created by the athlete and the environmental conditions)</td>
</tr>
<tr>
<td>VOL</td>
<td>Required oxygen consumption for a particular exercise</td>
</tr>
<tr>
<td>VOMAX</td>
<td>Variable for maximum oxygen capacity of a particular athlete</td>
</tr>
<tr>
<td>WMETPS</td>
<td>Wind velocity (m/s)</td>
</tr>
<tr>
<td>WMPH</td>
<td>Wind velocity (miles/hr)</td>
</tr>
<tr>
<td>WTLBS</td>
<td>Athlete's weight (lbs)</td>
</tr>
<tr>
<td>WW</td>
<td>Response to wind direction question</td>
</tr>
<tr>
<td>Y</td>
<td>Yes, answer to question</td>
</tr>
<tr>
<td>YA</td>
<td>Mole fraction of water in air</td>
</tr>
<tr>
<td>Z</td>
<td>Rate of mass transfer by evaporation (kg/hr)</td>
</tr>
</tbody>
</table>
SECTION 1: This section asks the user to input their physical characteristics, environmental conditions, and the desired type of exercise.

--- Enter physical characteristics

write(*,2) 'Please enter your name (50 character max): >'
read(*,4) NAME

write(*,2) 'Gender is used in calculating basal metabolic rate.'
write(*,1)
write(*,*) 'If you are a female, please enter F; if you are a male, please enter M: >'
read (*,4) GENDER

if ((GENDER .NE. 'F') .AND. (GENDER .NE. 'M') .AND. (GENDER .NE. 'f') .AND. (GENDER .NE. 'm')) then
    write(*,.5)
end if

write(*,2) 'This program is designed for athletes between the ages of 18 and 75.'
write(*,1)
write(*,*) 'Please enter your age in years: >'
read(*,*) AGE

if ((AGE .LT. 18) .OR. (AGE .GT. 75)) then
    write(*,.5)
end if

write(*,2) 'Please enter your height (feet,inches): >'
read(*,*) FT,IN

if ((FT .LT. 0) .OR. (IN .LT. 0) .OR. (IN .GT. 12) .OR. FT .GT. 7) then
    write(*,5)
end if

write(*,2) 'Please enter your body weight (60 - 300 lbs): >'
read(*,*) WTLBS

if ((WTLBS .LT. 60) .OR. (WTLBS .GT. 300)) then
    write(*,5)
GOTO 12
end if

13 write(2,'Please enter your approximate muscular build: >'
write(1,'small, medium, large')
read(4) FRAME

if ( (FRAME .NE. 'small') .AND. (FRAME .NE. 'large')
+ .AND. (FRAME .NE. 'medium')) then
  write(5)
  GOTO 13
end if

14 write(2,'Enter the number which best corresponds to your'
write(1,'clothing (in addition to your shoes): >'
write(1)
write(2) 'Shorts only, enter 1.'
write(2) 'Shorts and short-sleeve shirt or singlet, enter 2.'
write(2) 'Shorts and long-sleeve shirt, enter 3.'
write(2) 'Legs covered and long-sleeve shirt, enter 4.'
write(2) 'Legs, arms, hands, and head all covered, enter 5.'
read(4) ICLO

if (ICLO .NE. 1 .AND. ICLO .NE. 2 .AND. ICLO .NE. 3
+ .AND. ICLO .NE. 4 .AND. ICLO .NE. 5) then
  write(5)
  GOTO 14
end if

C — Environmental conditions

15 write(2,'Please enter the air temperature (-40 to 120 Deg. F): >'
read(4) TIF

if ( (TIF .LT. -40.0) .OR. (TIF .GT. 120)) then
  write(5)
  GOTO 15
end if

16 write(2,'Please enter wind velocity (0 - 50 miles/hr): >'
read(4) WMPH

if ( (WMPH .GT. 50.0) .OR. (WMPH .LT. 0.0)) then
  write(5)
  GOTO 16
end if

if (WMPH .EQ. 0.0) then
  WMPH = WMPH + 1.0 ! Add 1 mph to account for free convection
  GOTO 17
end if
write(*,1) 'On the average, is the wind opposing you (A) or'
write(*,*) 'following you (F), or neither (N)?'
write(*,*) 'Please enter either A, F, or N: >'
read(*,4) WW

if (WW .NE. 'A') .AND. (WW .NE. 'a') .AND.
+ (WW .NE. 'F') .AND. (WW .NE. 'f') .AND. (WW .NE. 'N') .AND. (WW .NE. 'n')) then
  write(*,5)
  GOTO 25
end if

write(*,2) 'Please enter the relative humidity as a decimal: >'
read(*,*) RHUM

if ((RHUM .LT. 0.0) .OR. (RHUM .GT. 1.0)) then
  write(*,5)
  GOTO 17
end if

— Enter activity information (duration,level,type)

write(*,2) 'Would you like the program to:'
write(*,3) '(1) recommend a duration of exercise?'
write(*,3) '(2) allow you to choose a duration of exercise?'
write(*,1)
write(*,*) 'Please enter 1 or 2: >'
read(*,*) IOPTION

if (IOPTION .NE. 1 .AND. IOPTION .NE. 2) then
  write(*,5)
  GOTO 18
end if

if (IOPTION .EQ. 1) then
  TTMAX = 300
else
write(*,2) 'Please enter the duration of exercise (1 - 300 min): >'
read(*,*) TTMAX
  if ((TTMAX .LE. 0) .OR. (TTMAX .GT. 300)) then
    write(*,5)
    GOTO 19
  end if
end if

if (TT .GT. 15) then
  ! Bypass activity information that
  ! does not change during subsequent
  ! tests of exercise conditions.
GOTO 41
end if

— The user's time for the mile run provides information about
maximal oxygen capacity and therefore maximal level of exercise
20 write(*,2) 'Do you know your best recent time for the mile?' write(*,*) 'If YES, please enter Y; if NO, please enter N: >' read(*,4) ANS

if ((ANS .NE. 'Y') .AND. (ANS .NE. 'N') .AND. (ANS .NE. 'y') + .AND. (ANS .NE. 'n')) then write(*,5) GOTO 20 end if

if ((ANS .EQ. 'Y') .OR. (ANS .EQ. 'y')) then write(*,2) 'Please enter your time for the mile (min,sec): >' read(*,*) MIN,SEC
if ((MIN .LT. 4) .OR. (MIN .GT. 20) .OR. (SEC .GT. 60) .OR. (SEC .LT. 0)) then write(*,5) GOTO 21 end if
else MIN = 0 SEC = 0 end if

30 write(*,2) 'If best time for the mile is unknown, then maximum' write(*,*) 'oxygen capacity is based on age and activity level.'

39 write(*,2) 'Please select your normal level of activity:' write(*,3) '1) Active (well trained in distance sports)' write(*,3) '2) Inactive (no continuous training)' write(*,1)
write(*,*) 'Please enter 1 or 2: >' read(*,*) ACTLEV
if ((ACTLEV .NE. 1) .AND. (ACTLEV .NE. 2)) then write(*,5) GOTO 39 end if

40 write(*,2) 'Please select level of acclimatization:' write(*,3) '1) Not acclimated to heat of cold' write(*,3) '2) Heat acclimated:' write(*,3) ' 7-10 days training, 2-4 hrs/day, > 95 Deg. F' write(*,3) '3) Cold acclimated' write(*,3) ' ' write(*,1)
write(*,*) 'Please enter 1, 2, or 3: >' read(*,*) ACCLEV
if ((ACCLEV .NE. 1) .AND. (ACCLEV .NE. 2) .AND. ACCLEV .NE. 3) then write(*,5) GOTO 40 end if
write(*,2)'Please choose a type of exercise from the list below: '
write(*,1)
write(*,*)'Walking, running, cycling, skiing, basketball'
write(*,*)'boxing, soccer, rowing, tennis, circuit training,'
write(*,*)'field hockey, football, squash, or aerobics.'
read(*,4)EXDESC

if ((EXDESC .NE. 'running') .AND. 
+ (EXDESC .NE. 'walking') .AND. 
+ (EXDESC .NE. 'cycling') .AND. 
+ (EXDESC .NE. 'skiing') .AND. 
+ (EXDESC .NE. 'basketball') .AND. 
+ (EXDESC .NE. 'boxing') .AND. 
+ (EXDESC .NE. 'soccer') .AND. 
+ (EXDESC .NE. 'rowing') .AND. 
+ (EXDESC .NE. 'tennis') .AND. 
+ (EXDESC .NE. 'circuit training') .AND. 
+ (EXDESC .NE. 'field hockey') .AND. 
+ (EXDESC .NE. 'football') .AND. 
+ (EXDESC .NE. 'squash') .AND. 
+ (EXDESC .NE. 'aerobics')) then
  write(*,5)
  GOTO 41
end if

if ((EXDESC .EQ. 'walking') .OR. (EXDESC .EQ. 'running')) then
  write(*,2)'Please enter your speed (1 - 16 miles/hr): >'
  read(*,*)VMPH
  if ((VMPH .LE. 0.0) .OR. (VMPH .GT. 16.0)) then
    write(*,5)
    GOTO 42
  endif
else if (EXDESC .EQ. 'cycling') then
  write(*,2)'Please enter your speed (7 - 25 miles/hr): >'
  read(*,*)VMPH
  if ((VMPH .LT. 7.0) .OR. (VMPH .GT. 25.0)) then
    write(*,5)
    GOTO 43
  endif
else if (EXDESC .EQ. 'skiing') then
  write(*,2)'Please enter your speed (2.5 - 8.8 miles/hr): >'
  read(*,*)VMPH
  if ((VMPH .LT. 2.5) .OR. (VMPH .GT. 8.8)) then
    write(*,5)
    GOTO 44
  endif
else if (EXDESC .EQ. 'boxing') then
  write(*,2)'In a ring (ring) or sparring (spar)? >'
read(*,4) BOXANS
if ((BOXANS .NE. 'ring') .AND. (BOXANS .NE. 'spar')) then
    write(*,5)
    GOTO 45
endif
end if

* SECTION 2: This section defines/calculates constants and initial
* values based on user input.
*
CA = 0.006949
CB = 0.86
GLU = 0.0
HVAP = 10.39
NUMDAT = 0
TSWEAT = 0.0

C --- Calculate total height (cm); convert weight to kg, temperature
to Deg. C, wind velocity to m/s, and velocity created by user to m/s.

HT = (12*FT + IN)*2.54
MKG = WTLBS * 0.4536
TIC = (TIF - 32.0)/1.8
WMETPS = 0.447 * WMPH
VMETPS = 0.447 * VMPH

C --- Calculate surface area of body used on various mechanisms of
heat transfer as a percentage of body surface area

BSA = 0.00718 * (MKG**0.425) * (HT**0.725)
AC = 0.94*BSA
AR = 0.78*BSA
AV = 0.15*BSA

PA = PSAT(TIC)
YA = RHUM * PA / 760.0
PSI = PSAT(40)

C --- Calculate basal metabolism (kcal/day) based on gender,
age, weight, and height

if ((GENDER .EQ. 'F') .OR. (GENDER .EQ. 'f')) then
    BASAL = 655.1 + 9.563*MKG + 1.850*HT - 4.676*AGE
else if ((GENDER .EQ. 'M') .OR. (GENDER .EQ. 'm')) then
    BASAL = 66.5 + 13.75*MKG + 5.003*HT - 6.775*AGE
end if
BASAL = BASAL/(24.0 * 60.0) ! Change units to kcal/min

C — Initial values for energy loss terms based on basal metabolism

QRES = 0.1*BASAL
QRAD = 0.6*BASAL
QEVAP = 0.1*BASAL
QCONV = 0.2*BASAL

C — Calculate initial skin temperature based on environmental temperature and body core temperature

TSCO = TBC - (TBC - TIC)/2.0

C — Determine volume of the body in cubic meters taking body build into account

BCM = WTLBS * 0.07 / 154.0

if (FRAME .EQ. 'small') then
   BCMB = BCM * 0.75
else if (FRAME .EQ. 'medium') then
   BCMB = BCM * 1.00
else if (FRAME .EQ. 'large') then
   BCMB = BCM * 1.25
end if

C — Determine clothing factor

if (ICLO.EQ.1) then
   CLOTHES = 'Shorts only'
   CLO = 1.0
else if (ICLO.EQ.2) then
   CLOTHES = 'Shorts and short-sleeve shirt or singlet'
   CLO = 0.70
else if (ICLO.EQ.3) then
   CLOTHES = 'Shorts and long-sleeve shirt'
   CLO = 0.55
else if (ICLO.EQ.4) then
   CLOTHES = 'Legs covered and long-sleeve shirt'
   CLO = 0.30
else if (ICLO.EQ.5) then
   CLOTHES = 'Legs, arms, hands, and head all covered'
   CLO = 0.25
end if

C — Set gain in sweat rate equation based on level of training

if (ACTLEV .EQ. 1) then
   GAIN1 = 1.65
else
C Define initial body core temperature (deg. C) and maximum sweat rate (kg/hr) based on level of acclimatization

if ((ACCLEV .EQ. 2) .AND. (ACTLEV .EQ. 1)) then
  MAXSR = 4.0
  TBC = 36.7
else
  MAXSR = 1.5
  TBC = 37.0
end if

— Calculate metabolic rate for the type of exercise selected

if ((EXDESC .EQ. 'walking') .OR. (EXDESC .EQ. 'running')) then
  if ((VMPH .GT. 0.0) .AND. (VMPH .LT. 2.0)) then
    MDOT = 125.0
  else if ((VMPH .GE. 2.0) .AND. (VMPH .LT. 3.0)) then
    MDOT = 151.0 + (VMPH - 2.0) * 82.0
  else if ((VMPH .GE. 3.0) .AND. (VMPH .LT. 4.0)) then
    MDOT = 233.0 + (VMPH - 3.0) * 133.0
  else if ((VMPH .GE. 4.0) .AND. (VMPH .LT. 5.0)) then
    MDOT = 366.0 + (VMPH - 4.0) * 210.0
  else if ((VMPH .GE. 5.0) .AND. (VMPH .LT. 6.0)) then
    MDOT = 576.0 + (VMPH - 5.0) * 46.0
  else if ((VMPH .GE. 6.0) .AND. (VMPH .LT. 8.0)) then
    MDOT = 622.0 + (VMPH - 6.0) * 43.5
  else if ((VMPH .GE. 8.0) .AND. (VMPH .LT. 10.0)) then
    MDOT = 709.0 + (VMPH - 8.0) * 172.5
  else if ((VMPH .GE. 10.0) .AND. (VMPH .LT. 12.0)) then
    MDOT = 776.0 + (VMPH - 10.0) * 210.0
  end if
end if

MDOT = MDOT * WTLBS/154.0

if (WMPH .EQ. 1.0) then
  VELTOT = VMETPS
end if

if ((WW .EQ. 'A') .OR. (WW .EQ. 'a')) then
VELTOT = VMETPS + WMETPS
else if((WW .EQ. 'F') .OR. (WW .EQ. 'f')) then
VELTOT = ABS(VMETPS - WMETPS)
else if((WW .EQ. 'N') .OR. (WW .EQ. 'n')) then
VELTOT = VMETPS
end if

--Calculate heat transfer coefficients for various mechanisms of
heating transfer based on the clothing factor and velocity

HC = CLO*6.4*VELTOT**0.67
HR = 4.3*CLO
HV = 11.9*CLO*VELTOT**0.6
KG = 0.0206332 * CLO*VELTOT**0.6

-- Calculate rate of air intake (mole/hr), and rate of
oxygen required for exercise (l/min)

VAIRL = 0.0264 * MDOT - 0.714
AIRMOL = VAIRL * 60.0 / (0.08206 * (TIC + 273.15))
VOL = 0.002768 * MDOT - 0.07164

-- Calculate maximal oxygen capacity for users who do not know their
best recent time for the mile run. Calculation is based on user's
activity, age, and weight.

if ((ANS .EQ. 'N') .OR. (ANS .EQ. 'n') .AND. ACTLEV .EQ. 1) then
VOMAX = (59.943 - 0.346*AGE) * MKG/1000.0
else if ((ANS .EQ. 'N') .OR. (ANS .EQ. 'n') .AND. ACTLEV .EQ. 2) then
VOMAX = (103.43 - 1.257*AGE) * MKG/1000.0
end if

MILE = MIN + SEC/60.0
VOMAX = (1608.0 + 30.0*MILE)/(5.0*(MILE + 1.0))*MKG/1000.0

-- Calculate percent maximum oxygen capacity required for
level of exercise selected

PVO = VOL / VOMAX * 100.0
IPVO = PVO
write(*,7) 'You are exercising at ',IPVO,' % of your capacity.'
write(*,98)

-- Calculate rate of glucose or carbohydrate consumption
at level of exercise selected

SGLU = 0.005827*PVO+0.00004545*(PVO**2)+0.000001667*(PVO**3)
if (ACTLEV .EQ. 1) SGLU = 0.75*SGLU
SECTION 3: This section calculates change in body temperature, weight loss, and carbohydrate usage with time. Data are written to data files every 5 minutes and printed to the screen every 15 minutes.

DO 150 TT = 15,300,15
DO 111 j = 1,3
DO 110 k = 0,4,9,0.1
   if (TT .EQ. 15 .AND. j .EQ. 1 .AND. k .EQ. 0) then
      TSC = TSCO
      TTSC = TSCO
   end if

   C -- Calculate thermal conductivity as function of body temperature
   to account for vasoconstriction (TBC < 37 Deg. C) or vasodilation
   C (TBC > 37 Deg. C)
   if (TBC .LT. 37.0) then
      SKO = 0.5*(1.0 - (37.0 - TBC)/6.0)
   else
      SKO = 0.5*(1.0 + (TBC - 37.0)/3.0)
   end if

   C -- Calculate new skin temperatures
   TNSC = TBC - ((QRES + QEVAP + QCONV + QRAD)/10.0)/(1.8*SKO)

   C -- Average last three skin temperatures
   TSC = (TSC + TTSC + TNSC)/3.0
   TTSC = TNSC

   TICL = TIC + 1.0
   TBCL = TBC - 0.5

   C -- Skin temperature cannot be < 1 Deg. C more than environmental temperature
   if (TSC .LT. TICL) TSC = TICL

   C -- Skin temperature cannot be > 1/2 Deg. C less than body core temperature
   if (TSC .GT. TBCL) TSC = TBCL

   PS = PSAT(TSC)
— Calculate rate of evaporative mass transfer

\[ Z = KG*AV*(PS - RHUM*PA) \]

— If core temperature < 37 Deg. C water loss is determined by the rate of evaporation

if (TBC .LT. 37.0) DSWEAT = Z

— Determine level of dehydration to modify slope of DWEAT vs. TBC relationship used in determining sweat rate. The gains defined with respect to a given level of dehydration are NOT specifically provided in literature, but have been arbitrarily estimated using a hypothesized trend.

if (TSWEAT .LT. 0.01*MKG) then
    GAIN2 = 1.0
else if ((TSWEAT .GE. 0.01*MKG).AND.(TSWEAT .LT. 0.02*MKG)) then
    GAIN2 = 0.95
else if ((TSWEAT .GE. 0.02*MKG).AND.(TSWEAT .LT. 0.03*MKG)) then
    GAIN2 = 0.85
else if ((TSWEAT .GE. 0.03*MKG).AND.(TSWEAT .LT. 0.04*MKG)) then
    GAIN2 = 0.75
else if ((TSWEAT .GE. 0.04*MKG).AND.(TSWEAT .LT. 0.05*MKG)) then
    GAIN2 = 0.65
end if

— Call subroutine to calculate sweat rate (water loss rate)

DSWEAT = WATERLOSS(TSC,TBC,MDOT,GAIN1,GAIN2)

if (DSWEAT .GT. MAXSR) DSWEAT = MAXSR

SWEAT = DSWEAT / 600.0                                       !Convert rate to kg/6 sec

— Calculate energy lost through respiration, evaporation, convection and radiation

PEXP = PSAT(TBC)
YEXP = PEXP/760.0

QRES = AIRMOL*(CA*(TBC - TIC) + HVAP*(YEXP - YA))/60.0
QEVAP = HV*AV*(PS - RHUM*PA)/60.0
QCONV = HC*AC*(TSC - TIC)/60.0
QRAD = HR*AR*(TSC - TIC)/60.0
QTOT = QRES + QEVAP + QCONV + QRAD - MDOT/60.0

EMAX = QEVAP*0.1                                              ! Convert rate to kcal/6 sec
DRIP = EMAX/3.0                                                ! Determine point at which run-off occurs ! (1/3 max evaporative capacity)

— Calculate body temperature change in 6 seconds by using
dividing new rate of heat loss and new body weight

\[ DTB = \frac{-QTOT}{10.0} \left( \frac{1}{MKG - TSWEAT} \right) \]

-- Calculate new body core temperature

\[ TBC = TBC + DTB \]

-- Add water loss in current period to the previous water loss.
If the sweat rate is greater than or equal to 1/3 maximum evaporative capacity then loss of sweat can occur by dripping. If the sweat rate
is less than 1/3 EMAX then loss of water occurs by evaporation.

\[
\begin{align*}
\text{if } (\text{SWEAT} \geq \text{DRIP}) & \text{ then} \\
TSWEAT &= TSWEAT + \text{SWEAT} \\
\text{else} & \\
TSWEAT &= TSWEAT + Z/600.0
\end{align*}
\]

\[
\begin{align*}
\text{if } (j .eq. 1) & \text{ then} \\
TS &= k+(TT-15.0) \\
\text{else if } (j .eq. 2) & \text{ then} \\
TS &= (5.0 + k)+(TT-15.0) \\
\text{else if } (j .eq. 3) & \text{ then} \\
TS &= (10.0 + k)+(TT-15.0)
\end{align*}
\]

-- Calculate the amount of glucose used in period

\[ DGLU = SGLU * 1.030 / 10.0 \]

-- Calculate total glucose usage

\[ GLU = GLU + DGLU \]

-- Determine whether maximum glucose usage has been surpassed

\[
\begin{align*}
\text{if } ((\text{EXDESC} \ .EQ. 'running') \ .OR. (\text{EXDESC} \ .EQ. 'walking')) & \text{ then} \\
\text{if } (\text{GLU} \ .GE. \text{CALF}) & \text{ then} \\
\text{write(*,100)} \\
\text{write(*,101)} \\
\text{GOTO 275} \\
\text{end if} \\
\text{else if } (\text{EXDESC} \ .EQ. 'cycling') & \text{ then} \\
\text{if } ((\text{GLU} \ .GE. (0.7 \ * \ \text{QUAD})) \ .OR. (\text{GLU} \ .GE. (0.3 \ * \ (\text{BICEP} + \text{TRICEP})))) & \text{ then} \\
\text{write(*,100)} \\
\text{write(*,101)} \\
\text{GOTO 275} \\
\text{end if} \\
\text{else if } (\text{EXDESC} \ .EQ. 'rowing') & \text{ then} \\
\end{align*}
\]
if ((GLU .GE. (0.5 * QUAD))
+ .OR. (GLU .GE. (0.5 * BICEP))) then
  write(*,100)
  write(*,101)
  GOTO 275
end if
else if (EXDESC .EQ. 'circuit training') then
  if ((GLU .GE. (0.2 * QUAD)) .OR. (GLU .GE. (0.2 * BICEP))
+ .OR. (GLU .GE. (0.2 * HAM)) .OR. (GLU .GE. (0.2 * TRICEP))
+ .OR. (GLU .GE. (0.2 * CALF))) then
    write(*,100)
    write(*,101)
    GOTO 275
  end if
else if (.NOT. ((EXDESC .EQ. 'running') .OR.
+ (EXDESC .EQ. 'walking') .OR. (EXDESC .EQ. 'cycling')
+ .OR. (EXDESC .EQ. 'rowing')
+ .OR. (EXDESC .EQ. 'circuit training'))) then
  if (GLU .GE. 92.7) then
    write(*,100)
    write(*,101)
    GOTO 275
  end if
end if

C — Determine if hypothermia has been achieved

if (TBC .LE. 34.0) then
  write(*,1) 'HYPOTHERMIA!!!'
  write(*,1) 'Body core temperature has fallen below 92 Deg. F.'
  GOTO 275
end if

C — Determine if hypothermia has been achieved

if (TBC .GE. 40.0) then
  write(*,1) 'HYPERTHERMIA!!!'
  write(*,1) 'Body core temperature has exceeded 104 Deg. F.'
  GOTO 275
end if

C — Determine if dehydration limit has been exceeded

if (TSWEAT .GE. 0.05*MKG) then
  write(*,1) 'DEHYDRATION!!!'
  write(*,1) 'Loss of body water exceeds 5% total body weight.'
  GOTO 275
end if

C — Determine if exercise duration has been exceeded
if (TT.GT. TTM) then
    write(*,1) 'Exercise duration is complete!'
    GOTO 275
end if

T = TS + 0.1

CONTINUE

C — Write data to output file

FTSC = 1.8 * TSC + 32.0
CBT = 1.8 * TBC + 32.0
HD = -QTOT
CBW = (MKG - TSW) * 2.2046
CU = GLU * 100.0/92.7

open (unit = 1,type = 'new',name = 'BODYTEMP.DAT')
open (unit = 2,type = 'new',name = 'QTOT.DAT')
open (unit = 3,type = 'new',name = 'BODYWT.DAT')
open (unit = 4,type = 'new',name = 'SKINTEMP.DAT')

write(1,99) T, CBT
write(2,99) T, HD
write(3,99) T, CBW
write(4,99) T, FTSC

C — Count number of data pts.

NUMDAT = NUMDAT + 1

CONTINUE

C — Print values to the screen every 15 min.

write(*,6) 'AFTER ',T,' MINUTES:'
write(*,1)
write(*,202) 'Rate of heat loss by respiration = ',QRES,' kcal/min'
write(*,202) 'Rate of heat loss by evaporation = ',QEVAP,' kcal/min'
write(*,202) 'Rate of heat loss by convection = ',QCONV,' kcal/min'
write(*,202) 'Rate of heat loss by radiation = ',QRAD,' kcal/min'
write(*,202) 'Heat accumulation in body = ',HD,' kcal/min'
write(*,1)
write(*,201) 'Skin temperature = ',FTSC,' Deg. F'
write(*,201) 'Current body temperature = ',CBT,' Deg. F'
write(*,201) 'Current body weight = ',CBW,' lbs'
write(*,269)
read(*,*)

C — Continue simulation if hyperthermia, hypothermia, dehydration or exhaustion have not been reached
CONTINUE

write(*,7) 'Total exercise duration = ', T, ' min'
write(*,269)
read(*,*)

SECTION 4: This section calls subroutines FUELUSE, PRINTAB, PLOTDATA to estimate fuel usage, print a summary and plot data from the simulation, respectively.

CALL FUELUSE(TT,VOL,PVO,TOTCAL,CHCAL,LIPCAL,CHUSED,LIPUSED)

CALL PRINTAB

write(*,2) 'Would you like to plot any of the following results from the simulation run?'
write(*,1)
write(*,3) '1) Body Temperature vs. Time'
write(*,3) '2) Heat Loss vs. Time'
write(*,3) '3) Body Weight vs. Time'
write(*,3) '4) Skin Temperature vs. Time'

write(*,1)
write(*,*) 'If YES, please enter Y; if NO, please enter N: ' read(*,4) ANS

if ((ANS .NE. 'Y') .AND. (ANS .NE. 'N') .AND. (ANS .NE. 'y') .AND. (ANS .NE. 'n')) then
    write(*,5)
    GOTO 285
end if

if ((ANS .EQ. 'Y') .OR. (ANS .EQ. 'y')) then
    call PLOTDATA(NUMDAT)
else
    GOTO 300
end if

write(*,2) 'Would you like to test some other conditions?'
write(*,*) 'If YES, please enter Y; if NO, please enter N: ' READ (*,4) ICASE

if ((ICASE .NE. 'Y') .AND. (ICASE .NE. 'y') .AND. (ICASE .NE. 'N') .AND. (ICASE .NE. 'n')) then
    write(*,5)
    GOTO 301
else if ((ICASE .EQ. 'Y') .OR. (ICASE .EQ. 'y')) then
  close (1)
  close (2)
  close (3)
  close (4)
  GOTO 14
endif

1 format(/,1X,A)
2 format,//,1X,A)
3 format(1X,TR5,A)
4 format(A)
5 format(/,1X,'You have entered an invalid response,
+ please try again.',/)
6 format (/,1X,A,F5.1,A)
7 format (/,1X,A,F5.1,A)
98 format(1X,60('-'),/)
99 format (1X,'EXHAUSTION!!!')
101 format(1X,'You have depleted the carbohydrate stores in the
+ working muscle(s).')
201 format (1X,A,F7.1,A)
202 format (1X,A,F7.2,A)
269 format(/,1X,TR20,'Please press <RETURN> to continue.',///)

STOP
END

******************************************************************************
This section contains FUNCTION and SUBROUTINE programs to print a summary table, plot the data, calculate saturated water vapor pressure, sweat rates, and fuel use.

******************************************************************************

SUBROUTINE PRINTAB

real   WTLBS,MKG,RHUM,MDOT,VMPH,TIF,CBW,CBT
real   TOTCAL,CHCAL,LIPCAL,LIPUSED,CHUSED,FTSC,VOL
character NAME*50,EXDESC*50,CLOTHES*50
integer AGE,FT,IN,MIN,SEC,TT,ACTLEV

common NAME,FT,IN,WTLBS,AGE,CLOTHES,MIN,SEC,ACTLEV,EXDESC
common MDOT,VOL,VMPH,TIF,RHUM,WMHP,TS,CBW,CBT,FTSC,TOTCAL
common CHCAL, LIPCAL, CHUSED, LIPUSED

write(*,9)
write(*,*) 'SUMMARY OF EXERCISE SIMULATION FOR: >'
write(*,*) NAME

write(*,2) '— Characteristics of the Athlete'
write(*,6) 'Height: ', FT, ' ft. ', IN, ' inches'
write(*,4) 'Weight: ', WTLBS, ' lbs.'
write(*,6) 'Age: ', AGE, ' years'
write(*,*) 'Clothing: ', CLOTHES
write(*,1)
write(*,6) 'Best recent time for the mile: ', MIN, ' min ', SEC, ' sec'
write(*,*) 'Where: 0 - not available'
write(*,1)
write(*,8) 'Activity level = ', ACTLEV
write(*,*) 'Where: 1 - Active, 2 - Inactive'
read(*,*)

write(*,2) '— Exercise Data'
write(*,3) EXDESC
write(*,1)
write(*,4) 'Metabolic rate = ', MDOT, ' kcal/hr'
write(*,4) 'Oxygen Consumption = ', VOL, ' liters oxygen/min'
write(*,4) 'Exercise Velocity = ', VMPH, ' miles/hr (0 = N/A)'
write(*,2) '— Environmental Conditions'
write(*,4) 'Air temperature = ', TIF, ' Deg. F'
write(*,5) 'Relative humidity = ', RHUM
write(*,4) 'Wind velocity = ', WMPH, ' miles/hr'
write(*,10)
read(*,*)

write(*,2) '— Final Simulation Values'
write(*,7) 'Duration of Exercise = ', TS, ' min'
write(*,4) 'Final body weight = ', CBW, ' lbs'
write(*,4) 'Final body temp. = ', CBT, ' Deg. F'
write(*,4) 'Final skin temp. = ', FTSC, ' Deg. F'

write(*,2) '— Fuel Use'
write(*,4) 'Total energy spent = ', TOTCAL, ' kcal'
write(*,4) ' - Carbohydrates = ', CHCAL, ' kcal'
write(*,4) ' - Fats = ', LIPCAL, ' kcal'
write(*,1)
write(*,4) 'Carbohydrates used: ', CHUSED, ' grams'
write(*,4) 'Fats used: ', LIPUSED, ' grams'
write(*,10)
read(*,*)
1 format(IX,/)
format (\/,1X,A,/)  
format (1X,TR5,A)  
format (1X,A,F7.1,A)  
format (1X,A,F7.2,A)  
format (1X,A,I3,A,I3,A)  
format (1X,A,TR2,F5.1,A)  
format (1X,A,I2)  
format (1X,60('-'),/)  
format (\/,1X,TR20,'Please press <Return> to continue.',/)  

RETURN
END

*-- SUBROUTINE PLOTDATA plots data calculated in the simulation. ------*

SUBROUTINE PLOTDATA(NUMDAT)

real LINE(0:100),STAR,SSCALE,X(100),XMAX,XMIN
real Y(100),YMAX,YMIN
integer CHOICE,NUMDAT,PF
character FILENAME*15,PRINTFILE*lS,YVAR*25,XVAR*15

290 write(*,1)
read(*,*) CHOICE
if (CHOICE .LE. 4 .AND. CHOICE .GE. 1) then
   XVAR = 'TIME (min)'
else
   write(*,2)
   GOTO 290
end if

if (CHOICE .EQ. 1) then
   FILENAME = 'BODYTEMP.DAT'
   PRINTFILE = 'BODYTEMP.TXT'
   PF = 5
   YVAR = 'BODY TEMP. (Deg. F)'
else if (CHOICE .EQ. 2) then
   FILENAME = 'QTOT.DAT'
   PRINTFILE = 'QTOT.TXT'
   PF = 6
   YVAR = 'HEAT LOSS (kcal/min)'
else if (CHOICE .EQ. 3) then
   FILENAME = 'BODYWT.DAT'
   PRINTFILE = 'BODYWT.TXT'
   PF = 7
   YVAR = 'BODY WEIGHT (lbs)'
else if (CHOICE .EQ. 4) then
   FILENAME = 'SKINTEMP.DAT'
PRINTFILE = 'SKINTEMP.TXT'
P = 8
YVAR = 'SKIN TEMP. (Deg. F)'
end if

-- Input data

open (unit = CHOICE, status = 'old', file = FILENAME)
rewind (CHOICE)
open (unit = FF, status = 'new', file = PRINTFILE)
rewind (PF)

do 6 i = 1, NUMDAT
   read (CHOICE, 12) X(i), Y(i)
6 continue

YMAX = Y(1)
YMIN = Y(1)

do 9 i = 1, NUMDAT
   if (Y(i) < YMIN) YMIN = Y(i)
   if (Y(i) > YMAX) YMAX = Y(i)
9 continue

SCALE = YMAX - YMIN

do 10 i = 0, 55
   LINE(i) = '*'
10 continue

-- Plot data

write(*, 3) PRINTFILE
write(PF, 4) 'X', 'Y'
write(*, 4) 'X', 'Y'

do k = 1, NUMDAT
   STAR = (Y(k) - YMIN)*55.0/SCALE
   LINE(STAR) = '*'
   write(PF, 5) X(k), Y(k), (LINE(i), i = 0, 55)
   write(*, 5) X(k), Y(k), (LINE(i), i = 0, 55)
   LINE(STAR) = '*'
end do

write(PF, 13)
write(*, 13)
write(PF, 14) XVAR, YVAR
write(*, 14) XVAR, YVAR

write(*, *) 'Would you like to plot some other data?'
write(*, *) 'If YES, please enter Y; if NO, please enter N: >'
READ (*,16) ICASE

if ((ICASE .NE. 'Y') .AND. (ICASE .NE. 'y') .AND. (ICASE .NE. 'N') .AND. (ICASE .NE. 'n')) then
    write(*,5)
    GOTO 295
end if

if ((ICASE .EQ. 'N') .OR. (ICASE .EQ. 'n')) then
    RETURN
else
    close (PF)
    write(*,11) '1) Body Temperature vs. Time'
    write(*,15) '2) Heat Loss vs. Time'
    write(*,15) '3) Body Weight vs. Time'
    write(*,15) '4) Skin Temperature vs. Time'
    GOTO 290
end if

format (/,1X,'Please enter 1, 2, 3, or 4: >')
format (1X,'You have entered an invalid response,'+ please try again. ,'/)
format (/,1X,'The output file will be named ','A,/)
format (3X,A1,TR7,A1,TR8,56('-'))
format (1X,F5.1,FI0.2,TR3,'1',56A1,'1')
format (/,1X,A)
format (1X,F5.1,FI0.2)
format (1X,TR19,56('-'),'/)
format (1X,Where: ','X = ','A10,4X,'Y = ','A20,/)
format (1X,A)
format (A)

RETURN
END

*---------------------------------------------------------------*
* FUNCTION PSAT calculates saturated vapor pressure (mmHg) of  *
* water at given temperatures using the Antoine equation. ------*
*---------------------------------------------------------------*

FUNCTION PSAT(T)

real T,A,B,C

C — Antoine constants for water

A = 8.10765
B = 1750.286
C = 235.0

PSAT = 10**((A - B/(T+C))
FUNCTION WATERLOSS(TSC, TBC, MDOT, GAIN1, GAIN2)

real TBC, TSC, MDOT, GAIN1, GAIN2

GAIN = GAIN1 * GAIN2

if (MDOT .LE. 300.0) then
DSWEAT = 0.046122 * GAIN * TBC - 1.16399
else if (MDOT .LE. 500.0 .AND. MDOT .GT. 300.0) then
  if (TSC .LE. 33.0) then
    DSWEAT = 0.063091 * GAIN * TBC - 1.53415
  else
    DSWEAT = 0.295611 * GAIN * TBC - 9.53531
  end if
else if (MDOT .LE. 700.0 .AND. MDOT .GT. 500.0) then
  if (TSC .LE. 33.4) then
    DSWEAT = 0.091916 * GAIN * TBC - 2.21063
  else
    DSWEAT = 0.512109 * GAIN * TBC - 16.9846
  end if
else if (MDOT .LE. 900.0 .AND. MDOT .GT. 700.0) then
  if (TSC .LE. 32.0) then
    DSWEAT = 0.223172 * GAIN * TBC - 6.03852
  else
    DSWEAT = 0.390976 * GAIN * TBC - 11.8576
  end if
else if (MDOT .LE. 1100.0 .AND. MDOT .GT. 900.0) then
  if (TSC .LE. 29.0) then
    DSWEAT = 0.439115 * GAIN * TBC - 12.3871
  else
    DSWEAT = 0.314289 * GAIN * TBC - 8.09200
  end if
else if (MDOT .LE. 1300.0 .AND. MDOT .GT. 1100.0) then
  if (TSC .LE. 28.6) then
    DSWEAT = 0.69908 * GAIN * TBC - 21.2381
  else
    DSWEAT = 0.227225 * GAIN * TBC - 4.99327
  end if
else if (MDOT .LE. 1500.0 .AND. MDOT .GT. 1300.0) then
  if (TSC .LE. 28.0) then
    DSWEAT = 0.053090 * GAIN * TBC + 1.639657
  else
    DSWEAT = 0.023962 * GAIN * TBC - 2.02455
  end if
else if (MDOT .LE. 1700.0 .AND. MDOT .GT. 1500.0) then
  if (TSC .LE. 27.6) then
    DSWEAT = 0.011510 * GAIN * TBC - 1.49867
  else
    DSWEAT = 0.003751 * GAIN * TBC + 0.20126
  end if
else
  DSWEAT = 0.000000 * GAIN * TBC + 0.00000
end if
end if

WATERLOSS = DSWEAT

RETURN
END

SUBROUTINE FUELUSE calculates (using fuel consumption data) total energy spent (kcal) and amount (grams) of carbohydrates and lipids oxidized for a given duration and intensity of exercise.

SUBROUTINE FUELUSE(TT, VOL, PVO, TOTCAL, CHCAL, LIPCAL, CHUSED, LIPUSED)

real R, CALEQ, TOTVOL, TOTCAL, CHFRAC, CHCAL, PVO
real VOL, LIPCAL, CHEQ, LIPEQ, CHUSED, LIPUSED
integer TT

SUBROUTINE VARIABLES

VARIABLE DESCRIPTION

CALEQ Calorific equivalent of 1 liter of oxygen consumed
CHCAL Calories derived from carbohydrates
CHEQ Equivalent carbohydrates oxidized (grams) per 1 liter oxygen consumed
CHFRAC Percentage calories derived from carbohydrates
CHUSED Total carbohydrate oxidized (grams)
LIPCAL Calories derived from lipids
LIPEQ Equivalent lipids oxidized (grams) per 1 liter oxygen consumed
LIPUSED Total lipids oxidized (grams)
PVO Athlete's percent maximal oxygen capacity at R Nonproteic respiratory quotient as function of PVO and duration of exercise
TOTVOL Total volume of oxygen consumed
TOTCAL Total kcal utilized
TT Duration of exercise (min)
VOL Oxygen consumption at given metabolic rate

exercise level selected

Determine the nonproteic respiratory quotient equation for the duration of exercise. The equations for R are correspond to the following durations: 0 min. (ex. sprinters), 30 min., 60 min., 120 min., 180 min., 240 min. and 300 min. For durations of exercise other than these values, R is
approximated using the equation defined at the nearest duration.

\[
\begin{align*}
\text{if (TT .LE. 2)} & \quad R = 0.0021 \times PVO + 0.765 \\
\text{if (TT .GT. 2 .AND. TT .LE. 45)} & \quad R = 0.0021 \times PVO + 0.753 \\
\text{if (TT .GT. 45 .AND. TT .LE. 90)} & \quad R = 0.0022 \times PVO + 0.737 \\
\text{if (TT .GT. 90 .AND. TT .LE. 150)} & \quad R = 0.0020 \times PVO + 0.740 \\
\text{if (TT .GT. 150 .AND. TT .LE. 210)} & \quad R = 0.0019 \times PVO + 0.735 \\
\text{if (TT .GT. 210 .AND. TT .LE. 270)} & \quad R = 0.0020 \times PVO + 0.713 \\
\text{if (TT .GT. 270)} & \quad R = 0.0021 \times PVO + 0.769 \\
\end{align*}
\]

if (TT .GT. 300) then
  write(*,1) 'Maximum duration limit is 5 hours.'
  write(*,2) 'Percentages of carbohydrates and fats used will be '
  write(*,2) 'based on this duration of exercise.'
end if

C — Calculate total energy expenditure.

CALEQ = 3.813 + 1.233 \times R
TOTVOL = TT \times VOL
TOTCAL = TOTVOL \times CALEQ

C — Calculate calories derived from each fuel

CHFRAC = (-239.32 + 340.32 \times R)/100.0
CHCAL = CHFRAC \times TOTCAL
LIPCAL = (1.0 - CHFRAC) \times TOTCAL

C — Calculate grams of carbohydrate and lipids oxydized

CHEQ = -2.977 + 4.195 \times R
CHUSED = TOTVOL \times CHEQ
LIPEQ = 1.722 - 1.717 \times R
LIPUSED = TOTVOL \times LIPEQ

1 format(/,1X,A) 2 format(1X,A,/) RETURN END
This program is designed to inform well trained and novice athletes how long they may exercise at a certain level before one of the following conditions occur:

a) hyperthermia: estimated core temperature surpasses 40 Deg. C (104 Deg. F)
b) dehydration: loss of body water exceeds 5% of body weight
c) estimated muscle glycogen supply exceeded
d) hypothermia: estimated core temperature drops below 34 Deg. C (92 Deg. F)

Please enter your name (50 character max): > Megan Scherb

Gender is used in calculating basal metabolic rate.

If you are a female, please enter F; if you are a male, please enter M: > f

This program is designed for athletes between the ages of 18 and 75.

Please enter your age in years: > 24

Please enter your height (feet, inches): > 5.0 4.0

Please enter your body weight (60 - 300 lbs): > 135.0

Please enter your approximate muscular build: > (small, medium, large) medium

Enter the number which best corresponds to your clothing (in addition to your shoes): >

Shorts only, enter 1.
Shorts and short-sleeve shirt or singlet, enter 2.
Shorts and long-sleeve shirt, enter 3.
Legs covered and long-sleeve shirt, enter 4.
Legs, arms, hands, and head all covered, enter 5.

Please enter the air temperature (-40 to 120 Deg. F): > 70.0
Please enter wind velocity (0 - 50 miles/hr): > 0.0

Please enter the relative humidity as a decimal: > 0.5

Would you like the program to:
 (1) recommend a duration of exercise?
 (2) allow you to choose a duration of exercise?

Please enter 1 or 2: > 1

Do you know your best recent time for the mile? If YES, please enter Y; if NO, please enter N: > y

Please enter your time for the mile (min, sec): > 7.0 30.0

If best time for the mile is unknown, then maximum oxygen capacity is based on age and activity level.

Please select your normal level of activity:
 1) Active (well trained in distance sports)
 2) Inactive (no continuous training)

Please enter 1 or 2: > 1

Please select level of acclimatization:
 1) Not acclimated to heat or cold
 2) Heat acclimated:
     7-10 days training, 2-4 hrs/day, > 95 Deg. F
 3) Cold acclimated

Please enter 1, 2, or 3: > 2

Please choose a type of exercise from the list below:

Walking, running, cycling, skiing, basketball, boxing, soccer, rowing, tennis, circuit training, field hockey, football, squash, or aerobics.

Please enter your speed (1 - 16 miles/hr): > 7.5

You are exercising at 60.4 % of your capacity.
AFTER 15.0 MINUTES:

Rate of heat loss by respiration = 0.40 kcal/min
Rate of heat loss by evaporation = 2.60 kcal/min
Rate of heat loss by convection = 4.03 kcal/min
Rate of heat loss by radiation = 1.00 kcal/min
Heat accumulation in body = 2.01 kcal/min

Skin temperature = 97.8 Deg. F
Current body temperature = 99.2 Deg. F
Current body weight = 134.9 lbs

Please press "<RETURN>" to continue.

AFTER 30.0 MINUTES:

Rate of heat loss by respiration = 0.42 kcal/min
Rate of heat loss by evaporation = 2.71 kcal/min
Rate of heat loss by convection = 4.19 kcal/min
Rate of heat loss by radiation = 1.04 kcal/min
Heat accumulation in body = 1.69 kcal/min

Skin temperature = 98.9 Deg. F
Current body temperature = 100.2 Deg. F
Current body weight = 134.7 lbs

Please press "<RETURN>" to continue.

AFTER 45.0 MINUTES:

Rate of heat loss by respiration = 0.43 kcal/min
Rate of heat loss by evaporation = 2.80 kcal/min
Rate of heat loss by convection = 4.32 kcal/min
Rate of heat loss by radiation = 1.07 kcal/min
Heat accumulation in body = 1.42 kcal/min

Skin temperature = 99.8 Deg. F
Current body temperature = 101.0 Deg. F
Current body weight = 134.5 lbs

Please press "<RETURN>" to continue.

AFTER 60.0 MINUTES:
Rate of heat loss by respiration = 0.44 kcal/min
Rate of heat loss by evaporation = 2.88 kcal/min
Rate of heat loss by convection = 4.42 kcal/min
Rate of heat loss by radiation = 1.10 kcal/min
Heat accumulation in body = 1.20 kcal/min

Skin temperature = 100.5 Deg. F
Current body temperature = 101.6 Deg. F
Current body weight = 134.4 lbs

Please press <RETURN> to continue.

AFTER 75.0 MINUTES:

Rate of heat loss by respiration = 0.45 kcal/min
Rate of heat loss by evaporation = 2.95 kcal/min
Rate of heat loss by convection = 4.51 kcal/min
Rate of heat loss by radiation = 1.12 kcal/min
Heat accumulation in body = 1.01 kcal/min

Skin temperature = 101.1 Deg. F
Current body temperature = 102.2 Deg. F
Current body weight = 134.2 lbs

Please press <RETURN> to continue.

AFTER 90.0 MINUTES:

Rate of heat loss by respiration = 0.46 kcal/min
Rate of heat loss by evaporation = 3.00 kcal/min
Rate of heat loss by convection = 4.59 kcal/min
Rate of heat loss by radiation = 1.14 kcal/min
Heat accumulation in body = 0.85 kcal/min

Skin temperature = 101.6 Deg. F
Current body temperature = 102.7 Deg. F
Current body weight = 134.0 lbs

Please press <RETURN> to continue.

AFTER 105.0 MINUTES:

Rate of heat loss by respiration = 0.46 kcal/min
Rate of heat loss by evaporation = 3.05 kcal/min
Rate of heat loss by convection = 4.65 kcal/min
Rate of heat loss by radiation = 1.15 kcal/min
Heat accumulation in body = 0.72 kcal/min
Skin temperature  = 102.1 Deg. F
Current body temperature = 103.1 Deg. F
Current body weight = 133.9 lbs

Please press <RETURN> to continue.

AFTER 120.0 MINUTES:

Rate of heat loss by respiration = 0.47 kcal/min
Rate of heat loss by evaporation = 3.09 kcal/min
Rate of heat loss by convection = 4.71 kcal/min
Rate of heat loss by radiation = 1.17 kcal/min
Heat accumulation in body = 0.61 kcal/min

Skin temperature  = 102.4 Deg. F
Current body temperature = 103.4 Deg. F
Current body weight = 133.7 lbs

Please press <RETURN> to continue.

EXHAUSTION!!!
You have depleted the carbohydrate stores in the working muscle(s).

Total exercise duration = 132.8 min

Please press <RETURN> to continue.

----------------------------------------
SUMMARY OF EXERCISE SIMULATION FOR: >
Megan Scherb

--- Characteristics of the Athlete

Height: 5.0 ft. 4.0 inches
Weight: 135.0 lbs.
Age: 24 years
Clothing: Shorts and short-sleeve shirt or singlet

Best recent time for the mile: 7.0 min 30.0 sec
Where: 0 - not available

Activity level = 1
Where: 1 - Active, 2 - Inactive

Please press <RETURN> to continue.
--- Exercise Data

running

Metabolic rate = 602.5 kcal/hr
Oxygen Consumption = 1.6 liters oxygen/min
Exercise Velocity = 7.5 miles/hr (0 = N/A)

--- Environmental Conditions

Air temperature = 70.0 Deg. F
Relative humidity = 0.50
Wind velocity = 1.0 miles/hr

Please press <Return> to continue.

--- Final Simulation Values

Duration of Exercise = 132.8 min
Final body weight = 133.6 lbs
Final body temp. = 103.6 Deg. F
Final skin temp. = 102.6 Deg. F

--- Fuel Use

Total energy spent = 1050.2 kcal
   - Carbohydrates = 563.4 kcal
   - Fats = 486.8 kcal

Carbohydrates used: 136.7 grams
Fats used: 52.6 grams

Please press <Return> to continue.

Would you like to plot any of the following results from the simulation run?

1) Body Temperature vs. Time
2) Heat Loss vs. Time
3) Body Weight vs. Time
4) Skin Temperature vs. Time

If YES, please enter Y; if NO, please enter N: > Y

Please enter 1, 2, 3, or 4: > 1

The output file will be named BODYTEMP.TXT

<table>
<thead>
<tr>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0</td>
<td>98.49</td>
</tr>
<tr>
<td>10.0</td>
<td>98.86</td>
</tr>
<tr>
<td>15.0</td>
<td>99.22</td>
</tr>
</tbody>
</table>
Where: $X = \text{TIME (min)} \quad Y = \text{BODY TEMP. (Deg. F)}$

Would you like to plot some other data?
If YES, please enter Y; if NO, please enter N:  

Y

1) Body Temperature vs. Time
2) Heat Loss vs. Time
3) Body Weight vs. Time
4) Skin Temperature vs. Time

Please enter 1, 2, 3, or 4:  

2

The output file will be named QTOT.TXT
Where: $X$ = TIME (min)    $Y$ = HEAT LOSS (kcal/min)

Would you like to plot some other data?
If YES, please enter Y; if NO, please enter N:  >

Y

1) Body Temperature vs. Time
2) Heat Loss vs. Time
3) Body Weight vs. Time
4) Skin Temperature vs. Time

Please enter 1, 2, 3, or 4:  >

The output file will be named BODYWT.TXT

<table>
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</table>

Where: $X$ = TIME (min)    $Y$ = BODY WEIGHT (lbs)

Would you like to plot some other data?
If YES, please enter Y; if NO, please enter N:  >

Y

1) Body Temperature vs. Time
2) Heat Loss vs. Time
3) Body Weight vs. Time
4) Skin Temperature vs. Time

Please enter 1, 2, 3, or 4:  >
The output file will be named SKINTEMP.TXT

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<td>102.55</td>
</tr>
<tr>
<td>130.0</td>
<td>102.65</td>
</tr>
</tbody>
</table>

Where: $X = \text{TIME (min)}$ \hspace{1cm} $Y = \text{SKIN TEMP. (Deg. F)}$

Would you like to plot some other data?  
If YES, please enter Y; if NO, please enter N: n

Would you like to test some other conditions?  
If YES, please enter Y; if NO, please enter N: n