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User's Instructions for the Cardiovascular Walters Model

This model is a combined, steady-state cardiovascular and thermal model. It was originally developed for interactive use by Dr. R. F. Walters, Department of Human Physiology, School of Medicine, University of California, Davis, California. The model has been converted to batch mode simulation for the Sigma 3 computer. The purpose of the model is to compute steady-state circulatory and thermal variables in response to exercise work loads and environmental factors. During a computer simulation run, several selected variables are printed at each time step. End conditions are also printed at the completion of the run.

R. C. Croston, Ph.D.

CONCURRENCES

Counterpart:
Medical Projects 04 Engr'g. & Advanced Programs
Unit Manager: CWGFulcher Subsection Mgr. WJBeittel

DISTRIBUTION
GE/AGS: Central Product File
R. F. Hassell
V. J. Marks
NASA/JSC:
Tech.Library/JM6 (1979 distribution)
PROGRAM DESCRIPTION

A. IDENTIFICATION

Program Name - WALTERS
Programmer  - R. C. Croston, GE/MSC, Houston
Date of Issue - April 6, 1972

B. GENERAL DESCRIPTION

This model is a combined, steady-state cardiovascular and thermal model. It was originally developed for interactive use by Dr. R. F. Walters, Department of Human Physiology, School of Medicine, University of California, Davis, California. The model has been converted to batch mode simulation for the Sigma 3 computer.

C. USAGE AND RESTRICTIONS

Machine and Compiler Required - XDS Sigma 3 and ANSI FORTRAN
Peripheral Equipment Required - Card reader and line printer.
Approximate amount of memory required - 2,465 hexadecimal

D. PARTICULAR DESCRIPTION

Equations Used and Derivations - See final report of Contract NAS9-11657, Modification 2C.
Definition of Terms Used - Terms are defined in the referenced math model and in the following descriptions of input and output variables.
Detailed Description - The mathematical model is summarized here by a functional block diagram, Figure 1. The purpose of the model is to compute steady-state circulatory and thermal variables in response to exercise work loads and environmental factors. During a computer simulation run, several selected variables are printed at each time step. End conditions are also printed at the completion of the run.

E. DESCRIPTION OF INPUT

Control and Program Cards - (begin in card column 1)

:JOB
:ASSIGN SI=14  (026 Keypunch Code)
:ASSIGN F:5=3
:ASSIGN F:6=4
:FORTRAN
COMBINED STEADY-STATE CIRCULATORY AND THERMAL MODELS

FIGURE 1.

WALTERS MODEL FUNCTIONAL BLOCK DIAGRAM
(SOURCE DECK)

:EOQD
:OLOAD
:256,0
:MP
:EOQD
:SEQ

(DATA DECK)

:EOQD

Program Cards - Listed at the end of this document.

Data Cards - (Card columns, format, name definitions)

Columns 1-10, 11-20, etc., 8 parameters per card for a 8F10.0 format of the following list of required input data:

AVCOR 0.138 RESTING A-V DIFF, CORONARY
AVBR 0.069 RESTING A-V DIFF, BRAIN
AVMR 0.067 RESTING A-V DIFF, MUSCLE
AVSKIN 0.010 RESTING A-V DIFF, SKIN
AVOTH 0.035 RESTING A-V DIFF, "OTHER"
AVRMP 0.040 RESTING A-V DIFF, RESPIRATORY MUSCLES
AVRSM 0.165 MAXIMUM A-V DIFF, MUSCLE
AVRSMX 0.060 MAXIMUM A-V DIFF, RESPIRATORY MUSCLE
EFASP 0.80 MAXIMUM EFFICIENCY, ARM MUSCLE
EFLGM 0.80 MAXIMUM EFFICIENCY, LEG MUSCLE
PCTWLG 0.25 WEIGHT PERCENT, LEG MUSCLE
PCTMAR 0.15 WEIGHT PERCENT, ARM MUSCLE
PCTARS 0.05 WEIGHT PERCENT, RESPIRATORY MUSCLE
PCTWCU 0.015 WEIGHT PERCENT, CORONARY MUSCLE
PCTWIM 0.035 WEIGHT PERCENT, INACTIVE MUSCLE
STOPTM 71.0 STOP TIME FOR LENGTH OF EXPERIMENT (min)
TINC 10.0 TIME AT WHICH VARIABLES ARE INCREMENTED (min) (fixed)
MXRSP 0.315  SLOPE FACTOR FOR INCREASE IN RESP MUSCLE O₂
TS 1.0  TIME STEP FOR MODEL (in minutes) (fixed)
VLPKE 0.04  PERCENT OXYGEN UPTAKE IN VENTILATION
TAIR 20.0  AIR TEMPERATURE (°C)
RHUM 0.50  RELATIVE HUMIDITY
PATM 760.0  ATMOSPHERIC PRESSURE (mm Hg)
PO₂ 160.0  PARTIAL PRESSURE OXYGEN (mm Hg)
V AIR 0.1524  WIND SPEED (m/sec)
C ORST 5000.0  RESTING CARDIAC OUTPUT (ml/min)
WGT 75.0  BODY WEIGHT (Kg)
HGT 175.0  HEIGHT (cm)
TB 36.8  BODY TEMP, INITIAL (°C)
H RREST 60.0  RESTING HEART RATE (beats/min)
HR MAX 200.0  MAXIMUM HEART RATE
V MAX 20000.0  MAXIMUM VENTILATION (ml/min)
T BMAX 41.0  MAXIMUM BODY TEMPERATURE (°C)
TPRINT 1.0  PRINT INTERVAL (min)

Col. 1-10, 21-30, 41-50, 61-70  8F10.0  Time to change work rate (sec)
11-20, 31-40, 51-60, 71-80  8F10.0  Work rate in KPM/min

(Seven of the above cards are required for a complete schedule.)

Time (seconds), oxygen uptake (ml/min), ventilation (ml/min), heart rate (beats/min), cardiac output (ml/min), body temperature (°C), and skin temperature (°C).

F. DESCRIPTION OF OUTPUT

The following variables are printed on the line printer. A sample printout is shown in Figure 2.
<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Oxygen Uptake (ml/min)</th>
<th>Carbon Dioxide Production (ml/min)</th>
<th>Oxygen Consumption (ml/min)</th>
<th>CO2 Production (ml/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2572.5</td>
<td>61311.9</td>
<td>196.8</td>
<td>16399.5</td>
<td>354</td>
</tr>
<tr>
<td>3300</td>
<td>8339.7</td>
<td>66.8</td>
<td>5569.7</td>
<td>354</td>
</tr>
<tr>
<td>2511</td>
<td>6277.9</td>
<td>60.2</td>
<td>5020.8</td>
<td>353</td>
</tr>
<tr>
<td>2433</td>
<td>6176.3</td>
<td>59.4</td>
<td>4945.7</td>
<td>353</td>
</tr>
<tr>
<td>2416</td>
<td>6156.2</td>
<td>59.3</td>
<td>4945.7</td>
<td>352</td>
</tr>
<tr>
<td>2416</td>
<td>6156.2</td>
<td>59.3</td>
<td>4945.7</td>
<td>351</td>
</tr>
<tr>
<td>2416</td>
<td>6156.2</td>
<td>59.3</td>
<td>4945.7</td>
<td>351</td>
</tr>
<tr>
<td>2406</td>
<td>6156.2</td>
<td>59.3</td>
<td>4945.7</td>
<td>350</td>
</tr>
<tr>
<td>2406</td>
<td>6156.2</td>
<td>59.3</td>
<td>4945.7</td>
<td>349</td>
</tr>
<tr>
<td>2406</td>
<td>6156.2</td>
<td>59.3</td>
<td>4945.7</td>
<td>348</td>
</tr>
<tr>
<td>2406</td>
<td>6156.2</td>
<td>59.3</td>
<td>4945.7</td>
<td>348</td>
</tr>
<tr>
<td>2406</td>
<td>6156.2</td>
<td>59.3</td>
<td>4945.7</td>
<td>347</td>
</tr>
<tr>
<td>2406</td>
<td>6156.2</td>
<td>59.3</td>
<td>4945.7</td>
<td>347</td>
</tr>
<tr>
<td>2406</td>
<td>6156.2</td>
<td>59.3</td>
<td>4945.7</td>
<td>346</td>
</tr>
<tr>
<td>2406</td>
<td>6156.2</td>
<td>59.3</td>
<td>4945.7</td>
<td>346</td>
</tr>
<tr>
<td>2406</td>
<td>6156.2</td>
<td>59.3</td>
<td>4945.7</td>
<td>345</td>
</tr>
<tr>
<td>2406</td>
<td>6156.2</td>
<td>59.3</td>
<td>4945.7</td>
<td>345</td>
</tr>
<tr>
<td>2406</td>
<td>6156.2</td>
<td>59.3</td>
<td>4945.7</td>
<td>344</td>
</tr>
</tbody>
</table>

**Summary of Conditions at Time of Stop:** 71 min

**Environment**
- Temperature: 23°C
- Humidity: 0.60
- Altitude: 760 ft
- Air Speed: 0 mph
- Leg Work: 33.5 ml O2/min
- Arm Work: 13.4 ml O2/min

**Body Status**
- Body Temperature: 37.3°C
- Skin Temperature: 32.7°C
- Ventilation: 6166.2 l/min
- Oxygen Uptake: 2466.6 l/min
- Cardiac Output: 4945.7 l/min
- Heart Rate: 59.3 bpm

**Oxygen Debt**
- Carbohydrate: 0.4 l/min
- Fat: 11.5 l/min
- Protein: 0.0 l/min
- Leg Rate: 2.386 ml O2/min
- Arm Rate: 0.0 ml O2/min
C. INTERNAL CHECKS AND EXITS

Exit - A normal exit gives end conditions and a stop.

H. INDEPENDENT SUBROUTINES

None

I. SYSTEM SUBROUTINES

No special subroutines.

J. COMPLETION OR FINAL CHECKOUT DATE

April 6, 1972.

K. PROGRAM LISTING
C

WRITE (6,95) H2TOT,H2R,H2LR,H2BR,02AL,02AR,02RSP,02SK,02IM,02OTH

95 FORMAT (1,H2TOT,8H4,2H,1H,02AL,02AR,02RSP,02SK,02IM,02OTH)

02CWO=0
02LEG=0
02BWO=0
01DABWO=0
01DTBLGW=0
V=02TOT/TS/VUPTKE

BFSKIN=BFSKNR
BFLEG=BFLEG
BFARM=BFARMR
BFASB=BFASPR
BFCON=BFCONR
HLSINC=0
WAINC=0
HUMINC=0
THPRINC=0
WAPINC=0
PBINC=0
VELINC=0

HTBTW=02BR*00*825
HLEG=02LR*00*825
HTAR=02BR*00*825
HTSKN=02SK*00*825
HTRSP=02RSP*00*825
PCRSD=VMAX/10.((VRSPV/VMAX=4.5))

02XPRE=0
IF (TB+LT+TSW+0R+TSK+LT+29.) GO TO 102
02Xrsp=02BR+02TH+02AR+02LR+02SK+02IM
OTS=MIN(13,(TB+TSW))
HLSX=MIN(TB+TSW)*TS
BFSKN=BFSKNR+BFSKN+0TS+7/3.
IF (MLSX+GT+MLSX0) MLSX=MLSX
GO TO 103

102 HLSX=0
OTS=0

103 CONTINUE

HTBT=HTBR+HTIM+HTOTH+HT2R+HTLEG+HTARM+HTSKN+HTRSP
WVEXP=10**8*051/(2353/(TB+273))**PRES/101.3
HLS5=E*W**6598/(WVEXP-WV)**2882/(1+452.7*60.5)*TS
HTNET=HTBT+HLRSP
HLSKIN=17.1*ABS(TSKIN-TAIR)*TS*0.8598/60.
HTSTORM=HTNET+HLSKIN
TIME=0

PRFIM=0
INCTLM=0
TPRM=1
JPR=6
GO 600 1=1,6
600 1PR=1=1

300 FORMAT (68A1)

C
C REMOVED INTERACTIVE SECTION
C

4000 CONTINUE

C

C***** MODEL EXECUTION
<table>
<thead>
<tr>
<th>Line</th>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>021M</td>
<td>021M * 100 + 825</td>
<td></td>
</tr>
<tr>
<td>020H</td>
<td>020H * 100 + 825</td>
<td></td>
</tr>
<tr>
<td>C****</td>
<td>CTHNK + COMPARTMENT</td>
<td></td>
</tr>
<tr>
<td>020H</td>
<td>020H * 100 + 825</td>
<td></td>
</tr>
<tr>
<td>C****</td>
<td>CORONARY COMPARTMENT</td>
<td></td>
</tr>
<tr>
<td>IF (FPNL + LTHW) &gt; HMRHRS?</td>
<td></td>
<td>240</td>
</tr>
<tr>
<td>BFCR = (HMRHRS1 * XCVCR + 0.02RH) + TS</td>
<td></td>
<td>241</td>
</tr>
<tr>
<td>BFCR = BFCR + (0.2080 / TS + 0.282) / AVCR</td>
<td></td>
<td>242</td>
</tr>
<tr>
<td>HTCR = 0.0280 + 0.0282</td>
<td></td>
<td>243</td>
</tr>
<tr>
<td>IF (BFCR / TS + 0.282) &lt; 1000</td>
<td></td>
<td>244</td>
</tr>
<tr>
<td>BFCR = BFCR / 0.282</td>
<td></td>
<td>245</td>
</tr>
<tr>
<td>IF (0.282 / TS + 0.282) &lt; 1000</td>
<td></td>
<td>246</td>
</tr>
<tr>
<td>WRITE (1, 2052) DBCR</td>
<td></td>
<td>247</td>
</tr>
<tr>
<td>0455</td>
<td>FORMAT 1: DEBT (CORONARY) EXCEEDS MAX. DEBT = 1, FB + 1</td>
<td></td>
</tr>
<tr>
<td>GO TO 0600</td>
<td></td>
<td>250</td>
</tr>
<tr>
<td>C****</td>
<td>LEG MUSCLE COMPARTMENT</td>
<td></td>
</tr>
<tr>
<td>0460</td>
<td>020L = 020L + TS</td>
<td></td>
</tr>
<tr>
<td>BFLG = BFLG + (0.20L + 0.02LEGR) / AVMX</td>
<td></td>
<td>253</td>
</tr>
<tr>
<td>IF (BFLG + LTLG) / AVMX</td>
<td></td>
<td>254</td>
</tr>
<tr>
<td>0460</td>
<td>BFLG = BFLG / AVMX</td>
<td></td>
</tr>
<tr>
<td>DTDLG = 0.20L + 0.02LGMX</td>
<td></td>
<td>256</td>
</tr>
<tr>
<td>IF (DTDLG + LTLG) / AVMX</td>
<td></td>
<td>257</td>
</tr>
<tr>
<td>WRITE (2, 4052) DTDLG</td>
<td></td>
<td>258</td>
</tr>
<tr>
<td>0452</td>
<td>FORMAT 1: RATE OF LEG MUSCLE 02 DEBT ACCUM EXCESSIVE (1, FB + 1)</td>
<td></td>
</tr>
<tr>
<td>GO TO 0600</td>
<td></td>
<td>260</td>
</tr>
<tr>
<td>0465</td>
<td>DBLEG = 0.02LEGR + DDLG + TS</td>
<td></td>
</tr>
<tr>
<td>IF (DBLEG + LT + DDLG + TS) / AVMX</td>
<td></td>
<td>262</td>
</tr>
<tr>
<td>WRITE (2, 4067) DBLEG</td>
<td></td>
<td>263</td>
</tr>
<tr>
<td>0467</td>
<td>FORMAT 1: LEG MUSCLE 02 DEBT EXCESSIVE (1, FB + 1)</td>
<td></td>
</tr>
<tr>
<td>GO TO 1000</td>
<td></td>
<td>265</td>
</tr>
<tr>
<td>0468</td>
<td>HLEG = 0.02LEGR + TS * 0.0282</td>
<td></td>
</tr>
<tr>
<td>IF (HLEG / TS) * 0.0282</td>
<td></td>
<td>267</td>
</tr>
<tr>
<td>IF (BFLG + GT + EFLGMX + 0.02LGMX) / AVMX</td>
<td></td>
<td>268</td>
</tr>
<tr>
<td>GO TO 4070</td>
<td></td>
<td>269</td>
</tr>
<tr>
<td>HLEG = HLEG + (0.20L + 0.02LEGR) / 0.0282 + TS</td>
<td></td>
<td>270</td>
</tr>
<tr>
<td>GO TO 4075</td>
<td></td>
<td>271</td>
</tr>
<tr>
<td>0470</td>
<td>HLEG + (EFLGMX + 0.02LEGR) / AVMX</td>
<td></td>
</tr>
<tr>
<td>IF (HLEG + 0.02LGMX + 0.02LEGR) / 0.0282 * TS</td>
<td></td>
<td>273</td>
</tr>
<tr>
<td>C****</td>
<td>ARM MUSCLE</td>
<td></td>
</tr>
<tr>
<td>0475</td>
<td>02AR = 02AR + TS</td>
<td></td>
</tr>
<tr>
<td>HFARM = HFARM + (0.20AR + 0.02ARM) / AVMX</td>
<td></td>
<td>276</td>
</tr>
<tr>
<td>IF (HFARM + LT + BFARMX) / AVMX</td>
<td></td>
<td>277</td>
</tr>
<tr>
<td>HFARM = HFARM</td>
<td></td>
<td>278</td>
</tr>
<tr>
<td>DTDBAR = 0.02AR + 0.02ARMX</td>
<td></td>
<td>279</td>
</tr>
<tr>
<td>IF (DTDBAR + LT + DFBARMX) / AVMX</td>
<td></td>
<td>280</td>
</tr>
<tr>
<td>WRITE (2, 4072) DTDBAR</td>
<td></td>
<td>281</td>
</tr>
<tr>
<td>0478</td>
<td>FORMAT 1: RATE OF ARM 02 DEBT ACCUM EXCESSIVE (1, FB + 1)</td>
<td></td>
</tr>
<tr>
<td>GO TO 1000</td>
<td></td>
<td>283</td>
</tr>
<tr>
<td>0480</td>
<td>DBARM = DBARM + DTDBAR</td>
<td></td>
</tr>
<tr>
<td>IF (DBARM + LT + DBARMX) / AVMX</td>
<td></td>
<td>285</td>
</tr>
<tr>
<td>WRITE (2, 4081) DBARM</td>
<td></td>
<td>286</td>
</tr>
<tr>
<td>0481</td>
<td>FORMAT 1: ARM MUSCLE 02 DEBT EXCESSIVE (1, FB + 1)</td>
<td></td>
</tr>
<tr>
<td>GO TO 1000</td>
<td></td>
<td>288</td>
</tr>
<tr>
<td>0482</td>
<td>HARM = 02ARMX + 0.0285 * TS</td>
<td></td>
</tr>
<tr>
<td>IF (HARM + LE + 0.02ARMX) / AVMX</td>
<td></td>
<td>290</td>
</tr>
<tr>
<td>HTARM = HTARM + (0.20ARMX + 0.02ARMX) / AVMX</td>
<td></td>
<td>291</td>
</tr>
<tr>
<td>HTARM = HTARM</td>
<td></td>
<td>292</td>
</tr>
</tbody>
</table>